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ABSTRACT

MIRAGE is a multi-region, multi-sector computable general equilibrium model, devoted to trade policy analysis. It incorporates imperfect competition, product differentiation by variety and by quality, and foreign direct investment, in a sequential dynamic set-up where installed capital is assumed to be immobile. Adjustment inertia is linked to capital stock reallocation and to market structure changes. MIRAGE draws upon a very detailed measure of trade barriers and of their evolution under given hypotheses, thanks to the database *MAcMaps*. Simulations of a trade liberalisation between the European Union and its periphery illustrate the sensitivity to the main assumptions.

JEL Classification: D58; F12; F13.
Key Words: Computable general equilibrium model, trade policy, dynamics, foreign direct investment, imperfect competition.

RÉSUMÉ

MIRAGE est un modèle d'équilibre général calculable multi-sectoriel et multi-régional, destiné à l'analyse des politiques commerciales. Il incorpore des éléments de concurrence imparfaite, de différenciation des produits par variétés et par gammes de qualité, et d'investissement direct à l'étranger, dans un cadre dynamique séquentiel où le capital installé est supposé immobile. Les inerties d'ajustement y sont liés à la réallocation du stock de capital et à l'évolution des structures de marché. MIRAGE s'appuie sur une mesure bilatérale très détaillée des barrières aux échanges et de leur évolution sous différentes hypothèses, grâce à la base *MAcMaps*. La sensibilité des résultats aux principales hypothèses est illustrée par des simulations d'une libéralisation commerciale entre l'Union européenne et sa périphérie.

Classification JEL : D58 ; F12 ; F13
Mots-clés : Modèle d'équilibre général calculable, politique commerciale, dynamique, investissement direct à l'étranger, concurrence imparfaite.

MIRAGE, A COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR TRADE POLICY ANALYSIS

NON-TECHNICAL SUMMARY

Almost ten years after Marrakech's agreements, and as Doha's Ministerial Conference launched a new round of multilateral negotiations, the stakes of trade policies are still very complex. In this context, delivering a rigorous and detailed quantitative analysis of a large scope of trade agreements is most useful, for policy-makers as well as for the public debate. This is the reason why the CEPII has decided to develop and to maintain, in collaboration with the ITC (International Trade Centre, UNCTAD-WTO, Geneva), a multi-sector, multi-region computable general equilibrium (CGE) model, nicknamed MIRAGE (for *Modelling International Relationships in Applied General Equilibrium*), devoted to trade policy analysis.

MIRAGE describes imperfect competition in an oligopolistic framework *à la Cournot*. It accounts for horizontal product differentiation linked to varieties, but also to geographical origin (nested Armington – Dixit-Stiglitz utility function). A new calibration procedure allows the available information on these aspects to be used efficiently. The modelling is done in a sequential dynamic set-up, where the number of firms by sector adjusts progressively, and where installed capital is assumed to be immobile, even across sectors. Capital reallocation therefore only results from the combined effect of depreciation and investment. It makes it possible to describe the adjustment lags of capital stock, and the associated costs.

Compared to previous applied CGE trade models, MIRAGE has in addition three main distinctive features, aimed at improving the description of trade policies' main transmission channels:

- FDIs are explicitly described, with a modelling both theoretically consistent (with agents' behaviour, and with domestic investment setting), and consistent with the empirical results about FDIs' determinants and their order of magnitude;

- a notion of vertical product differentiation is introduced, by distinguishing two quality ranges, according to the country of origin of the product;

- trade barriers are described by the *MAcMaps* database (see Bouët, Fontagné, Mimouni and Pichot, 2002), that provides with a measure of ad-valorem tariffs, and of the ad-valorem equivalent of specific tariffs, tariff quotas, prohibitions and anti-dumping duties, at the bilateral level, for 137 countries with 220 partners. Preferential agreements are taken into account in a quasi-exhaustive way. This information, available at the level of 5 000 to 10 000 products (HS6 or HS10 classification, according to the country), is used to describe the initial level of trade barriers, but also to build scenarios. Assumptions concerning the changes in these barriers can thus be made at the product

level, possibly depending on their initial level. Only then are these data aggregated in the model's nomenclature, according to a procedure designed to limit the extent of the endogeneity bias. As a result, MIRAGE is based on a description of trade barriers that, besides its precision, preserves the bilateral dimension of the information, contrarily to what is commonly done in applied modelling.

Except for data on trade barriers, the model uses GTAP 5 database (see Dimaranan and Mac Dougall, 2002). This allows a wide flexibility in choosing the sectoral and geographical aggregations of MIRAGE, that may be changed for each application.

For the sake of illustration, simulations are carried out to evaluate the impact of removing trade barriers between the EU and its periphery, defined in a broad sense as CEECs, Maghreb and Turkey. The results using the standard version of MIRAGE show that significant trade creation would take place between the two areas, mainly in agriculture and agro-food, in EU's vehicle exports, and in the periphery's textile and clothing exports. However, the welfare impact in the medium-term (after 13 years) would be (insignificantly) negative for the periphery: the asymmetric nature of the scenario (due to the higher initial bilateral barriers imposed by the periphery) would indeed induce a terms of trade loss for the periphery and, most of all, the removal of trade barriers with the EU only would confer the periphery a very inefficient protection structure, preventing this area from benefiting from such a liberalisation. In contrast, the welfare impact would be slightly positive for the EU.

These results are compared to those obtained using different assumptions in four key areas: vertical product differentiation, the nature of competition, the dynamic set-up, and FDIs. The differences appear to be significant, illustrating in particular the contribution of FDIs and of the pro-competitive effect to the impact on welfare. Vertical differentiation also matters, and it is of particular importance in shaping the trade effects. Finally, introducing a technological externality linked to FDIs is shown to have an overwhelming impact on welfare. This validates the cautious approach taken in MIRAGE of not introducing any externality in the standard version, for the sake of robustness.

MIRAGE, UN MODÈLE D'ÉQUILIBRE GÉNÉRAL CALCULABLE POUR L'ÉVALUATION DES POLITIQUES COMMERCIALES

RÉSUMÉ NON TECHNIQUE

Presque dix ans après les accords de Marrakech, et alors que la Conférence ministérielle de Doha a lancé un nouveau cycle de négociations multilatérales, les enjeux des politiques commerciales apparaissent toujours très complexes. Dans ce contexte, il apparaît plus que jamais nécessaire, pour les décideurs de politique économique comme pour le débat public, de disposer d'outils permettant une analyse quantitative rigoureuse et circonstanciée d'une large gamme d'accords commerciaux. C'est pourquoi le CEPII a décidé de développer et de maintenir, en collaboration avec le CCI (Centre du Commerce International, OMC-CNUCED, Genève), un modèle d'équilibre générale calculable (MEGC) multi-sectoriel et multi-régional, destiné à l'analyse des politiques commerciales : le modèle MIRAGE (*Modelling International Relationships in Applied General Equilibrium*).

MIRAGE décrit les imperfections de la concurrence dans un cadre oligopolistique à la Cournot. Il tient compte de la différenciation horizontale des produits liée aux variétés, mais aussi à l'origine géographique des biens (par emboîtement de fonctions de type Armington et Dixit-Stiglitz). Une procédure nouvelle de calibrage des paramètres correspondants permet une utilisation efficace de l'information disponible en ces domaines. La modélisation est faite dans un cadre dynamique séquentiel, où le nombre de firmes par secteur s'ajuste progressivement, et où le capital installé est supposé immobile, même entre secteurs. La réallocation du capital s'opère donc uniquement par l'effet combiné de la dépréciation et de l'investissement. Elle est inertielle, et permet de décrire les délais d'ajustement du stock de capital et les coûts associés.

Afin de mieux décrire les principaux canaux de transmission des chocs de politique commerciale, MIRAGE possède en outre trois caractéristiques distinctives importantes par rapport aux précédents modèles :

- les IDE sont décrits explicitement, avec une modélisation qui concilie la cohérence théorique (avec les comportements des agents et avec la détermination de l'investissement intérieur) et la cohérence avec les résultats des études empiriques sur les déterminants des IDE et les ordres de grandeur correspondants ;

- un élément de différenciation verticale des produits est introduit, en distinguant deux gammes de qualités, selon l'origine géographique du produit ;

- les barrières aux échanges sont décrites par la base de données *MAcMaps* (voir Bouët, Fontagné, Mimouni et Pichot, 2002), qui mesure l'équivalent tarifaire des droits *ad valorem*, des droits spécifiques, des quotas tarifaires, des prohibitions et des droits antidumping, au niveau bilatéral pour 137 pays et 220 partenaires en tenant compte de façon quasi-exhaustive des accords préférentiels existants. Cette information, disponible

au niveau de 5 000 à 10 000 produits (nomenclature SH6 à SH10, selon les pays), est utilisée comme source de données pour décrire le niveau initial des barrières aux échanges, mais également pour construire des scénarios. Les hypothèses d'évolution peuvent ainsi être formulées au niveau des produits, éventuellement en fonction de leur niveau initial de protection. Ensuite seulement, ces données sont agrégées dans la nomenclature du modèle, selon une procédure limitant le biais d'endogénéité. MIRAGE s'appuie donc sur une description des barrières aux échanges qui, outre sa précision, préserve le caractère bilatéral de l'information, contrairement à ce qui est fait dans la plupart des travaux de modélisation.

Excepté pour les barrières aux échanges, le modèle utilise la base de données GTAP 5 (Dimaranan et Mac Dougall, 2002). Cela lui confère une grande flexibilité dans le choix de l'agrégation sectorielle et géographique, qui peut être modifiée pour chaque application.

Dans le but d'illustrer la portée des choix retenus, des simulations sont effectuées pour évaluer l'impact d'une suppression des barrières aux échanges entre l'UE et sa périphérie, définie au sens large comme regroupant les pays d'Europe Centrale et Orientale (PECO), les pays du Maghreb et la Turquie. Les résultats obtenus en utilisant la version standard de MIRAGE montrent que la création de commerce serait importante entre les deux zones, en particulier dans l'agriculture et l'agroalimentaire, dans les exportations européennes de véhicules et dans les exportations de textile-habillement de la périphérie. Cependant, l'impact de moyen terme (13 ans) sur le bien-être serait très légèrement négatif pour la périphérie: la nature asymétrique du scénario envisagé (liée au niveau initial plus élevé des barrières bilatérales imposées par la périphérie) induirait à terme une détérioration des termes de l'échange pour la périphérie et, surtout, la suppression des seules barrières envers l'UE confèrerait à la périphérie une structure de protection très inefficace, l'empêchant de tirer bénéfice d'une telle libéralisation. En revanche, l'impact sur le bien-être serait légèrement positif pour l'UE.

Ces résultats sont ensuite comparés à ceux obtenus en effectuant des hypothèses différentes dans quatre domaines clés: la différenciation verticale des produits, la nature de la concurrence, la structure dynamique et les IDE. Les différences s'avèrent significatives, illustrant notamment la part que prennent l'effet pro-concurrentiel et les IDE dans l'impact induit sur le bien-être. La différenciation verticale des produits compte aussi, et elle est particulièrement importante dans la détermination des impacts commerciaux. Enfin, une simulation montre que l'introduction d'une externalité technologique liée à l'IDE a un effet démesurément fort sur le bien-être. Ce constat valide la démarche prudente adoptée dans MIRAGE, qui consiste à n'introduire aucune externalité dans la version de base, pour garantir sa robustesse.

MIRAGE, A COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR TRADE POLICY ANALYSIS

Mohamed Hedi BCHIR, Yvan DECREUX, Jean-Louis GUERIN and Sébastien JEAN[1]

1. INTRODUCTION

Almost ten years after Marrakech's agreements, and as Doha's Ministerial Conference launched a new round of multilateral negotiations, the stakes of trade policies are still very complex. Numerous new preferential agreements are in project, while the perspectives of multilateral liberalisation remain unclear. In this context, delivering a rigorous and detail quantitative analysis of a large scope of trade agreements is most useful, for policy-makers as well as for the public debate. This is the reason why the CEPII has decided to develop and to maintain, in collaboration with the ITC (International Trade Centre, UNCTAD-WTO, Geneva), a multi-sector, multi-region computable general equilibrium (CGE) model, nicknamed MIRAGE,[2] devoted to trade policy analysis.

Trade agreements can involve substantial changes in prices, in allocated resources and in income, that are frequently strongly contrasted across sectors and countries. Based on a robust and widely accepted modelling of agents' behaviour, CGE models are able to provide a detailed description of the impact of such shocks on the economy. A number of robust and well-identified mechanisms are quantified in a single, rigorous and consistent framework. Such an analysis makes it possible to put forward the main mechanisms, to give their sign and their order of magnitude.

During the last two decades, an extensive literature has been devoted to applying CGE modelling to the study of trade policies (see CEPII, 2000, for a survey). Compared to the pure walrasian tradition models,[3] several major improvements have been achieved, in particular thanks to the studies about the expected impact of the European Single Market, the NAFTA, or the Uruguay Round. Since Harris (1984), imperfect competition and horizontal product differentiation are commonly incorporated, notably based on the formalisations proposed by Smith and Venables (1988), and by Harrison, Rutherford and

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[1] The authors are economists with CEPII (bchir@cepii.fr, decreux@cepii.fr, guerin@cepii.fr, s.jean@cepii.fr). MIRAGE is part of a wider project devoted by the CEPII, in collaboration with the ITC (International Trade Centre, UNCTAD-WTO), to the analysis of trade policies. The authors gratefully aknowledge help from other members of this team, especially Antoine Bouët, Lionel Fontagné, Michel Fouquin, and Mondher Mimouni. The authors also wish to thank for their comments and advice the members of this project's "Comité de pilotage". The paper has also benefited from the comments made by participants in several conferences where the model was presented. Usual disclaimers apply.

[2] MIRAGE stands for *Modelling International Relationships in Applied General Equilibrium*.

[3] Such as, for instance, the one used by the World Bank for a global and prospective analysis of development issues, more than twenty years ago (World Bank, 1981).

Tarr (1997). Numerous studies have also gone beyond the static framework, in order to be able to describe adjustment periods, and the corresponding dynamic effects, notably after Baldwin (1989). Lastly, the nineties witnessed the increasing spreading of the GTAP database (Global Trade Analysis Project, Purdue University), that marked the sharing of the heavy data work required for this kind of models, making their access far easier.

The MIRAGE model builds on this literature, and intends to take a new step toward a better analysis of trade policies. It describes imperfect competition and horizontal product differentiation in a rather standard fashion, but with a new calibration procedure, allowing the available information to be used more efficiently. The modelling is done in a sequential dynamic set-up, where the number of firms by sector adjusts progressively, and where installed capital is assumed to be immobile, even across sectors. Capital reallocation therefore only results from the combined effect of depreciation and investment. It makes it possible to describe the adjustment lags of capital stock, and the associated costs. The model uses GTAP 5 database (see Dimaranan and Mac Dougall, 2002). In order to improve the description of trade policies' main transmission channels, MIRAGE has in addition three main distinctive features:

- FDIs are explicitly described, with a modelling both theoretically consistent (with agents' behaviour, and with domestic investment setting), and consistent with the empirical results about FDIs' determinants and their order of magnitude;
- a notion of vertical product differentiation is introduced, by distinguishing two quality ranges. Even though it remains rudimentary, this assumption is a first step toward taking advantage, in applied modelling, of the empirical progresses achieved in this domain during the last decade;
- trade barriers are described by the *MAcMaps* database (see Bouët, Fontagné, Mimouni and Pichot, 2002), that provides with a measure of ad-valorem tariffs, and of the ad-valorem equivalent of specific tariffs, tariff quotas, prohibitions and anti-dumping duties, at the bilateral level, for 137 countries with 220 partners. Preferential agreements are taken into account in a quasi-exhaustive way. This information, available at the level of 5 000 to 10 000 products (SH6 or SH10 classification, according to the country), is used to describe the initial level of trade barriers, but also to build scenarios. Assumptions concerning the changes in these barriers can thus be made at the product level, possibly depending on their initial level. Only then are these data aggregated in the model's nomenclature, according to a procedure designed to limit the extent of the endogeneity bias.[4] As a result, MIRAGE is based on a description of trade barriers that, besides its precision, preserves the bilateral dimension of the information, contrarily to what is commonly done in applied modelling.

The model's set-up is described in the following Section. For the sake of illustration, simulations are then carried out to evaluate the impact of removing trade barriers between the EU and its periphery. The results using the standard version of MIRAGE are presented,

[4] This procedure, described in Bouët *et alii* (2002), is based on weights computed at the level of reference groups of countries, not at the level of individual countries.

and compared to those obtained when using different assumptions in four key areas: vertical product differentiation, the nature of competition, the dynamic set-up, and FDIs.

2. THE MIRAGE MODEL

MIRAGE is a multiregional and multisectoral model, the regional and sectoral aggregation of which can be adapted to each application. This Section describes the structure of the model and focuses on a few key assumptions, namely those dealing with products quality ranges, imperfect competition, FDI, and dynamic aspects. The model's equations are displayed in Annex 4.

The demand side

Final consumption is modelled in each region through a representative agent,[5] whose utility function is intratemporal. A fixed share of the regional income is allocated to savings,[6] the rest is used to purchase final consumption goods. Below this first-tier Cobb-Douglas function, the preferences across sectors are represented by a LES-CES (*Linear Expenditure System – Constant Elasticity of Substitution*) function. Without excessive complexity, this allows the evolution of the demand structure of each region, as its income level changes, to be accounted for. With this kind of utility function, the elasticity of substitution is constant only among the sectoral consumptions over and above a minimum level.[7]

As far as consumption choices within each sector are concerned, a nesting of CES functions such as the one used in Harrison, Rutherford and Tarr (1997) allows the particular status of domestic goods, together with product differentiation according to geographical origin (the so-called Armington's assumption) and horizontal product differentiation between varieties to be taken into account.

Such a standard, nested Armington – Dixit-Stiglitz, subutility function does not account for vertical differentiation nor for specialisation across quality ranges, although their importance in trade has been widely illustrated by now (see e.g. Abd-El-Rahman, 1991; Fontagné and Freudenberg, 1997; Fontagné, Freudenberg and Péridy, 1997; Freudenberg, 1998; Greenaway and Torstensson, 2000). Even though it is not easy to model nor quantify, this is an important device as far as analysing the nature and intensity of competition is concerned. This is why a further CES nesting level is added to the subutility function, distinguishing between two quality ranges, defined on a geographical basis: goods

[5] This assumption can be thrown out to study the impact of a decision on poverty (see for instance Hertel *et alii*, 2001), but it requires detailed survey data, which are available only on a country by country basis.

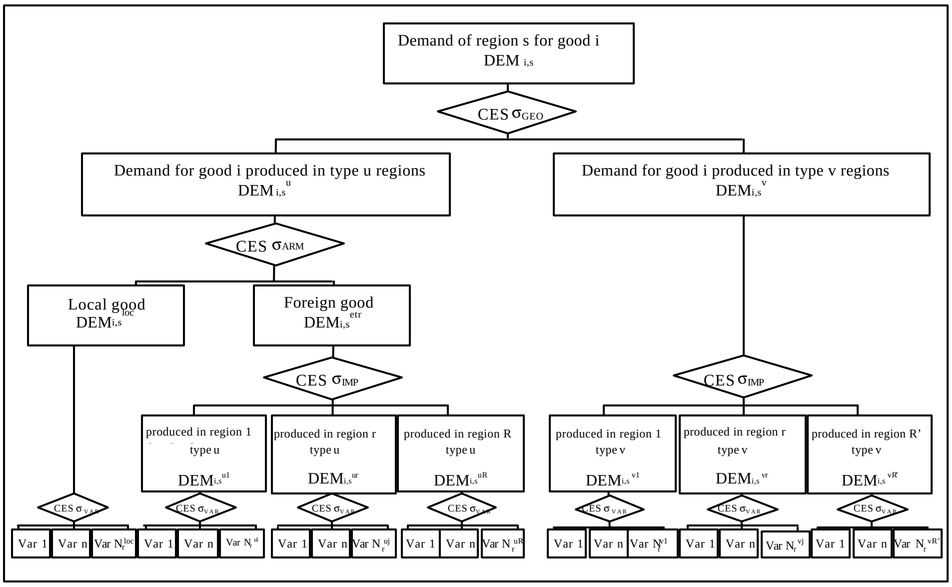
[6] This simplifying assumption doesn't allow to consider the indirect impact of liberalisation on savings, through a variation of the return rate of capital, though it can significantly alter the impacts of opening in a dynamic framework (Baldwin 1992, Francois *et alii* 1995; this point is discussed below).

[7] The minimum consumption is supposed to be one third of the initial consumption in developed countries, and two thirds in developing countries.

produced in a developing economy are assumed to belong to a different quality range than those produced in a developed economy (the demand nesting is displayed in Figure 1). The choice of substitution elasticities (the one between qualities is inferior to the Armington elasticity) implies that goods that do not belong to the same quality range are less substitutable than goods from the same quality range. This means for instance that, within a given sector, goods from a developing country compete more directly with goods from any other developing country, than with goods from any developed country. Even though it remains rudimentary, this formulation is a first step toward taking vertical differentiation into account in applied modelling.

Total demand is made up of final consumption, intermediate consumption and capital goods. Sectoral demand of these three compounds follows the same pattern as final consumption. The regional representative agent includes the government. He therefore both pays and earns taxes, and no public budget constraint has to be taken into account explicitly: this constraint is implicit to meeting the representative agent's budget constraint. Unless otherwise indicated (modelling a distorsive replacement tax does not raise any technical problem), this implicitly assumes that any decrease in tax revenues (for example as a consequence of a trade liberalisation) is compensated by a non-distorsive replacement tax. However, the magnitude of the tax revenue losses is an interesting information, to be displayed in the results.

Figure 1: Demand nesting for good *i*



Notes:

Type u regions are those who belong to the same quality range as the buyer; type v regions are the other ones.

Substitution elasticities are linked by the following relationships:

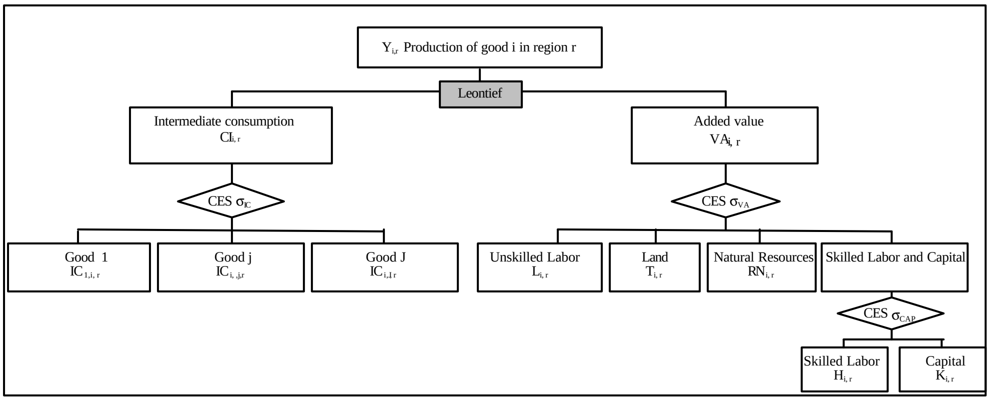
$$\sigma_{ARM} - 1 = \sqrt{2}\left(\sigma_{GEO} - 1\right) \; ; \; \sigma_{IMP} - 1 = \sqrt{2}\left(\sigma_{ARM} - 1\right) \; ; \; \sigma_{VAR} - 1 = \sqrt{2}\left(\sigma_{IMP} - 1\right)$$

The supply side

Production makes use of five factors: capital, skilled labour, unskilled labour, land and natural resources. Factor endowments are assumed to be fully employed and their growth rates are exogenous (zero for Land and Natural Resources, based on UNO demographic forecast for Labour), except for capital: even though saving rates are exogenous, total incomes vary and the regional and sectoral allocation of savings depends on capital returns as will be explained later.

Installed capital and natural resources are sector-specific, so that their rates of return may vary across sectors and regions. The three remaining factors are perfectly mobile across sectors,[8] but immobile across countries, with the only exception of the partial mobility of capital stock, through FDI.[9]

Figure 2: Structure of sector's *i* production function



The production function is described in Figure 2. In a standard fashion, perfect complementarity is assumed between value added and the intermediate consumptions. The sectoral composition of the intermediate consumption aggregate stems from a CES function, with the same elasticity as in the corresponding CES-LES for final consumption. For each sector of origin, the nesting is exactly the same as for final consumption, meaning that the sector bundle has the same structure for final and intermediate consumption.[10]

8 Factor market rigidity, particularly Labour market rigidity, can affect the impact of liberalisation processes (McKibbin, 1999).

9 These assumptions can be relaxed for some specific studies; for instance the use of Mirage to study the EU enlargement (Bchir et Maurel 2001) allows for migrations of the Labour force.

10 Based on the idea that firms collect information about products more easily than consumers, Mercenier (1992) assumes that substitution elasticities are higher within intermediate consumption than they are in final consumption. However the lack of empirical basis has led us not to adopt this assumption.

Value added is a CES function of land, natural resources, unskilled labour and a CES bundle of capital and skilled labour. This structure is intended to take into account the well-documented skill-capital relative complementarity. The elasticity of substitution within the capital and skilled labour bundle is assumed to be lower (0.6) than the elasticity between this bundle and all other factors (1.1).[11]

Some sectors, generally agriculture and transport[12], are assumed to be perfectly competitive with constant returns to scale. However, the need to consider imperfect competition and economies of scale when assessing the consequences of trade liberalisation episodes has been widely documented (see for instance Norman, 1990).

Oligopolistic competition is thus assumed to hold in the other sectors, with horizontal differentiation of products and increasing returns to scale, in the line of Krugman's (1979) theoretical model and of Smith and Venables' (1988) applied partial equilibrium model. The specification in MIRAGE is very close to that used by Harrison, Rutherford and Tarr (1997). Each firm produces its own and unique variety. The marginal production cost is constant at given factor prices, and production involves each year a fixed cost, expressed as a fixed quantity of output. Within each sector of each region, firms are assumed to be symmetrical. They compete in a Cournot-Nash way, i.e. they suppose that their decisions of production do not affect the volume of production of their competitors. Moreover they rule out the possibility that their production decision may affect the global level of demand through a revenue effect (the so-called Ford effect). However, firms take into account their market power, that is the influence they may exert on the sectoral or infra-sectoral price index (given the above-defined demand structure).[13] It follows from the absence of strategic interaction implied by the Cournot-Nash hypothesis, that the mark-up is given by the Lerner formula:

$$m_{irs} = \frac{P_{irs}}{MC_{ir}} = \frac{1}{1 - \frac{1}{EP_{irs}}} \quad (1)$$

[11] According to many studies (see Hamermesh, 1993, or Cahuc and Zylberberg, 1996 for extensive surveys), the elasticity of substitution between skilled labour or capital and unskilled labour is close to unity. However, using a CES function preserves the possibility for sensitivity analyses. Otherwise, the true value of substitution elasticities depends on the aggregation level (Decreux, Guérin and Jean, 2001).

[12] The transport sector plays a specific role: it covers both regular transport activities, that are demanded and can be traded like any other service, and international transport of commodities. The latter is a Cobb-Douglas bundle of regional supplies, and it accounts for the difference between fob and cif values of traded goods. The same bundle is used for any route. It is employed in fixed proportions with the volume of each good shipped along each route.

[13] This means that firms adopt *pricing-to-market* (see for example Goldberg and Knetter, 1997). They fix a different prices for each market. Pricing policy can depend on consumption destination (householders or firms), but it is not the case in MIRAGE.

Where m_{irs} is the mark-up applied in region *s* by each sector *i*'s firm producing in region *r*, *P* is the corresponding price, *MC* is the marginal cost of production (which does not depend on the market). Time subscript *t* has been omitted for all variables, for greater convenience. *EP* is the price-elasticity of demand, as perceived by the firm based on the above-mentioned assumptions (see formula in Annex 4); it increases with the elasticity of substitution between good *i* varieties produced in country *r* (this elasticity is a higher bound for *EP*) and with the elasticity of substitution between good *i* baskets from region *r* and from other regions; it is a decreasing function of the number of firms in sector *i* of region *r*, and of the global market share of region *r*'s producers taken together in the region *s*'s market for good *i*. This endogenous determination of firms' mark-up (already present, in a generic form, in Krugman, 1979), allows the pro-competitive effect of commercial shocks to be accounted for.

This formulation requires three types of parameters, describing respectively products substitutability, scale economies and competition intensity. Since these parameters are linked by the zero-profit condition in each sector, only two of them are usually drawn from external sources, and the third one is calibrated. This method is not fully satisfactory, either in terms of consistency or of robustness. This is why an original method is used in MIRAGE, that takes advantage of the whole available information for these three sets of parameters, not only about their value, but also concerning their variance. Once external estimates are collected for the three parameters, their calibrated values are jointly determined such as to minimise their distance from these estimates, subject to the consistency constraints imposed by the model. The inverted variance is used as a weight in calculating this distance, so as to make the adjustment borne more strongly by parameters which estimates have the greatest variance. A detailed description of this procedure is provided in Annex 3.

Changes in the number of firms are also an important matter: besides influencing firms' size and therefore profit rates, they modify the number of available varieties, thus affecting consumers' demand, given their taste for varieties. A binary approach is generally used in CGE model: in the short run, the number of firms is held constant and profits may vary; in the long-run, the free entry-exit of firms brings profits back to zero. In MIRAGE, the entry-exit of firms tends to bring profits back to zero, but the adjustment is progressive.

In addition, two categories of imperfectly competitive sectors are distinguished, according to their market structure dynamics. This classification is based on Sutton's (1991) seminal work, that introduced the distinction between fragmented sectors, where sunk costs are exogenous, and segmented sectors, where sunk costs are endogenous. Schematically, growth is mainly realised through increases in the number of firms in fragmented industries, whereas firms' size increases are dominant in segmented industries, where concentration cannot fall below a given level. Oliveira-Martins (1994) and Oliveira-Martins, Scarpetta and Pilat (1996), among others, have proved the usefulness of this taxonomy for sectoral empirical analysis, and it has already been used as a determinant of market structure dynamics in a CGE model by Cortes and Jean (1996, 1998) and by Jean and Bontout (1999).

This taxonomy is used in MIRAGE in the following way: at each period, the number of firms by sector is such that profits are 20% lower (in absolute value) in segmented sectors (50% lower in fragmented sectors), compared to the level they would have reached, had the number of firms remained unchanged[14]. This "law of motion" induces a progressive convergence of profits toward zero, with a higher speed for fragmented than for segmented sectors.

Capital, investment and macro-economic closure

Whatever its origin, a unit of capital invested in a given region is a bundle, obtained using the same CES nesting as for intermediate consumption. However, the distribution coefficients of the CES functions are different, according to the data. As for intermediate consumption, no factor service is required.

Installed capital is assumed to be immobile. This putty-clay hypothesis is important, because it implies that capital stock adjustment is gradual. The sectoral allocation of investment can thus be sub-optimal, and the corresponding loss can be interpreted as an adjustment cost for the economy. In addition, this *putty-clay*[15] assumption implies that the rate of return to capital may vary across sectors.

This confers investment an important role, as the only adjustment device for capital stock. As soon as trade policies are concerned, investment is also important through its cross-border component, that is FDI. In many models, among which the GTAP one (see Hertel, 1997), international financial flows are the results of the assumptions of perfect capital mobility and of cross-country equalisation in the rate of return to capital (including risk premium). This modelling is micro-funded, but it induces unplausibly high cross-border capital flows. On the other hand, using directly the results of econometric estimates for parameterising an ad-hoc relationship would give more realistic results, but it would lack theoretical consistency.

This is why an original modelling of FDI is used here, aiming at combining empirical realism and theoretical consistency. The latter objective requires, in particular, that domestic investment's setting is consistent with FDI's one, and that savings allocation behaviour is rational. In this context, the rate of return to capital is a natural determinant of investment sharing across sectors and countries. It is noteworthy that this rate of return incorporates the influence of many FDI determinants identified in the empirical literature, (see for example Chakrabarti, 2001, for a recent survey) such as market size, growth rate or

[14] This level is beforehand calculated in a separated simulation, where the number of domestic firms in each sector of each region is held unchanged. However, even in this case, FDIs can change the number of foreign firms.

[15] Note, however, that there is no technological difference between capital generations.

market potential.[16] As a consequence, these determinants need not be taken into account, over and above the sectoral rate of return to capital.

Practically, a single generic formalisation is used for setting both domestic and foreign investment. It stems from allocating savings across sectors and regions, as a function of the initial savings pattern, of the present capital stock and of the sectoral rate of return to capital, with an elasticity α:

$$\frac{PK_s I_{irs}}{S_r} = \frac{A_{irs} PK_s K_{is} e^{a\, wk_{is}}}{\sum_{i,s} A_{irs} PK_s K_{is} e^{a\, wk_{is}}} \tag{2}$$

Where PK_s stands for the price of capital good in region *s*, S_r for country *r* savings, I_{irs} for country *r* representative agent's investment in the sector *i* of country *s*, K_{is} for installed capital stock, A_{irs} for a calibrated parameter, wk_{is} for the capital remuneration rate in sector *i* of country *s*. Parameter *á* sets the adjustment speed of capital stock.[17] The capital good used in a given region is the same, whatever the capital's origin.

Equivalently, for the sake of clarity, introducing an endogenous variable B_r allows the problem to be rewritten as follows:

$$\begin{aligned} I_{irs} &= B_r A_{irs} PK_s K_{is} e^{a\, wk_{is}} \\ \sum_{i,s} PK_s I_{irs} &= S_r \end{aligned} \tag{3}$$

B_r can therefore be written as:

$$B_r = \frac{S_r}{\sum_{i,s} A_{irs} PK_s K_{is} PK_s I_{irs}} e^{-a R_r} \tag{4}$$

Where R_r can be interpreted as the shadow price of capital (including the depreciation rate) in region *r*.

Two types of FDI are looked at. The first one corresponds to the purchase of foreign firms by investors (brownfield investment), whereas the second one is the building of new firms (Greenfield investment). Both have the same objective but their consequences regarding the short run dynamics of the model are not exactly the same: purchasing an existing firm has

[16] Tariff jumping issues are left aside, because this mechanism cannot be modeled consistently without relying on a model of the multinational firm (see for instance Markusen and Venables, 2000).

[17] Since α cannot be calibrated, two static models were built, corresponding to a short run and a long run version of *Mirage*. We applied the same shocks to both of them and chose α so that half the adjustment of capital stocks towards the long run would be made in around 4 years, for a variety of small commercial shocks. It gave the value $\alpha = 40$.

no effect on the number of varieties, contrarily to creating a new firm. Based on long-term statistics on FDI, one third of total FDI is assumed to be greenfield.

Foreign owned firms are treated as domestic firms in all respects. The only difference is that the capital revenue goes back to the source country. By changing the number of firms, FDI may have an influence on productive efficiency. Nevertheless, it is worth emphasizing that FDI is not assumed to originate any technological spillover here. Although some empirical studies have shown that such spillovers may arise, they are not systematic nor robust enough to be taken into account in a model aimed at studying a large scope of trade policy shocks. However, for the sake of illustration, a simulation with technological spillover is presented below.

It is noteworthy, in addition, that product quality is assumed to depend only on the region of production. This contrasts for example with Petri (1997), who assumes that foreign affiliates produce the same quality as their parent company. In this framework, also adopted by Hanslow and *alii* (2000), and Lee and van der Mensbrugghe (2001), FDI liberalisation induces quality upgrading in developing countries, originating significant gains. Though interesting, this mechanism is not supported by robust enough empirical results.

Dynamic set-up

Adapting to a trade policy shock is neither immediate nor costless. Dynamics are thus useful, in order to be able to study the corresponding adjustment period, i.e. the short- and medium-run impacts. In addition, a number of effects are dynamic, in the sense that they are intrinsically linked to an accumulation or evolution process. Such effects are difficult to take into account in a static framework. They are mainly twofold: on the one hand, trade policy may modify the capital stock in the economy, through its impact on income or on the savings rate (see e.g. Baldwin, 1989); on the other hand, it may influence human capital and technology. Each of these two kinds of effects is likely to reach far higher orders of magnitude (for gains as well as for losses) than static effects, as evidenced for example by the results of Baldwin (1989, 1992) or of Francois, Mac Donald et Nordström (1995) concerning capital accumulation, and those of Baldwin and Forslid (1999) or of the World Bank (2001) as to introducing a technological externality linked to trade openness.

Now, empirical studies do not allow a definitive and robust conclusion to be reached about the existence of such growth effects (see e.g. Fontagné and Guérin, 1997, for a survey of this literature). In this context, a cautious approach is necessary, in order to prevent results from depending overwhelmingly on dubious (or at least not well-grounded) assumptions. This is why no technological externality linked to trade is introduced in MIRAGE, and why the savings rate is assumed to be constant over time in each region. Note, however, that capital accumulation is still influenced by income changes, that are proportionately transmitted to savings, and by the net balance of FDIs.

The model's dynamics is exclusively of a sequential nature: the equilibrium can be solved successively for each period. Time span can be freely chosen, usually around 15 to 20 years. Except for capital, the growth rate of production factors is set exogenously. The model does not consider any technical progress in the base case.

At each period, mobile factors adjust instantaneously (subject to the constraint of uniqueness of their unit cost in the economy), while capital stock only adjusts through investment. In imperfectly competitive sectors, the number of firms changes, according to the modalities described above. The model does not include any explicit adjustment cost. However, the sticky adjustment of capital stock and of the number of firms (i.e. of varieties) implies that the value of these sectoral variables is not necessarily optimal, and this may induce implicit adjustment costs.

3. AN ILLUSTRATION: ASSESSING THE IMPACT OF A TRADE LIBERALISATION BETWEEN THE EUROPEAN UNION AND ITS PERIPHERY

For the sake of illustration, this section assesses the impact of a trade liberalisation scheme between the EU and its periphery (defined as Central and Eastern European Countries, Maghreb countries, Turkey). 5 regions and 11 sectors are considered (see details in Annex 2), and the consequences of the agreement are studied within a 13-year time span. The initial levels of sectoral trade barriers (tariff equivalent of ad valorem duties, specific duties, tariffs quotas, prohibitions and antidumping duties) between the EU and its periphery, as measured by the *MAcMaps* database, are given in Table 1. The simulations are based on the assumption that those barriers are totally removed in four equal yearly steps. Four year after the agreement, there is thus free trade between the two regions.

Table 1: Initial level of trade barriers by sector between the EU and its periphery (%)

	EU's protection against its periphery	EU periphery's protection against EU
Agriculture and food products	12.8	21.4
Textile and clothing	9.6	8.0
Raw materials	1.5	4.3
Manufactured products	3.5	7.4
Motors and vehicles	2.9	17.0
Chemicals	3.3	5.0
Equipment	2.7	4.3

Source: *MAcMaps* database.

A first simulation is carried out using the standard version of MIRAGE, to underline the main mechanisms at work, and evaluate the impacts of such a trade agreement. So as to ascertain the relevance and the importance of the main modelling assumptions of the model, a sensitivity analysis is then carried out with respect to four key assumptions: product differentiation by quality, imperfect competition, foreign direct investment and the dynamic structure of the model.

Results using MIRAGE

The main impact of the trade barriers removal is the increase in the bilateral trade flows between the two partners (15.7% in volume towards the EU, 16.3% towards the periphery). The preferential access the two regions grant each other exerts, ex-ante, an upward pressure on the external demand they face. Under the assumption of quasi-stability of the current balance account (FDI excluded), this entails a real exchange rate appreciation in the two areas towards third regions (see Table 2). As a consequence, exports of the European Union and of its periphery to all the other regions decrease.

The preferential access following from the agreement also constitutes a relative handicap for third regions' exports toward both contracting economies' markets. As a matter of fact, almost all these exports decrease in volume, despite the real exchange rates changes, meaning that the competition effect dominates the real exchange rate effect. The agreement thus entails strong diversion effects. The competition effect suffered by exporters from third regions in the European and Periphery's markets is nevertheless not uniform. Its magnitude depends on the sensitivity to the competition exerted by producers benefiting from a preferential access, which in turn depends on the similarity in sectoral specialisation, but also in quality ranges. So the preferential access to the EU market granted to the periphery's producers is more penalising for other developing regions than for other industrialised countries, as the former are more direct competitors to the periphery's countries: their products are in the same quality range and therefore more easily substitutable. In contrast, European imports from other industrialised countries increase. For the same reasons, periphery's imports from that region are the most adversely affected. It is noteworthy that trade diversion effects are much bigger on the periphery's market than on the EU's one, as the EU is in relative terms a more important supplier to the periphery than the periphery is to the EU.

Table 2: Variations of the Real Effective Exchange Rate (%)

	t+1	t+5	t+10	t+13
Other Industrialised Countries	-0.01	-0.05	-0.05	-0.05
Europe	0.15	0.57	0.52	0.50
Developing Asia	-0.12	-0.50	-0.50	-0.49
European Periphery	-0.10	-0.17	0.01	0.04
Other Developing Countries	-0.09	-0.35	-0.31	-0.30

Source: authors calculations.

Note: the real effective exchange rate is the weighted average of the real exchange rates, weighted by trade flows. A positive variation means an appreciation.

At the sectoral level (see Table 3), the strongest effects are observed in the agricultural and agro-food sectors: bilateral trade flows in volume increase by 42% towards the periphery and by 37% to the EU [18] Generally speaking, the initial level of trade protection explains most of the sectoral pattern of bilateral trade changes; the increase of European vehicles exports to the periphery (+47%) is another example. However, the strong impact on the periphery's clothing exports to the EU comes not so much from the initial level of trade barriers (9.6%) than from the strong substitutability between products in that sector.

The periphery's clothing exports to the EU provide with a good illustration of the dynamic process of factors re-allocation. Five years after the end of the liberalisation period (so nine years after the first liberalisation), those exports are 53% higher than in the absence of liberalisation. Ten years after, the gap has risen to 68%, on account of the adjustment in capital stocks and in the number of firms. A significant part of the adjustment process comes late and is spread over a long time.

The macroeconomic impacts are of a low order of magnitude (see Table 3), because the initial protection levels between the EU and its periphery are low, and because the volume of trade flows is still moderate compared to the size of the regions, especially for the EU. The agreement entails some gains for the EU (with a rise in welfare of 0.09%), but also some losses for the periphery (where welfare does decrease by 0.01%).[19] Actually, as the EU is the main trading partner of the periphery, the bilateral liberalisation gives the latter a very inefficient protection structure, as that region grants strong preferential access to a large part of its imports. Such a protection structure creates negative distortions as it often leads to choosing the most favoured supplier, instead of the most efficient one. In that case, the consumer's gain is more than offset by the drop in tariff revenues collected by the government. Such a problem appears as soon as a liberalisation agreement increases the discrimination induced by protection, but it is of special importance for the periphery, given the EU's weight in its external trade, as witnessed by the sharp drop in tariff revenues (-1.2 GDP percentage points), but also by the importance of trade diversion effects.

[18] Unless otherwise indicated, the numbers given and discussed are the variations observed at the end of the time scope, that is 13 years after the agreement.

[19] At the same time, the real GDP of the periphery increases by 0.08%. The difference between real GDP and welfare changes stems from FDI. Profits of foreign firms operating in the periphery are taken into account when measuring the GDP. But as they are sent back to capital owners, they do not contribute to the region's welfare.

Table 3: Impact of a free trade agreement between the EU and its periphery, estimated with the standard version of MIRAGE (mainresults, in %)

Macroeconomic variables

	EU				EU periphery			
	t+1	t+5	t+10	t+13	t+1	t+5	t+10	t+13
Welfare	0.02	0.06	0.08	0.09	-0.00	-0.11	-0.04	-0.01
GDP (volume)	0.02	0.08	0.10	0.10	-0.01	-0.07	0.04	0.08
Terms of trade	0.12	0.51	0.48	0.47	-0.08	-0.21	-0.11	-0.09
Real effective exchange rate	0.14	0.57	0.52	0.50	-0.10	-0.17	0.01	0.04
Unskilled real wages	0.05	0.20	0.21	0.22	0.31	1.44	1.54	1.56
Skilled real wages	0.03	0.14	0.18	0.20	0.23	0.98	1.04	1.08
Real return to capital	0.04	0.13	0.10	0.08	0.29	1.26	1.17	1.12
Real return to natural resources	0.03	0.16	0.20	0.21	0.36	1.26	1.12	1.13
Real return to land	0.19	0.79	0.75	0.75	0.10	0.54	0.67	0.71
Exports (volume)	0.48	2.24	2.31	2.30	1.92	9.11	9.55	9.64
Imports (volume)	0.52	2.30	2.24	2.20	1.71	8.12	8.34	8.36
Inward FDI (volume)	0.22	0.92	0.69	0.58	1.03	5.45	5.15	4.93
Outward FDI (volume *)	-0.21	-0.61	-0.24	-0.08	-0.99	-4.27	-3.85	-3.66
Tariff revenue (points of GDP)	-0.02	-0.08	-0.08	-0.08	-0.28	-1.28	-1.25	-1.24

Bilateral external trade, for the whole economy (CIF value)

	EU					EU periphery				
	Initial level	t+1	t+5	t+10	t+13	Initial level	t+1	t+5	t+10	t+13
Exports to:										
Other Industrialised Countries	50.73	-0.20	-0.83	-0.79	-0.77	5.62	-0.12	-0.48	-0.46	-0.43
Europe						17.74	3.04	14.58	15.43	15.67
Developing Asia	11.91	-0.36	-1.61	-1.62	-1.59	1.67	-0.23	-1.64	-2.06	-2.08
European Periphery	20.69	3.38	15.67	16.20	16.32					
Other Developing Countries	20.29	-0.29	-1.14	-1.05	-1.03	2.41	-0.15	-0.74	-0.79	-0.79

	EU					EU periphery				
	Initial level	t+1	t+5	t+10	t+13	Initial level	t+1	t+5	t+10	t+13
Imports from:										
Other Industrialised Countries	48.92	0.23	0.94	0.89	0.87	6.37	-2.47	-9.42	-9.11	-9.06
Europe						20.69	3.38	15.67	16.20	16.32
Developing Asia	14.34	-0.61	-3.12	-3.38	-3.35	1.74	-0.13	-1.60	-2.42	-2.62
European Periphery	17.74	3.04	14.58	15.43	15.67					
Other Developing Countries	15.47	-0.34	-1.42	-1.44	-1.46	2.12	-0.35	-0.99	-0.58	-0.53

Bilateral external trade, by sector (volume)

	EU -> EU periphery					EU periphery -> EU				
	Initial level	t+1	t+5	t+10	t+13	Initial level	t+1	t+5	t+10	t+13
Agriculture and food products	1.860	8.43	41.75	42.63	42.80	0.942	8.34	38.39	37.50	37.38
Textile and clothing	1.831	5.31	22.54	21.47	21.25	2.555	9.00	53.74	65.26	68.31
Raw materials	0.939	2.48	10.53	10.93	11.09	4.754	1.06	4.10	3.74	3.66
Manufactured products	1.764	3.18	14.02	14.47	14.58	1.634	2.92	11.69	11.14	11.12
Motors and vehicles	1.951	9.21	44.99	47.27	47.49	0.796	4.62	15.95	12.85	12.89
Chemicals	3.686	1.87	8.23	8.71	8.83	2.048	2.43	9.70	9.33	9.33
Equipment	6.068	1.53	6.54	6.93	7.06	1.812	2.47	9.52	8.64	8.50
Houses	0.173	-0.33	-0.88	-0.48	-0.41	0.220	0.24	0.43	-0.02	-0.08
Transports	0.752	0.06	0.56	0.93	1.01	1.450	0.14	-0.09	-0.57	-0.62
Electricity, gas and water	0.138	0.12	0.95	1.41	1.50	0.151	0.24	0.11	-0.38	-0.41
Other services	1.532	0.02	0.45	0.86	0.94	1.383	0.13	-0.33	-0.90	-0.96

Production by sector (volume)

	EU					EU periphery				
	Initial level	t+1	t+5	t+10	t+13	Initial level	t+1	t+5	t+10	t+13
Agriculture and food products	121.60	0.08	0.53	0.59	0.59	33.44	-0.12	-0.62	-0.63	-0.61
Textile and clothing	30.00	-0.03	-0.42	-0.77	-0.83	10.91	1.57	13.16	18.04	19.08
Raw materials	42.22	-0.05	-0.31	-0.28	-0.25	24.97	0.04	0.07	-0.05	-0.06
Manufactured products	88.31	0.01	0.06	0.09	0.10	14.24	-0.02	-0.24	-0.37	-0.38
Motors and vehicles	60.15	0.21	1.49	1.68	1.62	6.00	-0.63	-5.01	-6.38	-6.39
Chemicals	121.50	0.00	0.02	0.06	0.07	21.06	-0.02	-0.13	-0.15	-0.12
Equipment	112.60	-0.01	-0.09	-0.07	-0.05	11.88	0.04	-0.25	-0.73	-0.84
Houses	140.30	0.01	0.04	0.04	0.04	21.58	-0.01	-0.06	-0.05	-0.04
Transports	238.00	-0.01	-0.06	-0.05	-0.04	38.91	-0.05	-0.35	-0.40	-0.39
Electricity, gas and water	23.65	-0.01	-0.05	-0.02	-0.01	11.39	-0.05	-0.37	-0.37	-0.35
Other services	520.70	-0.02	-0.08	-0.07	-0.06	52.89	-0.07	-0.48	-0.52	-0.52

Source: authors calculations.

Note: Impacts are measured as changes with respect to the base run, where trade policy is held unchanged. All changes are expressed in %, except tariff revenues, in GDP percentage points. For changes in value (bilateral trade), the numéraire is the average price index of world production. The initial levels are in tens of billions of 1997 US dollars.

Sensitivity to the assumption of a lower substitutability between quality ranges

So as to take into account quality ranges considerations, consumers preferences are modelled in MIRAGE by assuming that products coming from developed countries are more substitutable to each other than to products coming from developing economies. This assumption does constitute an innovation in CGE models and can have quite a strong impact on results, as substitution elasticities appearing in the utility function are amongst the most sensitive parameters when assessing the impacts of trade policies. In order to make clear what its influence is, alternative simulations are run doing away with this assumption.[20]

[20] In the alternative model, a level of the utility function is removed, the others remaining unchanged.

Table 4: Impact of the agreement on trade flows, with and without the assumption of a lower substitutability between quality ranges (%)

European Union trade

	Initial level	t+1 MIRAGE	t+1 Without qualities	t+5 MIRAGE	t+5 Without qualities	t+10 MIRAGE	t+10 Without qualities	t+13 MIRAGE	t+13 Without qualities
Exports to:									
Other Industrialised Countries	50.73	-0.20	-0.24	-0.83	-1.00	-0.79	-0.94	-0.77	-0.92
Developing Asia	11.91	-0.36	-0.29	-1.61	-1.34	-1.62	-1.34	-1.59	-1.30
European Periphery	20.69	3.38	4.23	15.67	20.16	16.20	21.07	16.32	21.35
Other Developing Countries	20.29	-0.29	-0.24	-1.14	-1.00	-1.05	-0.93	-1.03	-0.92
Imports from:									
Other Industrialised Countries	48.92	0.23	0.09	0.94	0.37	0.89	0.30	0.87	0.27
Developing Asia	14.34	-0.61	-0.21	-3.12	-1.41	-3.38	-1.62	-3.35	-1.58
European Periphery	17.74	3.04	3.85	14.58	18.73	15.43	19.97	15.67	20.31
Other Developing Countries	15.47	-0.34	-0.05	-1.42	-0.24	-1.44	-0.35	-1.46	-0.41

European Union's periphery trade

	Initial level	t+1 MIRAGE	t+1 Without qualities	t+5 MIRAGE	t+5 Without qualities	t+10 MIRAGE	t+10 Without qualities	t+13 MIRAGE	t+13 Without qualities
Exports to:									
Other Industrialised Countries	5.62	-0.12	0.17	-0.48	0.74	-0.46	0.83	-0.43	0.87
Europe	17.74	3.04	3.85	14.58	18.73	15.43	19.97	15.67	20.31
Developing Asia	1.67	-0.23	0.16	-1.64	0.01	-2.06	-0.55	-2.08	-0.64
Other Developing Countries	2.41	-0.15	0.24	-0.74	0.83	-0.79	0.59	-0.79	0.50
Imports from:									
Other Industrialised Countries	6.37	-2.47	-1.97	-9.42	-7.35	-9.11	-6.71	-9.06	-6.54
Europe	20.69	3.38	4.23	15.67	20.16	16.20	21.07	16.32	21.35
Developing Asia	1.74	-0.13	-1.69	-1.60	-7.67	-2.42	-8.16	-2.62	-8.21
Other Developing Countries	2.12	-0.35	-1.55	-0.99	-6.07	-0.58	-5.67	-0.53	-5.61

Source: authors calculations.

Note: Impacts are measured as changes with respect to the base run, where trade policy is held unchanged. All changes are in %. For changes in value (bilateral trade), the numéraire is the average price index of world production. The initial levels are in tens of billions of 1997 US dollars.

The most striking differences concern the two partners' trade patterns changes. As mentioned above, the impact of such a bilateral liberalisation can be split between a real exchange rate effect and a competition effect. The latter effect, favouring the contracting regions in their partner's market relatively to third regions, is significantly affected by the assumption of quality differentiation, that implies a higher degree of competition inside than across quality ranges. Without this assumption, the competition effect becomes much less geographically discriminatory, even though some differences persist, due to the different sectoral specialisation. Instead of being fully concentrated on the periphery's imports from the other industrialised countries, the ousting process now hits all non contracting regions. Given the specific specialisation of the other industrialised countries, their exports to the EU still increase, but not as much as before. Lifting out the quality differentiation assumption also entails stronger growth of bilateral trade flows between the two partners, because the substitutability between the goods they produce is then assumed to be higher than in the standard version.

At the macroeconomic level, the sensitivity of the quality differentiation assumption is lower. The welfare gains in the EU are unchanged. For the periphery, the loss in welfare does increase significantly under the alternative model (-0.15% versus -0.01% in the standard version): the higher discrimination resulting from the liberalisation has indeed stronger[21] impacts on trade under the alternative specification, thus increasing the corresponding drawbacks.

Sensitivity to imperfect competition

Since Krugman (1979) and Markusen (1981), the impact of trade policies under imperfect competition has been widely studied. So as to measure the importance of this assumption, results of the standard MIRAGE model are compared to those obtained when assuming that all sectors are perfectly competitive and have constant-returns-to-scale production functions. For the EU, macroeconomic impacts are unchanged, which can easily be explained by the fact that in a great region like the EU, the degree of competition is mainly defined by the rivalry between firms within the region, and should not be affected by a free-trade agreement with a small external region. Things are different for the periphery, where the internal market is smaller, and which liberalises trade with its main trading partner. For this region, the welfare loss reaches 0.28% under perfect competition. In other words, taking imperfect competition into account gives a less severe reading of the consequences for the periphery of the agreement.

Part of the differences stem from the pro-competitive effect of the agreement. Trade generally increases competition and diminishes firms' mark-ups. As MIRAGE takes into account the possibility for firms to set a market-specific price ("pricing to market"), this effect varies across markets (see Table 5). The increased market shares in the EU enables the periphery's firms to increase their mark-up rates. In contrast, their mark-up is reduced on their own markets, due to increased competition from EU firms, and this is a source of welfare gain for the region. When this results in a lower average mark-up for the region's firms (as is usually the case), it also entails, in the middle run, an increase in firms size, and therefore lowers production costs.

Nevertheless, the main impact of imperfect competition deals with the number of varieties produced[22] in each region. The agreement entails a rise in the production of several sectors (mostly those where the periphery has a comparative advantage towards the EU), resulting in an increase in each variety's output, but also in the number of varieties produced (see Table 6). When the initial number of varieties is quite high, each variety's output hardly

[21] Impacts are less contrasted across third regions, but bilateral trade creation is higher and trade diversion effects become stronger.

[22] Which is equivalent to the number of firms, as every firm produces only one good.

changes, and the bulk of the increase stems from the number of varieties. This is exemplified by the textile and clothing sectors, where the number of varieties increases by 18%. As consumers exhibit taste for variety, this increase in the number of varieties produced increases the periphery's markets share in the EU, but also in other markets.

Table 5: Impact on the European periphery's firms' mark-ups, by market (%)

	European Union	European Periphery	Other Industrialised Countries	Developing Asia	Other Developing Countries
Textile and clothing	0.017	-0.088	-0.003	-0.004	-0.003
Raw materials	0.026	-0.006	-0.003	-0.003	-0.004
Manufactured products	0.006	-0.003	0.000	0.000	0.000
Motors and vehicles	0.089	0.047	0.017	0.023	0.018
Chemicals	0.009	-0.007	0.000	0.000	0.000
Equipment	0.026	0.002	0.004	0.004	0.003
Houses	-0.002	0.001	-0.002	0.000	-0.001
Electricity, gas and water	-0.008	0.038	-0.010	-0.001	0.001
Other services	-0.004	0.047	-0.003	0.000	0.000

Source: authors calculations.

Table 6: Impact on the number of varieties produced in the European periphery (%)

	t+1	t+5	t+10	t+13
Textile and clothing	0.79	10.52	16.73	18.00
Raw materials	-0.01	-0.08	-0.15	-0.16
Manufactured products	-0.02	-0.27	-0.43	-0.44
Motors and vehicles	-0.21	-3.57	-5.90	-6.27
Chemicals	-0.01	-0.11	-0.16	-0.15
Equipment	-0.04	-0.49	-0.92	-1.02
Houses	0.00	-0.03	-0.03	-0.02
Electricity, gas and water	-0.01	-0.12	-0.20	-0.21
Other services	-0.03	-0.28	-0.37	-0.37

Source: authors calculations.

So as to better isolate the effects directly linked to the evolution in the number of varieties produced, another simulation was run keeping unchanged the number of firms by sector (see Table 7). An output increase is then only met by an increase in the production of each individual variety, inducing new economies of scale. The involved increased profits give incentives to invest in that sector, whose capital stock then increases. The marginal cost and the selling price decrease, strengthening the exports increase. This phenomena is important enough to offset partly the terms of trade decline observed under perfect competition. The real effective exchange rate even slightly appreciates. That said, the welfare loss remains significantly higher (0.12%) than under the standard version of MIRAGE, illustrating the importance of the gains linked to the increase in the number of varieties.

Table 7: Impact of the agreement on the main macro-economic variables, for different specifications (%)

Part A: European Union

EU

	MIRAGE	Without qualities	PC	Without FDI	K Mobile	Fixed nb of firms	Ext'ty FDI	MIRAGE	Without qualities	PC	Without FDI	K Mobile	Fixed nb of firms	Ext'ty FDI	MIRAGE	Without qualities	PC	Without FDI	K Mobile	Fixed nb of firms	Ext'ty FDI
	t+1							**t+5**							**t+13**						
Welfare	0.016	0.015	0.019	0.016	0.015	0.015	0.016	0.061	0.057	0.078	0.066	0.063	0.054	0.103	0.087	0.086	0.094	0.084	0.086	0.077	0.248
GDP (volume)	0.019	0.019	0.022	0.017	0.017	0.018	0.019	0.077	0.078	0.095	0.068	0.076	0.070	0.124	0.104	0.111	0.112	0.085	0.101	0.096	0.286
Terms of trade	0.125	0.119	0.142	0.119	0.126	0.126	0.127	0.512	0.487	0.610	0.510	0.510	0.525	0.552	0.473	0.446	0.583	0.502	0.478	0.483	0.453
Real effective exchange rate	0.145	0.142	0.163	0.139	0.126	0.147	0.148	0.570	0.560	0.683	0.573	0.510	0.583	0.599	0.500	0.476	0.637	0.535	0.478	0.495	0.456
Unskilled real wages	0.047	0.047	0.052	0.046	0.043	0.049	0.047	0.196	0.195	0.225	0.187	0.202	0.203	0.236	0.223	0.227	0.237	0.204	0.223	0.216	0.398
Skilled real wages	0.031	0.030	0.033	0.030	0.030	0.033	0.031	0.144	0.146	0.158	0.132	0.150	0.163	0.188	0.199	0.223	0.199	0.162	0.195	0.209	0.421
Real return to capital	0.038	0.037	0.040	0.035	0.036	0.039	0.038	0.133	0.131	0.154	0.140	0.137	0.150	0.165	0.084	0.073	0.108	0.115	0.092	0.099	0.108
Real return to natural resources	0.032	0.013	0.038	0.035	0.027	0.040	0.031	0.163	0.092	0.192	0.159	0.183	0.258	0.184	0.215	0.194	0.211	0.179	0.216	0.335	0.432
Real return to land	0.192	0.208	0.191	0.195	0.155	0.192	0.192	0.790	0.940	0.788	0.812	0.749	0.782	0.845	0.745	0.929	0.732	0.760	0.745	0.719	0.931
Exports (volume)	0.475	0.647	0.460	0.483	0.495	0.474	0.471	2.245	3.164	2.109	2.198	2.301	2.211	2.274	2.298	3.381	2.118	2.188	2.288	2.265	2.467
Imports (volume)	0.522	0.710	0.493	0.510	0.538	0.519	0.527	2.304	3.254	2.124	2.306	2.348	2.271	2.446	2.198	3.258	2.043	2.265	2.207	2.161	2.278
Tariff revenue (points of GDP)	-0.017	-0.016	-0.017	-0.017	-0.017	-0.017	-0.017	-0.083	-0.083	-0.080	-0.084	-0.085	-0.083	-0.083	-0.081	-0.083	-0.080	-0.081	-0.081	-0.081	-0.075

Part B: Periphery of the European Union

EU's periphery

	MIRAGE	Without qualities	PC	Without FDI	K Mobile	Fixed nb of firms	Ext'ty FDI	MIRAGE	Without qualities	PC	Without FDI	K Mobile	Fixed nb of firms	Ext'ty FDI	MIRAGE	Without qualities	PC	Without FDI	K Mobile	Fixed nb of firms	Ext'ty FDI
	t+1							**t+5**							**t+13**						
Welfare	-0.005	-0.013	-0.015	-0.011	0.016	-0.008	-0.006	-0.110	-0.174	-0.268	-0.138	-0.079	-0.155	0.264	-0.012	-0.146	-0.279	-0.078	-0.028	-0.117	0.952
GDP (volume)	-0.013	-0.025	-0.021	-0.022	0.006	-0.016	-0.014	-0.074	-0.150	-0.200	-0.149	-0.039	-0.110	0.214	0.076	-0.056	-0.144	-0.099	0.068	-0.020	0.893
Terms of trade	-0.080	-0.175	-0.131	-0.096	-0.033	-0.091	-0.084	-0.214	-0.621	-0.679	-0.317	-0.087	-0.338	-0.148	-0.092	-0.496	-0.742	-0.181	-0.088	-0.265	0.137
Real effective exchange rate	-0.101	-0.207	-0.171	-0.120	-0.033	-0.115	-0.106	-0.174	-0.607	-0.780	-0.280	-0.087	-0.294	0.007	0.036	-0.332	-0.783	-0.048	-0.088	-0.090	0.388
Unskilled real wages	0.305	0.267	0.282	0.298	0.330	0.299	0.300	1.445	1.331	1.233	1.388	1.493	1.371	1.696	1.562	1.410	1.267	1.404	1.550	1.451	2.290
Skilled real wages	0.225	0.228	0.202	0.221	0.210	0.235	0.222	0.976	0.964	0.856	0.908	0.924	1.092	1.178	1.079	0.889	0.946	0.839	1.047	1.212	1.799
Real return to capital	0.290	0.274	0.277	0.282	0.307	0.289	0.286	1.255	1.271	1.132	1.279	1.278	1.245	1.443	1.125	1.259	0.984	1.288	1.134	1.166	1.422
Real return to natural resources	0.365	0.473	0.405	0.387	0.218	0.380	0.367	1.262	1.726	1.748	1.328	0.929	1.404	1.086	1.127	1.350	1.779	1.051	1.078	1.321	1.067
Real return to land	0.098	-0.111	0.108	0.098	0.133	0.096	0.091	0.543	-0.446	0.575	0.512	0.602	0.522	0.709	0.714	-0.381	0.671	0.606	0.713	0.649	1.340
Exports (volume)	1.916	2.549	1.701	1.955	2.038	1.901	1.917	9.115	12.259	7.842	9.245	9.488	8.949	9.397	9.645	13.027	8.033	9.544	9.678	9.459	10.440
Imports (volume)	1.710	2.205	1.536	1.665	1.838	1.698	1.705	8.123	10.776	6.964	7.876	8.442	8.016	8.496	8.359	11.357	6.921	8.134	8.376	8.211	9.123
Tariff revenue (points of GDP)	-0.277	-0.267	-0.280	-0.278	-0.275	-0.277	-0.274	-1.280	-1.293	-1.311	-1.297	-1.280	-1.279	-1.211	-1.235	-1.245	-1.294	-1.255	-1.237	-1.231	-1.075

Source: authors calculations.

Note: column titles indicate which model specification was used, i.e. which modification was made to the standard version of MIRAGE. « Without qualities »: without the assumption of a lower substitutability between quality ranges; 'PC': perfect competition; 'K mobile': perfect mobility of capital between sectors; 'Without FDI': without taking FDI into account; 'Fixed nb of firms': fixed number of firms; 'Ext'ty FDI': under the assumption of a technological externality induced by FDI.

Sensitivity to foreign direct investment

Not considering FDIs mainly makes a difference for the EU's periphery (see Table 7), where the welfare loss reaches 0.08%, against 0.01% in the standard version. The impact of the agreement on FDIs is thus a source of gain for this region. The effects induced by FDIs in MIRAGE are linked to their impact on capital stocks and on the numbers of firms. As the trade agreement increases capital profitability in the periphery, it raises FDIs entering this region. This in turn entails a faster capital accumulation in the region, boosting GDP growth. The effect on welfare is less noticeable as FDIs profits fly back to capital owners, but it is still significant.

As discussed above, MIRAGE assumes that FDIs does not give rise to any additional effect on technology, contrarily to what is assumed in several other applied studies. In order to ascertain the importance of this assumption, an alternative simulation was run assuming that total factor productivity (TFP) at the sectoral level grew in line with the share of FDIs in total investment, with an elasticity of 5%.[23] Such an assumption results in welfare gains reaching almost 1% in the EU's periphery (compared to -0.01% using the standard version). This shows that such a technological spillover assumption is overwhelming in shaping assessed welfare gains. As trade liberalisation most often implies a rise in FDIs, such an assumption would thus lead to give a systematically positive assessment of their welfare impact, because it would be assumed to enhance production technologies. Such an assumption is thus problematic, as long as it is not based on a systematic and robust evidence. The same comments apply to another standard hypothesis in the literature (see for example World Bank, 2001, or Rutherford and Tarr, 2002), according to which trade flows bear a technological externality.

Sensitivity to the dynamic structure

The sequential dynamics of the model and the stickiness assumptions (installed capital is sector specific) imply that the return to capital may differ across sectors after a shock. In addition, the adjustment to a trade policy shock is not instantaneous, because some span of time is necessary for capital stocks to adapt to the new economic conditions. This is illustrated by the welfare impact curbs (see Graph 1), the evolutions of which persist long after the liberalisation is carried out.

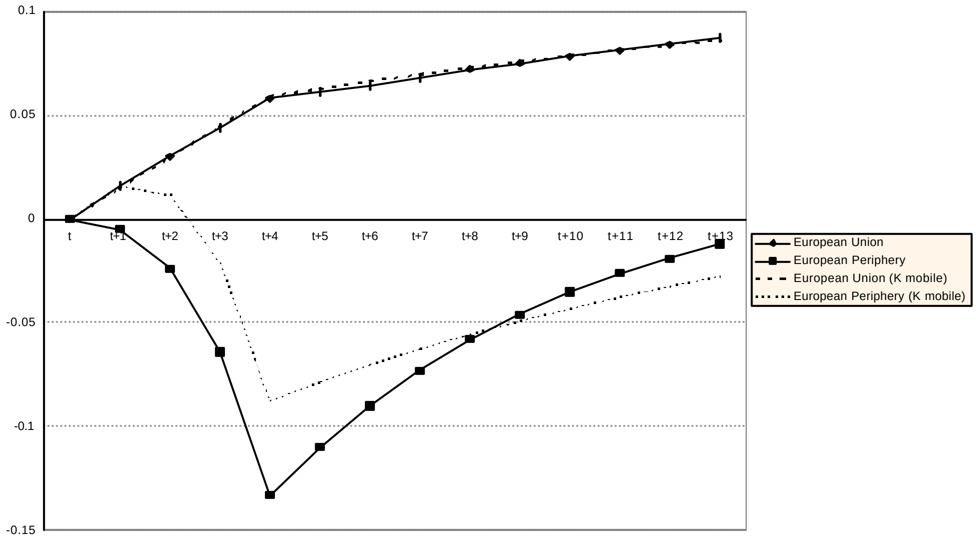
As a comparison, a simulation is run, assuming that capital is perfectly mobile between sectors. Investment follows the same logic as before but is not allocated to a specific sector. It increases the capital stocks of each region, and it is split across sectors under the constraint of cross-sector equality of rates of return.

Under this alternative specification, the effects of the free trade agreement appear faster; however, in the long run, this does not make any significant difference. This results from the high value of the elasticity of investors' allocation choices to the rate of return to

[23] So, if inward FDI amounts to 10% of total investment, TFP increases by 0.5% relatively to last year.

capital. This high degree of reactivity contributes to a quick equalisation of rates of return. As no explicit adjustment costs are accounted for, apart from the sub-optimality of capital stock allocation, this explains why the adjustment period has a limited impact in the long run.

Graph 1: Impact on welfare in the EU and its periphery (%)



Source: authors calculations.

4. CONCLUSION

The MIRAGE model makes a synthesis of the main recent developments of CGE models applied to trade policy analysis, and it proposes several innovations. It describes competition imperfections, horizontal product differentiation, delays and costs of adjustment. It introduces a notion of product quality, in order to improve the analysis of competition, and of trade diversion when necessary. It proposes an explicit, consistent and realistic description of FDIs. Lastly, it is based on a very detailed and complete measure of trade barriers. The simulations presented in this working paper illustrate the importance of these main choices in shaping the assessed impact of a liberalisation shock. However, the model has been conceived for a variety of applications, the specificities of which may call for modifications, additions or subtractions, to the database as well as to the specification of the model.

A number of further developments would be useful, in the near future:

- the description of quality is rudimentary. More in-depth work would help taking advantage of the empirical studies about vertical product differentiation in trade and country specialisation along quality ranges;

- FDIs modelling received special attention, in order to combine theoretical and empirical consistency. It is an important step, but it would be worth trying to incorporate in the model some recent developments of the multinational firm theory (e.g. Markusen et Venables, 2000);

- the same structural model is applied to each economy. Doing otherwise would be difficult, in a world-wide model devoted to varied applications. Nonetheless, this is a very strong hypothesis, and it could be worth using a different model, in particular for developing countries;

- agriculture is modelled in the same way as industrial sectors. Even though the model is not specifically designed for studying agricultural trade policies, a more realistic description of this sector, and of the support policies therein, would be useful.

This list is far from exhaustive, given the wide variety of trade policy topics and of the methodological problems they raise. MIRAGE aims at constituting an efficient tool devoted to the quantitative analysis of trade policy shocks, taking into account in a satisfactory and robust way their main systematic transmission channels, in order to enlighten the public debate, as well as policy makers. Doubts are frequently expressed as to the adequacy of CGE models to such objectives, this kind of model being accused of providing an oversimplified, if not oriented, vision of the economies, and in particular of the consequences of a trade liberalisation. But a model is no more than the quantified expression of a number of well-identified, robust mechanisms. The relevant point is about the way it is used. CGE models simulations are not an ending point, that would give a definitive answer to the question of the impact of a given trade policy decision. It is on the contrary a starting point making it possible, based on (often complex) protection scheme changes, to deliver a synthetic numbering of their main impacts. The interpretation then requires a well-suited analysis, taking into account the problems tackled, and the important mechanisms not included in the model.

This is the reason why the choices made in conceiving MIRAGE were guided by the willingness to take into account only those mechanisms that proved to be robust and systematic. This cautious choice allows the simulation results to be considered as a solid working basis, the ins and outs of which are well identified.

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ANNEX 1: DATA SOURCES

The GTAP 5 database (see Dimaranan and MacDougall, 2002) is used for data concerning output, value added, factor split, intermediate inputs, consumption goods, trade (fob and cif prices and transport. GTAP 5.2 allows to work with up to 5 production factors, 57 sectors and 76 geographical areas. The data are in value (US $), the reference year is 1997.

Investment data are built mainly based on the United Nations' World Investment Directory. These data suffer from numerous gaps. When the information about the cross-sector distribution is unavailable, the foreign-owned capital stocks are assumed to be proportionate to total capital stocks. Initial flows are then assumed to be equal to 15% of stocks.[24]

Demographic evolution forecasts are taken from the United Nations' Yearbooks.

The *MAcMaps* database (see Bouët *et al*., 2002) is used for protection.[25] As these data are different from GTAP5's ones, it requires an adjustment of the database. Indeed, for example, increasing tariff duties raises the value including taxes of the three types of consumptions. Concerning capital goods and consumption goods, this does not introduce any imbalance, since the corresponding tax revenue flies back to the regional representative agent. For intermediate consumption, however, this results in an increased value of product. The re-balancing is obtained by affecting the output in excess to final consumption. Generally speaking, imported intermediate consumptions are a small part of total intermediate consumptions, and the tariff changes are small, resulting in a weak impact on final consumption (seldom exceeding 2 to 3%).

The depreciation rate of capital is set to 4%. Demographic growth is assumed to be zero in the North, 1.5% in the South, for skilled as well as for unskilled labour.

MIRAGE is written using GAMS (*General Algebraic Modelling System*).

[24] Except for the EU, where this ratio was assumed to be 10% (except for raw materials, 3%).

[25] Except services, that are not available in *MAcMaps*, for which protection data is from GTAP.

ANNEX 2: AGGREGATION CHOICES FOR THE SIMULATIONS PRESENTED

Table A2.1: Sectoral aggregation

Mirage Nomenclature	Type of competition	Type of adjustment
Agriculture and food products	Perfect competition	-
Raw materials	Imperfect competition	fragmented
Textile and clothing	Imperfect competition	fragmented
Motors and vehicles	Imperfect competition	segmented
Chemicals	Imperfect competition	segmented
Equipment	Imperfect competition	fragmented
Other manufactured products	Imperfect competition	fragmented
Electricity, gas and water	Imperfect competition	segmented
Houses	Imperfect competition	fragmented
Transports	Perfect competition	-
Other services	Imperfect competition	fragmented

Table A2.2: Geographical aggregation

Region	*Mirage* Nomenclature	Level of development	Share in the World GDP in 1997 (%) *
Europe	EUR	North	29,2
European Periphery	PER	South	4,4
Other Industrialised Countries	RPI	North	50,3
Developing Asia	AED	South	6,4
Other Developing Countries	AFA	South	9,7

* Source: GTAP5 database.

Regions' composition:

Europe: EU and EFTA (Norway, Switzerland, Iceland and Liechtenstein).

European Periphery: Central Europe Free-Trade Agreement (Poland, Hungary, Czech Republic, Slovakia, Romania, Slovenia, Bulgaria), FSU countries, North-Africa (Turkey, Morocco, Algeria, Tunisia, Egypt, Libya).

Other Industrialised Countries: NAFTA, Australia, New-Zealand, Japan, South Korea, Hong-Kong, Taiwan, Singapore.

Developing Asia: other Asian countries.

Other Developing Countries: other African and South-American countries.

ANNEX 3: A NEW CALIBRATION PROCEDURE UNDER IMPERFECT COMPETITION

As soon as the theoretical structure of the model is defined, assuming the benchmark data to correspond to an equilibrium imposes some constraints on the parameters. While a number of parameters can be freely chosen, others have in contrast to be drawn from these constraints: this is the role of the calibration procedure. In each case, this procedure is in particular used to set the values of the share parameters of the model's utility and production functions. This is rather standard and straightforward, and it is done in MIRAGE in static fashion for the benchmark equilibrium, on the basis of GTAP5 database.

However, departing from the pure neoclassical framework raises less clear-cut issues for calibration. In particular, horizontal product differentiation, economies of scale and imperfect competition need to be adequately parameterized. This requires choosing, for each sector, three parameters:

- *The elasticity of substitution between goods*. In fact, as soon as a nested sectoral subutility function is used, various such elasticities need to be chosen, at least the "Armington elasticity", describing substitutability between geographical origins, and the "Dixit-Stiglitz elasticity", for the substitutability between varieties. In MIRAGE, two more elasticities are introduced, between the two quality ranges (goods from a low-income and from a high-income area), and between domestic and foreign goods. Nevertheless, these elasticities cannot be chosen independently one from another. Most of the time, only one degree of freedom is used for the choice of elasticities of substitution between goods for each sector. This means that, if there are various elasticities, choosing one of them is enough to set all the elasticities for the sector. This is in particular the case in MIRAGE, where a linear relationship is assumed to hold between the various elasticities used for a given sector (see Figure 1);

- The parameter characterizing *economies of scale* can be the scale elasticity, the cost-disadvantage ratio, or the unit fixed cost, depending on the form of the production or cost function. Under the zero-profit assumption, the mark-up ratio can be used as the primary information, as it is univocally linked to the cost-disadvantage ratio;

- *Competition intensity* has to be characterized through the degree of concentration (generally measured by an Herfindhal index), or by an equivalent number of symmetric firms. Note, however, that a given sector in the database can include various competition fields (that is the firms/products that are indeed directly in competition with each other), often named subsectors.

No information can be inferred directly from the data about the three corresponding sets of parameters, but the zero-profit assumption made in the benchmark provides a consistency constraint to be respected in their choice. This constraint has been used so far to calibrate one of these three sets of parameters. For instance, Smith, Venables and Gasiorek (1992) use scale elasticities and equivalent numbers of firms to calibrate elasticities of substitution. Mercenier (1992) uses elasticities of substitution and equivalent numbers of firms to calibrate the fixed costs. Cortes and Jean (1996) calibrate the equivalent number of firms, based on the values of elasticities of substitution and of mark-ups. Even though sectoral classifications do not overlap exactly, the results obtained are significantly different, even for similar sectors.

As illustrated by the diversity of methods used, some information is available on each of the three sets of parameters. Given their feeling about the relative reliability of the information on the corresponding parameters, the authors decide, for each sector, to use directly this information for two of them, in order to calibrate the third one. This approach is not fully consistent: the available information is only used for two out of three sets of parameters, and it is ignored for the third one. The consistency of the results is only assessed ex-post, through the credibility of the results obtained for the calibrated parameter. Moreover, there is no place for taking into account the information possibly available about the variance of the estimates used for the parameters.

Our approach here is to use all the available information, both on the level of the parameters and on the reliability of the estimates, for the three sets of parameters. This information is interpreted in terms of estimates of the parameters and of variance of these estimates. For each sector, the values to be used in the model are then chosen so as to minimize the distance from these estimates, weighted by the inverted variance of the logarithm of estimates, subject to the consistency constraint given by the zero-profit assumption:

$$\{s_i, CDR_i, n_i\} = \underset{s_i, CDR_i, n_i}{ArgMin}\left\{ \frac{1}{V(\ln \hat{s}_i)}\left(\ln\left(\frac{s_i}{\hat{s}_i}\right)\right)^2 + \frac{1}{V(\ln \hat{CDR}_i)}\left(\ln\left(\frac{CDR_i}{\hat{CDR}_i}\right)\right)^2 + \frac{1}{V(\ln \hat{n}_i)}\left(\ln\left(\frac{n_i}{\hat{n}_i}\right)\right)^2 \right\} \quad \text{(A.1)}$$

$$s.t. \begin{cases} s_i > 1,\ CDR_i > 0,\ n_i > 1 \\ p_i(s_i, CDR_i, n_i) = 0 \end{cases}$$

where, for sector i, ó is the Armington elasticity of substitution, CDR is the cost-disadvantage ratio, and n refers to the number of (symmetric) firms. A hat denotes an estimate, and V refers to the variance. The constraint is the zero-profit condition which, given the benchmark database (and the relationships between the various types of elasticities within each sector), depends only on these three parameters, according to the model.

Note that this general procedure includes those used previously: calibrating one out of the three parameters is equivalent to setting an infinite variance for the estimate of the calibrated parameter in (A.1).

The initial and calibrated values of elasticities, mark-up ratios and equivalent numbers of firms for the base year are presented in Table A3.1. Data sources are the following:

(i) *Elasticities of substitution*: The sectoral subutility function used in MIRAGE is a nesting of four constant elasticity of substitution (CES) functions. In this study, Armington elasticities are drawn from GTAP5 database,[26] and are assumed to be the same across regions. The other elasticities used in the nesting for a given sector are linked to the Armington elasticity by a simple rule: the distance to unity (ó-1) is divided by the square root of two when moving upward in the nesting and is multiplied by the square root of two when moving downward. Finally, the elasticity of substitution in the LES-CES function is set at 0.6.

[26] The only exception is the textile and clothing sector. As North-South trade is dominant in this sector, the GTAP5 Armington elasticity was assumed to reflect the substitutability between quality ranges, rather than between countries within a quality range.

(ii) *Mark-up ratios*: As outlined above, the cost-disadvantage ratio can be found directly from the mark-up ratio, using the zero-profit condition. Mark-up ratios are therefore taken as the source data here, because an extensive literature has lead to robust and precise estimates. The values chosen are based on estimates by Oliveira-Martins and Scarpetta (1999) for industrial sectors, and by Oliveira-Martins, Pilat and Scarpetta (1996) for service sectors, using Werner's (1995) method in both cases. Given the geographical aggregation used here, the European values are used for high-income areas, and the difference between the mark-up ratio and unity is multiplied by 1.5 for low-income countries.

(iii) *Concentration*: At first glance, concentration, or the number of firms, may seem to be the easiest parameter to assess among the three necessary here, since industrial statistics by size category are available. Assuming that firms are symmetric within each size category (except for the upper one, where for instance a Pareto distribution can be postulated, as in Gasiorek, Smith and Venables, 1992) is a priori likely to provide a rather good estimate of the Herfindhal index for the sector. But the real problem is elsewhere: a sector is not necessarily a competition field. Generally speaking, the sectoral breakdown used in CGE models implies obviously that firms are not all direct competitors to each other within a sector. A sector thus includes various competition fields, but it is very difficult to evaluate how many. As a consequence, sectors are generally divided in subsectors on a rather ad-hoc basis. This is indeed what is done here, by assuming that a competition field has the same size whatever the sector. The estimates by Davies and Lyons (1996) was thus used as a first estimate for the number of firms by sector in Europe. The number of subsectors within each sector was then assessed in order to average 5, and 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 of the number of firms, divided by the number of subsectors.[27] The number of firms in other areas is then assumed to be the same than in Europe.

The log-variance of estimates should ideally be drawn directly from an econometric study. However, this information is not always available. Here, the values used (superior for the number of firms than for the two other parameters) reflect mainly the idea that the numbers of firms have the most uncertain estimates, due to the difficulty in assessing the number of subsectors.

[27] This is very similar, for example to the procedure used by Smith and Venables (1988), but the way it is done here does not make it necessary to model explicitly subsectors: the average firm size in a sector in "artificially" multiplied by the number of subsectors, but this does not modify the results.

Table A3.1: Sectoral parameters

Sector	Armington elasticities	Equivalent number of firms					Average mark-up ratio				
		Other ind'd countries	UE	Dev'g Asia.	EU's periphery	Other dev'g countries	Other ind'd countries	UE	Dev'g Asia.	EU's periphery	Other dev'g countries
Agriculture & food prod.	2.30	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Textile and clothing	4.54	27.4	7.4	23.4	11.2	6.1	1.083	1.083	1.087	1.084	1.083
Raw materials	4.06	433.7	195.4	485.6	123.8	317.5	1.098	1.098	1.103	1.114	1.140
Other manuf. products	3.27	106.9	109.3	152.3	88.0	127.1	1.117	1.124	1.125	1.119	1.116
Motors and vehicles	4.09	51.7	48.5	55.9	45.6	51.8	1.162	1.163	1.134	1.130	1.121
Chemicals	3.95	29.0	46.7	27.9	40.6	62.1	1.096	1.100	1.096	1.095	1.095
Equipment	4.19	11.5	17.7	10.5	11.3	27.9	1.175	1.187	1.164	1.133	1.123
Houses	4.55	22.1	8.7	15.1	16.8	12.6	1.109	1.110	1.106	1.109	1.105
Transports	4.35	3.9	4.2	2.9	3.8	3.9	1.142	1.179	1.162	1.167	1.157
Electricity, gas and water	4.45	26.2	42.8	28.4	57.6	40.4	1.184	1.183	1.177	1.174	1.171
Other services	1.90	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Source: authors' calculations, based on the references cited in the text.

Note: « n.d. » stands for not defined.

ANNEX 4: EQUATIONS OF THE MIRAGE MODEL

A. Notations

The i and j indices refer to sectors, r and s refer to regions, t to periods.

B. Parameters definition

σ_{VAj}, σ_{CAPj}, σ_C, σ_{IC}, σ_{KG}, σ_{GEOi}, σ_{ARMi}, σ_{IMPi}, σ_{VARi}	Elasticities of substitution in production functions, utility functions, intermediate consumption demand functions, and capital good demand functions.
$cmin_{i,r}$	Minimal consumption of good i in the utility function of region r
$share_r$	Share of minimal consumption in the total final consumption of region r
epa_r	Saving rate in region r
$\mu_{i,r,s}$	Transport demand per volume
θ_r	Value share of region r transport sector in the world production of transport
a_T	Cobb-Douglas scale coefficient of the transport of commodities sector
$taxp_{i,r}$ $taxexp_{i,r,s}$ $taxcc_{i,s}$ $taxicc_{i,s}$ $taxkgc_{i,s}$	Tax rate applied on production, export, final consumption, intermediate consumption and capital good.
$DD_{i,r,s,t}$	Ad-valorem tariff rate applied by region s on its imports from region r
$cf_{j,r}$	Fixed cost per unit of output in imperfectly competitive sectors
$mmoy_{i,r}$	Mark-up average
α	Elasticity of investment to capital return rate
δ	Depreciation rate of capital

C. Variables definition

Price	The generic notation « P_var » is used to indicate the price of the variable « var »
Production	
$Y_{j,r,t}$	Output of sector j firms
$VA_{j,r,t}$	Value added
$CNTER_{j,r,t}$	Aggregate intermediate consumption
$Q_{j,r,t}$	Aggregate human capital and physic capital used in sector j
$L_{j,r,t}$	Unskilled labour used in sector j
$TE_{j,r,t}$	Land used in sector j
$RN_{j,r,t}$	Natural resources used in sector j
$H_{j,r,t}$	Skilled labour used in sector j
$K_{j,r,s,t}$	Capital stock originating from region s, used in sector j of region r
$KTOT_{j,r,t}$	Total capital stock used in sector j of region r

Factors	
$Lbar_{r,t}$, $TEbar_{r,t}$, $Hbar_{r,t}$	Total supply of unskilled labour land and skilled labour
Investment	
$INV_{i,s,r,t}$	Investment, originating from region s, in region r
$WK_{i,r,t}$	Capital return rate in sector i of region r
$INVTOT_{r,t}$	Total Investment in region r
$B_{r,t}$	Adjustment variable between saving and investment
Demand	
$BUDC_{r,t}$	Budget allocated to consumption
$PROFIT_{i,r,t}$	Profit
$SOLD_{r,t}$	Current account balance
$UT_{r,t}$	Utility
$P_{r,t}$	Price of utility
$C_{i,r,t}$	Aggregated consumption of good i in region r
$DEMTot_{i,r,t}$	Total demand of good i in region r
$DEMU_{i,r,t}$	Total demand, in region r, of good i originating from regions with the same development level than region r (including region r)
$DEMV_{i,r,t}$	Total demand, in region r, of good i originating from regions with a different development level than region r
$DEMETR_{i,r,t}$	Total demand, in region r, of good i originating from regions with the same development level than region r other than region r
$DEM_{i,r,s,t}$	Demand, in region s, of good i originating from region r
$DEMVAR_{i,r,s,t}$	Demand, in region s, of good i produced in region industry i r firm's
$IC_{i,j,r,t}$	Intermediate consumption of good i used in the production of sector j in region r
$KG_{i,r,t}$	Capital good demand of good i in region r
Transport	
$TRADE_{i,r,s,t}$	Exports to region s, of industry i in region r
$TR_{i,r,s,t}$	Transport demand
$MONDTR_{t}$	Transport aggregate
PT_{t}	Transport of commodities price
$TRM_{r,t}$	Supply of international transportation by region r
Monopolistic competition	
$EP_{i,r,s,t}$	Perceived price-elasticity of total demand
$NB_{i,r,t}$	Number of varieties (=1 for perfectly competitive sectors)
$SE_{i,r,s,t}$, $SU_{i,r,s,t}$, $SV_{i,r,s,t}$, $Sh_{i,r,s,t}$	Auxiliary variables corresponding to market share
Tax Revenue	
$RECPROD_{i,r,t}$, $RECDD_{i,r,t}$,	Revenue of[28] production tax, tariff, consumption tax, exports tax

[28] Tax revenues can be negative (expenditure), because tax rates can be negative (subsidies).

$RECCONS_{i,r,t}$, $RECEXP_{i,r,t}$	
$RQUOTA_{r,s,t}$	Implicit transfers due to quotas
$REV_{r,t}$	Regional revenue

Price

$PCIF_{i,r,s,t}$	CIF price

D. Equations of the model

Supply

Leontieff relation between value added and intermediate consumption:

$$NB_{i,r,t}\,(Y_{i,r,t} + cf_{i,r}) = aVA_{i,r}\,VA_{i,r,t} = aCNTER_{i,r}\,CNTER_{i,r,t}$$

$$NB_{i,r,t}\,PY_{i,r,t}\,(Y_{i,r,t} + cf_{i,r}) = PVA_{i,r,t}\,VA_{i,r,t} + PCNTER_{i,r,t}\,CNTER_{i,r,t}$$

Determination of factors demand by producers results from the following optimisation programs:

$$Min\ \ PVA_{i,r,t}VA_{i,r,t} = PL_{i,r,t}L_{i,r,t} + PTE_{i,r,t}TE_{i,r,t} + PRN_{i,r,t}RN_{i,r,t} + PQ_{i,r,t}Q_{i,r,t}$$

s.t.: $$VA_{i,r,t}^{1-\frac{1}{s_{VA_i}}} = a_{L\,i}L_{i,r,t}^{1-\frac{1}{s_{VA_i}}} + a_{Q\,i,r}\,Q_{i,r,t}^{1-\frac{1}{s_{VA_i}}} + a_{RN\,i,r}\,RN_{i,r,t}^{1-\frac{1}{s_{VA_i}}} + a_{TE\,i,r}\,TE_{i,r,t}^{1-\frac{1}{s_{VA_i}}}$$

and

$$Min\ \ PQ_{i,r,t}\,Q_{i,r,t} = PK_{i,r,t}\,KTOT_{i,r,t} + PH_{i,r,t}\,H_{i,r,t}$$

s.t.: $$Q_{i,r,t}^{1-\frac{1}{s_{CAP_i}}} = a_{K\,i,r}KTOT_{i,r,t}^{1-\frac{1}{s_{CAP_i}}} + a_{H\,i,r}H_{i,r,t}^{1-\frac{1}{s_{CAP_i}}}$$

The capital stock in region s is described by: $KTOT_{i,s,t} = \sum_r K_{i,r,s,t}$

Demand

LES-CES (first stage)

$$C_{i,r,t}\text{-}cmin_{i,r} = a_{Ci,r}\,UT_{r,t}\left[\frac{P_{r,t}}{PC_{i,r,t}}\right]^{s_C}$$

s.t.

$$P_{r,t}\,UT_{r,t} = \sum_i PC_{i,r,t}\left(C_{i,r,t} - cmin_{i,r}\right)$$

$$BUDC_{r,t} = \sum_i PC_{i,r,t} C_{i,r,t}$$

$$PC_{i,r,t} = PDEMTOT_{i,r,t} (1+taxcc_{i,r})$$

$$PKG_{i,r,t} = PDEMTOT_{i,r,t} (1+taxkgc_{i,r})$$

$$DEMTOT_{i,r,t} = C_{i,r,t} + \sum_j IC_{i,j,r,t} + KG_{i,r,t}$$

Groups of regions (second stage)

$$Min \; PDEMTOT_{i,r,t} DEMTOT_{i,r,t} = PDEMU_{i,r,t} DEMU_{i,r,t} + PDEMV_{i,r,t} DEMV_{i,r,t}$$

$$\text{s.t.:} \quad DEMTOT_{i,r,t}^{1-\frac{1}{s_{GEOi}}} = a_{Ui,r} DEMU_{i,r,t}^{1-\frac{1}{s_{GEOi}}} + a_{Vi,r} DEMV_{i,r,t}^{1-\frac{1}{s_{GEOi}}}$$

Armington (third stage)

$$Min \; PDEMU_{i,r,t} DEMU_{i,r,t} = PDEM_{i,r,r,t} DEM_{i,r,r,t} + PDEMETR_{i,r,t} DEMETR_{i,r,t}$$

$$\text{s.t.:} \quad DEMU_{i,r,t}^{1-\frac{1}{s_{ARMi}}} = a_{LOCi,r} DEM_{i,r,r,t}^{1-\frac{1}{s_{ARMi}}} + a_{ETRi,r} DEMETR_{i,r,t}^{1-\frac{1}{s_{ARMi}}}$$

Regions (forth stage)

For foreign regions with the same level of development

$$DEM_{i,r,s,t} = a_{IMPi,r,s} DEMETR_{i,s,t} \left[\frac{PDEMETR_{i,s,t}}{PDEM_{i,r,s,t}}\right]^{s_{IMPi}}$$

$$PDEMETR_{i,s,t} \; DEMETR_{i,s,t} = \sum_{r \in Etra(s)} PDEM_{i,r,s,t} DEM_{i,r,s,t}$$

For foreign regions with different levels of development

$$DEM_{i,r,s,t} = a_{IMPi,r,s} DEMV_{i,s,t} \left[\frac{PDEMV_{i,s,t}}{PDEM_{i,r,s,t}}\right]^{s_{IMPi}}$$

$$PDEMV_{i,s,t}^{(1-s_{IMPi})} = \sum_{r \in V(s)} a_{IMPi,r,s} PDEM_{i,r,s,t}^{(1-s_{IMPi})}$$

Varieties (fifth stage)

$$DEMVAR_{i,r,s,t} = DEM_{i,r,s,t} \; NB_{i,r,t}^{1-\frac{1}{s_{VARi}}}$$

$$PDEM_{i,r,s,t} = PDEMVAR_{i,r,s,t}\, NB_{i,r,t}^{\frac{1}{1-\sigma_{VARi}}}$$

Intermediate consumption

$$PIC_{i,j,r,t} = PDEMTOT_{i,r,t}\,(1+taxicc_{i,j,r})$$

$$IC_{i,j,r,t} = a_{ICi,j,r}\, CNTER_{j,r,t} \left[\frac{PCNTER_{j,r,t}}{PIC_{i,j,r,t}}\right]^{\sigma_{IC}}$$

$$PCNTER_{j,r,t}\, CNTER_{j,r,t} = \sum_i PIC_{i,j,r,t} IC_{i,j,r,t}$$

Capital good

$$KG_{i,r,t} = a_{KGi,r}\, INVTOT_{r,t} \left[\frac{PINVTOT_{r,t}}{PKG_{i,r,t}}\right]^{\sigma_{KG}}$$

$$PINVTOT_{r,t}\, INVTOT_{r,t} = \sum_i PKG_{i,r,t} KG_{i,r,t}$$

Commodity market equilibrium

$$Y_{i,r,t} = \sum_s DEMVAR_{i,r,s,t}$$

Transport sector

$$TRADE_{i,r,s,t} = NB_{i,r,t}\, DEMVAR_{i,r,s,t}$$

Transport demand

$$TR_{i,r,s,t} = \mu_{i,r,s}\, TRADE_{i,r,s,t}$$

$$MONDTR_t = \sum_{i,r,s} TR_{i,r,s,t}$$

Transport supply

$$Y_{Trt,r,t} = \sum_s TRADE_{TrT,r,s,t} + TRM_{r,t}$$

$$PY_{TrT,r,t}\ (1+taxp_{TrT,r})\ TRM_{r,t} = \theta_r\ PT_t\ MONDTR_t$$

$$MONDTR_t = a_T \prod_r TRM_{r,t}^{q_r}$$

Full use of factor endowments

$$Lbar_{r,t} = \sum_j L_{j,r,t}\ ,\quad TEbar_{r,t} = \sum_j TE_{j,r,t}\ ,\quad Hbar_{r,t} = \sum_j H_{j,r,t}$$

Revenues

For imperfectly competitive sectors:

$$profit_{i,r,t} = NB_{i,r,t} PY_{i,r,t} \sum_s \frac{DEMVAR_{i,r,s,t}}{\left(1+EP_{i,r,s,t}\right)} - (PVA_{i,r,t} VA_{i,r,t} + PCNTER_{i,r,t} CNTER_{i,r,t})$$

Tax revenue

$$RECPROD_{i,r,t} = taxp_{i,r}\ PY_{i,r,t}\ NB_{i,r,t} \sum_s \frac{DEMVAR_{i,r,s,t}}{\left(1+EP_{i,r,s,t}\right)}$$

$$RECEXP_{i,r,t} = NB_{i,r,t}\ PY_{i,r,t}\ (1+taxp_{i,r}) \sum_s taxexp_{i,r,s} \frac{DEMVAR_{i,r,s,t}}{\left(1+EP_{i,r,s,t}\right)}$$

$$RECDD_{i,s,t} = \sum_r DD_{i,r,s,t} PCIF_{i,r,s,t} NB_{i,r,t} DEMVAR_{i,r,s,t}$$

$$RQUOTA_{r,s,t} = \sum_{i \in TQUOTAQ_{r,s}} TQUOTA_{i,r,s,t} PCIF_{i,r,s,t} NB_{i,r,t} DEMVAR_{i,r,s,t}$$

$$RECCONS_{i,s,} = PDEMTOT_{i,s,t}\ (taxcc_{i,s}\ C_{i,s,t} + taxkgc_{i,s}\ KG_{i,s,t} + \sum_j taxicc_{i,j,s} IC_{i,j,s,t}\ )$$

Savings

$$BUDC_{r,t} = (1-epa_r)\ REV_{r,t}$$

Factor mobility

$$PL_{j,r,t} = PLbar_{r,t}$$

$$PTE_{j,r,t} = PTEbar_{r,t}$$

$$PH_{j,r,t} = PHbar_{r,t}$$

Prices definition

Sale price

$$PDEM_{i,r,s,t} = PCIF_{i,r,s,t}\,(1+DD_{i,r,s,t})$$

CIF Price

$$PCIF_{i,r,s,t} = (1+taxp_{i,r})\,(1+taxexp_{i,r,s})\,\frac{PY_{i,r,t}}{\left(1+EP_{i,r,s,t}\right)} + \mu_{i,r,s}\,PT_t$$

Imperfect competition

Definition of market shares

$$SE_{i,r,s,t} = \frac{PDEM_{i,r,s,t}DEM_{i,r,s,t}}{\sum_{rr\in Etra(s)} PDEM_{i,rr,s,t}DEM_{i,rr,s,t}}, \qquad SU_{i,r,s,t} = \frac{PDEM_{i,r,s,t}DEM_{i,r,s,t}}{\sum_{rr\notin V(s)} PDEM_{i,rr,s,t}DEM_{i,rr,s,t}},$$

$$SV_{i,r,s,t} = \frac{PDEM_{i,r,s,t}DEM_{i,r,s,t}}{\sum_{rr\in V(s)} PDEM_{i,rr,s,t}DEM_{i,rr,s,t}}, \qquad Sh_{i,r,s,t} = \frac{PDEM_{i,r,s,t}DEM_{i,r,s,t}}{\sum_{rr} PDEM_{i,rr,s,t}DEM_{i,rr,s,t}}$$

Mark-up in domestic markets

$$NB_{i,r,t}\left(EP_{i,r,r,t}+\frac{1}{\sigma_{VAR_i}}\right) = \left[\frac{1}{\sigma_{VAR\,i}}-\frac{1}{\sigma_{ARM\,i}}\right] + \left[\frac{1}{\sigma_{ARM\,i}}-\frac{1}{\sigma_{GEO\,i}}\right]SU_{i,r,r,t} + \left[\frac{1}{\sigma_{GEO\,i}}-\frac{1}{\sigma_{C\,i}}\right]Sh_{i,r,r,t}$$

Mark-up in foreign markets in countries with the same level of development

$$NB_{i,r,t}\left(EP_{i,r,s,t}+\frac{1}{\sigma_{VAR_i}}\right) = \left[\frac{1}{\sigma_{VAR\,i}}-\frac{1}{\sigma_{ARM\,i}}\right] + \left[\frac{1}{\sigma_{IMP\,i}}-\frac{1}{\sigma_{ARM\,i}}\right]SE_{i,r,s,t} + \left[\frac{1}{\sigma_{ARM\,i}}-\frac{1}{\sigma_{GEO\,i}}\right]SU_{i,r,s,t} + \left[\frac{1}{\sigma_{GEO\,i}}-\frac{1}{\sigma_{C\,i}}\right]Sh_{i,r,s,t}$$

Mark-up in foreign markets in countries with different levels of development

$$NB_{i,r,t}\left(EP_{i,r,s,t}+\frac{1}{s_{VARi}}\right)=\left[\frac{1}{s_{VARi}}-\frac{1}{s_{ARMi}}\right]+\left[\frac{1}{s_{IMPi}}-\frac{1}{s_{GEOi}}\right]SV_{i,r,s,t}+\left[\frac{1}{s_{GEOi}}-\frac{1}{s_{Ci}}\right]Sh_{i,r,s,t}$$

Investment

$$INV_{i,r,s,t} = a_{i,r,s}\ B_{r,t}\ KTOT_{i,s,t}\ e^{aWK_{i,s,t}}$$

$$WK_{i,s,t} = PK_{i,s,t} + \frac{PROFIT_{i,s,t}}{KTOT_{i,s,t}}$$

$$INVTOT_{s,t} = \sum_{i,r} INV_{i,r,s,t}$$

Regional equilibrium

$$REV_{r,t} + SOLD_{r,t} = \sum_{i,s} PK_{i,s,t}K_{i,r,s,t} + PROFIT_{i,r,t}\frac{K_{i,r,s,t}}{KTOT_{i,s,t}} +$$
$$\sum_{s} RQUOTA_{r,s,t} - RQUOTA_{s,r,t}$$
$$+\sum_{i}\left[RECPROD_{i,r,t} + RECEXP_{i,r,t} + RECDD_{i,r,t} + RECCONS_{i,r,t} + PRN_{i,r,t}RN_{i,r,t}\right]$$
$$+\sum_{r} Lbar_{r,t}PLbar_{r,t} + TEbar_{r,t}PTebar_{r,t} + Hbar_{r,t}PHbar_{r,t}$$

$$epa_r\ REV_{r,t} = \sum_{i,s} PINVTOT_{s,t}INV_{i,r,s,t}$$

Dynamics

$$K_{i,r,s,t} = K_{i,r,s,t-1}(1-\delta) + INV_{i,r,s,t-1}$$

$Lbar_{r,t} = d_r\ Lbar_{r,t-1}$, $Hbar_{r,t} = d_r\ Hbar_{r,t-1}$ (with $d_r = 1$ in developed countries, and d_r = 1,015 in developing ones)

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