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**Structural Simulation
in International Trade**

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Abstract

This thesis explores a way of representing the structure of the international trade system and of understanding its behaviour. Its main contribution is a model, developed following computer simulation methodology, that deals with interactions and interdependencies in international trade, and consequently, with the study of patterns of trade and trading bloc formation. The simulation model allows us to study dynamically the consequences of interaction between hypothetical countries when they trade. In particular, it facilitates the exploration of ways of representing algorithmically the complexity of the trade system. Furthermore, it offers us the means to analyse structural change generated by bottom-up and top-down mechanisms, which represent the continuous interplay between a global system and their components that transform each other. The model uses advanced computing tools, concepts of the evolutionary economic approach and the ideas of complex system theory in economics.

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Chapter 1

Introduction

In the last decades, the world has experienced a tremendous and steady increase of international trade and the international transactions of goods and services have augmented faster than world GDP. For example, as has been recently reported by the World Trade Organisation [WTO 2000], the average annual variation percentage of merchandise trade by major product group in the period 1950-99 was much higher than that of output (Figure 1-1). In particular, in the last decade, trade in agricultural products rose by over 6% points while output rose only by 2%; and the increase of trade in manufactured products was almost 7% compared to only 2% in output. In commercial services¹ the increase was also very important during the period 1990-99, an average change of 6% points [WTO 2000, p. 94]. As pointed out by Eun and Jeong [1999], the world's commodity and financial markets are likely to have become substantially integrated, forging close linkages between national markets.

There are many causes that contribute to the increase in international trade. The following three will be briefly discussed: the reduction and in some cases the elimination of trade barriers; globalisation; the advances in new technologies and their rapid propagation. These are all aspects of the emergence of a new world order, which produces many structural changes in the world economy².

¹ Commercial services include: transportation (sea, air, and other transports), travel and other commercial services (communication, construction, insurance, financial, computer and information, royalties and license fees services, etc.).

² Other structural changes faced by the global economy that help (at least in part) to increase international trade are: the rise (and relative recent decline) of south east Asian economies; the lack of development in the poorest countries; the change in the balance between public and private sector, with the former in the increasing; the dominance of trade blocs in the world economy; the integration of markets [Bucley 1999].

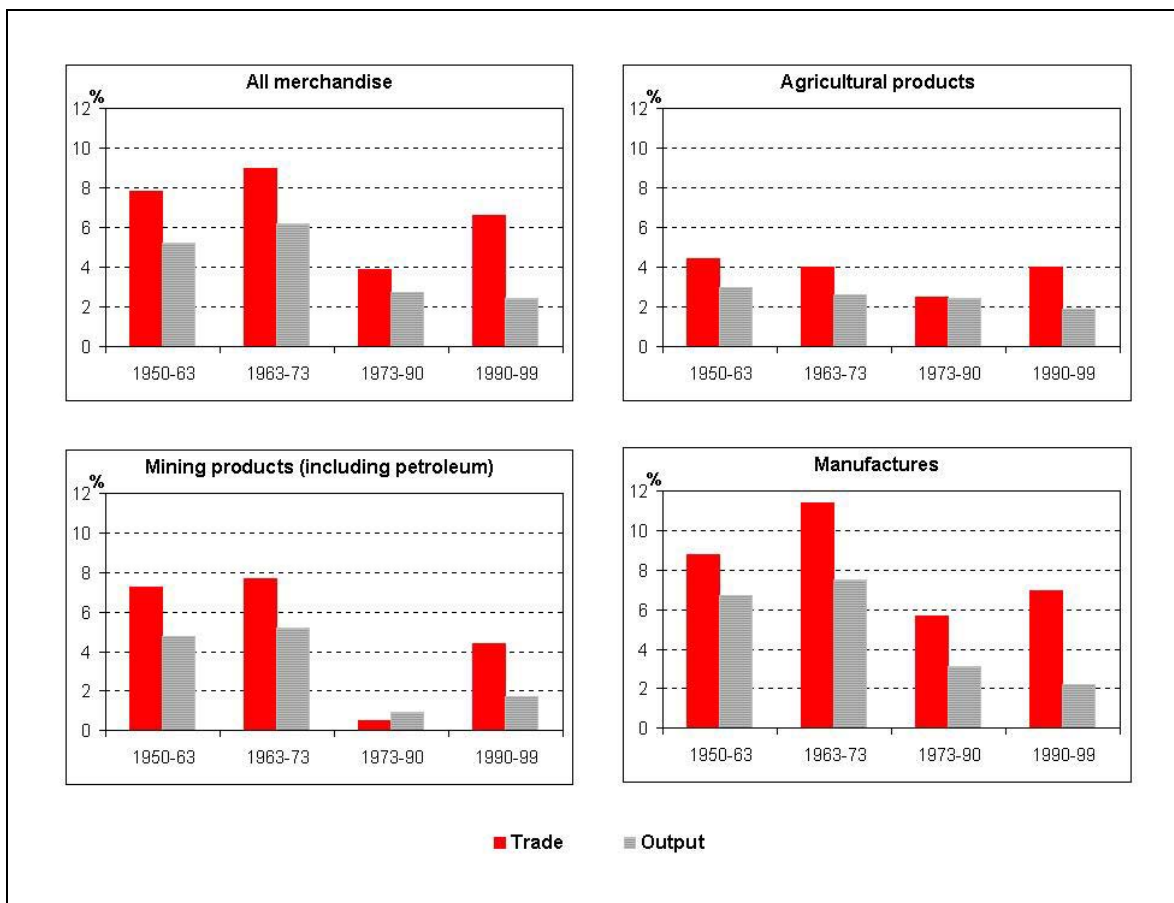


Figure 1-1 World merchandise trade and output by major product group, 1950-99
 (Average annual percentage change in volume terms)
 Source: WTO [2000]

- i. The lowering or the coming down of many international trade barriers. Up to the mid of last Century there was an increase in trade barriers in order to protect the national (and sometimes regional) production. This changed after the Second World War, when some countries started to look for new ways of trade. It was then that new economic blocs were created. A typical example is the European bloc created with the treaty of Rome in 1957. Treaties such as that of Rome aim, among others, to increase trade between members using at first the lowering of the trade barriers. During the last decades there were many similar treaties; in addition, international organisations, such as the WTO have tried to reduce the trade barriers at a global level in order to increase international trade.

It is important to note that the reduction (sometime even the elimination) of barriers has not produced (at least not yet) a balanced increase in trade. For

example, the increase in trade among industrialised nations was larger than among developed countries: in 1960 rich countries were sending 70% of their exports to other developed market economies. Despite the reduction of trade barriers during the last two or three decades this rate has not changed much; it was 71% in 1980 and 75% in 1992. Moreover, much of the three-quarters of the world's foreign trade consists of the exchange of similar manufactured goods [Pollard 1997]. In addition, it seems that trade treaties and lower barriers are not enough to foster trade. Competitiveness is also necessary. However, this is not a consequence of the previous condition (there is no direct cause-and-effect relation between the former and the latter). The recent case of Mexico is a good example. Mexico is a very open country with an index of import plus export in relation to GDP of 70%, one of the highest in the world; however it is no higher than 43 in the world competitiveness ranking for 2000.

- ii. The process of globalisation. Globalisation implies increasing interactions and interdependencies between national economic systems. Countries are becoming more closely interconnected thanks to modern communications and therefore economically, environmentally, socially and politically dependent on each other. In addition, many events taking place in one country cannot be separated from events taking place in another. For this reason, governments should pay attention to the effects of their actions on other countries as well as on their own. The world economy is involved in a process of globalisation or at least regionalisation in which every single country will be unable to live and develop without linkage (political, economic, cultural) to other countries. The phenomenon of globalisation affects in some degree all world countries. In some sense national isolation or autarchy seems to be no longer possible or at least quite difficult to maintain. Jones [1995] states that far from increasing autarchy, most economies, as they grow, develop and industrialise, reduce independence from the international economy. The globalisation process may be seen as a natural result

of the advantages observed by countries in trading³. Again the case of Mexico shows that globalisation is not a consequence of openness. Mexico is one of the more open markets, and yet it is still only 41 in the globalisation ranking.

The globalisation processes may be seen as a natural result of the advantage observed by countries in trading, combined with the explosion of new technologies (more efficient means of transportation, automatic processes using sophisticated computer resources, internet, etc.) that support it tremendously.

- iii. Advance in communication technology and its rapid diffusion worldwide, which is nowadays in part a cause of globalisation. Comparing with globalisation in the 19th-Century, which was driven by falling transport cost, globalisation is now driven by plunging communication cost.

Cheap and efficient communication networks allow firms to locate different parts of their production process in different countries while remain in close contact. Modern information technology also reduces the need for physical contact between producers and consumers and therefore allows some previously untradable services to be traded. Any activity that can be conducted on a screen or over the telephone, from writing software to selling airline tickets, can be carried out anywhere in the world, linked to head office by satellite and computer. [The Economist 1999, p. 8]

Technology and also the growth of multinational make it difficult to governments to impose capital controls and effective trade barrier. It seems that technology will continue to power globalisation.

International trade has been explained by using different economic theories. For example, the classical theories explain it as the result of countries' absolute advantages (Smith), or with comparative advantages (Ricardo) or with resource endowments (Heckscher-Ohlin). According to more recent theories, trade is primarily a result of imperfect competition, asymmetric information, economies of scale and product differentiation (Krugman 1980). International trade theory explains why trade exists and leads to increase material welfare for all or at least some trading partners. This is the key

³ Lowering of barriers of trade and globalisation are very much interrelated aspects of the new world order. It is evident that one reinforces the other and that it is impossible to determine which is the cause and which the effect.

argument for liberalising trade. If that were the case, maybe only transport costs and cultural differences would be seen as the causes of current patterns of trade, because all individual countries might be potentially trading with each other; but this is not yet the case. As it will be made clear in this thesis, to understand the process of trade it is necessary to understand aspects such as the dynamics of trading patterns and of bloc formation. In other words, it is important to take into account also political factors such as regulations, agreements and policy measures in general, which promote or prevent trade among countries and that can contribute to the formation, respectively destruction of economic alliances, co-operation or even economic integration.

The increase of trade generates additional interactions, linkages and interdependencies among national economies. In many cases, as stated above, these lead to the formation or emergence of economic blocs. Blocs may be formed for economics or social reasons as well as other reasons; there are for example cultural reasons, civilisation reasons, as Huntington [1998] points out. When a group of countries have similar political and economic interests, they may form a bloc. For example, a group of countries may decide in favour of the creation of special economic agreements that provide them with mutual advantages when they trade. Moreover, countries could decide to embark on a more complex process of political, economic and social integration. In any case, it seems that the aim is to take advantage not only of the expected direct beneficial effects among country members. But they may be stimulated by the higher power of negotiation they might enjoy when trading (or whatever other sort of negotiation) as a group with outsiders. The best example of bloc formation is the European Union, which is becoming a powerful trading bloc.

In addition to the bloc formation, it is interesting to explore the interdependence structure of the national commodity markets and the patterns that this structure follows in the international economic arena. It is also interesting to ask whether international trade reflects the existence of revealed, or immanent, interdependencies; or whether international trade is a cause, and possible the prime cause, of the dependencies that arise amongst national economies [Jones 1995].

This thesis presents a new approach to the analysis and understanding of international trade based on the determination of the dynamics of bloc formation and pattern of trade. In addition the thesis tries to answer questions that are not solved by the current theories of trade such as ‘who is trading with whom?’. Additionally, can actual patterns of trade throw any light on the emerging of virtual/real trading blocs? The thesis does not deal with the underlying causes of trade (though it presents and discusses the main ideas underlying international trade theory). On the contrary, it takes trade as something that happens and it analyses this as a trigger for the formation of economic blocs.

Its general aim is to explore structural dynamic processes using the relevant overlap of economic and technological interdependence. It is based on the use of new advanced computer tools such as simulation models, structural simulation, and emergent structure methodologies with applications in trading bloc formation and patterns of international trade. In addition, the thesis wants to explore possible structural changes induced by bloc formation, using a multi-country and multi-sector structural simulation model for international trade based on an artificial society. In sum, the specific and central objectives of this thesis are:

- (i) to produce a new methodological approach for understanding the complex processes that are involved in international trade;
- (ii) to discuss the use of new advanced tools and techniques that could be used in this approach, including simulation models, advanced computer methods, structural simulation, etc.;
- (iii) to build a simulation model that may be used to analyse different scenarios of bilateral or multilateral trade;
- (iv) to use data of artificial countries to discuss possible results that may be obtained with such a model.

Overview of the Thesis

Chapter 2 presents a review of the literature on international trade theory as a framework in which to insert the developed model of international trade. The survey shows that most of these theories continue to refer to international trade as a system, but the way in which it is generally studied is not precisely as a system. In addition, most of them analyse international trade from a static point of view. Time is not included, except for some few cases. The chapter ends with a claim for systemic tools that are able to deal with complexity and the dynamic characteristics of international trade. These tools are discussed in the next chapter.

Chapter 3 describes theories and frameworks that are more system oriented and preserve most of the basic system notions. In particular, we consider first the general concepts of systems and second the meaning of complex systems and evolutionary ideas in economics. In addition, two methodological approaches used in economics to deal with complex systems, the evolutionary economics approach and the Santa Fe approach, known as ‘complexity perspective’ or ‘the process-and-emergence perspective’, are also explored. The introduction of this chapter is explained by the fact that one fundamental key of the problem of interdependence or inter-relatedness between countries is the complexity of the interactions. The dynamics of the process underlying the formation of economic blocs is very complex, owing to the number of countries, sectors, non-linearities and the restrictions involved. The traditional theoretical economic tools, at least alone, are not able to deal with such a complexity. For these reasons, it is necessary to explore, for example, mechanisms that combine known methodologies from economic and non-economic areas. The idea is taken from a very interesting line of work called ‘the sciences of complexity’, in order to stimulate new ways of thinking about economic problems. For our purposes, the models that are used in this approach may be interpreted as models of clusters and, from the economic point of view, they might be seen as diffusion processes taking place inside, but also modifying, a cluster. This means that complexity may be seen as a characteristic that arise in a self-organised system. Furthermore, the methodologies used give special attention to the environment in which all such processes and cluster changes take place. This chapter discusses also the

emergence of structure in the international trade system, centring the attention on the network of shipments generated when a group of countries trade among them and the interdependencies that these exchanges create, as a first approximation of such structure. This sets the basic framework for the proposed model, which sees the international trade system as a *complex system* that *evolves* through time. In this evolving complex system there are two important components: trading blocs and patterns of trade.

Chapter 4 discusses the concepts of *trading blocs* and *patterns of trade*. The ways in which *trading blocs* and *patterns of trade* are tackled in mainstream economics are particularly through welfare analysis and ‘a-posteriori’ econometric analysis of their implications. However, less has been done to understand the emergence of an international trade structure and its evolution over time. How trade bloc formation affects patterns of trade among countries, and therefore specialisation and production, must be studied using models that allow the representation of processes that are dynamic by definition. The formation of economic blocs is an emerging property of the result of the interaction among countries via international trade. Once the formation of blocs looks like an adequate representation of real world, it is possible to proceed to the identification of structural change, through changes in individual countries that induce and cause change in the bloc configuration (via *bottom-up* processes) or even macro-bloc policies that may have an impact on their members (via *top-down* processes).

The analysis of the bloc formation, the pattern of trade and the identification of structural change in blocs are other characteristics that justify the use of simulation models as the one developed as part of this research for the understanding of trade.

Chapter 5 presents previous approaches based on the use of simulation models or related models for the international trade, such as computational general equilibrium models, interregional Input-Output models and world models. This chapter introduces the ideas of simulation of structural change in order to deal with a computational programme that includes the ideas of economic interdependence mentioned earlier, cluster (bloc) formation and dynamic processes. There are many new tools that are used in other fields to understand complexity. This chapter will explore some of them. Using these techniques, complexity may be gradually added to the model. So combining those

modelling simulation techniques with the economic theory (international trade theory and I-O techniques) it is possible to represent the complexity of the problem of international trade in a manageable way. On the other hand, the modelling simulation techniques can provide an opportunity for exploring some suggested insights into different lines of research that assume the problem of interdependence such as:

- Complex systems dynamics
- Emerging trade structure and international trade.

Chapter 6 describes a method for visualising the main partner countries in international trade, used in the simulation model presented in chapter 7. It puts forward some definitions for representing trade between countries, by using a trade matrix. Furthermore, it discusses the Quadratic Assignment Problem (QAP) as a method to deal with clustering or bloc formation. In other words, the QAP is used to find the best arrangement of a trade matrix, which allows us to highlight those countries whose trade exceeds a given benchmark. To assess the utility of this method, results are given by using real data for ten OECD countries.

Chapter 7 describes the model in general terms: the variables of the model, the data structure used to represent them, the general algorithmic description of the process, and the software used to develop it. It also enters into some details of the model. In particular, it presents the algorithms used: (i) for calculating the pattern of commerce by sector and the trade matrix in each period; (ii) for calculating the international prices; (iii) for simulating the export capacities and the import requirements and their evolution; (iv) for applying the cluster algorithm (discussed in Chapter 6) to find the best trade matrix; and (v) for calculating the terms of trade, changing tariffs, transport costs and prices.

Chapter 8 presents the results of some of the experiments carried out with the model. In particular it discusses in detail a basic simulation run and describes the rest generally.

Chapter 9 discusses some proposed extensions of the model and summarises the conclusions of this research.

The thesis includes four appendices. Appendix A presents the structural dynamics experienced by some OECD countries in their final demand, gross output, exports and

imports, as captured by the I-O matrices reported between 1970 and 1990 in the OECD Input-Output database. This may provide us with some clues about how to use I-O representation from a simulation point of view, to deal with interdependence in international trade and its relation with each country's economic system. Appendix B gives a brief summary of the best known trading blocs. Appendix C discusses in detail some simple numerical examples of the algorithm used in the model to determine all the possible combinations of patterns of trade among countries and to select the best of these. Finally, Appendix D presents the graphical results obtained through the basic simulation run presented in Chapter 8.

Before concluding this introduction, it is worth pointing out that our focus throughout has been on the development of a methodology that combines the above different lines of research and on the observation of possible behavioural laws based on simple properties following the ideas of artificial life and artificial society. Results are not based on data of real countries. On the contrary, the simulation experiments feature hypothetical countries (or regions) and aggregated sectors as elementary units of analysis. The preliminary idea behind the thesis may be deduced or identified by reading this introduction and the chapter of conclusions. This idea may be improved by reading the introduction and conclusion to each chapter. However, the full picture cannot be viewed without a careful reading of all the material.

Chapter 2

Studies on international trade

2.1 Introduction

This chapter presents a review of the literature on international trade theory as a framework in which to insert the developed model of international trade of this thesis. Section 2.2 presents some fundamental ideas on international trade theory. The section starts with a discussion on the following two types of models (subsections 2.2.1 and 2.2.2):

1. The models of Adam Smith's absolute advantages and David Ricardo's comparative advantages. Both try to explain why countries trade and put emphasis on the differences on labour productivity among countries.
2. The Heckscher-Ohlin model of factor-proportion. It states that comparative advantage is influenced by the interaction between countries' resources and, therefore, trade is largely driven by differences in their resources. Despite all the good reception that this theory has enjoyed in mainstream economics, some questions are raised about its empirical validity. The Leontief's paradox is a case in point.

Then (in subsection 2.2.3) we examine more recent explanations, new contributions of international trade theory that relies on imperfect competition and economies of scale, in particular the works of Balassa and Krugman. The last part (subsection 2.2.4) of this section ventilates some ideas about trade and growth in a dynamic approach, which relies on considerations about change on factors endowments, technological improvements, and change of tastes, which may cause comparative advantages change over time.

Section 2.3 gives some conclusions. We argue that the international trade is a very complex system that cannot be analysed with traditional tools. To understand and study it

and in particular to deal with the analysis of its dynamics, it is necessary to use new methodologies, tools, and methods based on the theories of complex systems, computational economics, structural change, and evolutionary economics.

2.2 Theoretical models of international trade

International trade is distinguished from domestic trade by the greater prevalence of factor movements and trade barriers (both natural, e.g. transport costs and artificial, e.g. tariffs and quotas), different currencies and autonomous governments, leading to a pattern of shocks which impact different countries in different ways [Chipman 1987]. Essentially, the international trade theory analyses the bases for and benefits from trade. The bases are presumably the benefits that a country may have if it embarks on trade. For example, countries could be induced to obtain overseas those goods and services that are not available, or relatively scarce, at home. They could also have different production costs, which make them economically more attractive to import than to consume homemade products. Or they could be in a position to reach economies of scale in production by increasing their products' markets outside their frontiers. All these factors generate profits and, in part, the theory of international trade tries to explain how large these gains are and how they are divided among trading countries. The explanation of trade flows, the effect of unilateral transfers on sectoral prices and resource allocation, and the effect of trade restrictions such as tariffs and quotas have been the most noteworthy problems in international trade theory since its beginnings [Chipman 1987]. International trade theory also tries to answer which commodities are exported and imported by each country, in other words, what the pattern of trade is.

Different models have been used to explain why differences between countries induce trade. In particular, the interest has been in those models capable of explaining observed patterns and flows of trade among countries.

2.2.1 Absolute and comparative advantage theories

Adam Smith was one of the first economists to formalise a model to explain international trade [Smith 1776]. This model, which became known after the publication

in 1776 of *The Wealth of Nations* as the absolute advantage model, explains how countries can gain when trading. Smith argues that when a country is more efficient in producing a commodity (which means the country requires less input to produce the same commodity compared with another country), it has an absolute advantage over another country. In addition, if the second country produces another commodity in which it has the absolute advantage, then both countries can gain if each specialises in the production of the commodity in which it has an absolute advantage and trade to meet their demands. However, Smith's model explains only in part the current form of trade between developed and developing countries.

After Smith, David Ricardo introduced the law of comparative advantage [Ricardo 1817]. By means of numerical examples, he showed that even when only one country has an absolute advantage in Smith's terms in producing both commodities, there still are bases for both countries to gain from trade¹. He argued that the less efficient country should specialise in the production and exporting of the commodity in which its absolute disadvantage is lower. Thus, for Ricardo, comparative advantages determined the pattern of trade. He explained the principle of comparative advantage in terms of the labour theory of value, but it has been argued that the assumptions on which this theory is based are not valid. It was Haberler [1936], in the 1st half of the twentieth century, who explained the principle of comparative advantages in terms of the opportunity cost theory². A country has a comparative advantage in producing a commodity if the opportunity cost of producing that commodity in terms of other commodities is lower in that country than it is in other countries [Krugman and Obstfeld 1997]. Thus, if a country wants to maximise gains from trade, it should specialise in producing those commodities for which it enjoys a comparative cost advantage. As pointed out by Pasinetti [1981], this has been the recommendation that traditional economic theory has been giving for almost two centuries. Pasinetti argues that this policy recommendation is, strictly speaking, incorrect or in any case incomplete, because 'comparative cost advantages are changing

¹ There is an exception to this principle, the absolute disadvantage that a country has with respect to the other is not in the same proportion in both commodities.

² According to the opportunity cost theory, the cost of a commodity is the amount of a second commodity that must be given up to release just enough resources to produce one additional unit of the first commodity [Salvatore 1998].

all the times, and in those few fields where they are permanent specialisation is inevitable anyhow' [Pasinetti 1981, p. 273].³

2.2.2 Factor-proportions theory

However, international differences in labour productivity are not the only causes of trade. Countries' resources may also be. Eli Heckscher [1919] and Bertil Ohlin [1968] have argued that trade is largely driven by differences in countries' resources. Their model, often referred to as factor-proportions theory, is based on the neo-classical principles of profit and utility maximisation and market clearing (a general equilibrium framework). It shows, subject to several restrictive assumptions⁴, that comparative advantage is influenced by the interaction between countries' resources (the relative abundance of factors of production) and the technology of production (which influences the relative intensity with which different factors of production are used in the production of different commodities). The fundamental result of their work has been stated as follows: a country will export the commodity whose production requires the intensive use of the country's relatively abundant and cheap factor, and import the commodity whose production requires the intensive use of the country's relatively scarce and expensive factor. Paul Samuelson [1948], building on Heckscher-Ohlin's result, showed that international trade will bring about equalisation in the relative and absolute returns to homogeneous factors across nations.

Nevertheless, there exists an important empirical result that contradicts the Heckscher-Ohlin theory: Leontief's work. Using a data set with 1947 records, Leontief found that US imports substitutes were more capital intensive than US exports:

³ For Pasinetti [1981, p. 273] "the essential point is that policies of specialisation in production cannot be stated independently of dynamic trends, more specifically, they cannot be stated independently of the rates at which productivity is changing over time".

⁴ Salvatore [1998, p. 110] list the assumptions of the model, which are: 1) There are two countries, two commodities (X and Y) and two factors of production; 2) Both countries use the same technology in production; 3) Commodity X is labor intensive and commodity Y is capital intensive in both nations; 4) Both commodities are produced under constant return to scale in both nations; 5) There is incomplete specialization in production in both countries; 6) Tastes are equal in both countries; 7) There is perfect competition in both commodities and factors markets in both countries; 8) There is perfect factor mobility within each country but no international factor mobility; 9) There are no transportation costs, tariffs, or other obstructions to the free flow of international trade; 10) All resources are fully employed in both countries; 11) International trade between the two countries is balanced.

America's participation in the international division of labour is based on its specialisation on labour intensive, rather than capital intensive, lines of production. In other words, this country resorts to foreign trade in order to economize its capital and dispose of its surplus labor, rather than vice versa. The widely held opinion that - as compared with the rest of the world - the United States' economy is characterized by a relative surplus of capital and a relative shortage of labor proves to be wrong. As a matter of fact, the opposite is true. [Leontief 1954, p. 25]

The empirical result is the opposite of the Heckscher-Ohlin's proposition because the United States was (and still is) the most capital-abundant country. This result is known as the Leontief paradox.

The Heckscher-Ohlin theory, however, faces questions not only regarding its empirical validity but also, and maybe more importantly, regarding the assumptions on which the theory is based, which are not realistic, leaving much more of today's international trade unexplained. In particular it cannot explain the intra-industry trade (two-way trade of the same commodity), which accounts for a large portion of all international trade, especially in manufactures. Therefore, the relaxation of those assumptions has caused a search for better explanations and for new international trade models.

2.2.3 New contributions in international trade theory

During the last 25 years new contributions in international trade theory have appeared. For example, economies of scale, product differentiation and monopolistic competition enter as new elements to be considered, keeping up the neo-classical framework. They may, in part, be the source of international trade explanation - as was pointed out by the researches of Balassa [1967] and Krugman [1979, 1980, 1990]. Balassa found that most of the volume of trade among countries of the European Union (the former Common Market), after the removal of tariffs and other trade barriers in 1958, was increased in differentiated products within each industry. This induced more specialisation in a few varieties or products in each country, which allows for the reduction of costs. Thus, differentiated products of the same industry (intra-industry trade) enter as an important portion of the output of modern economics, which must be taken into consideration to explain current patterns of international trade.

In the long run, the expansion of output induced by opening up of trade could reduce the average cost of a product, but also could lead to markets being dominated by few firms (oligopoly), or sometimes, by only one firm (monopoly). This is known in the economic literature as imperfect competition. As argued by Krugman [1979], economies of scales give countries an incentive to specialise and trade even when they are different in their resources or technologies. An important model of this kind is the monopolistic competition model. Within this model an industry contains a number of firms producing differentiated commodities (for example the same product with different qualities). Each firm acts as a monopoly. By joining, new firms will reduce the market share until monopoly profits are competed away. The market size plays an important role. The opening of trade increases the market, supporting a larger number of firms, each taking advantage of economies of scale and thus lower average costs. But the opening of trade also raises the number of varieties available. Therefore trade is beneficial for both these reasons.

Economies of scale are also important in explaining intra-industry trade and the existence of global oligopolies. Economies of scale, or increasing returns to scale, exist if increasing purchases in input will increase output by a higher percentage. The result is declining average costs of production as output increases. Krugman [1979] argues that trade need not be a result of international differences in technology or factor endowments as in the case of, generally speaking, the classic models discussed above. Instead, trade may simply be a way of extending the market and allowing exploitation of scale economies. In the presence of increasing returns, Krugman [1990] also argues that history matters, in the sense that a pattern of specialisation can be established as a result of accident or some initial difference in countries' resources, then get locked in by the cumulative advantage that go with large scales. But geography also matters in international trade. Owing to the fact that there are costs to transactions across space and economies of scale in production, industries tend to concentrate in space on a process that is self-sustaining [Krugman 1991].

Another important aspect of international trade theory is related to the instruments used in trade policy. The main concerns have been to try to answer how trade barriers (such as tariffs and quotas) affect prices, output and trade patterns, and special emphasis

is given to the economic welfare effects those barriers may cause at home and abroad [Kenen 1994]. Trade restrictions as tariffs or quotas are taken by traditional trade theory as exogenously controlled instruments in order to examine their effects. The emphasis has been on comparative static analysis, because it is argued that what is required is the analysis of the effects of country-specific shocks that are the result of independent national governmental policies.

It is precisely the total absence of trade barriers that implies free trade. Free trade is considered as a state of the international trade system that maximises world welfare [Salvatore 1998]. Then tariffs, as barriers of trade, are considered second-best policy instruments in international trade. In part, because they distort consumers' choices. However, tariffs (and also quotas) continue to be an important type of trade restrictions⁵, though they have declined considerably in the last 40 years. The theoretical framework in which tariffs and quotas are analysed in international trade theory is the general equilibrium theory (we discuss in Chapter 5 some international trade simulation models that uses the general equilibrium framework in their construction). This is known in the literature as the theory of tariffs and quotas. In this theory a country is perceived to be acting as a single rational agent (aggregative theory) or as introduced by Johnson [1960, cited in Chipman 1987] in which each factor of production, as well as the government, is treated as a rational agent (disaggregative theory). In this framework, it is important to analyse the costs and benefits of the trade policy from both consumers' and producers' viewpoints, the implication for government revenue (which implies also the analysis of redistribution effects) and, more generally, the overall national welfare.

2.2.4 Trade and growth: a dynamic approach

Recently, the study of economic growth and international trade has tried to emphasise the dynamic aspect of trade. The implication of change in factor endowments over time (normally identified as labour and capital), the improvements of technology and also changes of taste may cause the comparative advantages of a country also to change over time. However, as is pointed out by Salvatore [1998], dynamic trade theory

is still in its infancy. Much of the analysis is still made by means of comparative static analysis in order to analyse the effect on international trade resulting from changes in factor endowments, technology, and tastes.

Specialisation may also play an important role in the process of economic growth. Kaldor [1970] argued that dynamic increasing returns to scale are crucial in the process of economic growth. He pointed out that when production expands, new ways of doing things (learning-by-doing) are discovered, which makes productivity increase. He based his argument on Verdoorn's Law, which states that there is a close relationship between the long run growth of manufacturing productivity and that of output⁵. But this increase in productivity may, in its turn, lead to increased growth (by means of increasing exports, as Kaldor argued), which opens up possibilities for self-reinforcing mechanisms. This is known in the literature as the Kaldorian export-led growth theory [Laursen 2000b]. Another argument on this respect states that, because of the fact that some activities may provide larger growth opportunities than others, it matters in which activities a country specialises. In other words, the growth rate of an economy may depend on what the country specialises in and on how the specialisation patterns change over time. This is known in the literature as the Ricardian approach to the new growth theory [Laursen 2000b].

The theoretical literature on growth and trade emphasises that comparative advantage is dynamic and evolves endogenously over time [Proudman and Redding 2000]. Three main strands are identified by Proudman and Redding while explaining the evolution of international trade flows over time: first, the role of factor accumulation; second, the endogeneity of technological change; and third, the importance of agglomeration economies which is underlined by economic geography.

Another important consideration is the idea that countries are not dimensionless points, that spatial dimension affects the way countries linkage and interrelate between them, creating self-reinforcing mechanisms that make possible the emergence of different

⁵ See Chipman [1987] for a general treatment of contemporary theory of trade restrictions, for the case of two commodities, two factors, and two countries.

⁶ The importance of Verdoorn's Law according to McCombie for example is that "it argues that a substantial part of productivity growth is endogenous to the growth process, being determined by the rate of expansion of output through the effect of economies of scale" [McCombie 1987].

urban and industrial locations patterns (see for instance [Villar 1999] and [Fujita et al. 1999]). Villar, Fujita and others focus on how concentration of economic activities (such as manufacturing belt or farm belt, the existence of cities, industrial clusters), which induce specialisation patterns, is the result of a self-reinforcing process of agglomeration of economic activities. The idea is that:

all these concentrations form and survive because of some form of agglomeration economies, in which spatial concentration itself creates the favourable economic environment that support further or continued concentrations.' [Fujita et al. 1999, p. 4]

Porter [1998] has argued that competitive advantage rests on making more productive use of inputs and this may require continual innovation. Geographic, cultural and institutional proximity leads to productivity and innovation, and the more the world economy becomes complex, knowledge-based, and dynamic, the truer this is. According to Porter [1998], clusters which he defines as 'geographic concentrations of interconnected companies and institutions in a particular field', form to a great extent the economic map of the world. Thus, for him, in a global economy the enduring of competitive advantage, thanks to its current dynamics, lies increasingly in local elements such as knowledge, relationships, and motivation. For Porter, global competition nullifies traditional competitive advantages and exposes companies to the best rivals from around the world, which forces a growing number of multinationals to shift their home bases to more vibrant clusters.

Krugman [1996] pointed out that we must think not only of the effects of growth in trade, which has been till now the solid, well-established theory of growth and trade, but also on what he considers the more controversial subject of the effects of trade in growth. The first, growth in trade, considers the impact of growth on trading economy but without taking into account any feedback from trade to growth. The second, trade in growth, is concerned with precisely such feedback. The study of the relationships between trade and growth may be explored by using simulation models. Those feedbacks could be represented taking into consideration both effects in a world composed by countries that are in much dissimilar rather than different.

Finally, it is important also to mention that technological flexibility is an essential concept from the point of view of economic interdependence. Technological flexibility gives to countries the capacities of maintaining self-independence and induces dependency in others countries. This is in part the source of economic power than some nations enjoy. So the key questions that we may ask ourselves are: Who needs whom? and what is the cost of severing one economic relation?

2.3 Conclusions

In this chapter, we have shown the evolution of the main theories that have tried to explain why countries trade and what profits derive from trade. In sum, the different models to analyse the trade path may be grouped in models that base the differences in absolute, comparative and dynamic comparative advantages (Smith, Ricardo, Harbeler, Pasinetti), and in models that take into account the factor intensive use of resources (Heckscher-Ohlin). New theories have also tried to explain international trade on the basis of product differentiation and economies of scale arguments (Krugman).

All the above theories and models try to explain why international trade exists and how it increases the material welfare of the trading partners. But, what about the interdependencies that international trade generates between countries? They say almost nothing about it, though it is recognised that the level of interdependence in the world economy has increased very significantly [Chichilnisky and Heal 1986]. To use Jones's words:

dependence exists for any actor when a satisfactory outcome on any matter of significance for that actor requires an appropriate situation or development elsewhere. Interdependence exists for a grouping of two or more actors when each is dependent upon at least one other member of group for satisfactory outcomes on any issue(s) of concern.' [Jones 1995, p. 94]

In the present research the concern is the international trade system and the actors are countries and their economic sectors. The hypothesis is that trade creates patterns of economic interdependencies between countries in the sense that, whatever level of exports a country plans to reach in the international market, it will depend on how many

imported commodities other countries will choose to buy. The representation of the international trade system must be done using a holistic point of view. In other words, it has to be done using a system view, which takes into account the different aspects of the trade between the different partners. The individual performance of a country is important. What kind of product it may produce depends on its technology, resources and how well prepared its people are. These are characteristics (sometimes constraints, sometimes advantages) of its own economy. But in a world that becomes more globalised, in part because there are gains from trade, the entire system limits or allows the expansion of businesses. In other words, the constraints that the entire system imposes to a country are also important. These considerations must be addressed in models set up to deal with interdependencies. But the point is that the world is formed by countries that are not equal. As a matter of fact, it is dissimilarity that one notices above all in the real world and therefore it is not possible to consider all countries similar.

The contributions of all the above works are undoubtedly significant to the theory of international trade. However, most of them are still framed in models that are static, whereas emphasis should be placed on dynamics and on a systemic representation. Emphasis on dynamics means that the model used must deal with the time path and the underlined processes. The models discussed in this chapter do not consider the dynamics of the formation of patterns of trade. The dynamics requires to deal with the complexity of the world. The model has to find ways to represent the international trade system. Furthermore, it has to generate the network of shipments among countries and their sectors and how this network may change as decisions-making in each country/sector are made to follow a particular rational rule. International trade is a system that is formed by more than two sectors and two countries (as in many of the above theories and models); it is a system of n countries and m sectors. In other words, mainstream theories do not take into account the plurality of countries and commodities, and this is an important aspect to study interdependence. Furthermore, they do not consider the economic power and the asymmetric dependencies that are originated from them and the technological flexibility that some countries enjoy. Even though we recognise the importance of these aspects we do not consider them in our model and it is left as an interesting field of future research.

There are many ways to introduce dynamics and to deal with system's complexity. The evolutionary approach as well as the so-called Santa Fe approach in economics are two of these ways. In the next chapter, we explore the ideas of evolution and complexity in economics that have been carried out by those groups. But dealing with the dynamic of processes and their evolution and complexities implies also to face up structural changes that are the result of decisional interacting agents. Thus, for these reasons, we present also in the next chapter the ideas behind structural change as it is conceived in economic science, and also we discuss some other contributions concerning structural change in general.

Chapter 3

Complex systems in economics: structure and change

3.1 Introduction

In the previous chapter we have discussed the main international trade theories that try to explain the reasons why countries trade. Their contributions to our understanding of the welfare effects and the gains from trade are undoubtedly important. However, most of them continue to assume that international trade is a system, while the way it is generally studied is not precisely as a system. In part, this is due to the simplification that traditional neo-classical economics theory imposes on welfare economics analysis; but this is also in part due to the limitations of the tools used to manage its representation. We have evidenced the fact that most of them are static in essence. For these reasons, we describe in this chapter theories and frameworks that are more system oriented and that preserve most of the basic-system notion that the whole is greater than the sums of its parts.

Section 3.2 sums up first the general concepts of systems and second the meaning of complex systems and evolutionary ideas in economics. It discusses a concept of system as it is studied in systems thinking methodology with the aim to concentrate those relevant concepts necessary to identify the international trade system as such: in particular, the concepts of systems' structure and dynamics, relevant for the formulation of the developed model. Considerations on a system's structure and its dynamics lead us to think about a broader concept of structural change. Structural changes arise when some parts or properties are added or lost to the components, or some relations appear, disappear or change their form in a particular. The study of structural change has been an important research agenda in economics in recent years. For this reason, the fundamental

ideas behind the meaning of structural change in economics are presented in this chapter. On this basis, section 3.2 explores two methodological approaches used in economics (and elsewhere) to deal with complex systems: the evolutionary economics approach and the Santa Fe approach. In the former, we discuss in particular Nelson and Winter's work (among others), which emphasises concepts like adaptation and learning among economic agents, and that the economic system is subject to somewhat random variation and mechanism that select on that variation. In the latter, we explore the work of researchers at the Santa Fe institute, which generally speaking explores the potential usefulness of a broadly transdisciplinary research program on the dynamics of the global economy system, and the use of applying concepts like positive feedback, self-reinforcement, path-dependence and emergence, among others, to the study of the economy as a complex system.

Section 3.3, in the light of the concepts and methodologies discussed so far, includes an inquiry about the emergence of structure in the international trade system, focussing the attention on the network of shipments generated when a group of countries trade between them and the interdependencies that these exchanges create, as a first approximation of that structure. Section 3.4 summarises some conclusions in relation with the use of systems methodology, tools from the evolutionary economics fields or from the Santa Fe approach for the study of international trade.

3.2 The study of complex systems in economics

3.2.1 Basic concepts of systems

Throughout history, men have tried to understand the complexity of the world in which they have lived. The most common intellectual tool we have been using to confront complexity is perhaps the principle of divide and conquer. The representation of the real world has been achieved by using abstract concepts whose main aim is to facilitate studying and understanding it. In particular, a useful concept that has been introduced is that of system. System thinking is a reaction against of the divide and conquer (Cartesian) approach to the study of complexity. Diverse aspects of the real world have been classified into systems or sub-systems. Thus, we have identified

physical, biological, social and economic systems, among many others, on the real world. The first intention has been to isolate each particular system in order to study and understand it alone, as a complete unit that interacts with other systems. Our participation as direct actors in some of these systems make its characterisation and understanding difficult.

Defining what a system is depends largely on the point of view of the person that is trying to define it. As emphasised by systems theorists, it is important to recognise that other people, confronting the same system, may not agree with one another. In general we may say:

(1) A system is an organized assembly of components. ‘Organized’ means that there exist special relationships between the components. (2) The system does something, i.e., it exhibits a behaviour unique to the system. (3) Each component contributes towards the behaviour of the system and its own behaviour is affected by being in the system. No component has an independent effect on the system. (4) Groups of components within the system may by themselves have properties 1, 2, and 3, i.e., they may form subsystems. (5) The system has an outside—an environment—which provides inputs into the system and receives outputs from the system. (6) The system has been identified by someone as of special interest.

The crucial ingredients of a system are therefore its components, the relationships between the components, the behaviour or the activities of the system, its relevant environment, the inputs from the environment, the outputs to the environment, and the special interest of the observer. [Daellenbach 2001, pp. 30-1]

It may be also defined as a part of the world that is formed by parts or components that relate to each other [Domingo and Tonella 2000]. Figure 3-1 shows a graphic representation of what a system looks like according to Daellenbach.

What is it that makes a system complex? For Simon [1962] (though he refuses to give a formal definition of complex systems) ‘a complex system is roughly one made up of a large number of parts that interact in a non-simple way’. The interactions or the relationships between parts may be unidirectional or causal. Furthermore, they may be mutual. It is precisely the mutual influences or causality –emphasised by Simon as in a non-simple way– which increases the complexity of system behaviour [Daellenbach 2001]. A system is also said to be complex when it exhibits some type of order as a result

of the interactions of many heterogeneous objects [Durlauf 1997]. However, chaotic systems are also complex, even though they do not exhibit order.

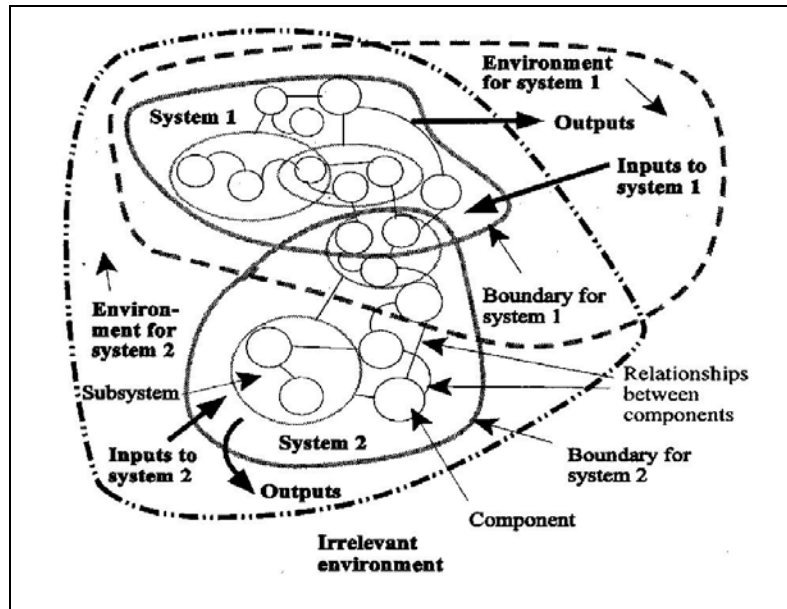


Figure 3-1 Environment, systems, subsystems, and components [Daellenbach 2001, p. 31]

One of the principles in systems theory is that the system as a whole is greater than the sums of its parts. In other words, as is pointed out by Simon, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole. When elements assemble forming a whole emergent properties appear. A relevant characteristic of systems is their hierarchy. A system may be composed of interrelated sub-systems, each sub-system being, in turn, hierarchic in structure. For Simon this architecture of complex systems may continue until we reach some level of elementary sub-system.

This abstraction of the real world as a system, however, is not enough to fulfil our primary intention of knowing or understanding the real world. Scientists have created models, which are also systems that try to represent real world systems. For Domingo:

a model of a system is another system which has elements and relationships that are in correspondence with those of the real system. In a real system there are always properties and relationships without any correspondence into its model and vice versa. This is why there are behaviour discrepancies of the real system and its model. [Domingo 1975, p. 4]

The economy has been considered as a system. And this is very familiar for us hearing to talk about the economic system. But, it is not clear how current mainstream economic methodology tackles the study of economics as the system it used to talk about.

3.2.2 Systems: their structure and dynamics

The structure of a system is generally defined as the way in which the parts of a system are arranged or organised. For Domingo [1975], the structure of a system is that part of the system that has its correspondence in a particular model. The structure is referred to the elements and relationships of the system which are represented in the model. In other words, the elements and relationships of the real system that find representation in the model constitute the structure. The structure of a system includes its states and state-transition mechanisms and it is described by the specification of its parts, their properties and their relationships [Domingo and Tonella 2000]. Knowing the system structure allows us to deduce (analyse, simulate) its behaviour [Zeigler 2000].

The way in which systems behave over time is known as their dynamics. The passage of time is fundamental to the notion of a dynamic system [Zeigler 2000]. The behaviour of a system is the result of change in its elements and/or change in their relationships. Thus, change and stability, which are two dimensions of time are directly connected with the dynamics of a system. Addressing issues of change implies carrying our attention on the history of the system. The understanding of change, as is pointed out by Hakansson and Lundgren [1997], ‘necessitates the reading of the past both interpreted and experienced by the actors’. An important contribution in the study of system dynamics has been the work initiated by Forrester [1968]. For him, the aim of system dynamics as a methodology is to determine the structure of systems in order to analyse their behaviour. The methodology consists in the level-rate-feedback structure through which systems are modelled, and that represents a fundamental and universal structure of real social and physical systems.

3.2.3 Structural change

Structural changes appear when some parts or properties are lost or added to the components; here some relations appear, disappear or change their form in a particular system [Domingo and Tonella 2000]. All these changes take place through processes. In many cases, structural change implies irreversibility. For Moss [1996] structural change means some alterations in the components and relationships among the components of a coherent system. He calls a system coherent if it can be represented formally by a mathematical network in such a way that, for every pair of nodes, there is either a path between them or a path to some common node.

Structural change has been also a research subject in economics. Pasinetti's work on structural change [Pasinetti 1981] and structural economic dynamics [Pasinetti 1993] has become fundamental in this respect. In this context, structural changes are defined as permanent changes in the composition of some basic magnitudes (such as gross national product, total consumption, total investments, total employment, etc.¹) associated with change in their absolute levels [Pasinetti and Scazzieri 1987]. In economic systems, genuine structural changes are considered permanent and irreversible. Those changes are sometime difficult to distinguish from purely transitory and reversible changes. Thus, it is the long run that allows to observe the changes that take place in the structure of the basic economic magnitudes². They are the inevitable effect of economic growth, and therefore, of technological progress [Galli 1997]. In Pasinetti's work, the economic growth process is analysed in terms of the structural dynamics of production, of prices and employment. His contribution is a model that deals with an analytical representation of an economic system in which the basic magnitudes are connected. For Pasinetti what is dynamic is industry,

because it implies production, i.e. the engagement and the applications of man's ingenuity to make and shape the products he wants. But since by doing and experiencing man learns, it is implicit in the very nature of carrying on a production activity that new and better methods of production will be discovered. [Pasinetti 1981, p. 3]

¹ For instance, persistence of slow growth and high unemployment in EU countries are considered as a 'structural problems' [Muscatelli 1996].

² See Quadrio Curzio and Scazzieri [1988] for a detailed discussion about the long-run as a basic tool to identify structural dynamics.

Thus, for Pasinetti, the primary and natural features of a production system takes the form of an evolving structure of the economic system. The economic structure

may be considered as a mapping of the set of features characterising any given economic system into a set of general and relatively simple characteristics common to a number of distinct economic systems under different circumstances. Just as an essential element of any concept of a static economic structure is its definition in terms of a pattern of relationships among the different elements of the given structure within a well-defined time interval, the dynamic counterpart of such a concept is the system of sequential (time dependent) relationships among the rates of change of the different elements that identify the static structure. [Landesmann and Scazzieri 1990, p. 96-7]

In this context there are two different approaches for the concept of structure:

One is that of equilibrium or 'settled' constellation of individual actions, based on a clearly stated set of behavioural principles that are essential in determining the way in which such a position is achieved and possibly maintained. The other is an analytical specification of patterns of interrelationship that is obtained by adopting as a starting point what may be called a 'descriptive-analytical' approach. In this case, factual and statistical material is used to describe the basic characteristics of an economic system. [Landesmann and Scazzieri 1990, p. 98]

The first concept of structure has been criticised mainly because that the principles on which it is based are too narrow and not supported by empirical tests of individual behaviours. This concept is more identified with the Santa Fe and artificial economic approaches that will be presented later on. The second concept offers a better stage for the testing of theoretical arguments because it is based on the characteristics of individual parts of an economy system and of their pattern of interaction and it is a more classical structural approach.

In particular, economic structure is generally described in such a way that certain elements of it are considered to be fixed while other elements are allowed to change. As a matter of fact, the analysis of structural dynamics is associated with a general postulate of relative invariance, according to which any given economic system subject to an impulse or force is allowed to change its original state by following an adjustment path that belongs to a limited set of feasible transformations. [Landesmann and Scazzieri 1990, p. 96]

The first approach is a bottom-up process where individual actions produce structural change; the second is a top-down process. Domingo [1975] argues that the best approach to study structural change is the combination of both. In the first, individual (or

independent sub-systems) behaviour assemble wholes or greater order that show emergent properties. In the second, restrictions to the individual parts and the emergent properties organise the individual parts and enter into structural relationships in a higher level. This combination of bottom-up and top-down processes are the key of structural change. Bottom-up processes concern the basic agents of a system and their interactions with each other. This generates a pattern at a level higher than the agents themselves. Such a pattern is often termed an 'emergent phenomenon' that will be discussed below. Top-down processes, on the contrary, are concerned with variables determining the outcome of decisions that are aggregated rather than the actions of individual agents [Casti 1997]. Top-down approaches deal with how a system as a whole constrains and directs individual part processes, while bottom-up approaches deal with the way system parts assemble and modify a structured whole [Domingo and Tonella 2000].

Other types of research go beyond the national frontiers and try to focus on the forces behind global economic change. For instance, Muscatelli [1996] discusses the nature of the challenge provided by the newly industrialising economies for the OECD countries, which is implied by the interdependence that is created in the ongoing process of globalisation, and also, how further integration among a group of economies likely affect a particular country's economic prospects³.

For North [1999] economic change is a result of changes in: a) the quantity and quality of human beings; b) the stock of human knowledge, particularly as it applies to the human command over nature; and c) the institutional matrix that defines the incentive structure of society. He argues that some broad implications of these considerations are first, that there is no way to make intelligent predictions of long term change, because we cannot know today what we will learn and believe tomorrow, and second, there is no such thing as *laissez-faire*, a market that is going to work well is structured and it is structured by deliberate efforts (government that set out the rules of the game). North pointed out that

The dominant beliefs, that is those of political and economic entrepreneurs in a position to make policies, result over time in the accretion of an elaborate structure of institutions, both formal rules and informal norms,

³ In particular, how UK's economic prospects are affected by further integration of the European economies.

that together determine economic and political performance. The resultant institutional matrix imposes severe constraints on the choice of entrepreneurs when they set out to create new or to modify existing institutions in order to improve their economic or political positions. The path dependence that results typically makes change incremental, although the occasional radical and abrupt institutional change suggest that something akin to punctuated equilibrium change in evolutionary biology can occur in economic change as well. Change is continually occurring although the rate of change will depend on the degree of competition among organisations and their entrepreneurs. Entrepreneurs enact policies to improve their competitive positions, resulting in alterations on the institutional matrix. What follows are revisions to perceptions of reality, and therefore new efforts by entrepreneurs to improve their position in a never-ending process of change. [North 1999, p. 11]

Similar to North, there are other approaches that recognise the economy as an evolving complex system. For example, the evolutionary approach and the Santa Fe approach. Without enter into details, in what follows, we provide some general ideas of both in the next two sections.

3.2.4 Evolutionary economics

The evolutionary approach in economics gives recognition to irreversibility and continuing processes in time, as evolution involves irreversible transformations in structure and acquisitions of knowledge (as was previously pointed out, these are also part of structural changes' recognition, which shows the overlapping of fundamental ideas that support both approaches).

An evolutionary paradigm in economics 'provides an alternative to the neo-classical 'hard core' idea of mechanistic maximisation under static constraints. It is a different way of perceiving and analysing economic phenomena, emanating from the science of life rather than the science of inert matter. [Hodgson 1994. p. 223]

The paradigm of evolution in complex systems serves to proxy the dynamics of such systems. The point is that through time, complex systems operate in a state of constant adaptation to changing conditions.

The general evolutionary paradigm posits a mechanism for adaptation and learning in complex systems using three basic interacting processes: information storage and transmission, generation of new alternatives, and

selection of superior alternatives according to some performance.
[Costanza and Wainger 1993]

One notorious contribution in this respect has been the work of Nelson and Winter [1982], in which they develop an evolutionary theory of the capabilities and behaviour of business firms operating in a market environment. Their models concentrate on firms as the key actors (and not individual human beings or countries as in our model). They borrow some basic ideas from biology to create their scheme, for example the idea of economic ‘natural selection’, in which ‘market environments provide a definition of success for business firms, and that definition is very closely related to their ability to survive and grow’⁴ [Nelson and Winter 1982, p. 9]. However it is important to highlight that selection explains why some structures are ruled out, but not why they are created. Nelson and Winter discuss three basic concepts for an evolutionary theory of economic change:

- a) the idea of organisational routine, which are for a firm a set of ways of doing things and ways of determining what to do;
- b) the use of the term ‘search’ to denote all those organisational activities which are associated with the evaluation of current routines and which may lead to their modification, to more drastic change, or to their replacement;
- c) the ‘selection environment’ of an organisation, which is the ensemble of considerations which affects its well-being and hence the extent to which it expands or contracts (for example, product demand and factor supply conditions)⁵.

The concept of evolutionary theory involves:

⁴ Nelson [1995] argues, however, that the ideas developed in evolutionary sociobiology are not adequate to deal with the questions of most interest to economists concerned with long run economic change, for example the evolution of technologies and institutions.

⁵ Nelson [1995] pointed out that the logic of these models defines a dynamic stochastic system. He describes a standard iteration as follows: ‘At the existing moment of time all firms can be characterised by their capital stocks and prevailing routines. Decision rules keyed to market conditions look to those conditions’ ‘last period’. Inputs employed and outputs produced by all firms then are determined. The market then determines the prices. Given the technology and other routines used by each firm, each firm’s profitability then is determined, and the investment rule then determines how much each firm expands or contracts. Search routines focus on one or another aspect of the firm’s behaviour and capabilities, and (stochastically) come up with proposed modifications, which may or may not be adopted. The system is now ready for next period’s iteration.’

focus of attention on a variable or set of them that is changing over time and the theoretical quest is for an understanding of the dynamic process behind the observed change. The theory proposes that the variable or system in question is subject to somewhat random variation or permutation, and also that there are mechanisms that systematically winnow on that variation. [Nelson 1995, p. 54]

Nelson uses the term ‘evolutionary’ to define a class of theories, or models, or arguments, that have the following characteristics:

- First, their purpose is to explain the movement of something over time, or to explain why that something is what it is at a moment in time in terms of how it got there; that is, the analysis is expressly dynamic.
- Second, the explanation involves both random elements, which generate or renew some variations in the variables in question, and mechanisms that systematically winnow on extant variation.
- Third, there are inertial forces that provide continuity of what survives the winnowing.

Furthermore, he stresses that the use of formal evolutionary theory in economics is still new, and the proponents of evolutionary theory are struggling with both techniques and standards. However, he also emphasises that one of the appeals of evolutionary theorising about economic change is that that mode of theorising does seem better to correspond to the actual complexity of the processes.

3.2.5 The Santa Fe approach

A second, more recent approach studies the economy as an evolving complex systems. It is the so called Santa Fe approach, adopted by researchers of the Santa Fe Institute⁶. Arthur et al. [1997] have defined the Santa Fe Approach (SFA) to economics

⁶ The name Santa Fe comes from the Santa Fe Institute (SFI) which is a private, non-profit, multidisciplinary research and education centre, founded in 1984, located in New Mexico, USA. Since its founding SFI has devoted itself to creating a new kind of scientific research community, pursuing emerging science. As is promoting on its web site, SFI is devoted to creating a new kind of scientific research community, emphasising multidisciplinary collaboration and focusing on what has come to be known as studies of complexity and complex adaptive systems. SFI seeks to break down the barriers between traditional disciplines, to spread its ideas and methodologies to other institutions, and to encourage the practical application of its results. The two dominant characteristics of the SFI research style are

as the complexity perspective or the process-and-emergence perspective⁷. Arthur stresses that the complexity perspective in economics is still very much under construction. The approach emphasises the discovery of structure and the processes through which structures emerge across different levels of organisation. The idea underlining this approach has been to explore the potential usefulness of a broadly transdisciplinary research programme on the dynamics of the global economy system, by bringing together a group of economists and a group of natural scientists who have developed techniques for studying non-linear dynamic systems and adaptive path in evolutionary systems [Anderson et al. 1988].

The complexity approach in economics was generated by taking into consideration the following six features of the economy that present difficulties for the traditional mathematics used in mainstream economics [Arthur et al. 1997]:

- Dispersed interaction: the aggregate results we observe in the economy are generated by the interaction of many dispersed and diverse agents acting in parallel.
- No global controller: competition and co-ordination are the mechanisms among agents that provide control, which means, there is no a global or central mechanism controlling interactions.
- Cross-cutting hierarchical organisation: there are many levels of organisation and interaction in the economy. Units at any level serve as 'building blocks' to form units at higher levels with the interactions being more than hierarchical.
- Continual adaptation: agents change as a result of changes in the system that are produced by the experience agents accumulate individually.
- Perpetual novelty: the creation of new niches produces new behaviours and structures that, again, stimulate the creation of new niches and so on.

commitment to an interdisciplinary approach and emphasis on the study of problems that involve complex interactions among their constituent parts. More information about the Santa Fe Institute may be found on its web site www.santafe.edu.

⁷ Two volumes have been produced as a result of the work carried out by the SFI staff. 1988 saw the publication of the proceedings entitled The Economy as an Evolving Complex System [Anderson et al. 1988]. It was the result of the first workshop entitled 'Evolutionary Path of the Global Economy'. In 1997, a second proceedings volume was published under the title of The Economy as an Evolving Complex System II [Arthur et al. 1997]. This volume gives us a synthesis of the work made during ten years of research on complexity in economics.

- Out-of-equilibrium dynamics: the perpetual novelty property makes it impossible to reach any optimum or global equilibrium. The economy operates in a sort of out-of-equilibrium dynamics.

Systems with these properties have been called Adaptive Non-linear Networks (ANN)⁸. These ANN can be identified in many aspects of everyday life. The economy is one of such aspects.

A main objection concerning how modern economics has made use of mathematical theory is pointed out by this approach. It says that in order to deal with real-world complexities, the standard mathematical approaches that emphasise equilibrium must be replaced by new mathematical tools capable of capturing behaviour when perpetual novelty is present. Nevertheless, there is no clear proposal of such tools. According to this approach they must be based on combinatorial analysis and population-level stochastic processes in conjunction with computer modelling. As we show in the next chapters, these are the sorts of tools used in our model in order to visualise the international trade system, i.e. the emergence of its structure and its dynamics.

The SFA has made clear a few points in which it may be compared with the neo-classical view. For instance Waldrop [1992] says that the neo-classical view emphasises decreasing returns, static equilibrium, perfect rationality, and the economy is seen as some kind of Newtonian machine. On the contrary, the SFA wants to emphasise increasing returns, bounded rationality and the dynamics of evolution and learning. In other words, the economy is seen as something organic, adaptive, surprising, and alive. Furthermore, the SFA points out that it is time to think about the world as a dynamic, ever-changing system poised at the edge of chaos. Although, this is an interesting point of view in economics, the Santa Fe team recognises that it is not totally new. They cite for instance the work of Schumpeter in the 1930s and, in particular, the work of Nelson and Winter in the 1970s on evolutionary movements in economics, described in the previous section.

Not only in the field of evolution there were predecessors to the Santa Fe project. There were also a few in complexity. See, for instance, Comim [2000] who argues that

⁸ John Holland was the first to introduce this term.

Marshall's views on complexity provide useful insights into complexity in economics. Complex economic systems are characterised by interactions between economic agents and, therefore, by the positive feedbacks that those interactions induce. Economic agents are conceptualised as decision-makers whose choice depends not only on the agent's own decisions but also on the decisions of others [Durlauf 1997]. Thus, interactions between economic agents mean that the behavioural choice of an economic agent makes more likely similar choices on the part of other agents. Complex economic systems may be also characterised by increasing returns to scale. They are also inherently non-linear in terms of the way in which components of the economic system move together or co-evolve⁹. This, in part, is because non-linearities are endemic when positive feedback effects are present [Durlauf 1997].

Dynamic systems of the self-reinforcing type—the kind of system commonly found in basic sciences and also in economics—frequently show a tendency to have a multiplicity of asymptotic states or possible ‘emergent structures’. The dynamics of the system may be the result of what was going on about early events or fluctuations and initial starting states of the system and therefore, to select the structure that the system eventually ‘locks in’. The famous example of the industry of Betamax and VHS is presented to illustrate how this happened in economics. Both video technologies exhibit market self-reinforcement in the sense that increased prevalence on the market encourages video outlets to stock more films titles in the particular video technology. When both competed, a small lead in market share gained by one of the technologies may enhance its competitive position and help it further increase its lead. There are positive feedbacks. If the self-reinforcement mechanism is strong enough, eventually one of the two technologies may accumulate enough advantage to take over the whole market, but without knowing in advance which could be. Systems with these characteristics present four properties [Arthur 1988].

- *Multiple equilibria*: however it is not possible a-priori to say which one might be;
- *Possible inefficiency*: for instance economic welfare is not always obtained;

⁹ The idea of co-evolution says that according to a kind of Darwinian principle of relativity every economic agent is adapting to everyone else.

- *Lock-in*: it is hard to exit from a solution when it is reached and, once it is reached, it reinforces itself;
- *Path-dependence*: early circumstances and initial saturating states can determine which solution prevails.

Additionally to complexity and self-reinforcing, change is another relevant concept for the SFA. The idea of perpetual novelty together with the previous discussion on ANN, lead us to think in a sort of continuous change, structures being redefined at any moment by processes that do not have a defined final state. The world is a matter of patterns that change, that partly repeat, but never quite repeat, that are always new and different. Thus, the SFA to economics encompasses the ideas of structural change in a particular way. At each point in time, the economic system is characterised by a historical evolution that influences its future and finds itself in a sort of continuous adaptation and with many alternatives that must be chosen according to a decision-making process.

Another property of complex systems used by the Santa Fe Approach is this intrinsic capacity to reach some sort of order from chaos [Kauffman 1993]. This is known in the complex systems literature as self-organisation. Self-organising systems are those systems that, even when starting from an almost homogeneous or almost random state, spontaneously form large-scale patterns [Kauffman 1995]. The metaphor of the pile of sand on a tabletop¹⁰ illustrates this concept rather well. The sand pile is self-organised in the sense that it reaches the steady state (all) by itself without anyone explicitly shaping it. However, it is in a state of criticality, in the sense that sand grains on the surface are just barely stable. For Krugman [1996], the economy is a self-organising system. He offers two examples in which this is particularly clear:

- 1) a metropolitan area (the economic self-organisation of space). For example, the strong organisation of space within Los Angeles metro is clearly something that has emerged, not because of any inherent qualities of different sites, but rather through self-reinforcing processes, and temporal self-organisation;

¹⁰ The metaphor was presented by the physicist Per Bak.

- 2) the business cycle: the pulses of expansion and contraction around a relatively stable long-run trend. The self-organisation concept is relevant for the study of economic systems. However, it is also important to emphasise the organisation that the whole imposes to the parts. This is not clearly mentioned in the literature.

Another crucial element of the SFA is the notion of emergence. No clear answer has been given so far as to its exact meaning. John Holland [1998] recognises that he does not have a definition to offer. He says that ‘the hallmark of emergence is this sense of much coming from little’. Think for instance in systems like ant colonies, internet, the global economy, all of them being complex adaptive systems, where the behaviour of the whole is much more complex than the behaviour of the part.

The concept of emergence is related to the basic principle of systems thinking that the whole is greater than the sum of its parts. The interaction of lots of parts produce emergent properties in the sense that the group of parts could do things collectively each individual apart could not. Economic agents try to satisfy their material needs by buying and selling and trading between them, which creates an emergent structure known as market. But the market is not present as a characteristic of any individual economic agent. It is something that comes into being only by the interaction which actually occurs between them. For Casti [1997] emergence must be at the core of what could be called a theory of complex systems, because it means having a set of principles by which systems organise themselves and behave.

But complexity is not necessarily an intrinsic characteristic of a system. Complexity in a system's behaviour, as is argued by Casti [1997], may arise from instabilities in two very different ways. The first is when the system dynamic itself is changed by varying the rule of motion of the system. The second is that we may encounter surprising, unpredictable behaviour simply because the system dynamics are sensitive to the initial condition. Sensitivity to initial conditions forms one of the most dramatic and important features of what have come to be termed chaotic dynamical systems.

One way of studying complex systems is by means of the so-called societies of silicon [Casti 1997] or artificial societies [Gilbert and Conte 1995]. Artificial societies are

computational and simulation models of ‘possible’ societies, their general processes, dynamics, and emergent properties. Their aim is to model features and processes which characterise natural target societies; it is not to reproduce the social world. Gilbert and Conte [1995, p.4] refers to this approach as a ‘new experimental methodology consisting of observing theoretical models performing on some testbed’. The methodology is defined by Gilbert and Conte as exploratory simulation. They argue also that the realisation, observation and experimentation with artificial societies allow to improve our knowledge and understanding of social phenomena whose structure and behaviour are so complex. The construction of artificial societies (or silicon worlds), as it is pointed out by Melanie Mitchell [Casti 1997] follows this sequence:

Simplify the real-world problem as much as possible, keeping only what appears essential to answering questions being asked.

Write a program that simulates the individual agents of the system, their individual rules for action and interaction, along with whatever random elements appear to be needed.

Run the program many times with different seeds for the random number generator, and collect data and statistics from the various runs.

Try to understand how the simple rules used by the individual agents give rise to the observer, global behaviour of the system.

Change parameters in the system to identify sources of behaviour and to pin down effects of different parameter settings.

Simplify the simulation even further, if possible, or add new elements that appear to be needed. [Casti 1997, p. 179]

A relevant aspect of the focus on complexity is its inclusion of the willingness to rely on the computer as an aid to theory, but as Krugman said, it cannot substitute for more specifically economic concepts. In addition, the study of complexity and complex systems has encouraged an interdisciplinary dialogue. However:

that dialogue has had little participation from serious economists, even though the relevance of complexity to economics seems obvious to all concerned. The results has been that a lot of ill-informed things are being said and published about the role of complexity in the economic system (and, inevitably, about the blindness of economists who have, of course, ignored things like the role of increasing returns). Since we are already doing what amounts to complexity theory in economics, I suggest that we acknowledge the fact and try to built bridges - we have something to learn, and we surely have a lot to teach. [Krugman 1995b, p. 42]

3.3 The emergence of structure in international trade system

In the last two sections discussed emergence as one of the main features of the evolutionary economics and the Santa Fe approach. This section analyses emergence of structure in relation with international trade. The structure of the international trade system emerges as a result of the interaction of many individual agents. Depending on the level of aggregation, it is possible to identify the following agents: the countries (represented by their governments), the economic sectors and the workers/consumers. The structure of the international trade system is the way all these actors organise themselves in order to buy and sell commodities in the international markets.

A decision-making process underlies the formation and change of that structure. Each agent may follow its own rules to cope with its economic objectives. But owing to the systemic characteristic of the international trade system, these rules may be modified as a consequence of changes in other agents' rules. Direct agreements between countries, for example, may encourage the increase of trade among their agents and discourage trade with outsiders.

The structure and the way it changes are defined not only by the agents' rules but also by international supply and demand. Each country's economic production system has its own characteristics, which are determined by the sort of technology that it uses to produce its commodities. From the international demand side, an economic sector buys commodities in the international markets in order to satisfy its domestic final demand, as well as to obtain the intermediate commodities not produced domestically that are used to its own production. This generates a sort of interdependence among economic sectors of different countries. The process of globalisation has increased this interdependence. In fact, it is common to hear how recession in a country may directly affect its commercial partners. For example, if a reduction of travellers limit air travel in USA then this will affect those oil producing countries that sell their products to USA's air industry¹¹, which contemporarily unchain other collateral effects in its own economy, through the internal economic sectoral interdependence. From the international supply side, however, economic sectors are interested in increasing their sales abroad, in order to benefit of the

¹¹ The recent air blockade of September 2001 has proven this.

economies of scale that it generates. It seems that the study of economic growth must be carried out not only at single country level but on a more global base.

Historical, cultural, political and other reasons may be behind the patterns of trade observed in the international trade system. However, it is also the result of economic constraints. The international trade system, however, largely differs from other kind of systems, as, for example, an organisation or an enterprise, due mainly in the way its structure emerges or changes over time. In the latter the aims of the system are well established, and in part, the means to tackle those aims are organised accordingly (or at least, it is the way it should be). In the former, the structure of the system emerges as a result of a unplanned, dense network of interactions. The structure is self-organised and adaptable. Furthermore, the international trade system may be seen as a complex system and therefore, it may be studied using the relevant of the overlapping methodologies early described in this chapter.

However, the interdependence observed in the international trade system, as described above, requires the study of each country economic system and a way of representing it in the model proposed. One way is to use Leontief's input-output model to represent a country production system from a simulation point of view (some preliminary results are presented in Appendix A)¹². This might allow us to observe how the kind of interdependence we are talking about here influence on and are influenced by changes in the way countries produce their commodities and in general organise their economy. However, due to the difficulties to obtain I-O data for developing countries, they were not included in the developed model¹³. It is something that could be explored as part of future research.

¹² Further remarks on the research presented in the Appendix A are given at the end of chapter 5.

¹³ We will expand these ideas at the conclusions' section of chapter 6.

3.4 Conclusions

This chapter has framed the way in which systems, and in particular complex systems, are studied in economics and elsewhere. A system, i.e. a part of the world, is formed by components that have relationships among them. As a whole, a system exhibits behaviour, has an environment, receives inputs from and sends output to it, and there is someone who is its observer. The study of systems states that a system as a whole is more than the sums of its parts. This peculiarity of systems makes not easy to infer their properties from the properties and laws of interactions of their parts. Thus, in order to understand a system, it is important to study ways of representing their structure and their dynamics. The structure, defined as the way in which the components of a system are arranged or organised, is closely related with those components and relationships of the system that are represented in a model. How the structure of a system changes over time is one of the main concerns of structural change. Structural change in a system occurs when some parts or properties are lost or added to the components, some relations appear or disappear or change their form. There is a continuous interplay between the global system and its components that transform each other. In economics, those changes are primarily concentrated on permanent change in the composition of some basic economic aggregated magnitudes (e.g. total employment, total consumption, etc.). Structural change, as it is studied in economics and in other fields, remains an interesting subject of research, whose insights may provide a theoretical framework for the analysis of economic system dynamics.

Furthermore, this chapter presented the Evolutionary and the Santa Fe approaches in economics, as methodologies that deal with dynamics and the study of complex systems. The former emphasises adaptation, learning, change and random variation or permutation as relevant concepts in the study of economic systems. The latter, which has been also called the complexity perspective or process-and-emergence perspective, emphasises processes, positive feedbacks in the interaction of economic agents, change as perpetual novelty, self-organisation and emergence. These approaches are still in their infancy, but hopefully, they will contribute to gain insights about the study and research on economic systems dynamics.

These approaches require that we think not only in terms of theoretical oriented models but also in terms of computer based models that use the computer resources we currently enjoy (and that for sure will be improved in the future) to better represent economic processes and systems. In other words, to represent processes that, by their own nature, are complex and dynamics.

As has been pointed out by Casti [1997], chance, co-evolution, organisation as process, as well as structure are the main principles that may be selected from the study of complex system. All these concepts are relevant for both the Evolutionary and the Santa Fe approaches in economics. The key insight underlying all these ‘nuggets of wisdom’ as Casti calls them, is that interaction between individual agents and aggregate patterns and behaviour mutually reinforce each other. These principles, however, are also found, in part, in the study of structural change in economics. All these approaches share a common core of concepts, as mentioned above, that may be exploited in order to study international trade as a system, by using the computer as a generator of dynamic scenarios of its complexity.

Section 3.3 suggested a way to observe the emergence of the structure in the international trade system by following the concepts presented in this chapter. The structure of the international trade system emerges from the interaction among a group agents. We have in particular identified three main agents: countries, economic sectors and workers/consumers. The way these agents organise themselves to buy and sell commodities in the intentional market (for example through the formation of trading blocs) is viewed here as a relevant part of the structure of the system. For this reason, it is necessary to discuss in some more details (see next chapter) the importance of trading blocs and patterns of trade as well as some other related concepts used in the recent economic literature. This allows us to capture the main insights traditional models in economics have provided to answer issues about trading blocs, and the welfare analysis implications of the recent wave of regionalisation. In addition, it will provide the framework for the developed model of chapter 7, which focuses on all these concepts: complexity, emergence structure, trading blocs, network of exchanges or patterns of trade, as well as their evolution over time.

Chapter 4

Trading blocs and patterns of trade

4.1 Introduction

In the last two chapters, we have discussed the main international trade theories and how to deal with complex systems in economics. These set the basic framework for the model of this thesis, which sees the international trade system as a *complex system evolving* through time. *Trading blocs* and *patterns of trade* are two of the main components of such a system. Both are among the main features included in the model that we develop. Because of their importance it is necessary to analyse them in detail in this chapter.

There are plenty of trading blocs and almost all countries belong to at least one trading agreement. The biggest and the most inclusive of all trading arrangements, the World Trade Organisation (WTO), numbers 138 member countries [WTO 2000]. In recent years, the proliferation of new forms of trade arrangements has continuously been at the core of the bilateral negotiations among countries. In the 1990s, in particular, a trend towards the formation of continent-sized blocs emerged, in which not only economic aspects, but also strengthened co-operation on foreign and security policy, justice, industrial policy, consumer affairs, health and education are considered as part of the arrangement. This was the already cited European Union case [Frankel 1997]. By 1994 more than thirty trading arrangements had been established¹. The patterns of trade may be changed, in part, as a result of bloc formation. Of course, the current patterns of trade observed in the real world are the result of many interacting factors. We shall

¹ In Appendix B we give some details about the World Trade Organisation and selected major Regional Trading Blocs.

explore the outcome of these patterns as a direct result of bloc formation. For this reason, we also discuss how different scholars deal with patterns of trade.

In section 4.2 we introduce the concepts related to trading blocs (such as the different types of regional agreements signed by countries) depending on the level of commitment reached by country members through the agreements on trade and other policies for deep integration. Some concerns about the effectiveness of trading blocs leading to a state of free trade are also discussed. In section 4.3 we analyse the sorts of questions regarding trading blocs that most researchers try to answer. Section 4.4 is devoted to exploring the kinds of models that are used in the literature to manage trading blocs and to answer the main inquiries about trading blocs. In particular we shall consider two types of models are generally used in the literature to study trading blocs: econometric models (*e.g.* gravity model) and theoretical models (*e.g.* monopolistic and oligopolistic competition models). Some of the consequences of bloc formation that have been highlighted in the literature surveyed are given in section 4.5. Subsequently, in section 4.6, we explore the ideas of patterns of trade. We have focused our attention on some studies providing insights into the evolution of patterns of trade over time, which also permits to observe the trends of specialisation followed by some countries. Finally, in section 4.7 some conclusions are provided.

4.2 Basic concepts on trading blocs

Countries trade goods and services among them. Each one establishes its own rules when doing business with the others. Sometimes the rules are laid down by the state to protect domestic industries by imposing import tariffs or other kinds of barriers, such as quotas. There is no common rule for fixing tariffs and, in many cases, there are no explanations for their existence. Governments may intervene or not. Sometimes, their interventions are justified by anything but economic reasons, as for instance, national defence, preservation of political power, etc. [Jackson 1998]. A quota is more damaging for world economic welfare, since quotas on foreign trade, unlike tariffs, break the link between domestic and foreign prices, and effectively prevent specialisation according to a country's emerging comparative advantage [Lal 1993]. According to Lal the current

movement towards regional trading blocs is a culmination of this trend towards what is called ‘managed’ trade.

The optimum tariff argument, first put forward by John Stuart Mill in the 18th century, says that a country could improve its terms of trade by levying such tariff. But, this requires no foreign retaliation. If there is foreign retaliation, then it will probably start off what in the literature is called a trade war, with uncertain effects on welfare. However, it has been argued that, though theoretically valid, its practical relevance is equally limited (see Whalley 1985, cited by [Lal 1993]). Nevertheless, this condition is also included in the model developed below.

In the case where a government does not intervene when countries trade between them, the trade is called a free trade.² Thus free trade implies no government intervention, which means no country should levy any tariff on imports or should remove any barrier to trade. Free trade is the first best from the economic welfare viewpoint because it may lead to the most efficient allocation of resources on a world scale and to the maximisation of world income [Pearce 1995]. Lal [1993] argues that the ideal policy for each and every country is to adopt free trade unilaterally in its own self-interest. For Frankel [et. al 1995], first best would be a world-wide regime of free trade but unlikely to be reached in practice.

But this practice has rarely (if ever) been applied by any country. On the contrary, for political or economic reasons, countries try to establish some type of treaty or agreement in order to stimulate trade of goods and services among them. These treaties could be ended by the formation of a trading bloc. A trading bloc is defined by Loxley [1998] as a region that is inwardly liberal and outwardly protective.³ This is what has been flourishing in recent times. The important features of this ‘current wave of regionalisation’ process [Jin and Frankel 1998] are that: 1) almost every country belongs

² Jackson [1998] talks about liberal trade instead of free trade, meaning the goal to minimise the amount of interference of governments in trade flows that cross national borders. This notion of liberal trade is, for him, a starting point for any discussion of policy for the international economic system.

³ Rollo [1994, p. 35] talks about true trading blocs by imposing the following, qualifying conditions: they are constituted by nation-states with a largely common commercial policy, and these states should have agreed to form a customs union, moving towards free internal trade in goods and services and free movement of labour and capital. He argues that only the European Community (current European Union) is

to at least one trade bloc; 2) most trade blocs have been formed among neighbouring countries and many are along continental lines; 3) regional agreements are put forward or accelerated in various parts of the world simultaneously.

Many other names have been given to the agreements that countries sign, but in essence their aim is to increase or fortify commercial relations between partners countries.⁴ The following are some of such alternative names and their definitions:

- Free Trade Area (FTA): a grouping of countries within which it has been decided to remove tariff and other barriers to trade, while each member country retains its own commercial policy to countries outside the area.
- Customs Unions (CU): a grouping of countries within which trade restrictions have been eliminated but which has a concerted commercial policy towards non members and a common external tariff on imports from them, though the tariff rate may vary between commodities.
- Common Market (CM): an area, usually combining a number of countries, in which all can trade on equal terms. Such a system requires the establishment of a customs union, with the free movement of factors of production as well as of goods and services, and considerable harmonisation of tax and other policies.
- Economic Community (EC): an economic union among countries, which have common external tariffs and commercial policies, and have removed restrictions on trade between member countries. Such a union ultimately involves the harmonisation of industrial and social policies, and concerted monetary and exchange rate policies as a step to common currency.
- Preferential Trading Arrangement (PTA): a grouping of countries within which tariff levels are reduced, but not necessarily eliminated, while each member country retains

in this respect is a true trading bloc in the world. See also Henderson [1994] for a discussion about the definition of trade blocs.

⁴ Whalley [1998] stresses that there are other objectives countries set for their involvement in regional trade agreements, such as: to underpin domestic policy reform, the desire to achieve firmer market access with large trading partners, the link between trade agreements and strengthened security arrangements, and the use of regional negotiations as a threat to driving multilateral negotiations forward.

its own commercial policy to countries outside the arrangement. It may also receive the name of Regional Trading Agreement (RTA) [WTO 1995].

- Regional Integration Agreements (RIA): this name is used by the WTO [1995] to refer to agreements that have been concluded by countries in the same geographic region or countries in different regions.

In the model presented in chapter 7, only Preferential Trading Arrangements (PTAs) are explored, because of their importance. PTAs are associated with significant intra-industry trade and imperfect competition. The general phenomena of falling tariffs and the increasing number of PTAs are certainly evident in the world. While the recent proliferation of PTAs has been seen, in part, as a response to the failure of GATT, some scholars think that the opposite is also true: ‘many of the current partnerships may actually be the result of success of the GATT in lowering tariffs’ [Freund 2000]. The interdependence structure that is created by PTAs’ formal arrangements makes the world commodity and financial markets more likely to become substantially integrated, forging close linkages among national markets [Eun and Jeong 1999]. There are many questions associated with PTAs. One of the most important questions for the study of bloc formation relates to its impact on the growth of output in member countries. We will try to answer it with the model presented in chapter 7.

Many concerns have arisen recently about the effectiveness of these trading blocs in leading the global economy to a state of free trade. Trading blocs, whatever their form, CUs, PTAs, FTAs, etc., are considered in the literature as a second best⁵. In any case, new arrangements are frequently established or signed between countries. In fact, this movement towards the definition of new and varied arrangements among countries has attracted the attention of many specialists who try to explain, in the light of economic arguments, the advantages or disadvantages, the good points or bad points of trading blocs.

⁵ GATT has been predicated on the assumption that second-best is a regime where each member accords another the status of Most Favoured Nation (MFN), i.e., treats its trading partners equally. [Frankel et al. 1995].

There are concerns that the world economy may break down into three large trading blocs: North America, Europe and Asia, each of them dominated by a major national economic pole around which the other national economies in the region would revolve. These poles are the USA, Germany and Japan, respectively:

At the root of these concerns lies the fact that globalisation has had a definite regional character and that there are clear trends towards institutionalising increased regional co-operation in both Europe and North America. [Loxley 1998, p. 73]

For most economists these blocs are likely to be net trade creating. But Lal [1993] argues that two serious worries remain: 1) rather than being a step towards multilateral free trade such blocs will lead to a retrogression; 2) the concentration of scarce political capital and energy on promoting regional trading blocs will divert the attention and support of traditional supporters of the global system towards these second-best schemes.

A hypothesis regarding also the formation of these large trading blocs is related to the notion of Natural Trading Blocs. However, the meaning of 'natural' is still fairly debatable. The 'natural trading partner' hypothesis, first introduced by Lipsey [1960; cited by Schiff 1999], has divided the opinion of many scholars with regard to what is known in the literature as 'Natural Trading Blocs'. For Lipsey, a customs union is more likely to raise welfare the higher the proportion of trade with the country's union partner and the lower the proportion with the outside world. Thus, the hypothesis is referred to the volume of trade. If two countries are 'natural trading partners', they are more likely to gain from a Preferential Trading Arrangement (PTA) between them. The volume of trade does not necessarily provide an objective measure of the extent to which trading partners are 'natural' [Schiff 1999]. The argument is that the volume of trade is itself affected by trade policy. Countries are defined as 'natural trading partners' if they tend to import what the prospective partner exports; in other words, if it is defined in terms of complementarity or substitutability in the trade relations of member countries rather than in terms of their volume of trade. Bhagwati and Panagariya [1996] argue also against the volume of trade criterion to define natural trading partners by pointing out that: 1) the criterion is neither symmetric nor transitive; 2) it is based on the view that a larger initial volume of trade between potential partners is less likely to cause loss because of trade

diversion; and 3) it ignores the tariff-revenue-redistribution effect. Frankel et al. [1995] define a Natural Trading Bloc as a bloc that by moving to free trade within it raises the welfare of its members. Amjadi and Winters [1997] argue that a Natural Trading Bloc must be defined as well in terms of transportation costs. As we will see in chapter 6, different criteria are used to define trading blocs, based not only on volume generated by trade but also on transportation cost.

Freud and McLaren [1999] have studied the dynamics of trade reorientation experienced when a country joins a regional trade bloc. They noticed that the joining country's trade reorientation toward bloc countries typically rises along an 'S'-shaped path. For the EU, NAFTA and Mercosur they found that over the period of adjustment (which Freud and McLaren estimate in twelve years) their trade share grows. This reinforces the idea that it takes time to observe the effects on trade pattern reorientation after a trading bloc is formed. Some of the experiments with the model proposed in this thesis will in part show this behaviour.

The creation of trading blocs may follow a particular path, depending on how integration is undertaken. Wellisch and Walz [1998] recognise that there is one procedure common to a number of countries. They argue that the first step is that countries liberalise trade flows among themselves by creating a Free Trade Area. However, after this step, nearly all free trade areas are very reluctant to open their borders for a free movement of people (see the examples of the EU and Turkey or NAFTA and Mexico, where FTA have been created, but no free movement of workers among the signatory states). They also argue that the attainable level of social welfare for rich countries is smaller in the case of free migration than with free trade when countries engage in redistribution - even if factor prices are identical. Thus, they suggest, an application for full integration (which includes free migration) of low-income country is quite undesirable for rich countries (this is in part what is going on in the case of the EU with countries like Turkey, in which a free trade zone has been implemented instead of the full EU membership. This contrasts with the case of Austria, Finland and Sweden (high-income countries), which were relatively quickly accepted as EU members).

4.3 What are the main concerns in the literature about trading blocs?

A non-exhaustive list of the main concerns about trading bloc formation to which economic literature has tried to find an answer includes among others:

- What are the welfare implications for both the world as a whole and the member countries? Perhaps this is the most important issue about trading bloc formation. For example: Frankel et al. [1995] ask whether the world is becoming more regionalised and what could be the welfare effects if the trading system were to settle for an array of regional blocs; Bond and Syropoulos [1996] ask how the expansion of trading blocs will affect their external tariffs, and thus the level of world welfare; and Casella [1996] asks whether small or large countries systematically benefit more from joining a free trade bloc.
- How much influence do these arrangements have on actual trade flow patterns? Frankel [1997] inquires whether the growth in trade may be biased toward trade within regions and away from trade between regions. Soloaga and Winters [1998] whether PTAs do really increase trade among members.
- How long does it take for a country to adjust fully to the change in trade policy implied by accession to a regional trade agreement? [Freund and McLaren 1999]
- Is the dynamic effect of the Preferential Trade Agreements (PTAs) to accelerate or decelerate the continue reductions of trade barriers toward the goal of reducing them worldwide? Time-path of MTN (Multilateral Trade Negotiations) vs. time-path of PTAs. This question has arisen in policy concerns and political decisions that ran ahead of the theory [Bhagwati and Panagariya 1996].
- How are production, prices and income of the existing members affected as a result of the expansion of the bloc. Does it matter whether the existing member is large or small? [Hacher and Hussain 1998]
- If a country has decided to form or join a trading bloc, what partner or partners should it select? [Schiff 1999]

4.4 Models used to deal with trade blocs

The incentives for a group of countries to create an economic bloc, or to expand or merge those that exist, are mainly determined by a political process rather than by welfare considerations [Andriamananjara 1998]. But the political process must be aware of economic and social factors when decision are taken and, more especially, of their consequences. Hence it is relevant and very interesting for economics to understand the dynamics of bloc formation and its economic consequences and, where possible, to give some advice to governments about it. Given the complexity of this problem, many scholars have tried to answer these issues by using a variety of models such as: a) econometric models and b) theoretical models.

The first group, i.e. the econometric models, are tools that allow researchers to explore issues *a posteriori* by testing hypotheses in order to confirm or not what happened in reality. These studies deal with real data and real countries. But they do not describe the dynamics that produce such data. Perhaps the most used has been the Gravity Model⁶ of bilateral trade, in which in its most basic form the trade between two countries is proportional to the product of their respective Gross Domestic Product (GDP) and inversely related to the distance between them. Trade is the dependent variable (imports plus exports) between pairs of countries in a given year and the two most important factors explaining bilateral trade flows are the geographical distance between the two countries and their economic size (represented by their GDPs). A gravity equation is formulated using dummy variables⁷ for bloc formation. Frankel, Stein and Wei [1995] and Frankel [1997] use this type of model to examine data on bilateral trade between pairs of countries in order to sort out the influence of geographical proximity versus preferential trading policies in creating regional concentration on trade. Their main conclusion has been that free-trade areas are indeed concentrating trade regionally. Additionally, Soloaga and Winters [1998] use a gravity model to explore the effects of

⁶ The gravity model was inspired by Newton's gravitational law which says that the attraction between two heavy bodies is directly proportional to the product of their masses and inversely proportional to the distance between them. It has been used to certain problems in regional economics and transport studies. Despite its common use, the model has been criticized as lacking firm foundations in economic theory [Frankel 1997].

⁷ Generally, a dummy variable indicates if two countries belong to the same bloc by taking the value of 1, and 0 otherwise.

PTAs (MERCOSUR; NAFTA; etc) on intra- and extra-bloc trade. They investigate in particular whether or not PTAs really increase trade among members and if they harm non-member countries. For some blocs, (EU and EFTA) they found convincing evidence of trade diversion and for other blocs (CACM and MERCOSUR) a positive trend for bloc members' imports.

Besides the gravity model, there are other types of econometric models that have been introduced to study bloc formation effects on trade. For example, Freud and McLaren [1999] use a trade intensity index as a measure of trade reorientation. This index describes how much one country trades with the other members of the union in comparison with how much the other members trade with the rest of the world. They study the dynamics of trade reorientation (expressed in the trade index) experienced when a country joins a trading bloc, to analyse or predict the effects of agreements such as EU, EFTA, MERCOSUR and NAFTA. They conclude that a pattern of a rough 'S' shape, with an accelerating and then decelerating adjustment, and a jump on the date of discrete change in tariffs, appears to be a good description of how trade orientation moves when a country joins a trading bloc.

The second group of models, theoretically oriented, tries to answer issues of welfare related to bloc formation, by using the neo-classical framework of analysis. In general, the aim of this second group is to identify the pre-agreement situation and analyse what happened after its formation. Characteristic works developed under this framework may be found in Frankel et al. [1995] and Jin and Frankel [1998]. They extend the differentiated product model under monopolistic competition *à la* Krugman to include transportation costs. Their main concern is to study the welfare implication of bloc formation. They found that

- a) continental Free Trade Areas (FTAs) under conditions of relatively low inter-continental transport cost could be welfare reducing blocs;
- b) partial liberalisation within a regional Preferential Trade Arrangement (PTAs) is better than 100% liberalisation and;
- c) multiple Free Trade Areas (FTAs) on each continent could lower welfare, but that multiple PTAs, with partial internal liberalisation, would raise welfare.

With some variants, Andriamanajara [1998] uses an oligopolistic competition framework to show that global free trade can be achieved through bloc expansion if trading blocs lower their external tariffs when they abolish their internal tariffs. Hacker and Hussain [1998] use a three-country duopoly model to examine the effects of reduced trade barriers when a new entrant joins a trading bloc that has two countries, one small and one large. Their analysis shows that as a result of a reduction on tariffs, there are greater gains for the small-country firm than for the large country firm.

In a similar way, Schiff [1999] distinguishes three countries, the home country A, the partner country B and the rest of the world C, as well as perfect competition and homogeneity. His main concern is to answer what partner or partners a country should select if it has decided to form or join a trading bloc. He argues that the volume of trade is not a useful criterion and that the PTA as a whole is likely to be better off if each country imports what the other exports. Finally, Bond and Syropoulos [1996] consider a simple exchange model in which there are N countries and N goods; all countries have identical preferences expressed by a utility function and each country has equal endowments in $N-1$ goods except in one, in which it has a comparative advantage (so they associate one good with one country). Using this perfectly symmetric world in preferences and that particular endowment structure, they analyse the effects of a symmetric expansion of trading blocs. They show that there is an incentive for blocs to add members (and for countries to want to enter large blocs) in the sense that, they argue, there is always a bloc size in which the expanding bloc can increase its welfare.

All the above-mentioned models used in mainstream economics are static in the sense that they do not take into consideration the process that might induce structural change. It is the equilibrium paradigm rather than the underlying processes that is mostly considered. Dealing with the underlying processes in bloc formation means observing not only the top-down approach of political agreements countries may reach but also the bottom-up approach⁸ of network of shipments formation. Bottom-up means taking into consideration prices, quantities, costs of transportation and barriers to trade and their

⁸ Top-down approaches deal with how a system as a whole constrains and directs individual part processes. On the contrary, bottom-up approaches deal with the way system parts assemble and modify a structured whole, as it was discussed in the previous chapter.

trends in the creation of the network of shipments. We argue that combining both approaches is a way of enriching and highlighting the reinforcement mechanisms present in the process.

In contrast with the above-mentioned models, the model presented in this thesis does not focus on a static equilibrium, but is concerned with the representation of a process that is dynamic. Therefore, our approach deals with the dynamics of the trade system induced by bloc formation and its consequences from a systemic point of view by using structural simulation techniques. 'Dynamic' means including a way of representing the world trade system's structure and its evolution through time. The systemic point of view means observing holistically the behaviour of the trade system, in the way it was discussed in chapter 3.

4.5 Some consequences of bloc formation

Despite the proliferation of trading blocs, not all of them may be considered as being effective, in the sense of playing a significant role in shaping the trade flows and/or policies of its members. One possible measure of a potential indicator of effectiveness of trading blocs is the expansion of trade among partners beyond the level that would have occurred in the absence of an agreement. In other words, a regional grouping is judged as effective if the data reveal that the share and/or intensity of intra-group trade in the years following the formation of the group is significantly larger than in the years before. On this basis, the following blocs are considered as effective. In Latin America: CACM (in the early years following its formation in 1960 and then again in the 1990s), the Andean Group, and Mercosur (all of them since the early 1990s). In Africa: CEAO/UEMOA and SACU. In the North/South groupings NAFTA and Israel/US FTA and the EU-Mediterranean initiative [Foroutan 1998]. More details on these trade blocs are given in Appendix B.

Tariffs, as they were discussed in section 4.2, are used in many cases for increasing the efficiency of a trading bloc. It is evident that bloc formations through tariff reductions may have a major effect between members of the group. For example, multilateral tariff reduction affects the incentive to join a PTA and the associated self-

enforcement mechanism. ‘As the multilateral tariff level falls, the forces pulling countries away from free trade and into bilateral agreements strengthen’ [Freund 2000]. Lowering tariff enhances competition, which leads to greater output and moves the economy closer to the efficient outcome. Tariffs (as *de facto* barriers created by differences in language and culture, lack of factor mobility, and the sheer nuisance caused by the existence of a border) are often enough to block the expansion of a successful industrial district beyond its national market [Krugman and Venables 1996]. For this reason, economic integration, a reduction in the costs of doing business across space, induces industrial agglomeration. This last is a very important force for interregional rather than international specialisation. On the other hand, changes in the size of trading blocs may produce changes in tariffs and also in welfare. This was found in the case when one trading bloc expands in size relative to other trading blocs [Bond and Syropoulos 1996]. In fact there is an incentive for blocs to add members (and for countries to want to enter large blocs) in the sense that there is always a bloc size at which the expanding bloc can increase its welfare above the free trade level.

The above considerations are all based on the idea that there is an agreement on tariffs. On the contrary, when countries are in a trade war, the role of tariffs may be completely different. For example, when two countries choose optimal tariffs in a trade war, specific tariffs are not equivalent to *ad valorem* tariffs even if all markets are competitive. Using a two-stage game, Lockwood and Wong [2000] found that two identical countries would choose *ad valorem* tariffs, making the trade war less severe. They also stressed that the type of protection a country chooses may depend on whether the consumer groups or producer groups are stronger in the political system in which trade policies are determined.

There are many other aspects, in addition to tariffs, that affects the efficiency of a trading bloc: for example persistence of past linkages, level of industrialisation, political conflicts, transportation costs, size of the bloc, GDP growth, etc. The importance of each aspect is different for each bloc or better for each individual country. Baier and Bergstrand [2001] have found that the growth of world trade among several OECD countries between the late 1950s and late 1980s could be explained approximately for 67-

69% by real GDP growth, 23-26% by tariff-rate reductions and preferential trade agreements, 8-9% by transport-cost declines.

In the case of the former Soviet Union, it was found that Russian regions traded 60 percent more with each other than with republics in the reform period (1994-96). By contrast, they did not trade significantly more with each other than with republics in the pre-reform period (1987-90). This suggests that the bias towards domestic trade in the reform period is primarily a result of tariff reduction and the persistence of past linkages. In addition, this is an interesting example of how disintegration may induce change in the determinants of trade flows. On the contrary, in some cases a creation of a bloc may produce drastic changes on the trade of each member towards their traditional markets. This was the case of Spain and Portugal. Their entrance into the EC has had a clear negative impact on the trade of those countries with South America. Entry to the EC led to Spain switching its coffee and cocoa purchases from Latin America to the ACP countries whose goods are not subject to the Common External tariff. Spain also reduced quite drastically its purchases of Argentinean corn and Brazilian oilseeds on entry to the EC [Loxley 1998]. Similar effects may be found for example in the history of trade before the Second World War. There is some evidence that the formation of formal trade blocs in the 1930s diverted the members' trade away from the rest of the world and toward fellow bloc members. This was the case for the members of the British Commonwealth and the German sphere of commercial influence [Eichengreen and Irwin 1995]. However, commercial and financial linkages that had developed over previous years contributed importantly to the prevalence of intra-bloc trade. There is evidence of significant impacts of trade policies (also currency policies) on the pattern of trade at the time, and these evidences suggest

caution for those tempted to attribute to preferential trade and currency arrangements all deviations in trade flows from those predicted by the readily observed characteristics of trading partners.. those deviations may reflect not just regional policy initiatives but also long-lived historical forces working to encourage disproportionate volumes of trade among certain countries, and perhaps encouraging those countries to cement their relationships through the adoption of preferential arrangements. [Eichengreen and Irwin 1995, p. 22]

Improvements in transportation and communications technology are another major cause in the increasing of trade [Krugman 1995a]. In addition, communication and transport infrastructures are a significant and quantitatively important determinant of transport costs and of bilateral trade flows. Transport costs provide an effective rate of protection that is for many countries considerably higher than that provided by tariffs [Limão and Venables 1999]. Remoteness and poor transport and communications infrastructure isolate countries, inhibiting their participation in global or regional production networks. On the other hand, countries should be stimulated by preferential policies because of their geographic proximity that normally implies better transport infrastructures. However, this is not always the case. In the Mercosur, though these countries seem to be natural partners as result of their geographical proximity, in transportation terms (transportation cost on trade between Mercosur countries are about 6 percentage points lower than on trade with the rest of the world), it is 'rather small and offer little justification for pursuing regional preferences' [Amjadi and Winters 1997, p. 24]. It seems that absolutely high transportation costs between a trading bloc and the rest of the world justify regional trade preferences. For this to apply, the introduction of trade preferences must cause the bloc countries to cease importing some goods from the rest of the world completely. In the case of Mercosur, transportation costs are certainly high and trade patterns suggest that very few goods will cease to be imported from countries outside the bloc [Amjadi and Winters 1997].

One of the aims of an economic bloc is that all its members may have the same benefits. However, this is seldom the case. In bilateral agreements the largest country normally can take most of gains. Park [2000], with the aid of a Ricardian model of bilateral trade between a small and a large country, shows that the large country can change the terms of trade in its favour by imposing a tariff. On the contrary, the small country cannot affect the terms of trade by its trade policy choices. Park based his analysis on a game theoretical framework to search for Nash equilibrium with trade and without trade. He argued that it is possible to negotiate an efficient trade agreement under which both countries are better off than in the Nash equilibrium. Other researches found that an enlargement of the bloc may generate positive effects for the small members. The enlargement, by increasing the size of the market to which all firms have relatively easy

access, decreases the importance of the domestic market and plays in favour of the small country. The gains from expanding the membership of the trade bloc will fall disproportionately on the small country [Casella 1996]. However, Casella also argues that even though the theoretical prediction is clear, the empirical analysis yields mixed results (this was in part the case when Spain and Portugal entry into the European Community in 1986).

4.6 Patterns of trade

The literature about patterns of trade is generally more empirically oriented than that about trading bloc formation. Proudman and Redding [2000] have proposed a study about the evolution of patterns of international trade over time that distinguishes two main components: (1) the extent of a country's specialisation in an individual industry (which is measured by an index of revealed comparative advantage); (2) the dynamics of international specialisation that corresponds to the evolution of the entire cross-section distribution of the index of revealed comparative advantage over time. The patterns of comparative advantage and international specialisation are determined by initial levels of productivity. But these patterns then affect rates of productivity growth and hence the evolution of international trade flows over time. In models of international trade and endogenous technological change there is a cyclical reinforcement mechanism in which the evolution of patterns of international trade over time is determined by rates of technological progress in each sector. In addition, these rates of technological change are themselves determined in part by the existing pattern of international trade.

The study of international trade patterns over time involves issues (such as persistence versus mobility in international trade flows) that correspond to questions of intra-distribution dynamics. Proudman and Redding [2000] found evidence of substantial mobility in patterns of international specialisation in the G-5 countries and no evidence of an increase in international specialisation in France, Germany, the United Kingdom and the United States. Only in Japan is there evidence of an increase in international specialisation over time. These findings are in contrast with what was reported by Brasili et al. [2000]. They latter found a highly persistent trade pattern in the six largest

industrialised countries, and a rapidly changing trade specialisation in eight fast-growing Asian economies. For them, this may suggest that rapid growth and factor accumulation is associated with a mobile trade pattern. Their conclusion is in line with traditional trade theory, in which changing comparative advantages is the determinant of a changing trade pattern.

Brasili et al. [2000] conclude that the theoretical literature on trade patterns evolution suggests that changing comparative advantage pushes in the direction of patterns of trade, and that increasing returns to scale tend to reinforce the existing specialisation locking trade patterns in. They also conclude that trade patterns dynamics are closely linked with the process of international knowledge diffusion. In the absence of knowledge spillovers, persistence and polarisation in international trade patterns are the most likely outcomes, and with knowledge flows, comparative advantages change which induces change in the trade patterns.

Apart from the trade patterns and its relations with specialisation, there is an increasing recognition of their complexity and relations. Sonis et al. [1995] argue that significant features of the structure of trade flows or patterns (for example size and importance, the existence of hierarchies and their stability and growth over time) have been hidden by models of international trade. The identification and interpretation as well as how those structures of trade flows are erected, may provide important insights into the nature and strength of inter- and intra-economy linkages.

Laursen [2000a] has found that for OECD countries: (a) trade specialisation and technological specialisation patterns are path-dependent (in the sense that unchanged specialisation patterns could not be rejected); (b) small countries are more specialised than large countries (Greece, Spain, Portugal). From these findings it is possible to conclude that,

while European integration has been on-going throughout the period of his research, there has been no tendency for European countries to specialise in terms of trade specialisation. [Laursen 2000a, p. 434]

An answer can be found in the fact that countries increasingly specialise according to consumer preferences (which is in line with models allowing increasing returns from product differentiation) rather than what is predicted by the Heckscher-Ohlin trade theory

(which predicts increasing specialisation under the process of integration). Structural change in the pattern of specialisation redefine the gains from trade making them dynamic.

A EU-6 country study, which developed and applied input-output decomposition analysis for 1975 and 1985 [Osterhaven and Hoen 1998], found positive valued-added impacts of changing trade patterns only in a few larger sectors. Those trends are caused by factors like shift from inputs produced within the EU-6 towards inputs produced in third countries.

Kaneko [2000] incorporates human capital accumulation into a dynamic trade model in order to examine the relationship between the growth rate and the specialisation pattern. He argues (on the basis of his model) that a small open economy may eventually specialise completely as long as the autarchy price differs from the world price, and that the impact of the terms of trade on the growth rate depends on the trade pattern.

In this thesis we explore other, additional reasons for the formation of patterns of trade, in particular the formation of trading blocs. The patterns of trade are very important features that allow us to observe the interdependence that is generated *via* trade between countries. Studying their dynamics and the processes that may produce them may provide additional insight into this interdependence.

4.7 Conclusions

In this chapter we have reviewed the basic concepts concerning trading blocs and patterns of trade. The international trade system is far from being in a state of free trade (the so-called first best from the welfare economics viewpoint). The tendency most frequently observed among countries is a sort of race in which each tries to ‘catch up’ convenient agreements with other countries in order to stimulate exchange of goods and services among them. This ‘wave of regionalisation’ has evolved in such a way that almost all countries of the world belong to a trade bloc; many of these trade blocs have been formed along continental lines and they formation has happened simultaneously. A trading bloc is defined as a region that is inwardly liberal and outwardly protective. The level of agreement reached by countries defines the type of trading bloc they form. As

seen above, the most common forms of trade agreements are the Preferential Trading Arrangements, Free Trade Areas, Customs Unions, Common Market and Economic Community. In trying to explain the formation of trading blocs a hypothesis of natural trading partners has been put forward. However, it is not clear what distinguishes one country's 'natural' partner from the other. It has been proposed to use complementarity or substitutability in the trade relations of country members, rather than the volume of trade and also to use transportation costs as a measure of natural country.

Two types of models are used in the literature to deal with trading blocs: a) econometric models, which are tools allowing researchers to explore issues *a posteriori*, but without describing the dynamics that produce such data, and b) theoretical models, which aim to identify the welfare effects of bloc formation, once the bloc is formed. We have argued here that all these models are static in the sense that they do not take into consideration the mechanisms and processes that might induce structural change. Thus more dynamic and process-oriented models are required to deal with bloc formation. Dynamic and process- oriented means taking into account a way of representing the world trade system's structure and evolution through time is precisely the objective of this dissertation.

The patterns of trade allow us to identify each country's specialisation and their dynamics through time. They affect the rates of productivity growth and hence the evolution of international trade flows over time. Patterns of trade are determined by change in comparative advantages, and increasing returns to scale tend to reinforce the existing specialisation locking trade patterns in. They provide important insights into the nature and strength of inter- and intra-economy linkages. In this thesis, patterns of trade are very important features enabling us to observe the interdependence that is generated *via* trade between countries. Studying their dynamics and the processes that may generate them might help us to understand this interdependence.

A way to deal with dynamics is to use simulation models. In the next chapter, we discuss the main features of simulation methodology and other advanced computational techniques. They are recognised, generally, as a good tool to manage complexity and systems dynamics. The next chapter also presents some international trade models, found

in the literature that make explicit use of simulation models for dealing with international trade representation.

Chapter 5

Simulation models of international trade

5.1 Introduction

In the previous chapter we have discussed how trading blocs and patterns of trade are studied by mainstream economists. We argued that the way these features of international trade are tackled concerns particularly welfare analysis and *a posteriori* econometric analysis of their implications. However, less has been done to understand the emergence of international trade structure and its evolution over time. How trade bloc formation affects patterns of trade among countries, and therefore specialisation and production, must be studied using models that allow the representation of processes that are dynamic by definition. For these reasons, in this chapter we introduce the use of simulation models as suitable tools to deal with dynamics and processes.

In section 5.2 we present the fundamental concepts of modelling and simulation, and discuss some reasons for, or advantages in, using computer simulation. Then, in section 5.3, we summarise some characteristics of three types of models that deal with simulation of international trade: (1) the simulation models of trade based on the Computational General Equilibrium Model; (2) the interregional input-output models; and (3) the analysis of international trade in world models. In the first type of model, we concentrate our attention on the Global Trade Analysis Project (subsection 5.3.1) [Hertel 1997], and a Numerical General Equilibrium Model for quantifying the Uruguay Round (subsection 5.3.2) [Harrison et al. 1997]. Some conclusions about trading blocs are drawn from selected recent applications that have used these simulation frameworks. The second type (and largely, also the third type) of model, shows the way in which international trade is represented using Input-Output methodology (section 5.4). The

main concern of these types of models is how to deal with the representation of interdependencies and linkages among regions or countries in a single structure, the multiregional input-output method. Finally, in the third type (section 5.5) we present two world models and how they represent bilateral trade flows¹ in order to build the structure of the trade system: the United Nations Study, 'The Future of the World Economy' (subsection 5.5.1), by Leontief et al. [1977]; and the world economic model presented in 'An Integrated System of World Models' (subsection 5.5.2), by Dayal [1981].

In section 5.6 we summarise opinions on simulation of structural change and explore some insights about their application to the structural simulation of international trade. Concluding remarks are presented in section 5.7.

5.2 Modelling and simulation

Modelling and simulation use four fundamental entities: the real system, the experimental frame, the model and the simulator [Zeigler 2000]. The real system is the part of the real world² that attracts our attention, whose behaviour we want to study. The experimental frame specifies the conditions under which the real system is observed or experimented with. The model is an abstraction of the real system and it is used to obtain predictions and to formulate control strategies. In particular, models are used to analyse the effects of several changes in the modelled system, which eventually may affect other aspects of the same system. In the simulation framework, the model is a set of instructions, rules, equations, or constraints for generating behaviour of the system under study. The simulator is the device capable of generating the input-output behaviour of the model by executing the model. A simulator may be any computation system (such a single processor, a processor network, or more abstractly an algorithm [Zeigler 2000, p. 30]).

¹ Bilateral trade flows are intended here as the trade between two countries. The quantity or value of goods one country exports to a partner and vice versa. There are many other world models, however information about most of the recent are not of public domain.

² The real world is defined by Gilbert and Troitzsch [1999] as the target and the model as a representation of the target.

The purpose of a simulation model is, as implied in the Latin word *simulare* from which it derives, is to mimic the real system so that its behaviour can be studied [Sterman 1991]. The purpose of simulations may be to anticipate how the system may behave if and when certain changes occur (foreseeing, but not forecasting), or test new decision-making strategies or organisational structures and evaluating their effects on the behaviour of the system (policy design). Simulation models are also called ‘what if’ tools, because they permit to obtain information and to clarify what would happen if a particular situation is tested. They allow researchers to conduct ‘experiments’ that are impossible, or prohibitively expensive in the real world.

The degree in which a model faithfully represents its real system counterpart is called validity, and defines the basic modelling relations between the entities of a real system, a model and an experimental frame. In particular, the concept of replicate validity is important, which is affirmed if the behaviour of a model and the system agree tolerable well when set into the experimental frame.

The main reasons for using computer simulation techniques are in general to obtain a better understanding of real world problems, to develop new tools to substitute for human capabilities, for training, for entertainment. In social sciences, simulation techniques may assist with discovery and formalisation [Gilbert and Troitzsch 1999], which has been a major reason why in recent times many social scientists have increasingly augmented their interest in these techniques. Indeed, social scientists can build very simple models, which focus on some small aspect of the social world and discover the consequences of their theories in the ‘artificial society’ which they have built [Gilbert and Troitzsch 1999].

Computer simulation is essentially similar to an experimental methodology. It is possible to build a simulation model and then execute it many times, varying the conditions in which it runs and thus exploring the effects of variation of the different parameters, etc. Computer simulation is concerned with processes and non-linear systems, which are almost impossible to understand analytically. This is because simulation is a technique specially suited to deal with complexity. The realism of the simulation is measured by the realism of the process, as opposed to the realism of the

data. Data is not the most important factor in assessing realism; rather, it is the process [Casti 1997].

Kollman et al. [1997] state that computer simulation techniques are especially valuable in political economy because they can complement and extend current theory. This methodology contrasts with traditional mathematical or non-mathematical methodologies. Mathematical analysis stems for its rigour, but relies on the assumptions that it must often be guided by tractability rather than realism. Verbal analysis offers more flexibility and realism at the cost of reducing certainty. But flexibility is obtainable at the cost of rigour. On the contrary, computational models [Holland and Miller 1991] reduce this cost because computer programs guarantee that logically consistent analysis proceeds from the encoded assumptions. But also the fact that computer programs can encode a wide range of behaviours allows for a gain in flexibility. In other words, simulation techniques have an advantage over mathematical and non-mathematical methodologies in dealing with dynamics. This feature makes simulation models particular useful to represent many social phenomena that are dynamic in nature;

perhaps the greatest contribution of computational methods will be an indirect one. Such models allow theorists to interact with a convenient “artificial world”. Such interaction extends a theorist's intuition and allows the computer to serve as a collaborator, in both the inspiration and refinement of theoretical ideas. [Kollman et al. 1997, p. 485]

However, simulation models are still no-well accepted and

the use of the computer as a theoretical tool is still quite controversial. First, because there is no much confidence in our numbers; second, the extraordinary power of the competitive general equilibrium model with its striking results proved from a few basic principles still defines our idea of what theory ought to look like. Finally, the absence of a strong experimental tradition means that we are not used to the idea of exploring a model by playing around and seeing what happens. [Krugman 1996, p. 31]

It is fair to point out the main problem of using simulation. While mathematical models provide a general solution that shows explicitly how the results depends on parameters and initial conditions, each simulation run gives the result corresponding to a unique set of values of parameters and initial conditions. Many runs are necessary to

study how the results are affected by such elements. A lot of techniques have been developed to accomplish output analysis [Law and Kelton 2000].

5.3 Computational General Equilibrium models

The main characteristics of Computable General Equilibrium (CGE) models are described as follows:

- (i) They include explicit specifications of the behavior of several economic actors (i.e. they are *general*). Typically they represent households as utility maximizers and firms as profit maximizers or cost minimizers. Through the use of such optimizing assumptions they emphasize the role of commodity and factor prices in influencing consumption and production decisions by households and firms. They may also include optimizing specifications to describe the behavior of governments, trade unions, capital creators, importers and exporters.
- (ii) They describe how demand and supply decisions made by different economic actors determine the prices of at least some commodities and factors. For each commodity and factor they include equations ensuring that prices adjust so that demands added across all actors do not exceed total supplies. That is, they employ market *equilibrium* assumptions.
- (iii) They produce numerical results (i.e. they are *computable*). The coefficients and parameters in their equations are evaluated by reference to a numerical database. The central core of the database of a CGE model is usually a set of input-output accounts showing for a given year the flows of commodities and factors between industries, households, governments, importers and exporters. The input-output data are normally supplemented by numerical estimates of various elasticity parameters. These may include substitution elasticities between different inputs to production processes, estimates of price and income elasticities of demand by households for different commodities, and foreign elasticities of demand for exported products. [Dixon and Parmenter 1996, 5]

CGE models also receive the name of Applied General Equilibrium (AGE) models. For Dixon and Parmenter, this name emphasises the idea that in CGE modelling the database and numerical results are intended to be more than merely illustrative. CGE models use data for actual countries or regions and produce numerical results relating to

specific real-world situations. Some examples of the use of CGE³ models to simulate international trade are: The Global Trade Analysis Project (GTAP) [Hertel 1997], and the Numerical General Equilibrium Model for quantifying the Uruguay Round [Harrison et al. 1997]. We give next some general description and features of these models⁴.

5.3.1 Global Trade Analysis Project (GTAP)

The aim of GTAP is to facilitate and conduct quantitative analyses of international economic issues in an economy-wide framework [Hertel 1997]. The project consists of several components:

- A global database. This database contains bilateral trade, transport, and protection data characterising economic linkages among regions, together with individual-country input-output databases that account for intersectoral linkages within each region.
- A standard modelling framework. The model is based on the theory of multiregion, applied general equilibrium model.
- Software for manipulating the data and implementing the standard model. The model was implemented using Release 5.1 of the GEMPACK software suite, developed at the IMPACT Project, Monash University.

The model is basically a comparative static general equilibrium model. Because of this, it does not account for macroeconomic policies and monetary phenomena. The model was designed, in part, for simulating the effects of trade policy and resource-related shocks on the medium-term patterns of global production and trade. It does not deal with time; in other words, it is neither an inter-temporal model nor sequenced through time. For these reasons, the model cannot capture the dynamic effects that may follow from trade

³ CGE models have been also applied to national economies. For example, the ORANI GE model of the Australian economy has been used extensively for policy analysis in Australia. A variant of this model (called ORANI-G) has been used both for teaching purposes and to serve as a basis from which to built new models. Adaptations exist for several countries, including Thailand, South Africa, Pakistan, Brazil, the Philippines, Japan, Indonesia, Venezuela, Taiwan and Denmark. Detailed information may be found in [ORANI-G 1998].

⁴ A description of a dynamic General Equilibrium Model of the world economy may be found in McKibbin and Sachs [1991].

liberalisation. Nevertheless, the model has been used for generating some comparative static results for trade reform scenarios. For example, Young and Huff [1997] have used GTAP to study some scenarios for APEC regional trade liberalisation. They conclude that ‘the formation of an APEC trading bloc could result in both winners and losers in the group as well as in the rest of the world’. Furthermore, the distribution of the gains and losses are affected by the assumptions that are made about the basis under which trade reform is carried out.

Yang et al. [1997] assessed the effects of the removal of the MFA (Multifibre Arrangement⁵) in the context of more general liberalisation under the Uruguay Round. From the industrialised countries' point of view, the phase-out of the MFA seems not to have had a great impact on them, because the textile and clothing sector is small and far less important than in developing countries. Their results pointed out the possibility that the developing country textile and clothing exporters, with larger quotas matching their production potential, may lose from the elimination of the MFA because of the increased competition from their more efficient competitors and the deterioration of their terms of trade. They found that speedy non-MFA reforms are in the interest of both efficient or inefficient countries. Thus, the abolition of the MFA seems to benefit most countries; countries that may lose from MFA reform may obtain substantial gains from non-MFA reforms.

The structure of the GTAP model presents the following features:

- Accounting relationships at these levels: Distribution of sales to regional markets; sources of household purchases; sources of firms' purchases and household factor income; availability and sources of regional income; global sectors (transportation and banking sectors).
- Equilibrium conditions and partial equilibrium closure.

⁵ The MFA (Multifibre Arrangement) refers to the arrangement that, since 1973, has allowed industrial and developing countries negotiate bilateral agreements on export quotas regulating textile trade. This is phasing out after the Uruguay Round.

- Behavioural equations: Firm behaviour; household behaviour; macroeconomic closure; fixed-capital formation and allocation of investment across regions; global transportation.

For Hertel [1997] an important feature of the GTAP applications is their emphasis on experimental design, which allows researchers to generate insights into problems that are too complex to be addressed analytically. Another important outcome of this is that the GATP has been the set-up of a database for AGE researchers. This database combines bilateral flows and input-output relationships in a micro-consistent fashion.

5.3.2 A Numerical General Equilibrium model for quantifying the Uruguay Round

Harrison et al. [1997] used a numerical General Equilibrium Model which incorporates increasing returns to scale (in some sectors, keeping a simple model based on constant return to scale and competitive markets for the others), 24 regions, 22 commodities, and steady-state growth effects. They used the GTAP database for 1992.

They conclude that there is an aggregate welfare gain from the Uruguay Round (they estimate this in the order of \$96 billion per year in the short run). Despite the global gains, they identify some developing countries that lose from the round in the short-run. They also conclude that in the long-run, almost everybody stands to gain, and the Round will allow developing countries to gain further through their own unilateral liberalisation.

5.4 Interregional Input-Output models

The Leontief Input-Output model have been used not only to represent the interdependencies within the economic sectors of a particular country but also as a method to represent interdependencies at a regional level. This framework of analysis has been used in particular by regional economists and, more recently, some applications have been devoted to study international trade, inter-linkages and bloc formation effects. Some examples of these models are the ones developed by Batten and Martellato [1988] and Sonis et al. [1996]. Some of their features are discussed here below.

Batten and Martellato [1988] identified two important assumptions that are behind the interregional input-output models, which are motivated essentially by a matter of statistical convenience:

- 1) that producers may be distinguished both by sectors and by region of production and;
- 2) that the regional origin of a shipment is irrelevant to users and the regional destination is irrelevant to producers, as is implied by the trade pool concept of Leontief [1977] (Leontief's trade pool concept will be discussed in the next section).

So a unique matrix contains both information on production and patterns of trade between countries.

This allows to observe the two-way interdependencies exist between the patterns of interregional trade and the location of economic activity. In other words, it cannot be determined the exact location of production without a clear picture of the trade pattern, nor can we fix the latter without knowing the former. [Batten and Martellato 1988, p. 206]

Patterns of trade and location of production co-evolve. But, operational interregional models tend to overlook this point, because the trade pattern is taken as given and fixed, and then used in the computation of production and trade by sectors and regions without due consideration to the existence of a link existence in the opposite direction. At least this is the case if the patterns of trade reflect the markets shares in the chosen reference year and remain fixed in successive periods. However, these patterns may change and differ significantly in the long run, where the trade flow matrix (its coefficients) is generally chosen by adopting two different strategies:

- 1) based on efficiency, where the choice is made according to an optimality criterion, which typically minimises the total cost of transportation. In this case, the coefficients are computed *ex post*.
- 2) as in the short run, chosen from a reference year and, it may be fixed *ex ante* or allowed to vary to a limited extent (this is known in the literature as a descriptive or simulation approach).

Trade flows are no longer governed by fixed requirement coefficients, but instead result from differences between locational supply and locational demand. Although the resulting balance equations cannot be solved uniquely without introducing additional constraints, the model is a normative tool of analysis in which optimal trade flows become a function of prices and cost. [Batten and Martellato 1988, p. 210]

Trade coefficients are initially given, but they are changed interactively whenever excess demand appears in the system. The solution to this non-linear model provides a description of the way in which the system has adapted to the bottleneck. Batten and Martellato [1988] wonder how to simulate changes in the technical coefficients; something we agree is quite convenient for simulating the evolution of production technology of a country, but not for simulating the way countries interchange commodities. The reason for this is simple: it does not allow for decision-making at a sectoral level.

On the other hand, Sonis et al. [1996] explore the effects of structural change in all sectors for some countries in multiregional input-output systems. They use a partition analysis of the multiregional, multisectoral input-output system. Their aim is to emphasise the propagation of intra- and interregional backward linkages on the rest of the economy and their representation of the changes in gross output within a country and the rest of the economy. This type of representation of interregional changes allows them to separate each country from the rest. Then, the changes that have occurred between time period 0 and t in a region are written in another matrix. Furthermore, the complete system is rewritten in order to reflect the intra- and interregional changes in direct input associated with the production structure for the region under consideration and for the rest of the countries. This methodology offers an opportunity for monitoring changes and characterising the structure of increased inter-country interdependence. In particular, their study on 8 EU countries based on the 1975 and 1985 input-output tables, shows evidence of decreasing dependence on domestic sources of inputs and increasing dependence on sources of other parts of Europe. They also pointed out that with the developments of inter-country tables for the major trading blocs of the world, it will be possible to capture the degree to which interactions, in an absolute sense, are increasing or merely being

diverted from one bloc to another. This could shed some light on understanding the complexities of trade evolution [Sonis et al. 1996].

5.5 World models

5.5.1 A global economic model of the world economy

The scope of this United Nations project, conducted by Leontief et al. [1977], was to study the environmental aspects of the world economy. The model was constructed with a view to displaying various possible interrelationships, as the world economy evolves over future decades, between environmental and other economic policies. The model was based on the state of the economy in 1970, and hypothetical pictures of the world economy in 1980, 1990 and 2000 were compared with it. It gave a set of tentative projections of the future course of development for the world economy (demographic, economic and environmental features).

A multiregional world Input-Output system⁶ formulation was used to provide the means of describing the complex and highly differentiated structure of the world economy in great detail. The world economy was divided into 15 regional blocks, and a set of 48 producing and consuming sectors. An important feature of this model was the estimation of structural coefficients for each region in the base year and the projections of changes in these base-year coefficients for the years 1980, 1990 and 2000. Leontief et al. argue that the projections of future input on consumption structures must take into account changes in regional per capita income, as well as whatever changes in technology and in the resource picture can be anticipated. Thus, most of the projections of the input structures had two components: one for income-dependent changes and another for exogenously estimated change in technology. Income-dependent changes are plugged in automatically as per capita income increases. For each time period a new set of structural coefficients is selected for each region, in accordance with its approximate new income per capita. Thus, as a region becomes richer, it takes on input-output coefficients

⁶ On multi-regional input-output analysis, see for instance Leontief [1967] and Batten and Martellato [1985].

characteristic of a higher income region. However, the report does not give details about how the model takes into account changes in the structural coefficients due to technological change.

It is not our intention to describe in detail the world model proposed by Leontief et al. Instead, what is important from the point of view of this thesis is how they dealt with the representation of bilateral trade flows between the selected regions. In this world model, the quantity of a particular type of commodity, exported from a given region, is treated as a fixed share of aggregate world exports of that commodity. Leontief argues that all the exports of a particular commodity can be viewed as if they were delivered to a single international trading pool and all the imports as if they were drawn from that pool. However, it was not in the interest of that project, or at least not at the stage it was reported in 1977, to involve any analysis of bilateral trade flows. In fact, detailed analysis and explanation of the network of international shipments can and should be separated from the analysis of long-run patterns of what might be called the inter-regional division of labour [Leontief et al. 1977]. The projection of the import coefficients and export share for most traded industrial goods were derived from cross-national regression studies using data from 1962 to 1979.

5.5.2 A world economy model

A second example of a world model that includes international trade is the one developed by Dayal [1981]. The model was built to discover how the various economic components of the economic system at the regional and global levels are determined, what their future trends are likely to be and how the alternative development strategies can be used to shift the various economic components from the undesirable or the less desirable paths to the more desirable ones. The model was conceived as long-term only, thus short-term fluctuations were excluded from its scope.

The model itself provides a multi-sector, multi-region framework in which each sector is integrated with the others through an input-output system and each region is inter-linked with the others through a system of trade network and international financial flows.

The main components of the model were:

- Population and labour force (or economically active population)
- Capital stock and depreciation of capital
- Technical progress
- Gross domestic product and sectoral added values
- Total and sectoral gross output
- Inter-sectoral (i.e., intermediate) flows
- Final demand
- Gross investment: total and by sectors of destination and by sectors of origin
- Total and sectoral consumption
- All-product and sectoral consumption (private and government)
- Bilateral trade flows among the various geographical areas for the various product categories as well as for all-product international trade
- Gross and net financial flows, investment income receipts or payments and the stock of total financial assets or liabilities of the various regions.

As in the previous Leontief world model, from the above mentioned components, we are interested, in particular, in the bilateral trade flows representation between the various geographical areas. Dayal [1981] pointed out that the assumption that bilateral trade share remains constant over time is very debatable. He argues that bilateral trade flows between any two regions are influenced primarily by the export capacity of the exporting region and the import requirements of the importing region. Furthermore, the existing pattern of trade, represented in his model by the trade matrix, would also significantly influence the way the new pattern of trade flows evolve. The trade matrix embodies the influence of relatively fixed factors, such as bilateral links, complementary needs, competitiveness in production, etc. Trade flows from one period to another would depend on the export capacities and import requirements of all the countries for the next period and the bilateral trade flow matrix of the current period. Dayal uses a simple algorithm: the new projections are calculated by simply using the ‘rule of three’, which is made in three steps: 1) projecting the import requirements, 2) projecting the export capacities if world export capacities are smaller than world import requirements and, 3)

vice versa, otherwise. This procedure tries to capture the complexity of the interdependencies created between countries when trading, in the sense that the exports and imports of a country are determined not only in relation to its own demand and supply, but in relation to the demand and supply situation of all the other countries as well. Nevertheless, the model says nothing about the trading network formation.

Dayal discusses many other alternative approaches for dealing with the representation of trade flows, such as:

- a) the share approach, in which all source imports of the various regions for product category are estimated and then the fixed (or projected) bilateral import shares are used to estimate all-destination exports of the various regions;
- b) the probability approach, in which the probability that two countries may be involved in a bilateral transaction is given by the product of the proportion of the exporting country's entire destination exports to the total world trade and the proportion of the importing country's entire source imports to the total world trade;
- c) the input-output approach, in which the whole world is considered as a single unit and foreign trade is treated as an endogenous part of the input-output system. In this model, trade flows are assumed to be a constant proportion of the output of the importing country.

All of these suffer essentially from the same drawback: no explanation is given of the process of the network's formation and change over time.

5.6 Structural simulation models

We summarise here some conceptions of simulation of structural change for modelling economic bloc formation and the dynamic of patterns of trade. The simulation of structural change may be managed in several ways. For example, the designer of the model indicates the set of conditions for changing from a given structure to another [Domingo et al. 1996]. The whole process is represented by a tree in which the nodes are

the points of structural change and the arcs emerging from them are the possible structures resulting from the changes. The simulation process determines when the changes happen and selects the new structure that will appear under the given conditions. Thus, the structural path of the system is simulated. The simulation process can bring out one, many, or all possible structural paths. A generalisation of such a technique may be developed using agents with a view to exploring the combination of bottom-up processes, which assemble to produce and modify a structured whole, and top-down process, in which this whole constrains and directs the individual process. Again, as it was pointed out in the previous chapters the combination of bottom-up and top-down processes may be a source of important structural changes.

The use of simulation techniques permits us to manage effectively the complexity involved in the trade system. This may be done, for example, creating an artificial society⁷ [Gilbert and Conte 1995] and its system's operational rules by using the computer as the main working tool. In this context, countries are represented by groups of variables and system rules by algorithmic procedures. Structural simulation involves the generation of system behaviour from a given structure, as in normal simulations, but it also includes the generation of structures from that behaviour.

The structure of the trade system is represented in the model proposed in this dissertation by the network of shipments created when countries trade and by the trade agreements reached by countries through political processes. The network of shipments may be considered as a pure bottom-up process while a trade agreement may be considered as a pure top-down process. Structural change of the trade system will occur when:

- a) the network of shipments changes by changing structural factors like, for example, tariffs and no-tariffs barriers, export subsidies, transport cost,

⁷ Artificial societies are computational and simulation models of 'possible' societies, their general processes, dynamics, and emergent properties. Their aim is to model features and processes which characterise natural target societies; it is not to reproduce the social world. Gilbert and Conte [1995] refer to this approach as a 'new experimental methodology [which they define as exploratory simulation] consisting of observing theoretical models performing on some testbed'. They argue, also, that the realisation, observation and experimentation with artificial societies allow to improve our knowledge and understanding of social phenomena whose structure and behaviour are so complex.

historical ties and consumer tastes, or by changing variables, for example, quantities and prices;

- b) by adding or removing countries to and from the current trade blocs, or by creating new blocs, or by eliminating those already formed.

All these changes alter the trade system behaviour and may not be represented in traditional trade models.

5.7 Conclusions

Although the contributions considered in this chapter vary considerably from the viewpoint of modelling philosophy, they provide a representative sample of previous and current methods utilised for modelling and simulation of international or interregional trade and for dealing with the effects of trade blocs. These ideas were, in part, used by the developed model. What is important to highlight, as stated by Sterman, is that

computer modelling is thus an essential part of the educational process rather than a technology for producing answers. The success of this dialectic depends on our ability to create and learn from shared understandings of our models, both mental and computer. Properly used, computer models can improve the mental models upon which decisions are actually based and contribute to the solution of the pressing problems we face. [Sterman 1991, p. 226]

Modelling and simulation has been recognised as a useful technique to deal with complexity and process representation. Simulation models are nowadays a good tools to manage dynamics and complexity thanks, in part, to the non-stop development of computers' capacities. These reasons have encouraged us to use modelling and simulation as a basic tool of the methodological framework used.

We have also summarised in this chapter some features of three types of models that deal with simulation of international trade. Our general criticisms for them are:

- 1) Models based on the *Computational General Equilibrium* framework (Global Trade Analysis Project (GTAP) and A Numerical General Equilibrium model for quantifying the Uruguay Round) are comparative static general equilibrium models, though they are neither inter-temporal nor sequenced through time. For this reason,

they cannot capture the effects that may follow from trade liberalisation in the long run. General equilibrium framework does not allow for surprises and decision-making during the process, which is relevant for dealing with bloc formation.

- 2) Models based on an *interregional input-output framework*: in these models are based in a unique matrix that contains both information on production and patterns of trade between countries. The trade pattern is taken as given and fixed, and then used in the computation of production and trade by sector and region without due considerations for the existence of a link in the opposite direction. This sort of model requires to hypothesise about how technical coefficients that represent patterns of trade change over time (if simulations are run for more than two periods). It is very difficult to do this at a national level when I-O matrices are known in time series (see Appendix A). For this reason, we consider that a unique structure is not useful for dealing with bloc formation and patterns of trade.
- 3) *World models* (a global economic model of the world economy and a world economy economic model) deal with dynamics in the long run. They were not conceived, however, to study the international trade system in detail. Indeed, the international trade system was a subsystem of those models. Leontief's model does not take into consideration how the patterns of trade are formed and evolve. In contrast, in Dayal's model, attention is paid to the fact that I-O coefficients used to represent the patterns of trade change over time. It is also recognised that trade flows are affected by export capacities and import requirements of all countries. However, because of the I-O framework used in the analysis, the model does not allow for the representation of decision-making.

The I-O model is perhaps one of the most important works that have been developed to deal with interdependence among sectors in an economy. It is as simple as it is elegant in its formal representation. As has been discussed in this chapter, it has been also used in the literature to deal with regional representation of interdependence. As part of the research work for this dissertation, we have explored the use of I-O modelling for representing international trade structure. We studied in great detail some of the OECD countries' I-O matrices. The initial idea was to exploit the convenience of having a single

structure of an I-O matrix to represent the entire world economic structure, as is the case of multiregional studies⁸, and its interdependence. However, such representation results in many ways restrictive because it does not allow for decision-making at a bottom-up (sectors) bases. It must be computed once and for all in order to maintain equilibrium (even in the dynamic approach⁹). In the following chapters, our intention is to represent interdependence between countries in a non-equilibrium world. Equilibrium from a complex system point of view may occur, but is the exception, not the rule. Moreover, it is very difficult to elaborate such a matrix, though some models were built. For this reason, it was decided to separate the interdependence issue into two parts: one referring to the representation of the production system of a single economy, as is the case of the general Leontief I-O model; the other, to study the way countries exchange commodities in the international market. This way of representing the international trade system is more flexible. A first version of such a model directed its attention to dynamic comparative advantages and specialisation among two countries with two aggregated sectors [Domingo et al. 1998] and was part of this research.

Moreover, as stated in Chapter 3, we have studied some OECD countries' I-O matrices in order to understand the way they could be managed into a simulation model. In particular, our interest was centred on finding some sort of functional 'law of motion' for some I-O coefficients, and their relation with final demand, import and export curves through time. Results and details about this work are presented in Appendix A. They are preliminary results that must be undertaken and refined in order to have a better idea of how dealing with their representation into a simulation model. Understanding the dynamics of I-O coefficients implies understanding the way technology and productivity change through time, and its relation with the movements of final demand. But also, it is important to take into consideration how related or even affected they are with respect to change in pattern of production-consumption overseas. I-O would be used to link international trade with national economies. This is not explored in this thesis, but it may be an extension worth exploring in the future.

⁸ About multiregional input-output analysis see for instance Leontief [1967] and Batten and Martellato [1985].

⁹ for dynamic multiregional input-output models see Aulin-Ahmavaara [1990], Baranov and Pavlov [1994] and Campisi and Gastaldi [1996]

In the next chapters we present a general description of the model for dealing with the representation of exchanges between artificial countries through decision-making processes rather than through the more used computational general equilibrium or the regional I-O models that were discussed in this chapter. In Chapter 6 we explore a method to find out potential trading blocs among a group of countries, while in Chapter 7 we describe the model. This is to a large extent a ‘new way’ of thinking about exchanges in the international trade system precisely as a system, in the way it was presented in Chapter 3.

Chapter 6

Finding ‘trading blocs’

6.1 Introduction

In Chapter 4, we introduced the main concepts concerning trading blocs and in Chapter 5, some of the current models used in economics to deal with them. These models, essentially, concentrate the attention on the welfare effects of such blocs, although some of them point out the criteria of natural partnership, if any, in order to set up a bloc. However, if in part the idea behind trading blocs, at least from an economic point of view, is to increase trade between members, it is necessary to have a sort of method or tool that visualises the main partners in international trade. For this reason, before continuing the discussion towards a simulation model of international trade, it is necessary to present the methods used for the determination and visualisation of bloc formation.

Given a trade matrix for n countries, we explore a method to find out potential trading blocs among those countries. By changing rows and columns, we look for the best set-up of the trade matrix which concentrates the large values (of the trade matrix) around its main diagonal and the small ones outside it. This action puts together those countries which have large amounts of trade between them, and separates them from those which have small amounts of trade. Once the arrangement is completed, we choose a benchmark in order to highlight those countries whose trade goes over this value. In this way, we observe bloc formation between countries.

Section 6.2 presents the Quadratic Assignment Problem (QAP) (formally defined in section 6.2.1) as the method used to find the ‘best arrangement’ of a trade matrix. Two heuristic algorithms are presented in section 6.2.2 in order to solve the QAP: a) the Taboo

Search method, and b) the Inertial Moment method. As long as the number of countries is not too big (i.e. 10), it is also possible to perform all the permutations ('brute force method') and find the absolute optimum solution of QAP. We do this to compare the results given by the two heuristic algorithms. It also permits us to find the absolute best arrangement of the trade matrix when n is small.

Section 6.3 presents the method to highlight or to find trading bloc formation through a trade matrix. Different ways of representing the trade matrix among countries are discussed in section 6.3.1. Then, in section 6.3.3, the QAP is formulated as the method to deal with clustering or bloc formation in matrices. Section 6.3.4 presents a way to define benchmark values for bloc formation. Using real data for 10 countries (Austria, Brazil, Canada, France, Germany, Italy, Mexico, Switzerland, the United States and Venezuela), we apply the method in section 6.4. Finally, some conclusions concerning bloc formation using this method are given in section 6.5.

6.2 The quadratic assignment problem (QAP)

6.2.1 Definition of the QAP

The QAP is a combinatorial optimisation problem that was first applied in facility location planning by Koopmans-Beckmann [1957]. It may be formulated as follows: given two $n \times n$ matrices $T = t_{ij}$ and $W = w_{ij}$, find a permutation π^* of the T matrix (t_{ij}^π) (where π is a permutation of the set of permutations of n elements) which minimises the objective function

$$f(\pi) = \sum_{i=1}^n \sum_{j=1}^n t_{ij}^\pi w_{ij} \quad 6.1$$

In facility location planning, T is a flow matrix, i.e. the flow of materials from one facility to another, and W is a distance (or cost) matrix, i.e. the distance (or cost of transportation) between the locations in which the facilities must be placed. The objective is to find an assignment of all facilities to all locations such that the total cost of the operation is minimised. A special case is the well-known 'travelling salesman' problem

(which is obtained when the values in T are restricted to be 0 - 1, with $\sum_j t_{ij} = 1$, for every i ; that is the problem concerning the choice of the best route for a salesman who has to visit n cities).

6.2.2 Algorithms to solve the QAP

There are many algorithms to solve the QAP. As long as the number of rows/columns of the T matrix is not too big (i.e. 10), it is possible to perform all the column and row permutations of that matrix, and search the permutation π^* that generates the optimum solution, $f(\pi^*)$, which gives the best arrangement of the T matrix. An algorithm that lists and performs all the permutations (also called by Koopmans and Beckmann [1957] the 'brute force method') of n number (1, 2, 3, ..., n) was programmed.¹ This method has a drawback: it is not possible to perform all the permutations in a reasonable amount of time when n is higher than 25, which is a modest size for many problems which are formulated as QAPs² [Deineko and Woeginger 1998]. In fact, the QAP is considered as one of the challenges in combinatorial optimisation and continues to be one important subject of research among the operational research community [Burkard et al. 1996]. However, the 'brute force method' serves to compare the results obtained from any programmed heuristic algorithm when n is small, and to infer of the goodness of the results of large-scale QAPs.

In order to solve the computational problem presented above, many heuristic algorithms³ have been developed. For example, a network-based formulation approach was used by Ball et al. [1998], a genetic algorithm was used by Tate and Smith [1994] and by Ahuja et al. [1997], and more recently 'Ant Colonies' was used by Gambardella et al. [1999]. The main scope of these algorithms is to find the optimal solution or a good solution in a reasonable computation time.

¹ The algorithms presented here have been programmed using Borland DELPHI programming language, version 4.0 for windows NT [Borland 1998].

² Think for instance of the travel salesman problem or the assignation of economic facilities to different locations.

³ There are many heuristic algorithms to solve large-scale QAPs. These algorithms have been classified as: construction algorithms, improvement algorithms, and graph theoretic algorithms. See Li and Smith [1995] for more details about it.

Two heuristic algorithms are discussed here (although others deserve closer investigation):

- The first is called the Taboo search method. The method is described by Taillard [1991], and implemented in PASCAL language and used by Taillard [1995]. We have implemented for our purposes this algorithm by re-writing it in Delphi 4.0 programming language [Borland 1998]. The programme solves the problem a specified number of times, and provides average and best solution values for those runs. A target solution value must be provided (the programme launches the next run if the solution value found is lower or equal to the target solution value). This algorithm works remarkably well compared to the total permutations algorithm (for $n=10$ or smaller) in the sense that it has always given the best solution in a shorter computation time. Therefore, it may be used when n increases.
- The second was called the inertial moment method [Gourlay 1976]. Let us use an example to explain the algorithm. Imagine that the T matrix has 6 rows and columns named A, B, C, D, E and F, and that its first arrangement is given by A B C D E F (where A corresponds to the first column and the first row of T matrix, B corresponds to the second column and the second row, and so on) The following set of permutations is tested:

1	A	B	C	D	E	F
2	B	A	C	D	E	F
3	C	B	A	D	E	F
4	D	B	C	A	E	F
5	E	B	C	D	A	F
6	F	B	C	D	E	A

which means to inter-change A's position with all other countries' positions (the list of the six permutations shown above). Then the following set is tested:

7	A	B	C	D	E	F
8	B	A	C	D	E	F
9	A	C	B	D	E	F
10	A	D	C	B	E	F
11	A	E	C	D	B	F
12	A	F	C	D	E	B

In this second set, B's position has been inter-changed with all other countries' positions listing another six permutations (some of them already tested). The same is

done for C, D, E, and F, listing the respective set of permutations. Function $f(\pi)$, given by Equation 6.1 above, is calculated for each of these permutations.

The initial arrangement for the next step will be the arrangement that gives the minimum value of the $f(\pi)$ function. In other words, the permutation that reduces the total weight of $f(\pi)$. In the civil engineering field, this is equivalent to finding the minimal inertial moment. This value is saved as the last solution and used to compare results later on.

Imagine that the arrangement D B C A E F gives the smallest value of $f(\pi)$ so far. Starting with this new arrangement, the next step is to try the following permutations:

1.	D	B	C	A	E	F
2	B	D	C	A	E	F
3	C	B	D	A	E	F
4	A	B	C	D	E	F
5	E	B	C	A	D	F
6	F	B	C	A	E	D

which means to exchange D's position with all other column/row' positions listing another set of six permutations (arrangements 1 to 6). Then, the following set is tested:

7	D	B	C	A	E	F
8	B	D	C	A	E	F
9	D	C	B	A	E	F
10	D	A	C	B	E	F
11	D	E	C	A	B	F
12	D	F	C	A	E	B

In this second set, B's position has been inter-changed with all other column/row' positions, listing another set of six permutations (arrangements 7 to 12). The same is done with all other columns/rows listing the respective set of permutations. The $f(\pi)$ function is computed for all of them and the best result is chosen. If this new result is better than the previous one, it becomes the best permutation so far; it is picked up and the procedure is repeated again. Otherwise, the last solution remains the best. The algorithm is repeated until a complete round of the matrix gives no better solution in comparison with the last found.

This algorithm works well compared with total permutation algorithm (for $n=10$ or smaller) in the sense that it has always given the best solution in a much shorter time of computation. The only problem is that it depends on the initial arrangement of the matrix elements; so it is necessary to repeat it with different initial sequences in order to obtain the best result, i.e. the global optimum (otherwise, it may yield only a local optimum solution).

6.3 Trading blocs formation through a trade matrix

6.3.1 Different representations of the TRADE matrix

To use the above quadratic assignment algorithms for the problem of international trade it is necessary to obtain a 'trade matrix'. There is no unique trade matrix. Some of the possibilities are presented below. Suppose that the network of shipments formed among countries when they trade is saved in a trade matrix (TRADE). Each element of this TRADE matrix, which is represented by $trade_{ij}$, could be the amount of exports, in monetary units, country i sends to country j or the relative percentage country i exports to country j out of all its exports, etc. These values are relative to a period of time, for example a year.

The TRADE matrix may be defined differently depending on which particular measure of linkages in trade is used. For instance, each element ($trade_{ij}$) of the TRADE matrix could be defined by one of the following 5 types:

- a) The amount of **total trade** in monetary units country i exports to country j (x_{ij}):

$$trade_{ij} = x_{ij}$$

- b) The amount of trade in monetary units resulting from **adding up exports** from country i to country j (x_{ij}) **and exports** from country j to country i (x_{ji}). In this case

TRADE becomes a symmetric matrix. This is the most frequently used measure for international trade studies and trading bloc effects on trade *via* econometric models⁴:

$$trade_{ij} = x_{ij} + x_{ji}$$

- c) The **percentage of exports** country i sells to country j (out of country i total exports), defined as:

$$trade_{ij} = \frac{x_{ij}}{\sum_k x_{ik}} * 100$$

where x_{ij} is the amount of total trade in monetary units country i exports to country j and $\sum_k x_{ik}$ represents the total world exports of country i (where k stands for all the countries of the world).

- d) The **percentage of imports** country j buys from country i (out of country j total imports), defined as:

$$trade_{ij} = \frac{m_{ji}}{\sum_k m_{jk}} * 100$$

where m_{ji} is the amount of imports country j buys from country i and $\sum_k m_{jk}$ is the total world imports of country j .

- e) The **average of the following four relative numbers**: $x\%_{ij}$ the percentage of exports country i sends to country j out of country i 's total exports; $x\%_{ji}$ the percentage of exports country j sends to country i out of country j 's total exports; $m\%_{ij}$ the percentage of imports country j receives from country i out of country j 's total imports; and $m\%_{ji}$ the percentage of imports country i receives from country j out of country i 's total imports. The average is a measure of relative linkage on trade between countries i and j . The measure would be as follows:

⁴ See for instance J. Frankel (1997).

$$trade_{ij} = \frac{x\%_{ij} + x\%_{ji} + m\%_{ij} + m\%_{ji}}{4}$$

Observe that $trade_{ij} = trade_{ji}$, which means that TRADE is a symmetric matrix.

The intuition behind this last measure is that the total value of exports a country i sends to another country j has a relative importance from each country's viewpoint. For country i , the value represents a relative part of all its exports and for country j , the value represents a relative part of all its imports. The analysis applies also from the imports' point of view (then, four relative measures of this kind may be defined concerning trade between two countries i and j , as they are defined above). These relative amounts are not necessarily the same. In any case, they represent the relative importance one country has with respect to the other. This measure takes into consideration not only the relative importance of a country's exports, but also the relative importance of that amount from the importer's point of view. In other words, it indicates to what extent or degree the two countries are related.

6.3.2 Observing trading blocs formation through the trade matrix

The TRADE matrices defined in section 6.3.1 are used to identify trading bloc formation among countries. The idea is that countries, which trade more, are considered to take part in a trading bloc. On the other hand, countries whose trade level is lower or nil do not take part in a trading bloc. Then, the bloc formation may be observed through clustering formation in the TRADE matrix, which pulls together (or at least draws closer) those countries whose mutual exchanges are broader, and far apart those whose exchanges are smaller.

Clustering formation may be obtained by rearranging rows and columns of the trade matrix. By doing this, an equivalent trade matrix may be obtained in which the greater elements are clustered in sub-matrices along the diagonal. These clusters correspond to possible blocs when some measure of concentration is exceeded (a benchmark value, defined in section 6.3.4). So, the problem is to find a permutation of the initial trade matrix (called here 'initial arrangement') that produces the equivalent

matrix we are looking for (called here 'best arrangement'). The QAP presented above may be used in order to find the 'best arrangement' of the trade matrix.

6.3.3 Clustering or bloc formation in matrices by using the QAP

Clustering or bloc formation in a matrix could be tackled as a QAP, where the W matrix of the QAP formulation (see Equation 6.1) may be defined as a squared Euclidean distance matrix:

$$w_{ij} = (i - j)^2$$

For example, Table 6-1 shows the squared Euclidean matrix (the $W = w_{ij}$ matrix) in the case of six rows and columns matrix ($N=6$).

0	1	4	9	16	25
1	0	1	4	9	16
4	1	0	1	4	9
9	4	1	0	1	4
16	9	4	1	0	1
25	16	9	4	1	0

Table 6-1 Square Euclidean Matrix for $n=6$

This particular configuration of the W matrix (a distance matrix) makes it possible to find permutations of the TRADE matrix that concentrate large values on the main diagonal and small values outside it, when Equation 6.1 is solved (this is so because Equation 6.1 becomes minimum). In other words, the QAP algorithm puts together those countries that trade more.

Different arrangements (an arrangement is a permutation of rows and columns π) of the TRADE matrix (the T matrix of Equation 6.1) will produce different values for function $f(\pi)$. The minimum of this function will be reached precisely when the major values of the TRADE matrix are placed along the main diagonal, which enables us then to observe clustering in the TRADE matrix and, consequently, bloc formation in the terms expressed above.

An example may help to explain the method. Table 6-2 shows a trade matrix, which may be read as the monetary amount of exports country i sends to country j , where $i=A, B, C, D, E, F$ and $j=A, B, C, D, E, F$.⁵

	A	B	B	D	E	F
A	0	0	0	12	0	120
B	0	0	30	0	50	0
C	0	22	0	0	100	0
D	50	0	0	0	0	100
E	0	10	67	0	0	0
F	140	0	0	80	0	0

Table 6-2 A TRADE Matrix before applying an algorithm to solve the QAP

The algorithm arranges the TRADE matrix and gives the result show in Table 6-3.

	B	E	C	D	F	A
B	0	50	30	0	0	0
E	10	0	67	0	0	0
C	22	100	0	0	0	0
D	0	0	0	0	100	50
F	0	0	0	80	0	140
A	0	0	0	12	120	0

Table 6-3 A TRADE Matrix after an algorithm to solve the QAP is applied

which is a permutation of the original TRADE matrix. This Table shows B, E and C forming a cluster and D, F and A forming another cluster. This new arrangement of the TRADE matrix minimises the $f(\pi)$ function of Equation 6.1, and therefore it allows observing bloc formation, something that is not possible in the first matrix.

6.3.4 Benchmark for bloc formation

After applying an algorithm to solve the QAP (which gives the 'best arrangement' of the TRADE matrix), a benchmark value is introduced, to help find or highlight the

⁵ This example has been chosen in such a way that countries C, B and E trade with each other only and countries A, D, and F trade with each other only for the sake of clarity.

potential trading blocs or the main partners. This value is exogenously chosen. We propose to use the following three steps procedure to select this benchmark value:

1. Select the maximum amount of exports for each country (which corresponds to the maximum value by row). Pick up the minimum value among them.
2. Select the maximum amount of imports for each country (which corresponds to the maximum value by column in the TRADE matrix). Pick up the minimum value among them.
3. Choose the smallest value of the two previous minimum values.

This procedure finds at least one major partner for each country. It also serves to find out all partner countries whose measure of trade goes above that benchmark value, therefore, the main trading partners or trading blocs.

6.4 Numerical examples of trading blocs determination

Because of the complexity of trading blocs determination, this section include some examples with real trade data obtained by ITCS [OECD 1996] and DATA INTAL [BID 1996]. The examples will allow a better understanding of the trading bloc formation included in the simulation model presented in the next chapter. Results are given using all five types of TRADE matrix T suggested (subsection 6.3.1), in order to analyse possible differences between them. The countries used are: Austria (AT), Brazil (BR), Canada (CA), France (FR), Germany (DE), Italy (IT), Mexico (MX), Switzerland (CH), United States (US) and Venezuela (VE). The point was to include countries from two different continents (Europe and America): some large OECD countries (USA, CA, DE, FR, IT), some small OECD countries (AU, CH) and some developing countries from Latin America: one of them belonging to OPEC (VE), another oil producer country not a member of the OPEC (MX), and a large non oil exporter developing country (BR).

The following information is shown for each example presented below:

- An arbitrary initial arrangement of the TRADE matrix.

- The best arrangement of the TRADE matrix after applying the total permutation algorithm.
- The benchmark value used to choose main partners or bloc formation.
- The minimum value of the target function $f(\pi^*)$ calculated by the total permutation algorithm.
- A list of the main partners or potential blocs.

The countries sending to, and/or receiving from another, above the benchmark of its total exports/imports are shaded with a light grey. In other words, a highlighted element of the matrix means that there is a strong link between the two countries identified by the row and the column.

The results are presented in two parts. The first part presents the results for the year 1996, for the five types of the TRADE matrix discussed in subsection 6.3.1. The second part presents the results for three different years (1988, 1992, 1996), using the *a* and *e* type of the TRADE matrix of subsection 6.3.1, in order to observe possible dynamics in these matrices.

6.4.1 Results for 1996

The following five results for 1996 are obtained using the five different types of TRADE matrix presented in section 6.3.1:

- 1) Table 6-4 shows the initial TRADE matrix of total US\$ exports from country *i* -a row in the TRADE matrix- to country *j* -a column in the TRADE matrix (case a of subsection 6.3.1). After applying one of the previously discussed algorithms to solve the QAP and a benchmark of 4,192,063, we obtain the TRADE matrix shown in Table 6-5. The minimum value of the target function $f(\pi^*)$ calculated by the total permutation algorithm was 4,471,352,179 while for the initial TRADE matrix was 17,376,943,834.

	AT	BR	CA	FR	DE	IT	MX	CH	US	VE
AT	0	272606	445500	2249934	16490634	4743811	78258	3104427	2268953	19101
BR	83636	0	831597	1840117	3218203	1890174	498520	229286	9296201	381798
CA	404543	1256992	0	1779032	3216177	1856973	1478559	334247	1.6E+08	305903
FR	3102355	1339724	2494161	0	46896977	27998814	890989	9035420	19178756	186678
DE	31817507	4774567	3536686	48270592	0	38242887	2904244	24560112	39989239	425487
IT	5665702	2910282	1994789	28100509	36267898	0	761406	8396144	19000068	346882
MX	29105	945897	4426450	506615	659413	245308	0	75618	74108156	377465
CH	2538703	767465	687892	6837375	17378247	8840198	776052	0	7930245	68223
US	2181574	11682432	1.16E+08	22417369	31480907	10171277	73154423	5612040	0	4192063
VE	735	969288	532520	203438	428378	241676	188553	7206	13718876	0

Table 6-4 Total US\$ exports from a country -row- to another country -column- (1996): Initial arrangement

	VE	BR	MX	CA	US	FR	DE	IT	CH	AT
VE	0	969288	188553	532520	13718876	203438	428378	241676	7206	735
BR	381798	0	498520	831597	9296201	1840117	3218203	1890174	229286	83636
MX	377465	945897	0	4426450	74108156	506615	659413	245308	75618	29105
CA	305903	1256992	1478559	0	1.6E+08	1779032	3216177	1856973	334247	404543
US	4192063	11682432	73154423	1.16E+08	0	22417369	31480907	10171277	5612040	2181574
FR	186678	1339724	890989	2494161	19178756	0	46896977	27998814	9035420	3102355
DE	425487	4774567	2904244	3536686	39989239	48270592	0	38242887	24560112	31817507
IT	346882	2910282	761406	1994789	19000068	28100509	36267898	0	8396144	5665702
CH	68223	767465	776052	687892	7930245	6837375	17378247	8840198	0	2538703
AT	19101	272606	78258	445500	2268953	2249934	16490634	4743811	3104427	0

Table 6-5 Total US\$ exports from a country -row- to another country -column- (1996): Best arrangement

Within this representation of the TRADE matrix, it is possible to highlight seven potential blocs in 1996. Six with two countries: (VE, US), (BR, US), (MX, US), (CA, US), (DE, AT) and (IT, AT); and one with five countries: (US, FR, DE, IT, CH). As was previously indicated, the highlighted cells, in both the initial and the best TRADE matrix are those cells which values go over the benchmark value. For example, the exports of VE to US and the exports of US to VE are both over the benchmark. This is the reason why we considered them as a potential trade bloc. The analysis is similarly extensible to the others highlighted potential trading blocs.

As may be seen from Table 6-5, when the TRADE matrix is defined as total US\$ exports from country *i* to country *j* (absolute values of trade are used), the re-arrangement of the TRADE matrix, and therefore the visualisation of major trade partners, does concentrate trade among European countries plus the United States.

- 2) Table 6-6 shows the initial TRADE matrix of adding US\$ total exports from country i -row- to country j -column- and US\$ total exports from country j -row- to country i -column- (case b of subsection 6.3.1). After applying one of the previously discussed algorithms to solve the QAP and a benchmark of 17,910,939, we obtain the TRADE matrix shown in Table 6-7. The minimum value of the target function $f(\pi^*)$ calculated by the total permutation algorithm was 8,948,851,124 while for the initial TRADE matrix was 35,055,074,572.

	AT	BR	CA	FR	DE	IT	MX	CH	US	VE
AT	0	356242	850043	5352289	48308141	10409513	107363	8716467	4450527	19836
BR	356242	0	2088589	3179841	7992770	4800456	1444417	996751	20978633	1351086
CA	850043	2088589	0	4273193	6752863	3851762	5905009	1022139	2.75E+08	838423
FR	5352289	3179841	4273193	0	95167569	56099324	1397604	15872795	41596124	390116
DE	48308141	7992770	6752863	95167569	0	74510785	3563657	41938359	71470146	853865
IT	10409513	4800456	3851762	56099324	74510785	0	1006714	17236341	29171345	588558
MX	107363	1444417	5905009	1397604	3563657	1006714	0	851670	1.47E+08	566018
CH	8716467	996751	1022139	15872795	41938359	17236341	851670	0	13542285	75429
US	4450527	20978633	2.75E+08	41596124	71470146	29171345	1.47E+08	13542285	0	17910939
VE	19836	1351086	838423	390116	853865	588558	566018	75429	17910939	0

Table 6-6 Adding US\$ total exports from country i -row- to country j -column- and US\$ total exports from country j -row- to country i -column- (1996): Initial arrangement

	VE	BR	MX	CA	US	FR	DE	IT	CH	AT
VE	0	1351086	566018	838423	17910939	390116	853865	588558	75429	19836
BR	1351086	0	1444417	2088589	20978633	3179841	7992770	4800456	996751	356242
MX	566018	1444417	0	5905009	1.47E+08	1397604	3563657	1006714	851670	107363
CA	838423	2088589	5905009	0	2.75E+08	4273193	6752863	3851762	1022139	850043
US	17910939	20978633	1.47E+08	2.75E+08	0	41596124	71470146	29171345	13542285	4450527
FR	390116	3179841	1397604	4273193	41596124	0	95167569	56099324	15872795	5352289
DE	853865	7992770	3563657	6752863	71470146	95167569	0	74510785	41938359	48308141
IT	588558	4800456	1006714	3851762	29171345	56099324	74510785	0	17236341	10409513
CH	75429	996751	851670	1022139	13542285	15872795	41938359	17236341	0	8716467
AT	19836	356242	107363	850043	4450527	5352289	48308141	10409513	8716467	0

Table 6-7 Adding US\$ total exports from country i -row- to country j -column- and US\$ total exports from country j -row- to country i -column- (1996): Best arrangement

Within this representation of the TRADE matrix, it is possible to highlight seven potential blocs in 1996: six with two countries: (VE, US), (BR, US), (MX, US), (CA, US), (DE, CH) and (DE, AT); and one with four countries: (US, FR, DE, IT).

In this second case, when the TRADE matrix is defined adding US\$ total exports from country i to country j and US\$ total exports from country j to country i (absolute values of trade are used), the re-arrangement of the TRADE matrix, and therefore the visualisation of major trade partners, does concentrate trade among European countries plus United States. This result is similar to the one obtained in the first case.

- 3) Table 6-8 shows the initial TRADE matrix of percentage of exports country i -row- sends to country j -column- (case c of subsection 6.3.1). After applying one of the previously discussed algorithms to solve the QAP and a benchmark of 9.0 %, we obtain the TRADE matrix shown in Table 6-9. The minimum value of the target function $f(\pi^*)$ calculated by the total permutation algorithm was 2,860.8 while for the initial TRADE matrix was 8,594.5.

	AT	BR	CA	FR	DE	IT	MX	CH	US	VE
AT	0.0 %	0.4 %	0.7 %	3.9 %	36.7 %	7.7 %	0.1 %	4.6 %	2.9 %	0.1 %
BR	0.2 %	0.0 %	1.1 %	1.9 %	4.4 %	3.2 %	1.4 %	0.9 %	19.2 %	1.0 %
CA	0.2 %	0.5 %	0.0 %	0.7 %	1.2 %	0.5 %	0.5 %	0.4 %	80.6 %	0.2 %
FR	1.1 %	0.5 %	0.7 %	0.0 %	17.3 %	9.3 %	0.3 %	3.9 %	6.1 %	0.1 %
DE	5.5 %	0.9 %	0.5 %	10.6 %	0.0 %	7.3 %	0.5 %	4.7 %	7.6 %	0.1 %
IT	2.4 %	1.2 %	0.7 %	12.5 %	17.4 %	0.0 %	0.3 %	3.7 %	7.3 %	0.2 %
MX	0.0 %	0.9 %	2.3 %	0.4 %	0.7 %	0.1 %	0.0 %	0.4 %	83.9 %	0.4 %
CH	3.1 %	0.9 %	0.8 %	9.3 %	22.7 %	7.5 %	0.5 %	0.0 %	9.4 %	0.1 %
US	0.3 %	2.1 %	20.5 %	2.3 %	3.8 %	1.4 %	9.4 %	1.3 %	0.0 %	0.8 %
VE	0.0 %	3.2 %	1.3 %	0.4 %	2.1 %	0.7 %	0.6 %	0.0 %	58.8 %	0.0 %

Table 6-8 Percentage of exports that a country -row- sends to another country -column- (1996): Initial arrangement

	VE	MX	US	CA	BR	FR	IT	DE	CH	AT
VE	0.0 %	0.6 %	58.8 %	1.3 %	3.2 %	0.4 %	0.7 %	2.1 %	0.0 %	0.0 %
MX	0.4 %	0.0 %	83.9 %	2.3 %	0.9 %	0.4 %	0.1 %	0.7 %	0.4 %	0.0 %
US	0.8 %	9.4 %	0.0 %	20.5 %	2.1 %	2.3 %	1.4 %	3.8 %	1.3 %	0.3 %
CA	0.2 %	0.5 %	80.6 %	0.0 %	0.5 %	0.7 %	0.5 %	1.2 %	0.4 %	0.2 %
BR	1.0 %	1.4 %	19.2 %	1.1 %	0.0 %	1.9 %	3.2 %	4.4 %	0.9 %	0.2 %
FR	0.1 %	0.3 %	6.1 %	0.7 %	0.5 %	0.0 %	9.3 %	17.3 %	3.9 %	1.1 %
IT	0.2 %	0.3 %	7.3 %	0.7 %	1.2 %	12.5 %	0.0 %	17.4 %	3.7 %	2.4 %
DE	0.1 %	0.5 %	7.6 %	0.5 %	0.9 %	10.6 %	7.3 %	0.0 %	4.7 %	5.5 %
CH	0.1 %	0.5 %	9.4 %	0.8 %	0.9 %	9.3 %	7.5 %	22.7 %	0.0 %	3.1 %
AT	0.1 %	0.1 %	2.9 %	0.7 %	0.4 %	3.9 %	7.7 %	36.7 %	4.6 %	0.0 %

Table 6-9 Percentage of exports that country i sends to country j (1996): Best arrangement

From Table 6-9 it is possible to see that from the point of view of exports, there are no doubts about the importance of the US for VE, MX, CA, BR and also CH in 1996. Nevertheless, only MX and CA were also relatively important for US exports in that year. FR and IT as well as FR and DE sent each other a high relative amount of their exports. So the link was strong in both directions. It is also interesting to observe how for CH three countries (DE, US and FR) were over the benchmark for its exports. In addition, the US exported for two countries (MX and CA) over the relative benchmark, while DE did it only for FR.

It is important to highlight that, in contrast with the two previous cases, when the TRADE matrix is defined as percentage of exports that country i sends to country j (in other words, relative values of trade are used), the re-arrangement of the TRADE matrix shows clearly a continental separation.

- 4) Table 6-10 shows the initial TRADE matrix of percentage of imports country j buys from country i (case c of subsection 6.3.1). After applying one of the previously discussed algorithms to solve the QAP and a benchmark of 10.6 %, we obtain the TRADE matrix shown in Table 6-11. The minimum value of the target function $f(\pi^*)$, calculated by the total permutation algorithm, was 3,357.5 while for the initial TRADE matrix was 9,069.6.

	AT	BR	CA	FR	DE	IT	MX	CH	US	VE
AT	0.0 %	0.5 %	0.3 %	0.8 %	3.7 %	2.3 %	0.1 %	4.0 %	0.3 %	0.2 %
BR	0.1 %	0.0 %	0.5 %	0.7 %	0.7 %	0.9 %	0.6 %	0.3 %	1.1 %	4.1 %
CA	0.6 %	2.4 %	0.0 %	0.7 %	0.7 %	0.9 %	1.7 %	0.4 %	19.5 %	3.3 %
FR	4.6 %	2.5 %	1.5 %	0.0 %	10.6 %	13.5 %	1.0 %	11.6 %	2.4 %	2.0 %
DE	46.8 %	9.0 %	2.1 %	17.6 %	0.0 %	18.5 %	3.3 %	31.4 %	4.9 %	4.6 %
IT	8.3 %	5.5 %	1.2 %	10.2 %	8.2 %	0.0 %	0.9 %	10.7 %	2.3 %	3.7 %
MX	0.0 %	1.8 %	2.6 %	0.2 %	0.2 %	0.1 %	0.0 %	0.1 %	9.1 %	4.1 %
CH	3.7 %	1.4 %	0.4 %	2.5 %	3.9 %	4.3 %	0.9 %	0.0 %	1.0 %	0.7 %
US	3.2 %	21.9 %	68.8 %	8.2 %	7.1 %	4.9 %	81.8 %	7.2 %	0.0 %	45.0 %
VE	0.0 %	1.8 %	0.3 %	0.1 %	0.1 %	0.1 %	0.2 %	0.0 %	1.7 %	0.0 %

Table 6-10 Percentage of imports a country -column- buys from another country -row- (1996): Initial arrangement

	MX	CA	US	VE	BR	FR	IT	DE	CH	AT
MX	0.0 %	2.6 %	9.1 %	4.1 %	1.8 %	0.2 %	0.1 %	0.2 %	0.1 %	0.0 %
CA	1.7 %	0.0 %	19.5 %	3.3 %	2.4 %	0.7 %	0.9 %	0.7 %	0.4 %	0.6 %
US	81.8 %	68.8 %	0.0 %	45.0 %	21.9 %	8.2 %	4.9 %	7.1 %	7.2 %	3.2 %
VE	0.2 %	0.3 %	1.7 %	0.0 %	1.8 %	0.1 %	0.1 %	0.1 %	0.0 %	0.0 %
BR	0.6 %	0.5 %	1.1 %	4.1 %	0.0 %	0.7 %	0.9 %	0.7 %	0.3 %	0.1 %
FR	1.0 %	1.5 %	2.4 %	2.0 %	2.5 %	0.0 %	13.5 %	10.6 %	11.6 %	4.6 %
IT	0.9 %	1.2 %	2.3 %	3.7 %	5.5 %	10.2 %	0.0 %	8.2 %	10.7 %	8.3 %
DE	3.3 %	2.1 %	4.9 %	4.6 %	9.0 %	17.6 %	18.5 %	0.0 %	31.4 %	46.8 %
CH	0.9 %	0.4 %	1.0 %	0.7 %	1.4 %	2.5 %	4.3 %	3.9 %	0.0 %	3.7 %
AT	0.1 %	0.3 %	0.3 %	0.2 %	0.5 %	0.8 %	2.3 %	3.7 %	4.0 %	0.0 %

Table 6-11 Percentage of imports a country -column- buys from another country -row- (1996): Best arrangement

Here, it is important to highlight how dependent MX, CA, VE and BR were from US with respect to their imports in 1996. Although for US, MX and CA they were also important. On the other hand, it is quite interesting to observe how the interdependence in Europe was more balanced. There, only AT depended heavily on DE, and CH depended on FR, IT and DE. For FR, IT and DE the dependence on imports was equally high.

As in the previous case, when the TRADE matrix is defined as percentage of imports country j buys from country i (in other words, relative values of trade are used), the re-arrangement of the TRADE matrix shows also a clear continental separation.

- 5) Table 6-12 shows the initial TRADE matrix of the average of relative exports and imports as defined previously (case e of subsection 6.3.1). After applying one of the previously discussed algorithms to solve the QAP and a benchmark of 6% (this benchmark is the percentage for the matrix that divides it into two major blocs), we obtain the TRADE matrix shown in Table 6-13. The minimum value of the target function $f(\pi^*)$, calculated by the total permutation algorithm, was 3,331.5 while for the initial TRADE matrix was 8,843.4.

	AT	BR	CA	FR	DE	IT	MX	CH	US	VE
AT	0.0 %	0.3 %	0.4 %	2.6 %	23.2 %	5.2 %	0.1 %	3.8 %	1.7 %	0.1 %
BR	0.3 %	0.0 %	1.1 %	1.4 %	3.7 %	2.7 %	1.2 %	0.9 %	11.1 %	2.5 %
CA	0.4 %	1.1 %	0.0 %	0.9 %	1.2 %	0.8 %	1.8 %	0.5 %	47.3 %	1.3 %
FR	2.6 %	1.4 %	0.9 %	0.0 %	14.0 %	11.4 %	0.5 %	6.8 %	4.7 %	0.6 %
DE	23.2 %	3.7 %	1.2 %	14.0 %	0.0 %	12.8 %	1.1 %	15.7 %	5.8 %	1.7 %
IT	5.2 %	2.7 %	0.8 %	11.4 %	12.8 %	0.0 %	0.4 %	6.6 %	4.0 %	1.2 %
MX	0.1 %	1.2 %	1.8 %	0.5 %	1.1 %	0.4 %	0.0 %	4.7 %	46.0 %	1.3 %
CH	3.8 %	0.9 %	0.5 %	6.8 %	15.7 %	6.6 %	4.7 %	0.0 %	4.7 %	0.2 %
US	1.7 %	11.1 %	47.3 %	4.7 %	5.8 %	4.0 %	46.0 %	4.7 %	0.0 %	26.6 %
VE	0.1 %	2.5 %	1.3 %	0.6 %	1.7 %	1.2 %	1.3 %	0.2 %	26.6 %	0.0 %

Table 6-12 Average of relative exports and imports (1996): Initial arrangement

	VE	CA	US	MX	BR	CH	FR	DE	IT	AT
VE	0.0 %	1.3 %	26.6 %	1.3 %	2.5 %	0.2 %	0.6 %	1.7 %	1.2 %	0.1 %
CA	1.3 %	0.0 %	47.3 %	1.8 %	1.1 %	0.5 %	0.9 %	1.2 %	0.8 %	0.4 %
US	26.6 %	47.3 %	0.0 %	46.0 %	11.1 %	4.7 %	4.7 %	5.8 %	4.0 %	1.7 %
MX	1.3 %	1.8 %	46.0 %	0.0 %	1.2 %	4.7 %	0.5 %	1.1 %	0.4 %	0.1 %
BR	2.5 %	1.1 %	11.1 %	1.2 %	0.0 %	0.9 %	1.4 %	3.7 %	2.7 %	0.3 %
CH	0.2 %	0.5 %	4.7 %	4.7 %	0.9 %	0.0 %	6.8 %	15.7 %	6.6 %	3.8 %
FR	0.6 %	0.9 %	4.7 %	0.5 %	1.4 %	6.8 %	0.0 %	14.0 %	11.4 %	2.6 %
DE	1.7 %	1.2 %	5.8 %	1.1 %	3.7 %	15.7 %	14.0 %	0.0 %	12.8 %	23.2 %
IT	1.2 %	0.8 %	4.0 %	0.4 %	2.7 %	6.6 %	11.4 %	12.8 %	0.0 %	5.2 %
AT	0.1 %	0.4 %	1.7 %	0.1 %	0.3 %	3.8 %	2.6 %	23.2 %	5.2 %	0.0 %

Table 6-13 Average of relative exports and imports (1996): Best arrangement

In this case we find seven potential blocs: six with two countries: (VE, US), (CA, US), (US, MX), (US, BR) and (DE, AT); and one with four countries: (CH, FR, DE, IT). Similarly, when the TRADE matrix is defined as the average of relative exports and imports (as defined in the two previous cases), the re-arrangement of the TRADE matrix shows a clearer continental separation. It is important to notice here that this way of representing trade takes into account the total world exports, which means that this measure gives a better understanding of real trade linkages among the ten chosen countries in 1996.

6.4.2 Discussion

The results of the five cases presented above, which define a trade matrix between countries (by means of absolute and relative measures), point out to some interesting features regarding international trade interdependence between these countries. The first

two definitions (the amount of total trade in monetary units a country exports to another, and the amount of trade in monetary units resulting from adding up exports from country i to country j - x_{ij} - and exports from country j to country i - x_{ji} -), both of which use absolute values, put together large countries as US, FR, DE, IT. The first case includes also CH. This indicates the enormous amount of trade that these countries exchange but, in particular, the strength of trade between the selected European countries, which are members of the European Union.

By contrast, the remaining three measures defining a trade matrix (the percentage of exports a country i exports to country j -out of country i 's total exports-, the percentage of imports a country buys from another, and the average of relative exports and imports for both countries as a measure of relative linkage on trade between countries), which use relative values, cluster countries around hegemonic power countries like the US and DE in both continents. This shows the extreme importance that these markets represent for the others along the same continent. In particular, when the percentage of imports a country buys from another is used (Table 6-9), the countries that belongs to one of the two biggest trading blocs (EU and NAFTA) in the world cluster together.

Finally, when a measure of relative linkage on trade between countries (the average of relative exports and imports from the viewpoint of both countries) is used, remarkably ones finds a benchmark that divides the trade matrix into two blocs, corresponding to the geographical continental (Europe and America) separation (see Table 6-13).

In summary, when absolute values of trade are used, the re-arrangement of the trade matrix, and therefore the visualisation of major trade partners does concentrate trade among European countries plus the United States (see subsection 6.4). On the contrary, when relative measures of trade are used, the outcome is a clearer continental separation.

6.4.3 Results for 1988, 1992, and 1996

In this second part, we present the results obtained for cases a (the amount of total trade in monetary units a country exports to another) and e (relative trade links between

countries) of the TRADE matrix introduced in subsection 6.3.1, for three different years: 1988, 1992 and 1996. This allows us to compare these matrices and also to observe the evolution of partnerships between those countries during this period. In other words, we are trying to observe broadly the dynamics of bloc formation using the method proposed.

Table 6-14, Table 6-15 and Table 6-16 show the TRADE matrices of total US\$ exports from country i to country j (case a of subsection 6.3.1) for 1988, 1992, and 1996, respectively. When absolute values of trade (exports from one country to another) are used, as in this case, it is observed that the arrangement of each of these matrices is the same. The major partners were the US, FR, DE, IT, and CH. Equally observable is the strong linkage between US and VE, US and BR, US and MX, and US and CA. On the other hand, DE and AT and IT and AT were also major partners (though IT and AT did not achieve the benchmark in 1992).

1988	VE	BR	MX	CA	US	FR	DE	IT	CH	AT
VE	0	192071	6652	374055	5887431	104788	619000	133011	9328	1762
BR	654433	0	356450	972066	11486560	1603877	2802779	1678184	248682	200577
MX	112358	136175	0	1081974	16564802	614761	424025	145216	38418	44115
CA	306508	417801	400146	0	79907744	1301922	1885941	972560	209140	151488
US	2426580	3837666	19971154	70089715	0	13709192	15463199	7770350	3128467	1244496
FR	469303	745659	542726	2350412	11888229	0	29353365	20577805	5947328	1440289
DE	747014	1449128	935543	3174389	25428001	35445140	0	30401141	19258237	16464000
IT	597230	426269	249168	1592544	11368384	20651097	22569250	0	5697235	3267114
CH	172463	334594	195678	569471	4142264	4456595	10499650	6204854	0	1612910
AT	56651	28477	18015	232067	1095769	1523990	10413050	3320161	2175807	0

Table 6-14 Total US\$ exports from country i to country j (case a of subsection 6.3.1) for 1988
Benchmark: 2426580

1992	VE	BR	MX	CA	US	FR	DE	IT	CH	AT
VE	0	339593	153800	277329	8636476	142455	936616	103902	5265	5979
BR	576586	0	1029262	596910	8144452	1668415	3423013	1848911	218770	156953
MX	196899	405306	0	2297389	35865045	556013	556013	169667	31417	88521
CA	282828	520763	810938	0	1.01E+08	1545849	2528110	1472779	252068	275810
US	5178436	5441571	45640600	79905068	0	20113372	25718996	9870408	4194408	2136289
FR	358034	634313	1260217	2227427	15247890	0	48134207	27277084	7073284	2402890
DE	621892	1773153	2318560	2925835	29594947	44628670	0	40688794	21906698	23201023
IT	635526	865450	954780	1447640	12842859	25420734	37029018	0	6559238	4668014
CH	133996	337502	630269	539711	5732662	5390140	15374963	8490588	0	2166939
AT	41442	62520	89907	250193	1346634	2065547	17487480	4120755	2562258	0

Table 6-15 Total US\$ exports from country i to country j (case a of subsection 6.3.1) for 1992
Benchmark: 5178436

1996	VE	BR	MX	CA	US	FR	DE	IT	CH	AT
VE	0	969288	188553	532520	13718876	203438	428378	241676	7206	735
BR	381798	0	498520	831597	9296201	1840117	3218203	1890174	229286	83636
MX	377465	945897	0	4426450	74108156	506615	659413	245308	75618	29105
CA	305903	1256992	1478559	0	1.6E+08	1779032	3216177	1856973	334247	404543
US	4192063	11682432	73154423	1.16E+08	0	22417369	31480907	10171277	5612040	2181574
FR	186678	1339724	890989	2494161	19178756	0	46896977	27998814	9035420	3102355
DE	425487	4774567	2904244	3536686	39989239	48270592	0	38242887	24560112	31817507
IT	346882	2910282	761406	1994789	19000068	28100509	36267898	0	8396144	5665702
CH	68223	767465	776052	687892	7930245	6837375	17378247	8840198	0	2538703
AT	19101	272606	78258	445500	2268953	2249934	16490634	4743811	3104427	0

Table 6-16 Total US\$ exports from country *i* to country *j* (case a of subsection 6.3.1) for 1996
Benchmark: 4192063

Table 6-17, Table 6-18 and Table 6-19 show the TRADE matrices of the average of relative exports and imports (case e of subsection 6.3.1) for 1988, 1992, and 1996, respectively. In this case, a benchmark of 6.0% has been chosen for all the three matrices presented. When relative measures are used to represent trade linkages between countries, the configuration of the best arrangement of the trade matrix is clearly separated into two major blocs (in particular two continental trading blocs). It is also observed that the US is placed at the centre of one of them, and DE is placed in the centre of the other. The arrangement of the matrix for 1988 is the same as that of the 1996 matrix. The arrangement changes for the 1992 matrix. However, the two major blocs remain unchanged. The changes take place on the arrangement of countries inside each bloc, which could suggest changes in the relative international trade importance among countries belonging to the same continental area.

1988	VE	CA	US	MX	BR	CH	FR	DE	IT	AT
VE	0.0 %	2.4 %	40.6 %	0.4 %	1.3 %	1.9 %	0.7 %	2.2 %	0.5 %	0.1 %
CA	2.4 %	0.0 %	43.8 %	1.7 %	1.7 %	1.4 %	1.1 %	1.6 %	0.6 %	0.4 %
US	40.6 %	43.8 %	0.0 %	19.7 %	15.3 %	5.4 %	4.8 %	5.9 %	3.9 %	1.9 %
MX	0.4 %	1.7 %	19.7 %	0.0 %	2.5 %	1.3 %	1.6 %	3.1 %	0.5 %	0.2 %
BR	1.3 %	1.7 %	15.3 %	2.5 %	0.0 %	2.7 %	2.3 %	4.7 %	1.0 %	0.4 %
CH	1.9 %	1.4 %	5.4 %	1.3 %	2.7 %	0.0 %	13.8 %	15.2 %	6.4 %	2.7 %
FR	0.7 %	1.1 %	4.8 %	1.6 %	2.3 %	13.8 %	0.0 %	14.5 %	7.9 %	6.1 %
DE	2.2 %	1.6 %	5.9 %	3.1 %	4.7 %	15.2 %	14.5 %	0.0 %	16.3 %	21.9 %
IT	0.5 %	0.6 %	3.9 %	0.5 %	1.0 %	6.4 %	7.9 %	16.3 %	0.0 %	4.6 %
AT	0.1 %	0.4 %	1.9 %	0.2 %	0.4 %	2.7 %	6.1 %	21.9 %	4.6 %	0.0 %

Table 6-17 Average of relative exports and imports (case e of subsection 6.3.1) for 1988
Benchmark: 6.0%

1992	MX	CA	US	VE	BR	FR	IT	DE	CH	AT
MX	0.0 %	2.2 %	42.3 %	0.8 %	1.8 %	1.0 %	0.6 %	1.4 %	0.5 %	0.2 %
CA	2.2 %	0.0 %	45.4 %	1.1 %	1.3 %	1.2 %	1.0 %	1.4 %	0.5 %	0.4 %
US	42.3 %	45.4 %	0.0 %	25.5 %	13.0 %	5.6 %	4.3 %	6.1 %	4.3 %	1.9 %
VE	0.8 %	1.1 %	25.5 %	0.0 %	2.5 %	1.0 %	1.5 %	2.9 %	0.3 %	0.1 %
BR	1.8 %	1.3 %	13.0 %	2.5 %	0.0 %	2.2 %	2.7 %	4.8 %	0.8 %	0.3 %
FR	1.0 %	1.2 %	5.6 %	1.0 %	2.2 %	0.0 %	12.8 %	15.4 %	6.1 %	2.8 %
IT	0.6 %	1.0 %	4.3 %	1.5 %	2.7 %	12.8 %	0.0 %	15.2 %	7.8 %	5.7 %
DE	1.4 %	1.4 %	6.1 %	2.9 %	4.8 %	15.4 %	15.2 %	0.0 %	16.4 %	23.0 %
CH	0.5 %	0.5 %	4.3 %	0.3 %	0.8 %	6.1 %	7.8 %	16.4 %	0.0 %	4.2 %
AT	0.2 %	0.4 %	1.9 %	0.1 %	0.3 %	2.8 %	5.7 %	23.0 %	4.2 %	0.0 %

Table 6-18 Average of relative exports and imports (case e of subsection 6.3.1) for 1992
Benchmark: 6.0%

1996	VE	CA	US	MX	BR	CH	FR	DE	IT	AT
VE	0.0 %	1.3 %	26.6 %	1.3 %	2.5 %	0.2 %	0.6 %	1.7 %	1.2 %	0.1 %
CA	1.3 %	0.0 %	47.3 %	1.8 %	1.1 %	0.5 %	0.9 %	1.2 %	0.8 %	0.4 %
US	26.6 %	47.3 %	0.0 %	46.0 %	11.1 %	4.7 %	4.7 %	5.8 %	4.0 %	1.7 %
MX	1.3 %	1.8 %	46.0 %	0.0 %	1.2 %	4.7 %	0.5 %	1.1 %	0.4 %	0.1 %
BR	2.5 %	1.1 %	11.1 %	1.2 %	0.0 %	0.9 %	1.4 %	3.7 %	2.7 %	0.3 %
CH	0.2 %	0.5 %	4.7 %	4.7 %	0.9 %	0.0 %	6.8 %	15.7 %	6.6 %	3.8 %
FR	0.6 %	0.9 %	4.7 %	0.5 %	1.4 %	6.8 %	0.0 %	14.0 %	11.4 %	2.6 %
DE	1.7 %	1.2 %	5.8 %	1.1 %	3.7 %	15.7 %	14.0 %	0.0 %	12.8 %	23.2 %
IT	1.2 %	0.8 %	4.0 %	0.4 %	2.7 %	6.6 %	11.4 %	12.8 %	0.0 %	5.2 %
AT	0.1 %	0.4 %	1.7 %	0.1 %	0.3 %	3.8 %	2.6 %	23.2 %	5.2 %	0.0 %

Table 6-19 Average of relative exports and imports (case e of subsection 6.3.1) for 1996
Benchmark: 6.0%

This exercise suggests to us the importance of considering long periods of time when we study trade formation.

6.5 Conclusions

This chapter presents a method for highlighting potential trading blocs in a group of countries. Given an initial trade matrix for n countries, the method re-arranges the matrix in order to group together (or closer) those countries whose mutual exchanges are larger, and far apart those countries whose mutual exchanges are smaller. In this way, we observe bloc formation. The Quadratic Assignment Problem has been presented as a method to deal with the re-arrangement of the trade matrix.

To analyse which algorithms and which types of TRADE matrix to use in the simulation model of international trade discussed in the next chapter, the QAP was applied using data from ten countries. Choosing arbitrarily a benchmark using an algorithm to solve the QAP with the different types of TRADE matrix, we have drawn attention to some potential trading blocs or major partners. The results indicate that:

- When absolute values of trade are used, the re-arrangement of the trade matrix, and therefore the visualisation of major trade partners, does concentrate trade among European countries plus the United States (see subsection 6.4).
- When relative measures of trade are used, the continental separation turns out to be clearer. This is particularly true when we introduce an index of relative importance not only from the point of view of exports but also from the point of view of imports (see subsection 6.4).

For this reason, it seems reasonable that a simulation model of the international trade system with real data has to be run with at least the above two different types of TRADE matrix.

A weakness of the method for finding potential trading blocs (or major trading partners) presented in this chapter is the use of a benchmark value exogenously given, in order to visualise that formation. Nevertheless, the point is not to deal with a precise method of bloc formation, but, once a bloc has been formed, to try to answer, for instance, questions as to what happens with that structure when common policies are applied.

From the selection of the above countries, it is evident that two basic blocs could be extracted: one formed by the US, CA, MX and perhaps VE and BR; and another one formed by DE, FR, IT, CH, AT. As was shown in each case, we were able to identify partnerships between two or more countries. Trade is concentrated around the US on one bloc and around Germany on the other. But, because of the large amount of trade the US and DE share, both could be part of an independent partnership, seems to be valid in all cases.

The simulation model introduced in the next chapter will use the algorithm presented in this chapter. In particular, it will use different types of trade matrix, the algorithm for identify bloc formation in those matrices, and their dynamics during the simulation period.

Chapter 7

The model

7.1 Introduction

In this chapter we describe the proposed model to deal with trading bloc formation and patterns of trade, the two main features of the international trade system discussed in Chapter four. Section 7.2 defines the algorithmic approach used in the chapter for representing economic mechanism. By algorithmic approach we mean the specification of a set of instructions that must be followed in a fixed order to solve or calculate an answer to a problem, in particular when the specification is oriented to be programmed in a computer language. Section 7.3 makes a general description of the model, describing the sort of artificial society used in the model. Then, the variables and the data structure used to represent them are defined (subsection 7.3.1). The initial conditions (subsection 7.3.2), a general algorithmic description of the process (subsection 7.3.3) and the software used are specified. In section 7.4, a detailed description of the model's components is presented. An algorithm to simulate the patterns of trade among a group of countries is proposed (subsection 7.4.1). The idea has been, basically, to represent the complexity and the parallelism that characterise the network of shipments between a group of countries when they trade. Then, subsection 7.4.2 specifies the way in which international prices are computed and used in the model. The network of shipments between countries is formed according to the export capacities and import requirements of each country by period of time. They change from period to period by a percentage point. In the model, this percentage point is a uniformly distributed random variable that may vary inside a band of mark-ups, chosen from real data (subsection 7.4.3). This simulates a path of growth in each sector for each country of the production side and of the demand side of the economy. However, they could also change as result

of constraints generated by the system as a whole. World export capacity and world import requirement in each sector co-evolve, so, subsection 7.4.4 introduces a feedback mechanism to simulate such co-evolution. Once the patterns of trade is formed in a period, which allows to compute the trade matrix, clustering formation in the trade matrix is used to observe bloc formation (subsection 7.4.5), following the main ideas described in the previous chapters. The last four parts of this section deal with the calculation of terms of trade (7.4.6), and the ways how tariff (7.4.7), transport costs (7.4.8) and prices (7.4.9) change are simulated in the model.

7.2 Language description and other specifications

Throughout this chapter we adopt an algorithmic approach for the description of economic mechanisms.¹ By algorithmic approach we mean the specification of a set of instructions that must be followed in a fixed order to solve or calculate an answer to a problem. The reasons for using this specification are (a) it is very helpful to increase the ability to describe in a clear and flexible way different evolutionary mechanisms and (b) it is a natural way of specifying computing programming languages. As was pointed out by Andersen:

the importance of the algorithmic approach is that it helps to depict the basic mechanism which connects cause and effect in an evolutionary process whose concrete path is essentially irreversible. [Andersen 1996, p]

Two basis structures FOR .. DO and IF .. THEN, which are present in almost all computing programming languages, will help in defining the general algorithms. The FOR .. DO statement serves to iterate the same commands or group of sentences a specified number of times. The IF .. THEN statement serves to decide which path follows after a decision rule (or a logical condition) has been applied. The parentheses ‘{’ and ‘}’ help to define the group of sentences boxed in by the structure.

In general algorithmic form:

¹ The use of the algorithmic approach in economics has been recently emphasized by Anderson [1996]. Particularly, he discusses the elements covered by what he suggests to call Artificial Economic Evolution, which in part is referred to as "the ability to synthesize mechanisms concerning the creation, transmission, and selection of behavioral rules into computer based studies as a first step on the way towards a real understanding of the process of capitalist and post capitalism evolution".

```

FOR each item DO {
    group of sentences;
    .
    .
}

```

here, the group of sentences are performed for all the items specified (it is called unconditional iteration and "each item" is normally a counter and way to move the counter), and

```

IF logical condition THEN {
    group of sentences;
    .
    .
}

```

in this case, whenever logical condition holds, group of sentences must be executed.

Among the group of sentences we could place other FOR and/or IF structures if necessary in a nested way.

A third basic structure is the assignment structure represented by

```
Y := F(.);
```

which assigns to a variable Y the value of the result of a computed function or a general mathematical expression F(.). $Y:=X$ in computer science is different from $Y=X$ in mathematics. The first means that Y takes the value of X. The second represents the logical test of equality and the whole may take on a 'true' or 'false' value.

7.3 The model: general description

The model describes an artificial society. The world has a number of countries (CN). The economy of each country is divided into the same aggregated number of sectors (SN). No differentiated products are considered. Each sector in a particular country produces a generic product measured in physical units at a unique price. Goods

and services across countries are homogeneous. Each country is flexible to change its production levels in every sector. Preferences over goods and services are assumed to be identical in all countries. All countries use the same currency and are subject of tariff regulation only (no quotas or other exchange controls are considered, although they could be added). The tariffs levied by governments are *ad valorem*.

A country decides how much it wants to export and import in each sector at each period. Following simple rules explained later on, the model finds the way countries exchange their goods and services each period. As the process advances, each country will observe what is happening on the international market in every sector and will try to make adjustments and/or improve its position with respect to the other countries by changing its desired amounts of imports and exports. For example, if a country observes that the exports in a sector it would like to sell on the international market have not been sold out to the rest of the countries, it must reduce exports in next period. If the amount of imports it would like to buy in a sector exceeds what is actually offered on the international market, it must reduce them. So, the feedback in each period will determine the path followed by the variables of the model and, in the long run, the outcome. The final exchange is decided by the model.

At each period, the model calculates trade between countries. The trade is stored in a TRADE matrix (see Chapter 6). By re-arranging columns and rows, the model finds an equivalent matrix in which the greater elements are clustered in sub-matrices along the diagonal. In other words, the arranged TRADE matrix collects together those countries with large amounts of trade between them and separates those with small amounts of trade. The new arrangement of the TRADE matrix shows the major trade partners and suggests that they are forming a trading bloc.

Moreover, bloc formation could be the result of political preferential trade agreements exogenous to the model. Those agreements may be specified to have effect during some periods of time during the simulation run. Whether or not these agreements will have some effects on the bilateral trade flows, and consequently on the trade network induced, may be observed in the TRADE matrix.

As part of those agreements, only changes in tariffs are allowed in the model's current version. For example, in a world of six countries, three of them decide to cut their tariffs between each other and keep previous tariffs with countries outside the agreement. The other three could do something similar. This allows exploring dynamically the consequences of some economic policies involving tariff variations, not only on countries' trade performances but also on the linkages created.

7.3.1 The variables of the model and the data structure used to represent them

The basic data structures used in the model are vectors, matrices and three-dimensional arrays. We represent the relationships between countries by a first type of matrix with CN columns, one for each country and CN rows, one for each counterpart country. The variables with this type of configuration are:

- **TRADE**[C,R] for registering the total trade from a country (C) to another country (R) in a period of TIME. The value of each cell is expressed in \$ (dollars).
- **Tr**[C,R] for registering the costs of transporting one unit of product from a country (C) to another country (R) in a period of TIME. Each one of its cells is measured in dollars. We assume that the cost of transporting one unit of product from country C to country R is the same of doing the reverse, which implies that this matrix is symmetrical. These transport costs are c.i.f. (cost, insurance and freight).

A second type of matrix represents countries and their sectors. This type of matrix has SN columns, each for a sector and CN rows, each for a country. The variables with this type of configuration are:

- **P**[C,S] for registering the prices by sector (S) for each country (C) in a given period of TIME. Each of its cells is measured in dollars.
- **EX**[C,S] for registering the export capacities in each country (C) by a sector (S), in a given period of TIME. Each of its cells is measured in physical units.
- **IM**[C,S] for registering the import requirements in each country (C) by a sector (S) in a given period of TIME. Each of its cells is measured in physical units.

- **minEXr[C,S]** for registering the minimum rate of growth in the export capacities by country C in sector S.
- **maxEXr[C,S]** for registering the maximum rate of growth in the export capacities by country C in sector S.
- **minIMr[C,S]** for registering the minimum rate of growth in the import requirements by country C in sector S.
- **maxIMr[C,S]** for registering the maximum rate of growth in the import requirements by country C in sector S.

Finally, a three-dimensional array represents relationships between countries by sector. The variables with this type of configuration are:

- **Ta[S,C,R]** for registering the tariffs in sector S a country (C) applies to imports from a country (R) in a period of TIME. Each of its cells is measured in a percentage of price. These tariffs are *ad valorem*.
- **STRADE[S,C,R]** for registering by sector S the trade from a country (C) to another country (R) in a period of TIME. Each of its cells is measured in physical units.

The model also includes the following variables:

- **TIME** is the current period of simulation. The period of TIME is equal to one year.
- **IntPri[S]** is a vector of international prices by sector (S) in a given period of TIME. Each one of its cells is measured in dollars.

7.3.2 The initial conditions

Initial conditions are given for the following variables: exports (**EX**), imports (**IM**), tariffs (**Ta**), transport costs (**Tr**), prices (**P**), the rates of growth of **Ta**, **Tr** and **P** and the bounded limits of growth rates for exports (**minEXr**, **maxEXr**) and imports (**minIMr**, **maxIMr**).

7.3.3 A general algorithmic description of the process

Following the above general description of the model, it is possible to introduce a more precise and logical style to express the general process.

```
For each TIME DO {  
  Find pattern of commerce by sector: Compute STRADE and TRADE matrix;  
  Compute International Prices (IntPri);  
  Compute export capacities (EX) and import requirements (IM);  
  Compute evolution of export capacities and import requirements;  
  Find 'best trade matrix';  
  Compute terms of trade;  
  Report selected variables;  
  
  Prepare variables for next period:  
  Change tariffs (Ta);  
  Change transport costs (Tr);  
  Change prices (P);  
}
```

The simulation model runs for a pre-set number of periods. In each TIME or period, the general algorithm tells the sequential order in which calculations are made. Each instruction in the general algorithm to compute or to change parameters is described below in the corresponding subsection (from 7.4.1 to 7.4.9).

7.3.4 Software used

The model has been programmed using the GLIDER for windows simulation system, version 1.2, which runs on the Borland Delphi 4.0 programming language for Windows NT. GLIDER is a language for simulation of both continuous and discrete systems [Domingo et al. 1993]. It was developed at the University of "Los Andes" in Mérida, Venezuela.

7.4 The model: a detailed description of its components

7.4.1 Pattern of commerce by sector and the trade matrix in each period

As it was seen in Chapters 2 and 3, the trade between countries is a very complex process that depends on many different variables. This process involves not only economic but also political, cultural and historical factors. No matter which representation is used, it will always be a stylised and a grossly approximated one. However, dealing with a representation of the process allows us to understand a little better what is going on in the real world.

An important characteristic of trade is that it takes place in parallel. In other words, many negotiations and exchanges happen at the same time involving almost all countries together with a huge amount of different agents and commodities. This parallelism, which is typical in economic processes, increases the complexity of the problem (see Chapter 3). We are searching for mechanisms that may exploit the computational resources available now, in order to represent that complexity. So, we want to deal with a simple (again stylised) sequential algorithm that simulates the parallelism involved by using simple rules for exchanging goods and services. Thus, the algorithm creates a network of shipments, which is stored in the STRADE and in the TRADE matrices. The TRADE matrix is computed using the definition given in subsection 6.3.1. In particular, the types a and e . However the results presented in Chapter 8 use only type a . Appendix C gives details for this algorithm and a numerical example. In this section the process of this algorithm is presented only verbally.

At each period (TIME), countries know the prices, tariffs and transport costs with which they will trade with other countries. Importers decide who to buy from, according to the best price option they have. For "best price" we mean the minimum value after adding up price and transport and applying the respective tariff. The network of shipments is searched by sector, which implies that the way countries trade from sector to sector may change considerably.

The purchasing procedure runs as follows: a country buys up from the country that offers it the best price (this means that each country ranks all other countries

according to the best price criterion). It may happen that the seller does not satisfy the buyer's requirements. In this case, the buyer moves on and buys up from the country that offers it the second best price. This continues until the buyer satisfies all its requirements or no more supplies are available. This procedure can be changed by introducing a limit on the amount of imports that a country buys from another on each iteration. In other words, this is like to divide the process into k times. It is similar to take into account that the process of buying occurs k times in a period rather than only once. For example once every week in the year, 52 times ($k=52$), rather than only once in the year. Experiments were done using different k , however, the results presented in the next chapter are based on $k=1$.

Imagine that a purchase sequence is decided: who buys first, who second, and so on, which means that the first country will satisfy its imports requirements at the lowest cost (leaving the countries buying subsequently with fewer possibilities, so they may have to buy at higher prices elsewhere), then the second one, and so on. Evidently, the first country to buy starts in a position of advantage. In this purchase sequential order, we are introducing non-equal opportunities for every country and parallelism is not considered at all. So, a way to overcome the difficulty is by using an artifice to simulate parallelism: the model computes all the purchase sequential orders and selects from them the one that satisfies the following two conditions:

- The maximum import requirements and/or the maximum export capacities are traded. It will depend on which one is the smallest. So doing, each country will be better off because it is actually reaching its international trade objectives (expressed in the model by its export capacities and import requirements). This may be thought as a measure of effectiveness of markets in the sense that all the desired transactions are satisfied if possible.
- It may be possible to find many purchase sequential orders for which the previous condition holds. We know interchanges take place in reality only in a way but not in a sequential order. So, the question is which one of those previously found alternatives could serve as a proxy of the parallel interchanges? We propose to choose the purchase sequential order that reduces the total costs of world trade. Countries *agree*

to spend collectively as little money as possible on trade. In other words, we are choosing the more efficient sequential order.

The algorithm requires that all the permutations of purchase sequential orders be performed. We recognise an inherent inefficiency from a computational point of view: no application may calculate all the possible orders, when the number of countries² exceeds 10 (with the computational resources currently utilised). However we defend the proposition of this algorithm as a basic bottom-up mechanism when dealing with a reduced number of countries. Of course, we are not claiming that it is the best, but only one possibility that produces interchanges. There is, however (without going into the details of its implementation), an alternative to bypass the computational problem. The two conditions described above constitute the basis for solving an optimisation problem: to minimise the amount of money globally expended on trade subject to the maximum import requirements and/or the maximum export capacities traded. It is possible to use genetic algorithms to find the purchase sequential order, although it may not be the best. In any case, we now prefer to concentrate our attention on the whole process rather than on how to implement better and/or viable computational solutions when the number of countries rises.

Once a purchase sequential order is selected, the model is able to compute the STRADE and TRADE matrices. STRADE saves at each period the network of shipments in physical units by sectors, which results from the application of the purchase sequential order selected. Then, the calculation of the TRADE matrix is straightforward by adding-up, in monetary units, the purchases a country has made from another in all sectors.

7.4.2 International prices

International prices by sector are computed in the model as the weighted average of all country prices in the sector. The weight is the respective amount of exports in each country, as it can be seen in the following statement:

² The number of permutations to be performed are $CN!$ (factorial of CN).

```

FOR all S DO {
  IntPri[S] := ( $\sum_c \text{Pri}[C,S] * \text{EX}[C,S]$ ) / ( $\sum_c \text{EX}[C,S]$ );
}

```

The international prices are used, in the model, by any country to decide whether or not to increase or reduce import requirements and export capacities. In other words, they serve in this model as a general reference for countries in order to make decisions, as it will be shown in section 7.4.4.

International prices are calculated this way because we think that bigger export countries are more likely to exert influence on the amounts of commodities that are exchanged in the international markets than smaller ones. If a country decides to boost its imports, it is probably going to buy from those countries whose export capacities are bigger. However, the prices that must be paid will be set by the latter.

7.4.3 Export capacities and imports requirements

At the beginning of the simulation (TIME=0), the amounts of world export capacities and world import requirements for each sector are the same. So, after applying the patterns of commerce algorithm, all countries have exported their capacities and imported their requirements. However, this balance is not obligatory.

Export capacities and import requirements by sector and by country vary (or even grow) from period to period by some percentage points. This may be observed in the data reported in the international trade statistics of the World Trade Organisation (WTO) in the last 10 years, for example, this may be seen in the leading exporters and importers of manufactures in 1999 [WTO 2000] where the annual change percentage in exports for the United States varied between 1 and 14 percentage points; for France between -8 and 7 percentage points; and for Italy from -6 to 4. On the other hand, the annual change percentage in imports for the United States varied between 8 and 11 percentage points, for France between -3 and 12 percentage points, and for Italy from 0 to 9. The information is also reported for the other aggregated sectors considered in the model, such as agricultural products, mining products and commercial services.

We propose to use those mark-ups to simulate the percentage change of imports requirements and export capacities by defining them as uniformly-distributed, random variables that swing between those limits. In other words, the minimum value and the maximum value of percentage change are specified as exogenous mark-ups. Their objective is fundamentally to allow a range of variations while keeping out unrealistic exaggerations. They could also be used as part of the experiments made with the model. The important thing to remember here is that they generate a path of growth in each sector for each country.

Nevertheless, this is a first approximation for modelling the changes in export capacities and import requirements in a particular country. Though the causes of change are not considered, which is something we should explore in order to make them evolve endogenously to the model, this first approximation does not affect the algorithmic approach of linkages we are dealing with.

As a result of the previous considerations, in subsequent periods the clearing of all sectors markets is no longer guaranteed. As a matter of fact, each rate of growth in a country's export capacities and import requirements behaves randomly between some limits in the model. This might generate very dissimilar international supply and demand patterns, which would be unrealistic. Therefore, countries must take into account what is happening in each sector of the international markets when acting on their export capacities and import requirements. The export growth depends not only on the willingness and capacity of a country to sell on international markets, but also on the willingness or requirements from other countries to buy its commodities. So, each country must adjust those limits in order to be aware of what is going on across the borders. When all countries behave this way, the result is a very interesting path of mutual reinforcement that collectively controls the outcome.

Thus, the adjustments in each country's export capacities and import requirements are doing by taking into consideration the excess of export and imports at each period. This is integrated into the model as follows: the STRADE matrix shows how much is actually traded by sector between countries. So, what the model does is to subtract those

quantities from the export capacity matrix EX and from the import requirement matrix IM in order to obtain excess of exports and imports by sector and country.

In general algorithmic terms:

```

FOR all S DO {
  FOR all C DO {
    e_EX[C,S] := EX[C,S] -  $\sum_R$  (STRADE[S,C,R]);
    e_IM[C,S] := IM[C,S] -  $\sum_R$  (STRADE[S,R,C]);
  }
}

```

The excess of exports and imports' matrices are used in the model to introduce a feedback to correct the variation of import requirements and export capacities in a controlled way, as is shown in the next subsection.

7.4.4 Evolution of export capacities and import requirements

As part of the change in export capacities (EX) and import requirements (IM), we introduce an element called here market signal. Each country may modify the percentage of change in its export capacities or import requirements for the next period in an exogenous pre-set amount (in other words, not randomly).

What a country does depends not only on its performance but also on that of others. We first compute for each country and for all its sectors the excess of exports (e_EX) and the excess of imports (e_IM) it could have in the current period. In general algorithmic terms:

```

Compute excess of exports (e_EX);
Compute excess of imports (e_IM);
FOR each country C DO {
  FOR each sector S DO {
    IF e_EX [C,S] > 0 THEN {
      decrease C's EX in sector S next period;
      FOR each country R ≠ C DO {
        If P[C,S] < P[R,S] THEN
          increase R's IM in sector S next period;
      }
    }
  }
}

```

```

    }
    IF  $e_{IM}[C,S] > 0$  THEN {
        decrease C's IM in sector S next period;
        FOR each country  $R \neq C$  DO {
            If  $P[R,S] < IntPri[S]$  THEN
                increase R's EX in sector S next period;
        }
    }
}

```

This simple algorithm introduces a feedback mechanism through which the amounts of world export capacity and world import requirement in each sector co-evolve. Notice, however, that they are not necessarily in equilibrium. Also, as a direct consequence, the feedback influences the path of each country's imports and exports. We call this an evolutionary and adaptive procedure for both world import requirements and world export capacities. It is evolutionary in the sense that changes are made gradually, and adaptive in the sense those countries show their ability to change to suit different conditions in the international trade system.

The procedure takes into consideration what is going on outside a single country and allows it to decide how to act by exploiting its absolute advantages when confronting all other countries and making correctives if necessary.

A country that tries to export too much will try to reduce its exports in the next period. It also gives some signals to other countries, which might increase their imports (from this country) provided it offers them a better price than they already have at home. On the other hand, a country that tries to import more than the international market actually offers, will reduce its imports in the next period. It also gives some signals to other countries that would like to increase their exports to that country. We assume that only those countries that have a price below the international price may succeed in selling their products subsequently. Therefore only them will increase their export capacities.

We are not dealing here with equilibrium in its strict sense. Whatever the desired amounts of exports a country offers, it must necessarily take into consideration how much import other countries demand. Otherwise, the export country will increase its production

without any hope of selling it. Of course, the export country could keep the excesses as inventories to be sold in future, but we do not want to deal with this here yet.

At the same time, if a country increases strongly its import requirements, it might awaken the production process in other countries. So, rather than thinking about capacities and requirements that are in equilibrium, we prefer to think of them as adapting and evolving one with each other, like dancers moving the step, performing synchronised movements.

7.4.5 The best trade matrix

As stated above, one of the main objectives of this model is to explore possible structural changes induced by bloc formation. The TRADE matrix is a good variable for dealing with this objective. It is difficult to represent abstract concepts as trading blocs, though they actually exist as treaties, general agreements, etc. Two or more countries may enter into negotiations leading them to general agreements that would yield important benefits for the parts (at least this is the expectation). After a deal has been reached, it is assumed that a trading bloc has been formed.

The basic idea is that the more countries exchange goods and services between them, the more economic interdependence they face, so augmenting the willingness to enter new negotiations that will potentially increase their mutual benefits. Therefore, we propose to observe possible clustering formation in the TRADE matrix, trying to put together (or closer) those countries whose mutual interchanges are broader, and far apart those whose interchanges are smaller. In this way, we observe bloc formation through clustering formation.

In general, a cluster is defined as a set of usually similar objects. The similarity is specified in terms of judgements that must be identified in the data characterising a clustering problem [Hartigan 1975]. In this model, the objects are countries. The volume of trade is considered here as a measure of similarity judgement. An example of similarity judgements in bloc formation could be of the form: country A trade more with country B than it does with country C, so A and B are more likely to be part of a bloc

formation. In other words, we use the flows expressed in the trade matrix as a measure of bloc formation.

Dealing with clustering formation in matrices may be done by means of rearranging rows and columns of the trade matrix (see subsection 6.3.1) for some alternative definitions of the trade matrix. By doing this, an equivalent matrix in which the greater elements are clustered in sub-matrices along the diagonal may be obtained. These clusters correspond to possible blocs when some measure of concentration is exceeded. So, the problem is to find a permutation of the trade matrix that produces the equivalent matrix we are looking for. One way of dealing with is to use the Quadratic Assignment Problem (QAP) introduced in the previous chapter.

A numerical example illustrates what the algorithm does in terms of the TRADE matrix. If we have the following trade matrix (AA, BB, etc means different countries and the number are amount of trade between them):

	AA	BB	CC	DD	EE	FF
AA	0	0	0	12	0	120
BB	0	0	30	0	50	0
CC	0	22	0	0	100	0
DD	50	0	0	0	0	100
EE	0	10	67	0	0	0
FF	140	0	0	80	0	0

Table 7-1 A TRADE matrix before clustering

the algorithm arranges it and produces the following matrix:

	BB	EE	CC	DD	FF	AA
BB	0	50	30	0	0	0
EE	10	0	67	0	0	0
CC	22	100	0	0	0	0
DD	0	0	0	0	100	50
FF	0	0	0	80	0	140
AA	0	0	0	12	120	0

Table 7-2 A TRADE matrix after clustering

which is the same matrix as before, but now it shows BB, EE, and CC countries forming a cluster and DD, FF and AA countries forming another cluster. Observe that the algorithm concentrates large values on the main diagonal and small values outside it (this

is so because, that way, equation (1) of Chapter 6, becomes minimum) and therefore, putting together those countries that trade more.

Depending on the particular tariff cutting programmes and, more generally on the dynamics of the model, we can observe how the configuration of this matrix evolves. Countries that initially were placed next to each other, may end up apart after a while.

7.4.6 Terms of trade

Once the TRADE matrix is computed, the calculation of the terms of trade for all countries is quite straightforward, following the general procedure:

```
FOR each country C DO {
  Terms[C] := total imports[C] / total exports[C];
}
```

where Terms[C] is a vector for registering the terms of trade of each country C. Furthermore, total imports and total exports are computed using the TRADE matrix. They are calculated in each period. The program allows visualising their dynamics through time. It is also possible to apply a feedback mechanism to make the terms of trade near to 1. In other words, the model allows changing export capacities and import requirements as an alternative to improve the terms of trade.

7.4.7 Tariffs

Exogenously to the model, it is decided to set up a treaty (a PTA, preferential trade agreement, for instance, see Chapter 4) among a group of countries. By doing this, treaty country members agree, for example, to reduce tariffs between each other in some percentage and keep unvaried the tariffs for extra-treaty countries, during an interval of time. The same might occur with other groups of countries which agree maybe in a more or less fashionable way, but with a quite different scheme of cutting tariffs and time of application. As it will be discussed in Chapter 8, the model offers a tool for experimenting and for answering the ‘what-happens-if’ type of questions.

7.4.8 Transport costs

In the model, costs of transportation decrease according to a fixed rate during the time of simulation. This is to represent changing in costs as those caused by technological progress, which normally reduced steadily over time. This has been extensively documented by Frankel [1997]. Only one type of means of transportation is considered. However, this could be modelled differently, adding more types of transportation with different rates of costs change for each one.

7.4.9 Prices

Prices also change exogenously to the model. We use a UNIFORM distribution and specify for each sector the interval of maximum and minimum percentage of change allowed. However, their change may be simulated locally in each country by means of Leontief's I-O system [Leontief 1953] or Pasinetti's multi-sector dynamic model [Pasinetti 1981]. This means making prices depend on wages and profits.

7.5 Conclusions

The model presented in this chapter describes an artificial society formed by a number of countries (CN). The economy of each country is divided into the same aggregated number of sectors (SN). The simulation model consists of a sequence of steps that are computed repeatedly from period to period. These steps could be summarised by:

First, at the beginning of the simulation run, it is known by each country its exports capacities and imports requirements, but they do not know to whom will buy from and whom will sell to.

Second, a network of shipments or patterns of trade is created by using an algorithm to determine bilateral trade flows by sectors. Each country decides to buy from another country that offers it the best price. In this way, decision making is introduced in the model, and it could vary among countries.

Third, once the trade matrix is calculated, it is rearranged in order to find or observe clustering or bloc formation between countries. An algorithm to deal with

clustering in matrices has been proposed (Quadratic Assignment Problem, which was discussed in details in Chapter 6). The algorithm search the ‘best trade matrix’, which is the arrangement of the trade matrix that puts together (or closer) those countries whose mutual interchanges are broader, and far apart those whose interchanges are smaller. In this way, we observe bloc formation through clustering formation.

Forth, each country computes how much exports were in excess and/or how much imports were in excess (if any) in each sector. Export capacities and import requirements vary randomly (because its rate of growth has been defined as a random variable that varies between a pre-established band). Nevertheless, each sector in a country may decide to increase or reduce subsequently, by a deterministic value, the next period offer or export capacities and demand or import requirements, depending on the excess resulted previously. But, in this artificial society, all countries know everyone else's performances. A country that tries to export too much will try to reduce its exports in the next period. It also gives a signal to other countries, which might increase their imports (from this country) provided it offers them a better price than they already have at home. On the other hand, a country, that tries to import more than the international market actually offers it, will reduce its imports in the next period. It also gives a signal to other countries that would like to increase their exports to that country. We assume that only those countries that have a price below the international price may succeed in selling their products subsequently. Therefore, only they increase their export capacities. It is important to highlight that this introduces a feedback mechanism through which the amounts of world export capacity and world import requirement in each sector co-evolve (this will be showed graphically in the next chapter).

Fifth, all the other variables of the model are changed: tariff, transport costs and prices, following some simulation techniques to deal with their dynamics.

Finally, terms of trade for all countries are calculated and some selected variables are reported. The process described is repeated a specified number of times.

The model is a tool for doing experiments basically oriented to gain insights in the processes conduced by decision making. Also, it offers the opportunity to observe the dynamics of the international trade system represented by aggregated sectors of a group

of countries inside an artificial society. It is very stylised. Nevertheless, it offers a base tool to do computational experimentation. Many features could be relatively easy added in order to improve ‘similarity’ with the structure of its target system: the international trade system.

The sort of experimentation that may be done using this model, will be discussed in the next chapter. For example, exogenously, through a political process, a group of countries may decide to reduce tariffs among them, only in one sector, or maybe in all, keeping them unvaried with third countries. The idea is then to observe the effect of these political agreements on patterns of trade. It is interesting also to explore how these agreements may influence the patterns of specialisation of each country, and compare them between countries.

Because the model represents an artificial society, the validation of the model is given by the behavioural coherence that it produces when some parameters are changed. Our next step in Chapter 8 is to formulate and carry out some experiments and give an explicit interpretation on the light of all that we have discussed so far.

Chapter 8

Results

8.1 Introduction

In this chapter we present some selected simulation results obtained with the model proposed in chapter 7. First, we discuss in detail the results obtained through what we call the basic simulation run. This allows setting the dynamics of the system with the chosen parameter and variable values. Second, we describe five experiments, simulations with carefully chosen experimental frames, which simulate shocks in the system. Experiment 1: A disaster in the agricultural sector of country AA. Experiment 2: A boom in the mining sector of country DD. Experiment 3: Introduction of new technology in country CC (with price reduction in the manufacture sector). Experiment 4: A change in the bloc formation: country EE enters the bloc formed by countries AA, BB, DD. Finally, we discuss in experiment 5 agreements to form three blocs: countries AA & EE, countries CC & DD, and countries BB & FF.

It is important to emphasise that the results are not exhaustive. Simulation models give users a chance to formulate their hypotheses, to set the parameters accordingly, to run the simulations, and finally to analyse the dynamics obtained.

8.2 Initial conditions

Let us assume that our artificial society consists of six countries and five sectors. The six countries are identified by the two letter codes¹: AA, BB, CC, DD, EE, FF. AA

¹ Examples of the two-letter codes for real countries are: US for United States, CH for Switzerland, IT for Italy, etc.

and EE are big countries; CC and DD are medium-sized countries; BB and FF are small countries. Each country is represented by five sectors: AGR (agriculture), MNI (mining), MAN (manufactures) and SER (services), and CON (construction). In other words, the five sectors represent the economy of each country. We assume that there is no international trade in the CON sector. This sector is introduced to help define the interdependence in each country by the I-O representation (which is proposed as part of future research).

Tariffs are *ad valorem*: 100% of prices in all sectors, and all countries.

Transport costs are arbitrarily chosen in order to reflect a world with a spatial distribution of countries as shown in Figure 1. There is only one mean of transport (ships) and all countries have access to it. So, it is distance and not technology that distinguishes the transport cost chosen at the beginning of the simulation.

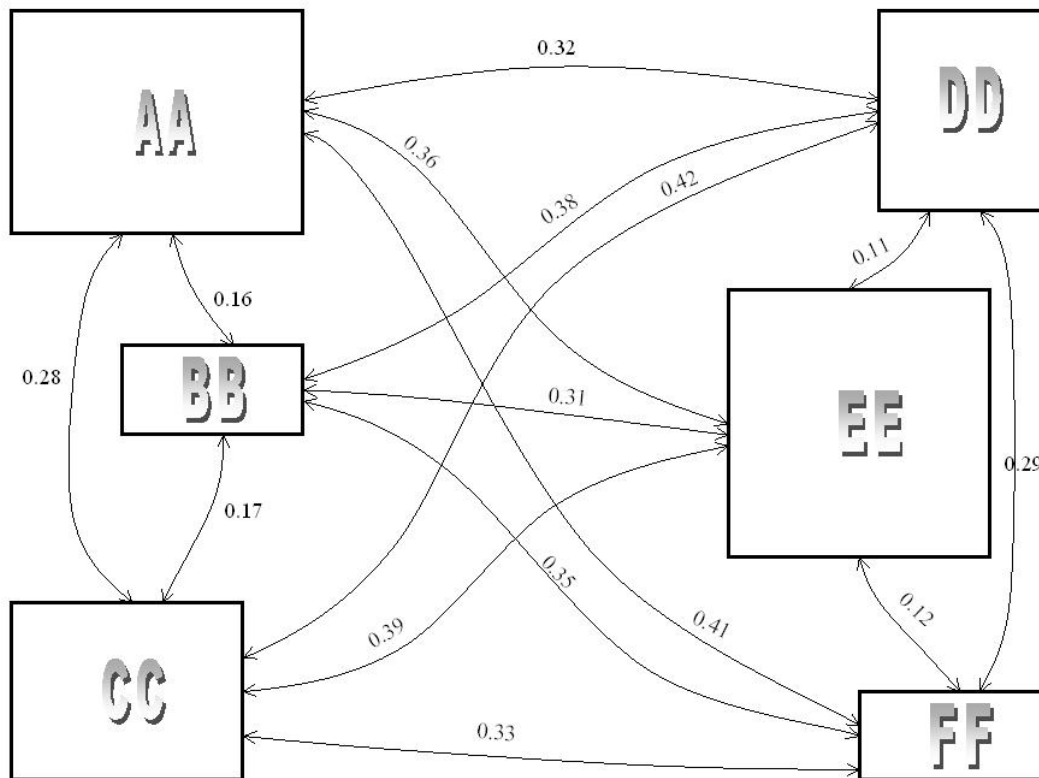


Figure 8-1 Transport costs

In matrix form, the cost of transportation may be represented as shown in Table 8-1:

Tr	AA	BB	CC	DD	EE	FF
AA	0	0.16	0.28	0.32	0.36	0.41
BB	0.16	0	0.17	0.38	0.31	0.35
CC	0.28	0.17	0	0.42	0.39	0.33
DD	0.32	0.38	0.42	0	0.11	0.29
EE	0.36	0.31	0.39	0.11	0	0.12
FF	0.41	0.35	0.33	0.29	0.12	0

Table 8-1 Transport costs (Tr) in \$\$ per unit of product

Table 8-2 shows the initial prices by country and sector. These prices are changed during the simulations as indicated in subsection 7.4.9.

	AGR	MNI	CON	MAN	SER
AA	1.5	2.0	3.0	4.0	3.3
BB	2.1	3.3	2.0	6.0	2.2
CC	1.7	2.5	2.2	5.5	2.0
DD	1.6	2.0	2.1	4.0	3.8
EE	2.0	1.8	2.7	2.1	3.0
FF	1.9	1.5	1.7	3.5	2.1

Table 8-2 Prices (P) in \$\$

Table 8-3 shows the interval of minimum and maximum percentage of change of prices to be used as indicated in subsection 7.4.9.

AA		BB		CC		DD		EE		FF	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
-2%	2%	-1%	4%	-4%	3%	-2%	1%	-2%	5%	0%	5%

Table 8-3 Interval of minimum and maximum percentage of change of prices

Table 8-4 shows the initial exports in physical units by country and sector.

	AGR	MNI	CON	MAN	SER
AA	250	100	0	883	495
BB	25	72	0	220	14
CC	65	77	0	378	128
DD	35	83	0	283	49
EE	110	66	0	1230	297
FF	15	155	0	157	5

Table 8-4 Exports (EX) in physical units

Table 8-5 shows the initial imports in physical units by country and sector.

	AGR	MNI	CON	MAN	SER
AA	100	239	0	1103	396
BB	20	16	0	283	10
CC	130	100	0	315	118
DD	115	27	0	473	79
EE	125	166	0	757	376
FF	10	5	0	220	9

Table 8-5 Imports (IM) in physical units

Table 8-6 and Table 8-7 show the interval of minimum and maximum percentage of change of import requirements and export capacities respectively, to be used as indicated in subsection 7.4.3.

	AGR		MNI		CON		MAN		SER	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
AA	3%	13%	5%	12%	0%	0%	4%	8%	8%	16%
BB	-1%	9%	-1%	13%	0%	0%	0%	25%	-1%	17%
CC	-2%	4%	4%	8%	0%	0%	2%	9%	-10%	7%
DD	-3%	5%	-1%	10%	0%	0%	4%	17%	3%	9%
EE	-1%	16%	4%	15%	0%	0%	-4%	9%	3%	10%
FF	-2%	8%	-2%	10%	0%	0%	-21%	8%	9%	46%

Table 8-6 Interval of minimum and maximum percentage of change of import requirements

	AGR		MNI		CON		MAN		SER	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
AA	-2%	12%	-1%	6%	0%	0%	1%	9%	6%	20%
BB	-1%	18%	1%	11%	0%	0%	12%	19%	-20%	30%
CC	-4%	1%	3%	12%	0%	0%	-1%	13%	-9%	4%
DD	-1%	8%	1%	15%	0%	0%	2%	9%	4%	12%
EE	-2%	15%	-2%	4%	0%	0%	-1%	10%	0%	11%
FF	-3%	20%	-1%	20%	0%	0%	-11%	11%	-6%	12%

Table 8-7 Interval of minimum and maximum percentage of change of export capacities

At the beginning of the simulation run, a political agreement signed by some countries is specified. For example, three of them, AA BB & DD, decide, as part of the agreement, to cut tariffs on imports by 10% each period, while countries EE CC & FF decide, also by agreement, to cut tariffs on imports by 4%. Countries outside each agreement are levied a 100% *ad valorem* tariff on imports. In the first experiment, called

the basic simulation run, we keep these initial conditions through the simulation run and all the results are referred to it.

8.3 Figures

The model allows us to observe graphically the dynamics of different variables during a simulation run. At the beginning of the simulation run, we may specify which figure to look at by selecting from the following list:

- 1: Sector AGR, Imports & Exports by country
- 2: Sector MNI, Imports & Exports by country
- 3: Sector MAN, Imports & Exports by country
- 4: Sector SER, Imports & Exports by country
- 5: World export capacities and import requirements by sectors
- 6: World exports and imports by sectors
- 7: Terms of trade
- 8: Country AA Imports & Exports by sector and terms of trade
- 9: Country BB Imports & Exports by sector and terms of trade
- 10: Country CC Imports & Exports by sector and terms of trade
- 11: Country DD Imports & Exports by sector and terms of trade
- 12: Country EE Imports & Exports by sector and terms of trade
- 13: Country FF Imports & Exports by sector and terms of trade
- 14: Total Trade by Country (\$)
- 15: International Prices
- 16: Prices by country
- 17: Prices by sector
- 18: Trading blocs (absolute values)

19: Trading blocs (relative values)

Moreover, all those figures may be visualised after a simulation run using the same GLIDER simulation software [Domingo et al. 1993]. The model also generates the time series of the variables, saving them in a text file that may be used with more sophisticated graphic software, for example Excel².

8.4 Results obtained through the basic simulation run

Among the results obtained, the following are presented:

- Imports & exports by country of sector AGR.
- World export capacities and import requirements by sectors and its evolution over time.
- Trading blocs: matrix and graphic representation.

8.4.1 Imports & exports by country of sector AGR

Figure 8-2 shows the results of a basic run for 25 periods in the agricultural sector. The first six subfigures show the dynamics of imports and exports (in physical units, in the x axis named Q in the figures) in each country (AA, BB, CC, DD, EE, and FF). The last two subfigures show: (1) the World Export Capacities and Import Requirements (identified by a differentiated legend from the others); (2) the World Exports and Imports (bottom centre, only one because those quantities are equal at world level).

Figure 8-2 shows:

- a) The feedback mechanism discussed in 7.4.4 regulates the quantities offered and demanded internationally in the sector. The effect of this feedback mechanism is that world agricultural export capacities growing in relation to world agricultural imports requirements (as may be observed graphically in Figure 8-2, on the bottom left corner). In other words, they evolve and adapt to each other.

² Some Excel's worksheets have been developed to visualize the results.

- b) Even though this is happening at a global level, each country's imports and exports behave in remarkably different ways.

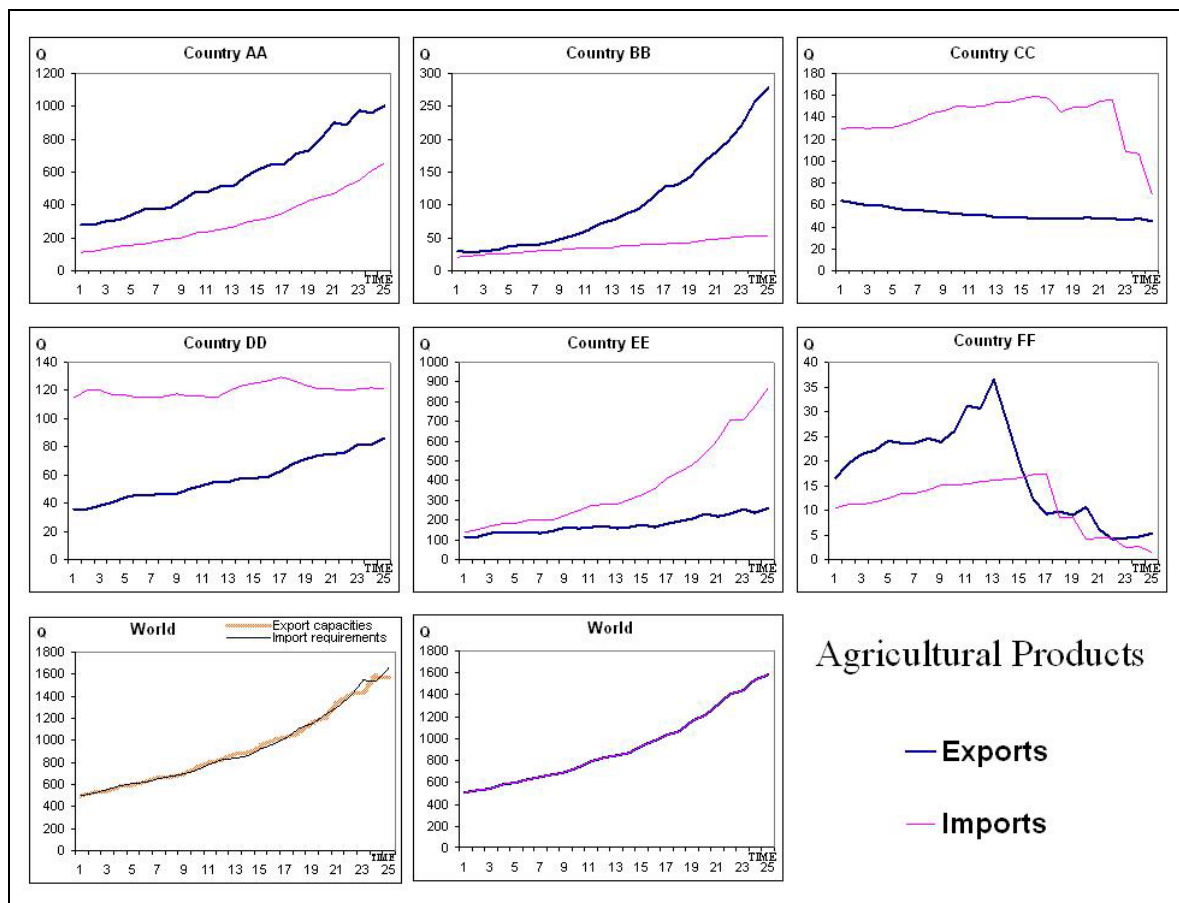


Figure 8-2 Agricultural products: Exports and Imports

- c) Linkages in the agricultural sector, at a global level, have made three countries net exporters and three countries net importers (country FF shows a particular pattern switching more than once from net exporter to net importer).
- d) The outcome of the process is self-organised and collectively path dependent. It is 'self-organised' in the sense that it is not possible to tell in advance what those patterns should be. It is collectively 'path dependent' in the sense that it results in part from the evolution of each country's own trend but also in part from the interactions between countries. A country's willingness to augment agricultural exports is, among other things, intrinsically connected with the willingness of others to import and vice versa.

8.4.2 World export capacities and import requirements by sectors and its evolution over time

We have been discussing the evolution of world export capacities and import requirements in the agricultural sector. Results for other sectors are given in Appendix D. These findings are similar to those shown in the agricultural sector, in the sense that imports and exports behave differently in each country, but at world level export capacities and import requirements grow in relation to each other. Figure 8-3 shows the world export capacities and import requirements by sectors in the basic, referential, simulation run.

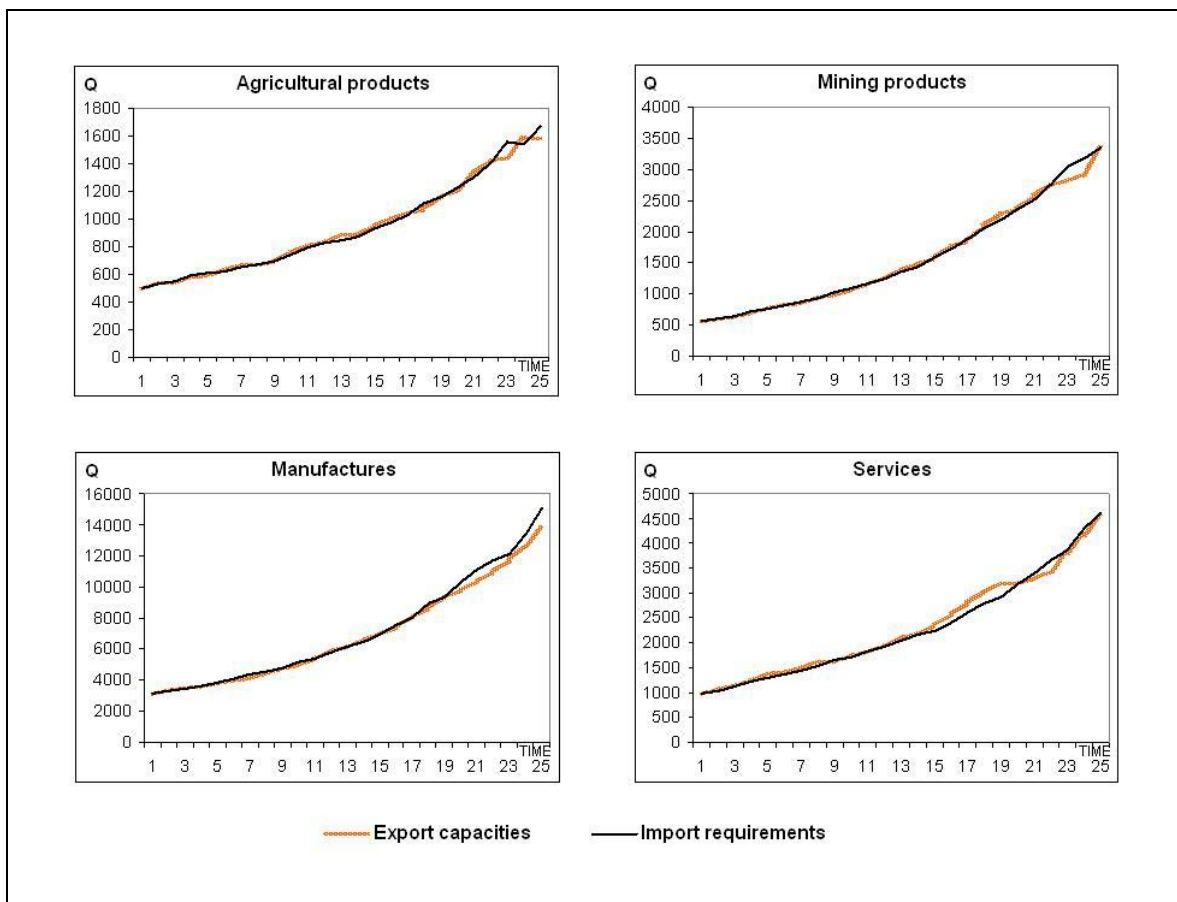


Figure 8-3 World export capacities and import requirements by sectors

The feedback mechanism, introduced to make world export capacities and world import requirements co-evolve in each sector, works quite well, as may be seen in the figures above. It is triggered by each country's own interest and by collective

performance. Collective performance exerts and conditions each country's decisions (for example, a country may not export more than the amount internationally demanded). However, each country's decisions may also induce changes in the collective behaviour (the willingness to sell to a country sends a signal to those countries for which it is more convenient to buy from, therefore augmenting their future import requirements).

8.4.3 Trading blocs: matrix and graphic representation

As was previously shown, the model registers the TRADE matrix for each period. Moreover, the TRADE matrix is automatically arranged in such a way that countries are located closer to each other the more they trade, and far away otherwise. This is the way bloc formation is captured in the model. However, the visualisation of the dynamics of such configuration is not simple (the model writes in a text file all the matrices, so that they may be seen after the simulation run). In order to capture bloc formation, we observe how the arranged TRADE matrix changes during the simulation run. For example:

At TIME=1 the trade matrix for the basic simulation run is:

	BB	CC	AA	EE	DD	FF
BB	0	505	2888	0	0	0
CC	0	0	5639	0	0	0
AA	2566	4113	0	5493	289	38
EE	0	0	4462	0	2914	1048
DD	0	0	333	2883	0	0
FF	0	0	71	1633	22	0

Table 8-8 Trade Matrix (TIME = 1)

This is an indication that countries BB, CC and AA trade with each other and thus could be seen as a trading bloc; and also that countries AA, EE, DD and FF, which also trade with each other and also may form another trading bloc. At the end of the simulation run the TRADE matrix is:

	BB	DD	AA	EE	CC	FF
BB	0	40677	159482	12658	3115	13
DD	45702	0	55923	6264	0	0
AA	172343	136304	0	235197	34964	27981
EE	4529	173223	281664	0	67992	8619
CC	204	900	49748	154641	0	6141
FF	75	7939	37933	65559	4834	0

Table 8-9 Trade Matrix (TIME = 25)

At the beginning of the simulation run, one notices that country DD was a major partner of countries EE and FF, while at the end, this country was better placed between countries BB and AA. Something similar happened to country CC, which originally was a major partner of BB and AA and ended up being better placed between countries EE and FF. The reason why this occurred was that countries BB, DD and AA had decided to reduce import tariffs between them. So, too, did countries EE, CC and FF.

The first arrangement BB CC AA EE DD FF changes to BB DD AA EE CC FF during the simulation run. The complete pattern of arrangements may be observed through time. This is given in Table 8-10 (from TIME=9 to TIME=25 the arrangement does not change, as indicated by dots in Table 8-10).

1	BB	CC	AA	EE	DD	FF
2	BB	CC	AA	EE	DD	FF
3	BB	CC	AA	EE	DD	FF
4	BB	CC	AA	EE	DD	FF
5	BB	CC	AA	EE	DD	FF
6	BB	DD	AA	EE	CC	FF
7	BB	DD	AA	EE	CC	FF
:	:	:	:	:	:	:
:	:	:	:	:	:	:
:	:	:	:	:	:	:
25	BB	DD	AA	EE	CC	FF

Table 8-10 Countries arrangements through time

The model transforms this text representation into a graphic representation (see Figure 8-4). Each country is plotted by a little cube (with a line that connects them horizontally) and it is positioned, at any given time, next to its major trade partners. The movements of those cubes give an idea of the structural change induced by bloc formation. In other words, major commercial partners might change because of changes

in the tax-cut as a result of political agreements (see how in period seven original arrangement BB CC AA EE DD FF changes to BB DD AA EE CC FF; this new arrangement remains so until the end of the simulation run).

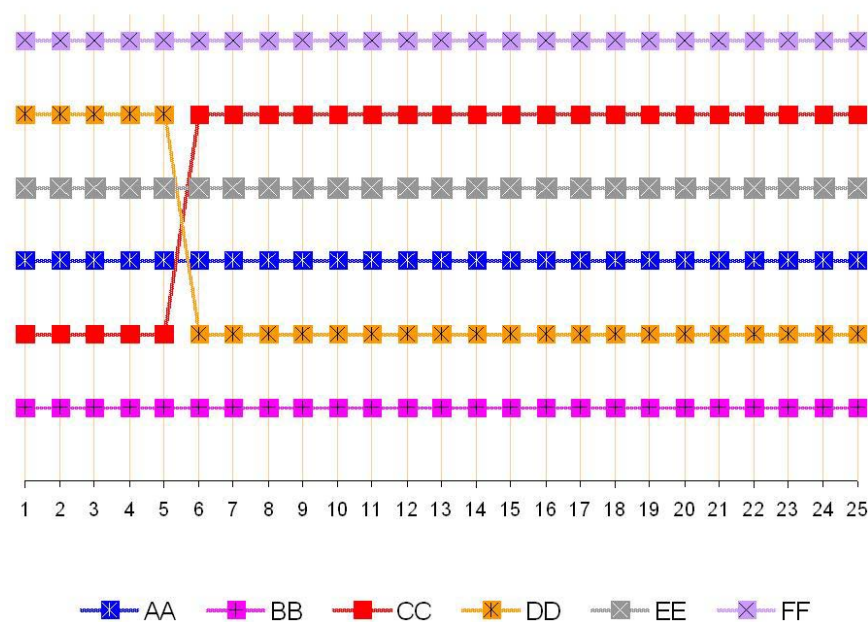


Figure 8-4 Country clusters

Countries AA and EE maintain their partnership through the simulation run. The main reason is that their export capacities and import requirements are high, and therefore they complement each other. It is noticeable how DD is placed between EE and FF at the beginning of the simulation and after some periods (seven in this case), it is best placed between BB and AA, and stays there till the end of the simulation run.

Figure 8-4 gives a general idea of trading bloc formation by showing how partnership between countries has been preserved or changed through the simulation run.

8.5 Results obtained through other experiments

8.5.1 Experiment 1: A disaster in the agricultural sector of country AA

Description

Let us suppose that after a time period ($\text{TIME} > 10$) country AA drops dramatically its exports in sector AGR because of a disaster in its agricultural sector. We want to observe what happens with the dynamics in this sector through the simulation run. In particular, we will focus on the trajectories of import and exports.

Results

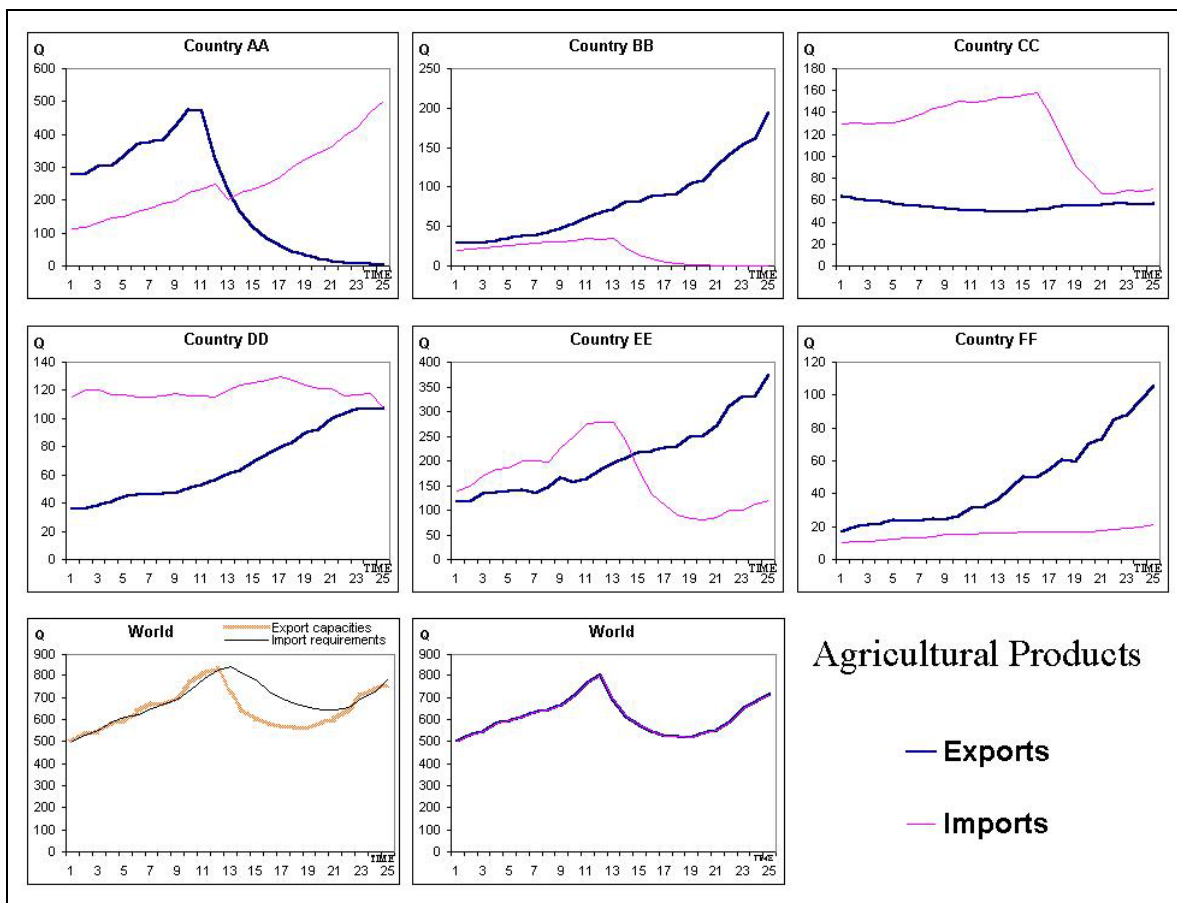


Figure 8-5 Experiment 1. Agricultural sector: export and imports

Figure 8-5 shows the dynamics obtained in the simulation. Observe the exports of country AA declining after $\text{TIME}=10$, which we set up as a working assumption. AA is a big country. This implies that if it drops its exports, it will cause a contraction in the

whole agricultural sector. It is particularly interesting to observe that even countries that are not part of the bloc of which AA is a member suffer quite extensively from the consequences. This is the case of country EE, for which the consequences are similar to AA's, as in fact both countries require the largest volume of imports of the sector. Country BB has also diminished its imports. This sort of dynamics is appropriate for studying the interdependence between economies whose entire systems co-evolve. However, country FF exploits these circumstances to boost its exports, which transforms FF in a net exporter country (FF could not increase its exports in the basic simulation run). Finally, world export capacities and import requirements show more clearly the effects that this dramatic decrease in a big country's exports may have in the whole international trade system. The bloc formation in this case has remained the same. Thus, we observe a particular sector's dynamics that does not affect the major partners observed in the basic simulation run.

8.5.2 Experiment 2: A boom in the mining sector of country DD

Description

Experiment 2 tests the model as to the dynamics observed when country DD has a boom in its mining sector. We assumed that this happened after TIME=10. The rate of growth in country DD's exports is maintained positive after that point.

Results

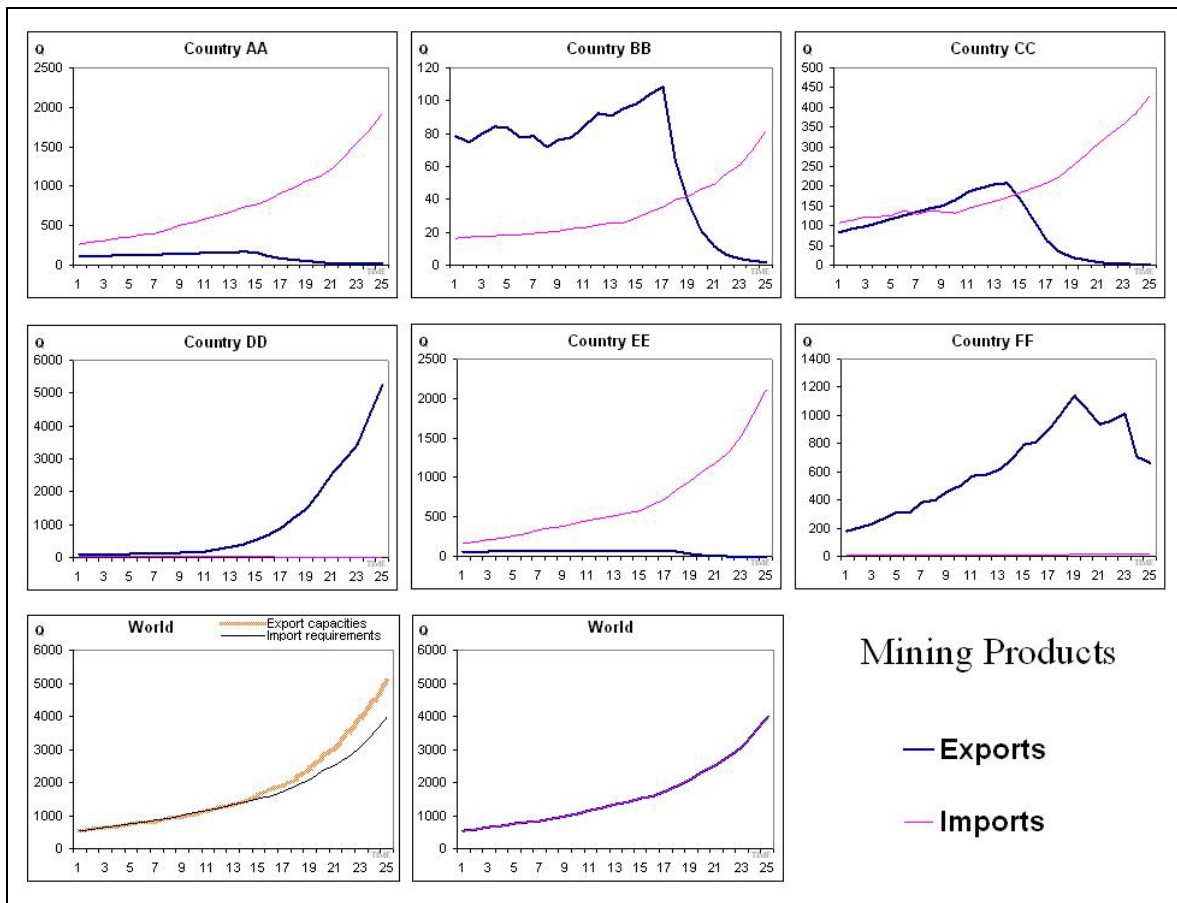


Figure 8-6 Experiment 2. Mining sector: exports and imports

The continuous and sustained growth of country DD's exports produces a very interesting dynamics in this sector. Observe that country BB continues to supply its exports to the international market as it happened in the basic simulation run. But at some point (TIME=17) its exports fell dramatically because its price was too high and the other countries decided to buy from other countries. After this point, country DD has better total price to offer to other countries, making its exports more attractive and actually selling more, because it has many more units of mining products to offer. Something similar happens with country CC. However, DD's overproduction together with its low price gives no chance to these countries to sell their products. What is interesting to observe is the natural delay that the system reaches before the change is produced. As in experiment 1, the main blocs remain unchanged.

8.5.3 Experiment 3: Introduction of new technology in country CC (with reduction of price in the manufacture sector)

Description

Imagine now that country CC is in a position to offer products manufactured by means of a new technology (or technological diffusion, see Pasinetti [1993]). This implies, for our discussion, that country CC is able to offer its manufactured products at a better price. We assume that country CC is in fact able to reduce its manufacture price as is shown in Figure 8-7. How does this change in country CC's competitiveness affect the dynamics of our simulated trading system?

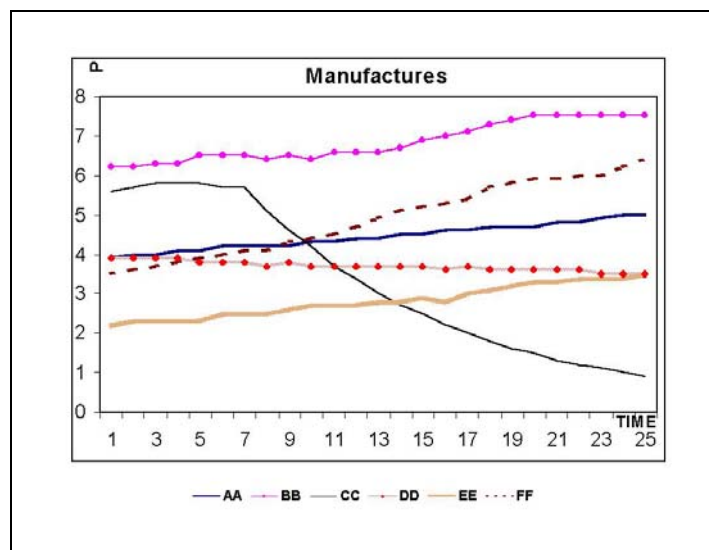


Figure 8-7 Experiment 3. Prices in the manufacturing sector

Results

Figure 8-8 shows the dynamic obtained through this experiment. Country CC was already a major partner of all countries in the basic simulation run because it offered a large quantity of manufactured goods on the international market, so countries must buy from it in order to satisfy their imports requirements (we have deliberately not considered budget restrictions for countries). But country AA also had a higher price in manufactures. Improving its competitiveness makes this country an attractive option to buy from, which allows them to fulfil all its imports requirements at a better price. Countries DD and FF lose relative competitiveness with respect to country CC and this is

reflected in the sharp decrease of its exports. In this case, exports capacities and import requirements were evolving concomitantly as expected from the feedback mechanism that allows countries to decide how to change its requirements and capacities of the trade system.

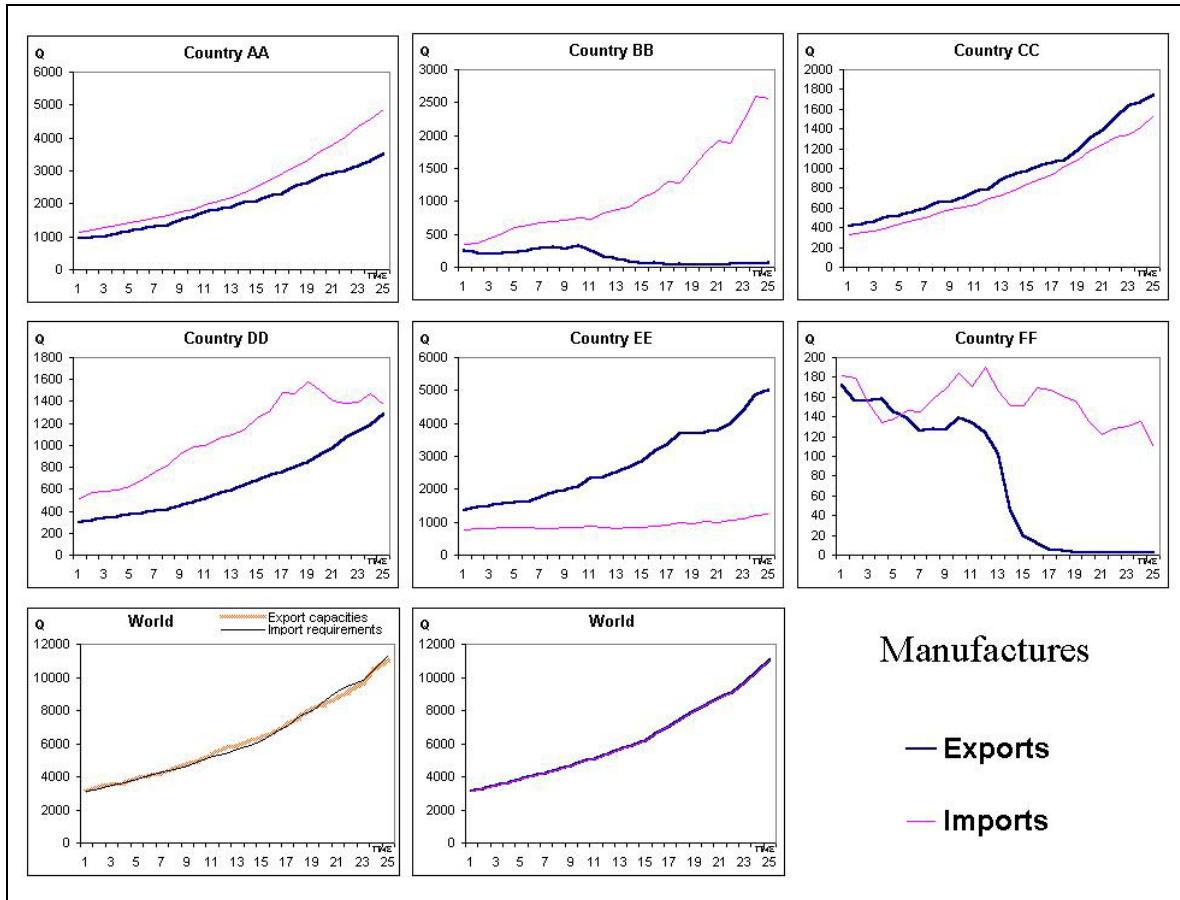


Figure 8-8 Experiment 3. Manufactures sector: exports and imports

8.5.4 Experiment 4: A change in the bloc formation: country EE enters to the bloc formed by countries AA, BB, DD

Description

In this experiment we keep the same conditions as in the basic simulation run and we postulate that country EE is allowed to enter as member of the bloc formed by countries AA, BB, DD after TIME=4. Country EE sets the same tariff enjoined by its partners. The purpose of this experiment is to explore the effect on the model of the

presence of one country in two blocs simultaneously and, as in the previous experiments, the dynamics experienced by the whole trading system.

Results

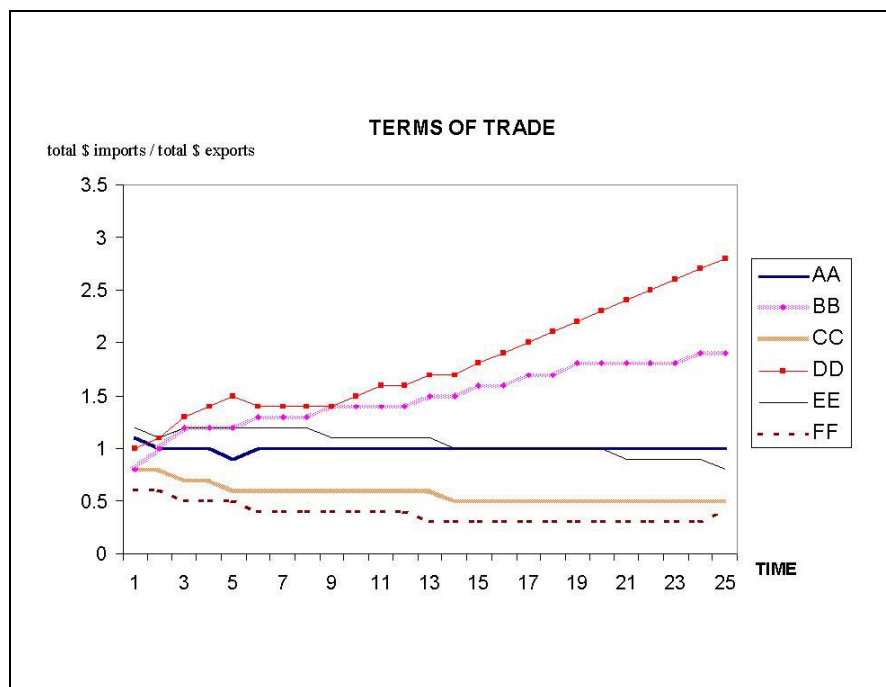


Figure 8-9 Experiment 4. Terms of trade

In this experiment we found the same configuration of major partners. However, the dynamics experienced by all sectors with the introduction of EE makes more complex the analysis. Changing tariffs make relative prices different and this generates an outcome in each sector that seems to depend on precisely the relative advantage of each country. Therefore, we prefer rather than make the previous analysis, to observe the terms of trade and compare them with the basic simulation run. Figure 8-9 shows the terms of trade obtained in the experiment. The inclusion of country EE into the preferential agreement with bloc AA, BB, DD has notably modified the terms of trade of two countries (see Appendix D for the results of terms of trade obtained in the basic simulation run). Country DD improves its terms of trade during the first periods of simulation. The inclusion of EE has improved the position of a member of its new bloc, but country BB suffers from the terms of trade decline. The other countries have changed their terms of trade a little. So, in this case, the major effects occur inside the new bloc. These effects

are viewed thanks to the interdependence that this sort of model allows to represent. As a whole, the trading system adjusts to the new situation.

8.5.5 Experiment 5: Agreements to form three blocs: countries AA & EE, countries CC & DD, and countries BB & FF

Description

At the beginning of the simulation run, a political agreement is signed by pairs of countries with similar size. For example, AA & EE, CC & DD, and BB & FF decide, as part of the agreement, to cut tariffs on imports by 10% each period. Countries outside each agreement are levied a 100% *ad valorem* tariff on imports.

Results

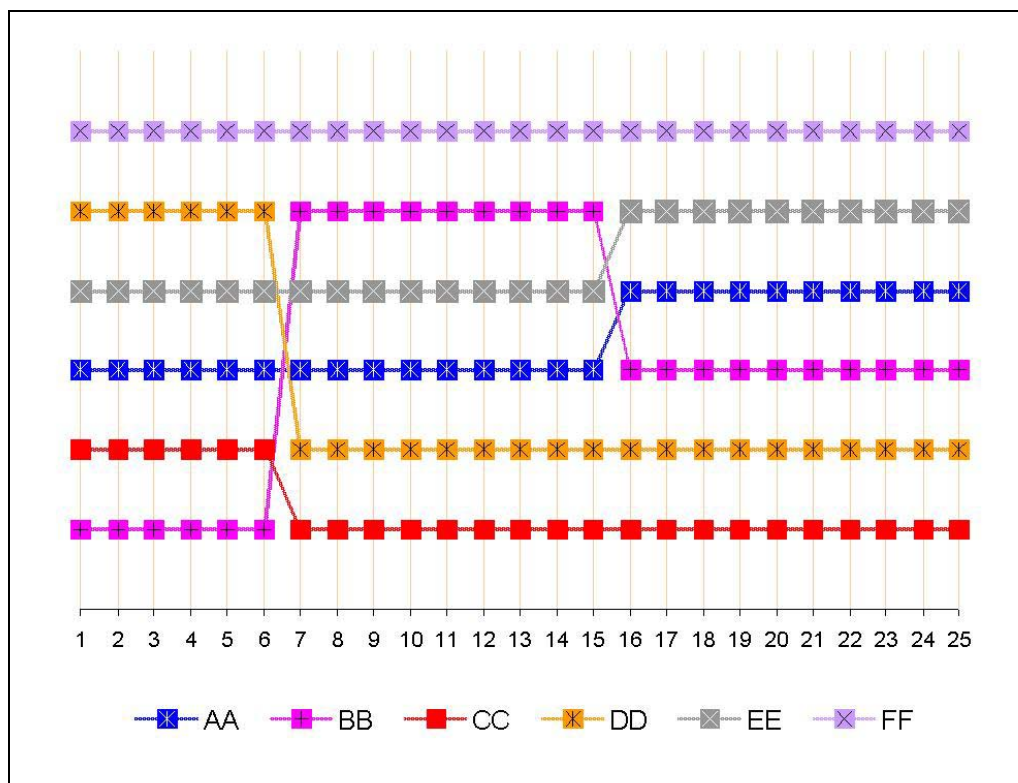


Figure 8-10 Experiment 6. Trading blocs

Figure 8-10 shows the configuration of trading blocs resulting from this experiment. Two major changes are noticeable during the simulation run. Until TIME=6 the major partners were BB CC AA EE DD FF. Since TIME=7 we observe the effect of

tariff reduction between the pairs of countries, which placed closer each pair of countries that have signed the agreement. But this arrangement is no longer sustained after TIME=16. As a matter of fact, country BB was better placed between countries AA and DD, even though they are not part of the agreement. This means that an established agreement is not a guarantee to support a partnership. In this case, the requirements of BB are supplied by other countries, which changes the initial configuration of the major partners. The dynamics of the entire trade system, as specified in the simulation run, force the two small countries BB and FF to keep their major partnership.

8.6 Conclusions

In this chapter we have presented the results obtained through the basic simulation run and five selected experiments. We have chosen initial values that create a configuration of the world comprising two big, two medium-sized and two small countries. We discussed in detail, the results of the agricultural sector in the basic simulation run, emphasising how the feedback mechanism, which allows world exports capacities and world import requirements by sector to co-evolve, can be visualised in the figures. We have also explained the way experiment results are visualised.

It is important to emphasise that all the results obtained through the model depend on the initial conditions and the way parameters are fixed through simulations. The user of the model may define his/her own initial values, formulate the hypothesis to be tested, and analyse the results. One may also compare the results with real trajectories to validate the outcomes of the model. We do not expect to put forward definitive policy recommendations from these experiments, not at this stage of the work. We do expect to understand and represent, in algorithms, complex processes that involve decision-making, as is the case with the world trading system.

Chapter 9

Conclusions

9.1 The methodology used and major results obtained

In this thesis we have studied a representation of the structure of the international trade system that is quite different from those usually employed in mainstream economic theory, as for example mathematical analytical models with a small set of variables, or econometric models for the analysis of large set of data. Neither of these two approaches is usable in the case of the international trade system. International trade is a very complex system with different facets that cannot be studied by means of mathematical representation with few variables.

As Zadeh's incompatibility principle suggests, when a system becomes more complex, it is more difficult to make mathematical statements (as the traditional economic theory wants to do) that are both precise and meaningful. On the other hand, data on international trade are not always available at the same level for all the regions or countries, making difficult the use of econometric models. Instead of a mathematical representation or the development of an econometric model, this thesis suggests an alternative way, i.e. the use of simulation modelling to deal with complexity. Modelling is not only desirable by also necessary to maintain manageability of the analysis of systems and to gain comprehension. It focuses the debate through its process of putting together symbols to obtain an ordered set, the so-called model. The main contribution of this thesis is a model that allows the simulation of the dynamics of international trade. The model accounts for interactions and interdependencies in international trade and, consequently, supports the study of bloc formation. This is a computer model for simulation based on the principles of evolutionary economics. Computer simulation was

adopted as the research strategy because in a computational model, behavioural and decision rules, describing dynamic systems, can be more easily represented than through analytical tools. In other words, this kind of model is better suited for dealing with complexity, one important characteristics of socio-economic systems.

The main features of the model presented are:

- An algorithm to represent bilateral trade flows;
- A feedback mechanism to allow world exports capacities and world import requirements by sectors to co-evolve;
- An algorithm to represent and observe through time the evolution of bloc formation. We have proposed to use the trade matrix and its rearrangements as a way to observe clustering or bloc formation;
- A general process and elaboration of graphical representation, to observe the results of the simulations.
- Selected results that permit to observe the behaviour of the model.

The model serves to highlight useful information (e.g., co-evolution of import requirements and export capacities, bloc formation, etc.) regarding the dynamics of international trade and the representation of its emergent structure. By ‘structure of international trade’ we mean the network of interchanges created among countries when they decide to do business and also the interdependencies that this implies. The model learns the results in a period and adjusts its behaviour by making decisions about the following periods. In other words, a learning element is implicitly included in the model. This is a clear advantage for this sort of model compared with those discussed in Chapter 2 (the theoretical, econometric-oriented models).

The model is a tool to gain insight in the processes of international trade. It may therefore be used for decision-making and strategic planing. It offers the opportunity to observe the dynamics of an international trade system composed of aggregated sectors of a group of countries inside an artificial society. We have not completely validated the model against real societies and real international trade. We decided to concentrate our

attention on a reasonable artificial society and validate the model by the behavioural coherence achieved in selected experimental frames.

To summarise, the research makes a positive contribution in three different areas. First, in the area of international trade, it offers a better understanding of this complex system and in particular of two processes: bloc formation and patterns of trade. Second, with respect to economic modelling, it is an attempt to analyse economic problems from a more systemic point of view, including, for instance, learning and adaptability into the models. Finally, but not the least, with respect to modelling and simulation, it offers a set of computational tools to study socio-economic phenomena.

9.2 Further research

Further research may include:

- To introduce price competition among countries into the model. A way to do it is to use a feedback mechanism that allows countries to modify their sector prices according to what is observed on the international market, progressively improving their comparative advantages;
- To improve the algorithmic representation of how exchanges are made. The development of the algorithm used is a first approximation. We could add new relevant features incrementally in order to increase the model's similarity to its target system (the real international trade system). Another way of improving the algorithm is to introduce product differentiation, so that the countries in the model have an opportunity to buy according to quality ranking rather than only by price ranking.
- To search for new ways of representing processes like the formation of patterns of trade. For example, as suggested in appendix C, a new algorithm that divides each period of the simulation in several steps may help. Each country would have the opportunity to buy from other countries only a portion of their import requirements, allowing all other countries to buy from their best sellers. This may improve the intrinsic parallelism of the trade system with respect to the solution represented by the model proposed in this thesis. Some preliminary tests have been conducted and their

results already suggest new possibilities for such a representation. There is no tradition in economics, except for the evolutionary approach and the Santa Fe approaches, of thinking about processes algorithmically. For this reason, it is not easy to present results. Nevertheless, far from being a disadvantage, this is an advantage because it stimulates new ways of thinking for understanding economic phenomena.

- To include for each national economy a Leontief input-output model or a Pasinetti vertical integrated sectors model to represent their production system. Both deal with interdependence in a single economy. The inclusion of one of these types of models would enable us to integrate the effects of international trade and bloc formation into each economy (through top-down mechanisms) and the effects on trade of the performance of each economy (bottom-up effects).
- To test the model with some real data at a global or regional scale. At a global level the main problem is related to the aggregation of countries; on the contrary, at a regional level, the difficulty would be related to the representation of the imports-exports of the region with the rest of the world.
- To represent technological flexibility. This is a key point for future research. Technological flexibility implies that countries can change their comparative advantages by adapting themselves to new forms of production or to new products.
- To use external tariffs between countries. This may be an incentive for countries forming the bloc to improve their terms of trade (for example, by reducing trade volume to drive up the price of exports and drive down the price of imports [World Bank 2000]).

The suggested improvements and the simulation of many new experiments will lay the foundations for a future research line, altogether more theoretically oriented: the discovery through the use of the model of new advancements in the theory of international trade, in particular for an analysis of its endogenous behaviour. This future research would require, to begin with, a lot more experiments with real data and/or artificial societies and the exploration of all the above ideas on how to improve the

model. The suggested improvement will provide more evidence on the validity of the model and on its learning power, so that it can be used as a tool by policy makers. Without these future researches, it is only possible to indicate (see next section) some very preliminary policy implications obtained from the results of Chapter 8 and from the theoretical considerations presented in the other chapters.

9.3 Policy implications

The analysis of trading bloc formation, their dynamics and behaviour from the point of view adopted in this dissertation may prove to be a new way of thinking about the interdependence observed in the international trade system. Even though the model developed in this thesis is far from being a complete representation of the real world trading system, it may encourage the use of modelling and simulation techniques to test the effect of policy measures.

Models that allow the representation of interdependence and the endogenously determined dynamics in a context of decision-making are better suited, we believe, to study the consequences of some policies not only for those countries direct involved but also for third parties. A holistic observation of the international trade system may help to capture the effects in all parts, taking into consideration the fact that countries are not equal and that the world is far from being at equilibrium.

Questions such as: How much regionalisation is good and possible? What are the effects of some kinds of trade barriers on the overall patterns of trade? What might happen to the entire system and to its parts (countries, economic sectors) when some shocks occur? How does a trade bloc affect people and real integration that may go beyond mere tariff reduction? The model proposed does not respond to these questions; but it provides clear indications that the effects are very sensitive to the shocks and policy designed in the experiments. A lot more work has to be done before answers may be offered. But what is important is, we believe, the effort of thinking differently about approach complex and dynamic phenomena, such as those associated with international trade. In the process, answers may arise, probably from the insights gained when trying to

understand what happens in reality as much as from the results obtained through the model itself.

Our model suggests that when we take into account a systemic approach, it is relatively easy to display the effects on the entire trade system that may be induced by changes in single sectors and how the system itself hampers the evolution of each single economy. This simple but encouraging result stimulates the research that our work may inspire.

Tools to explore consequences of policy choices concerning trading blocs may help policy makers to forecast the implication of their decisions on a global basis, as opposed to thinking merely in terms of an isolated country or a group of countries. Policy makers need a global appreciation of the different features in order to evaluate the acceptability of their policies. In addition, they need to see the trade system as a whole and to understand all the aspects involved. This can be obtained with the developed simulation model. The possibility of simulating new scenarios facilitates for learning on the complex structure of the international trade system.

There are many other more specific policy implications. For example:

- (i) We have focussed this research on the effects of tariffs on trade and bloc formation. However, many other trade barriers should be explored. For example, the economic and social implications of restricting trade to countries that are against the current wave of regionalisation or globalisation, or that are against the use of products that do not respect the environment (e.g. transgenics).
- (ii) The creation and proliferation of trade blocs in recent years have been the results of powerful forces driving these processes and these forces have been basically political ones. Security, bargaining power, co-operation, and many others, are probably the main political motors for regional integration. This process has also economic and social implications, which may be studied in part with the sort of model presented here.

It is important to stress that the results obtained through simulations are to be considered simply as a guide for policy makers. It is only a guideline for dealing with complex systems, but in many cases a necessary one.

Appendix A

Input-Output dynamics in OECD countries

A.1 Introduction

As stated in chapter 3 and in Chapter 5, the interdependence observed in the international trade system requires the study of each country's economic system and a way of representing it in the model proposed. One possibility, explored within this thesis, is to use the Leontief Input-Output (I-O) model to represent a country production system from a simulation point of view. This might allow us to observe how the interdependencies between countries influence and are influenced by changes in the way countries produce their commodities and organise their economy in general. The OECD I-O database [OECD 1993]¹ of 9 countries for some years (from 1968 to 1990) was used to analyse the dynamics of the following 7 sectors: Agriculture, forestry & fishing (AGR)²; Mining & quarrying (MNI); Petroleum & coal products (PET); Office and computing machinery (OFF); Motor vehicles (VEH); Construction (CON) and Finance & insurance (FIN). These sectors were arbitrarily chosen. However, others (or all 31 sectors) could be easily included and visualised. The countries examined are³: Japan, France, Canada, the United States, Denmark, the United Kingdom, Germany, Australia, and the Netherlands. In the following sections we present and compare the patterns of final demand, gross output and I-O coefficients of these countries and sectors.

We have constructed tools to visualise the dynamics of those variables during the periods for which the data is available. Using the spreadsheet facilities provided by the

¹ The OECD Input-Output (I-O) Database may be downloaded from the web site: <http://www.oecd.org/dsti/sti/stat-ana/index.htm>

² In parenthesis we indicate the acronym we will use on some figures.

³ These countries have at least four I-O matrices in the OECD database. This is one of the criteria used in the selection of the countries.

Microsoft Excel software, some programs (macros) were developed in order to facilitate the user's analysis of each of the figures or the comparison of all or some of them. Furthermore, user can focus on a specific country or on a specific sector figures (these details are not included here). The results presented below are only some aspects of what may be obtained. As specified above, results are presented only for 7 out of 31 sectors.

The aim is to visualise the structural dynamics experienced by those economies in respect of their final demand, gross output, exports and imports, as captured by the I-O matrices reported over those years in the OECD Input-Output database. These patterns may provide us with some insights about how to use I-O representation from a simulation point of view. In other words, this work might help us construct 'appropriate' input-output schemes for representing hypothetical countries in simulation models. Unfortunately, it was not possible to include data from less developed countries, because of the unavailability (at least of public domain, to our knowledge) of data covering this period of time.

The data for Germany, Australia, the Netherlands and the United Kingdom have 4 matrices covering the period from 1968 to 1990. For Japan, France, Canada, Denmark and the United States, data include 5 matrices covering the same period of time. Each of the I-O tables presents total domestic plus imported transactions in a particular year based on constant prices⁴. Despite the fact that the number of observations is quite small, it might give us a general idea of the dynamics we could expect when using I-O modelling to represent national production systems.

The observed dynamics (from 1968 to 1990) is presented for the following variables:

- Final demand (FD), gross output (GO), exports (Exp) and imports (Imp) for each sector of the 9 countries (section A.2).

⁴ For Japan: Billions of Yen, at 1985-based constant prices. For France: Millions of FF, at 1980-based constant prices. For Canada: Millions of C\$, at 1986-based constant prices. For United States: Millions of US\$, at 1982-based constant prices. For Denmark: Millions of Kroner, at 1980-based constant prices. For the United Kingdom: Millions of Pound sterling, at 1980-based constant prices. For Germany: Millions of Deutsche Mark, at 1985-based constant prices. For Australia: Millions of A\$, at 1989-based constant prices. For the Netherlands: Millions of Guilders, at 1980-based constant prices.

- Input-Output coefficients for AGR, OFF, VEH and CON sectors of the 9 countries (section A.3)

In addition, Figure A-19 summarises the dynamic of the population for the 9 countries during the period 1968 and 1990.

A.2 Final demand, gross output, exports and imports

The figures with uneven number from A-1 to A-13 show the trends of **Final Demand (FD)**, with a light line) and **Gross Output (GO)**, with a bold line) for each country and sector: Figure A-1 (sector: Agriculture, forestry & fishing), Figure A-3 (sector: Mining & quarrying), Figure A-5 (sector: Petroleum & coal products), Figure A-7 (sector: Office and computing machinery), Figure A-9 (sector: Motor vehicles), Figure A-11 (sector: Construction), and Figure A-13 (sector: Finance & insurance - FIN).

The figures with odd number from A-2 to A-14 show the trends of **Exports (Exp)**, with a light line) and **Imports (Imp)**, with a bold line) also for each country and sector: Figure A-2 (sector: Agriculture, forestry & fishing), Figure A-4 (sector: Mining & quarrying), Figure A-6 (sector: Petroleum & coal products), Figure A-8 (sector: Office and computing machinery), Figure A-10 (sector: Motor vehicles), and Figure A-12 (sector: Construction), and Figure A-14 (sector: Finance & insurance - FIN).

Each figure includes 9 subfigures, one for each country. Each subfigure shows data over 5 years. The years may differ from country to country; however, they are all between the period from 1968 to 1990. The name of the country appears on the top right-hand corner of the subfigures; the year in the X axe and the amount (in US\$) in the Y axe.

A.2.1 Agriculture, forestry & fishing (AGR)

Figure A-1 shows the final demand (FD) and gross output (GO) for AGR sector. It is remarkable that GO is always bigger than FD for all the countries. Throughout those years, both curves have shown quite similar shapes, the United Kingdom being an exception during the 1970s when FD decreased and GO continued to grow.

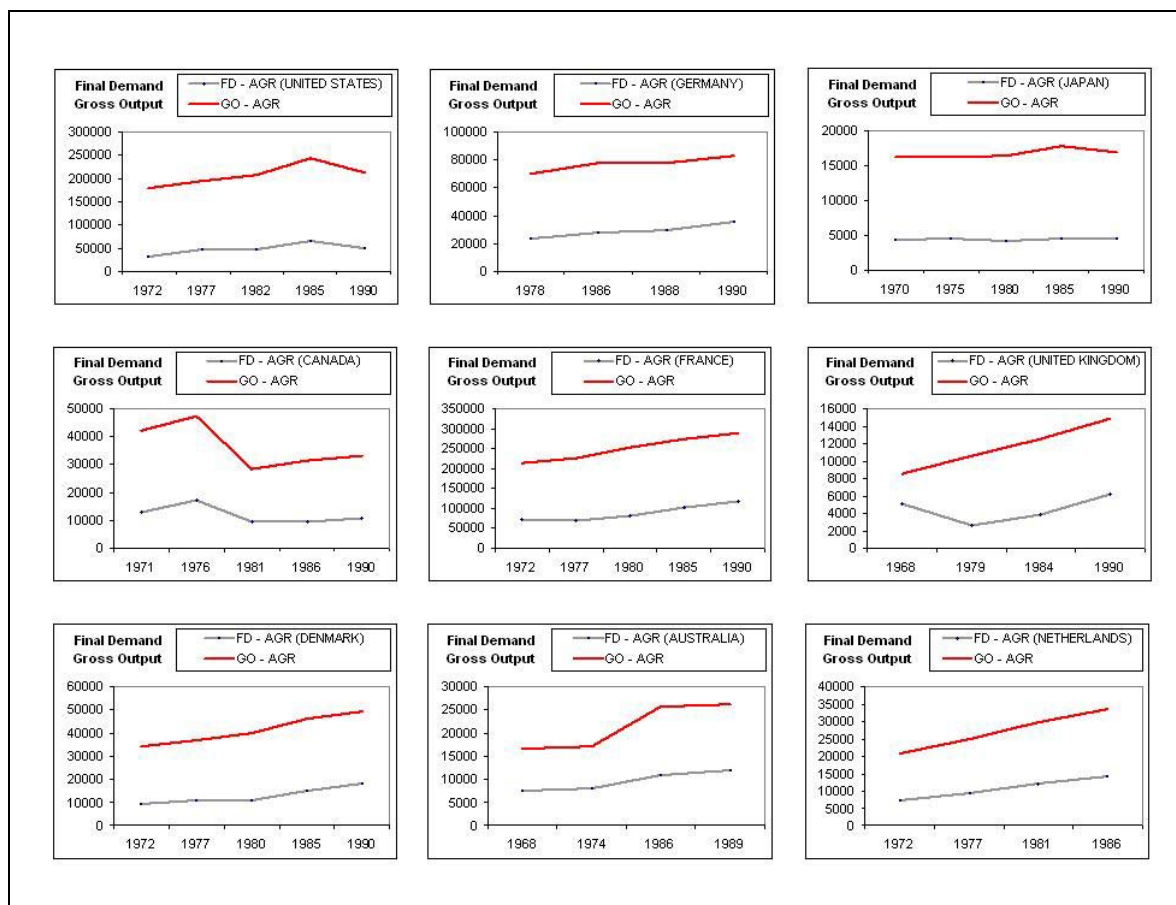


Figure A-1 Final Demand and Gross Output: Agriculture, forestry & fishing

Figure A-2 shows exports (Exp) and imports (Imp) for AGR sector. Three countries (Japan, Germany and the United Kingdom) were net importers while other three (Canada, the United States and Australia) were net exporters in AGR. The other three (France, Denmark and the Netherlands) changed their role of net importers to net exporters during this period.

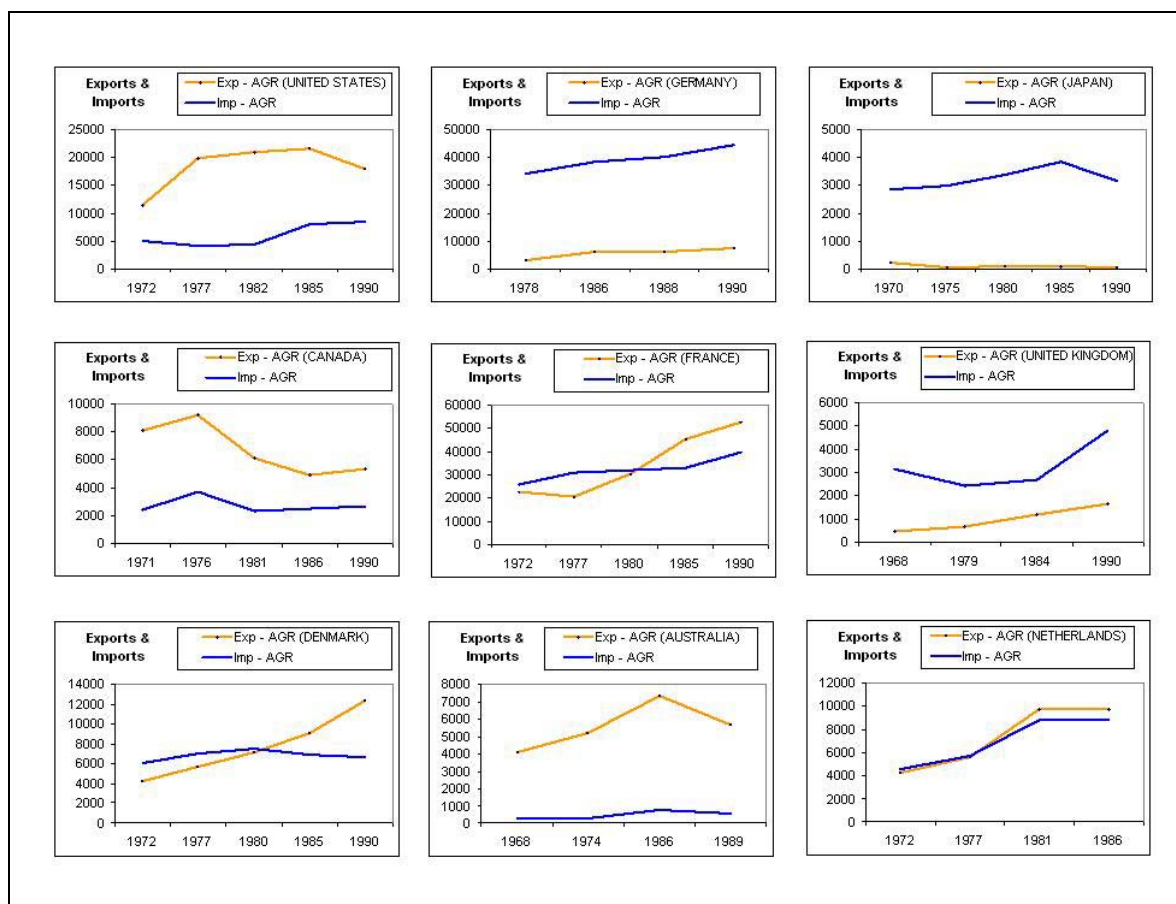


Figure A-2 Exports and Imports: Agriculture, forestry & fishing

A.2.2 Mining & quarrying (MNI)

Figure A-3 shows the final demand (FD) and gross output (GO) for MNI sector. Also in this sector the GO surpasses FD for all the countries considered. However, one curve not always takes the shape of the other, or, at least, this is less clear than it was in AGR sector. Some countries clearly increased both GO and FD (Denmark, Australia, the United Kingdom and the Netherlands) and others clearly decreased both GO and FD (Japan, Canada and Germany).

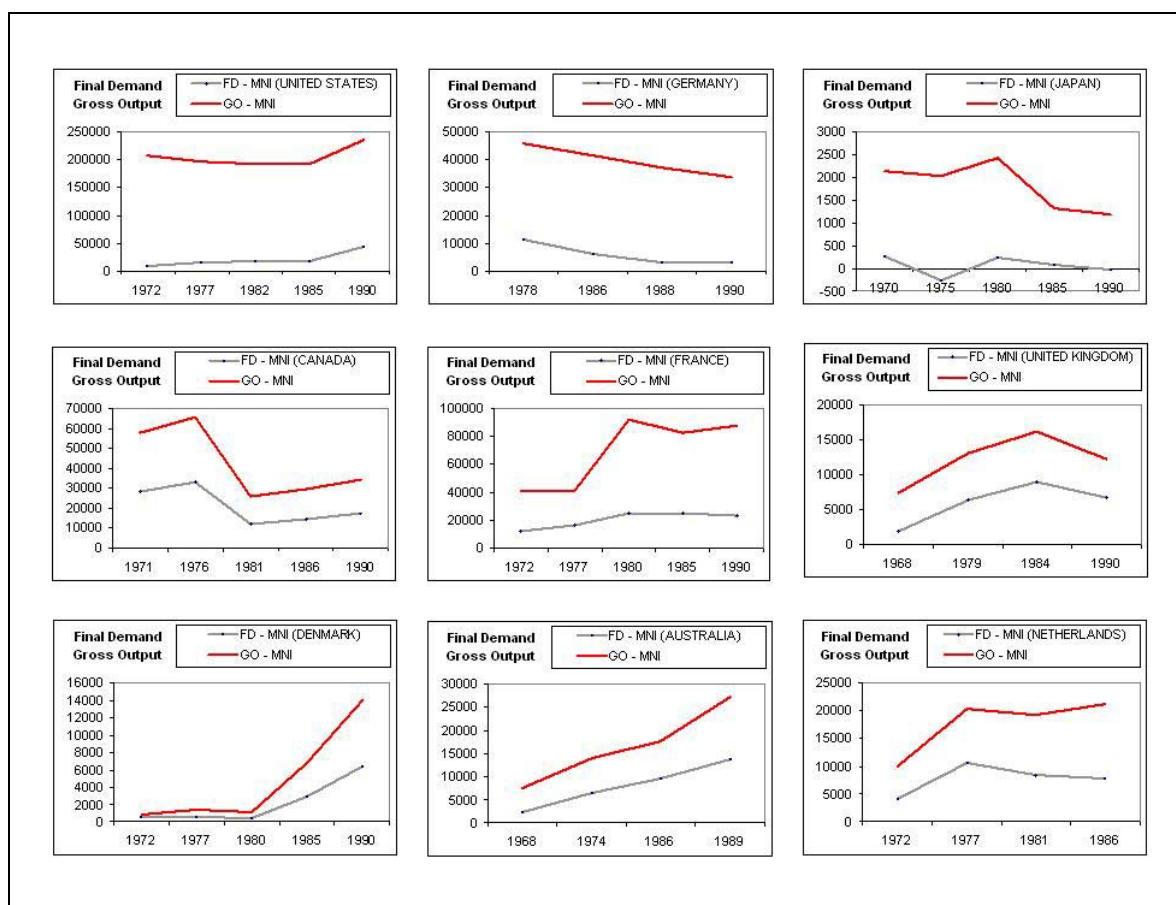


Figure A-3 Final Demand and Gross Output: Mining & quarrying

Figure A-4 shows exports (Exp) and imports (Imp) for MNI sector. This sector allows us to observe an intuitive fact: when GO increases in a country Exp increases and Imp decreases and vice versa (see for instance the case of France and more clearly Denmark and Australia). Japan, France, the United States, Germany, Denmark and the Netherlands were net importers and Australia and Canada were net exporters. Only the United Kingdom changed from net importer to net exporter twice. Denmark shows a clear tendency to become a net exporter and Australia to augment its advantage of net exporter.

For Japan, the United States and Germany, international trade provides an important amount of MIN domestically used by them.

This sector shows patterns of specialisation or, even, exploitation of comparative advantage for some of them and, for others, a clear dependency on third countries.

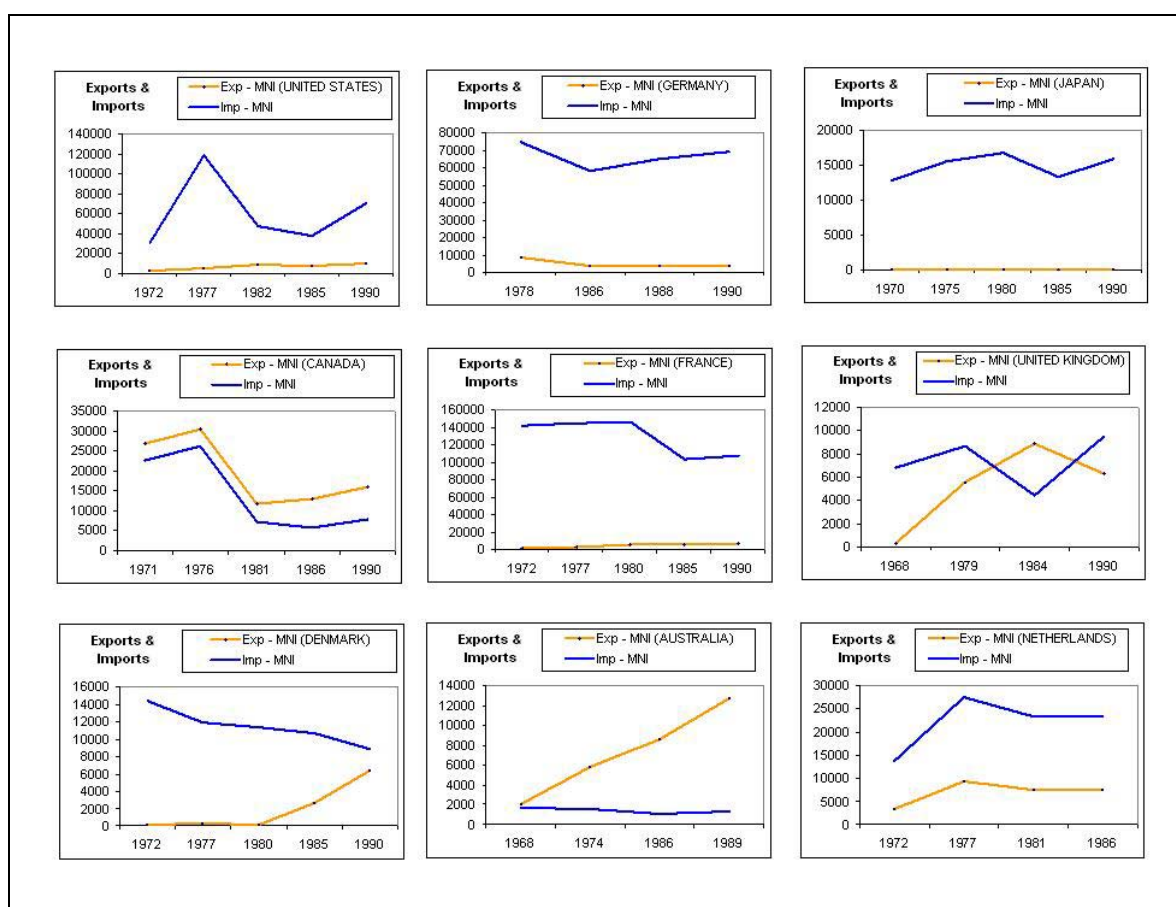


Figure A-4 Exports and Imports: Mining & quarrying

A.2.3 Petroleum & coal products (PET)

Figure A-5 shows the final demand (FD) and gross output (GO) for petroleum & coal products. Denmark is the only country that shows, for some periods, a FD higher than GO. However, this changed towards the early 1980s. For all other countries GO was always greater than FD. For the United Kingdom, FD increased while GO decreased. For Denmark, it was the opposite. All other countries show a similar shape for both curves.

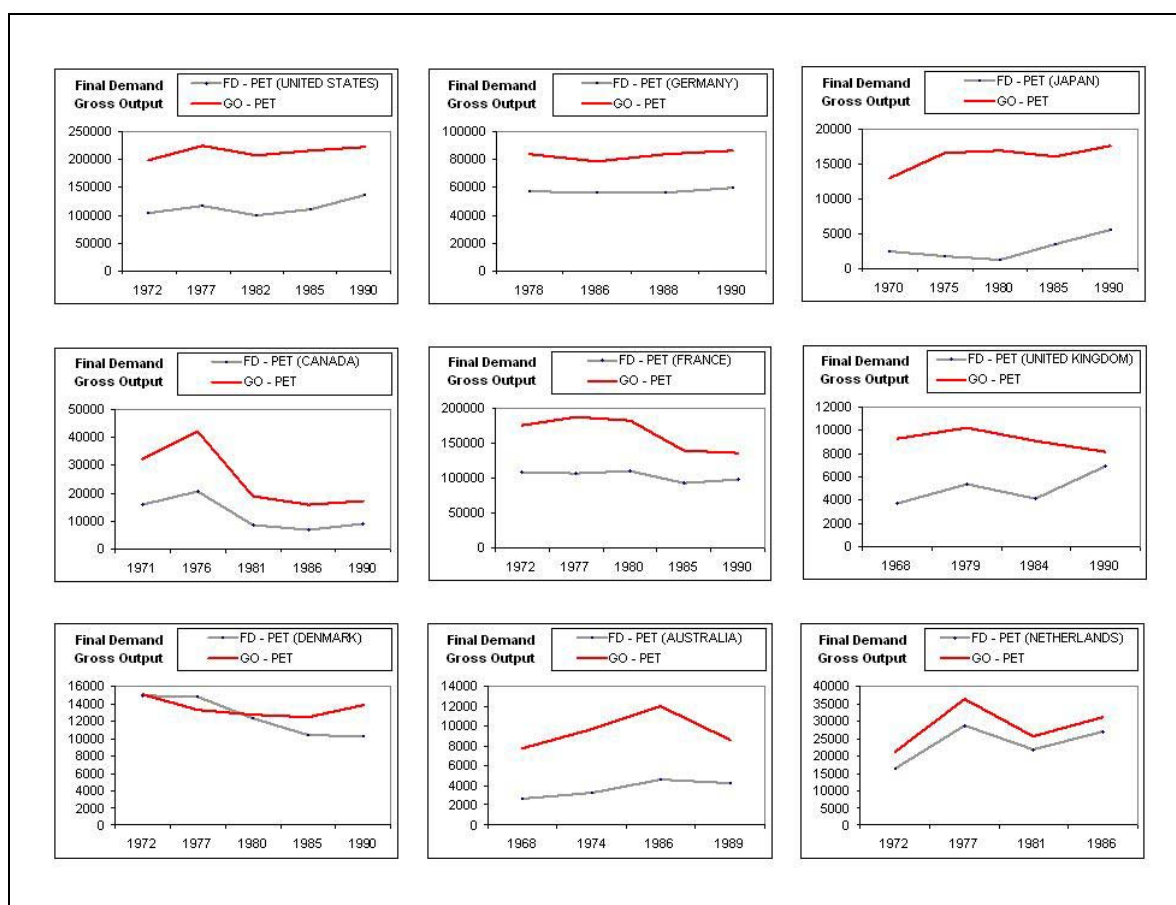


Figure A-5 Final Demand and Gross Output: Petroleum & coal products

Figure A-6 shows exports (Exp) and imports (Imp) for PET sector. The Netherlands was the only net exporter country in this group. In the late 1970s, France changed from net exporter to net importer. Canada shows a sharp decrease of its imports during the 1970s and both curves converged in the late 1980s. In the United Kingdom at the end of the 1980s imports slightly overtook exports. All other countries were net importers.

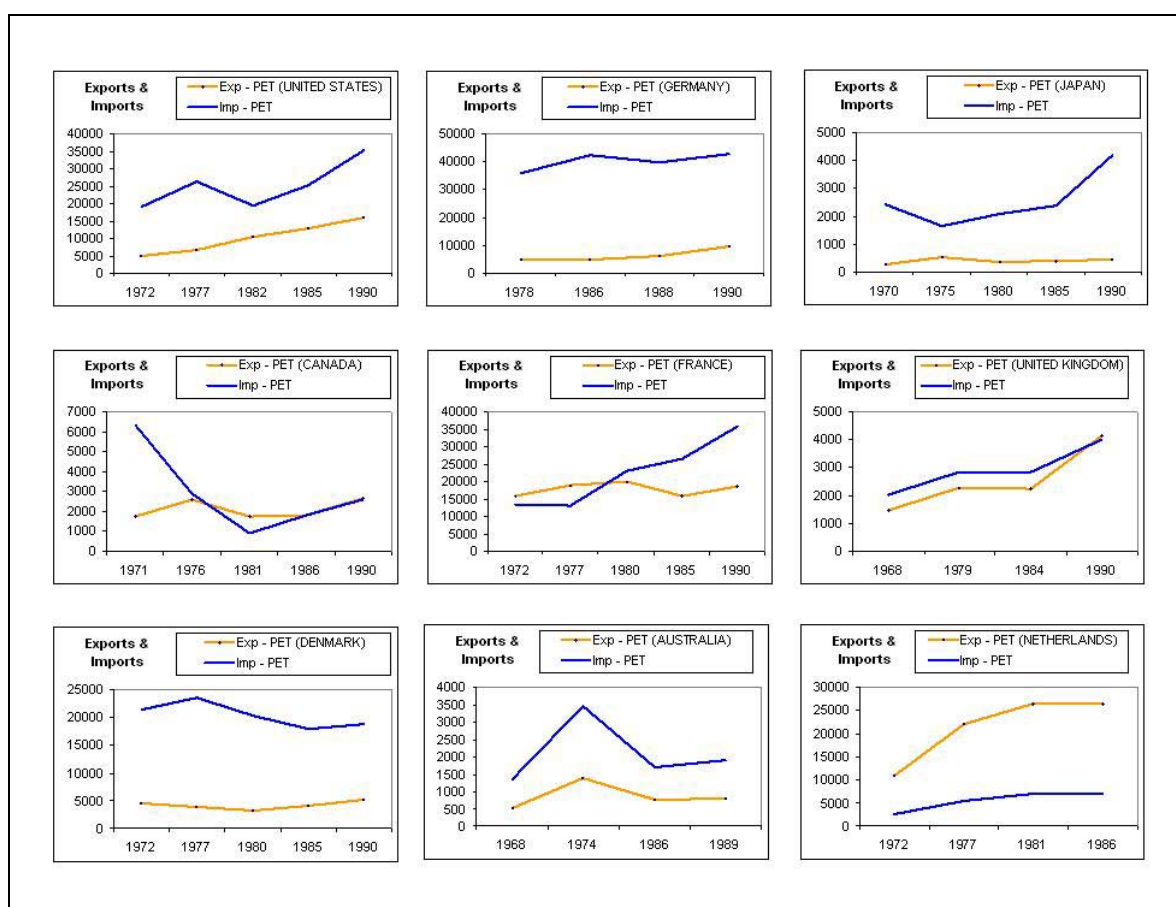


Figure A-6 Exports and Imports: Petroleum & coal products

A.2.4 Office and computing machinery (OFF)

Figure A-7 shows the final demand (FD) and gross output (GO) for office and computing machinery. Only Japan and the United States show a GO bigger than FD (but the United States changed this configuration at the end of the 1980s). All other countries did not produce domestically enough to satisfy their internal demands.

There is no data available for Denmark and Australia, hence no graphics are shown in the respective figures. The increase of both FD and GO in all countries is more than evident. Japan and the United States show almost the same curves for FD and GO. Only Japan shows a GO higher than FD. The United States show the same pattern until 1985; after that the pattern changes. For all the other countries, FD increased more than GO did.

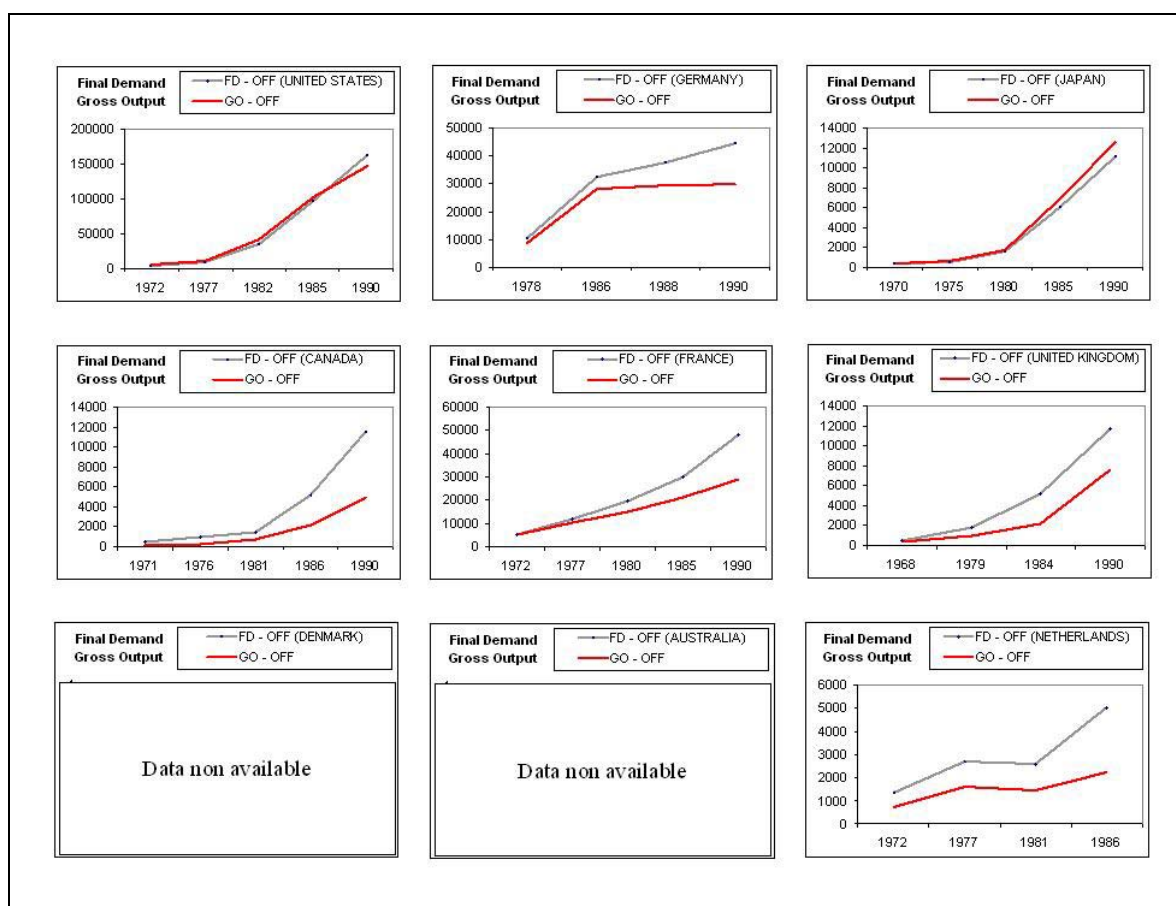


Figure A-7 Final Demand and Gross Output: Office & computing machinery

Figure A-8 shows exports (Exp) and imports (Imp) for OFF sector. Japan and the United States show Exp bigger than Imp, but it is interesting to observe how Japan has risen its Exp sharply than Imp, while the United States shows both curves rising more or less with the same rate. All other countries are net importers with Imp rising more sharply than Exp. International trade has increased in this sector in all the countries for which data is available.

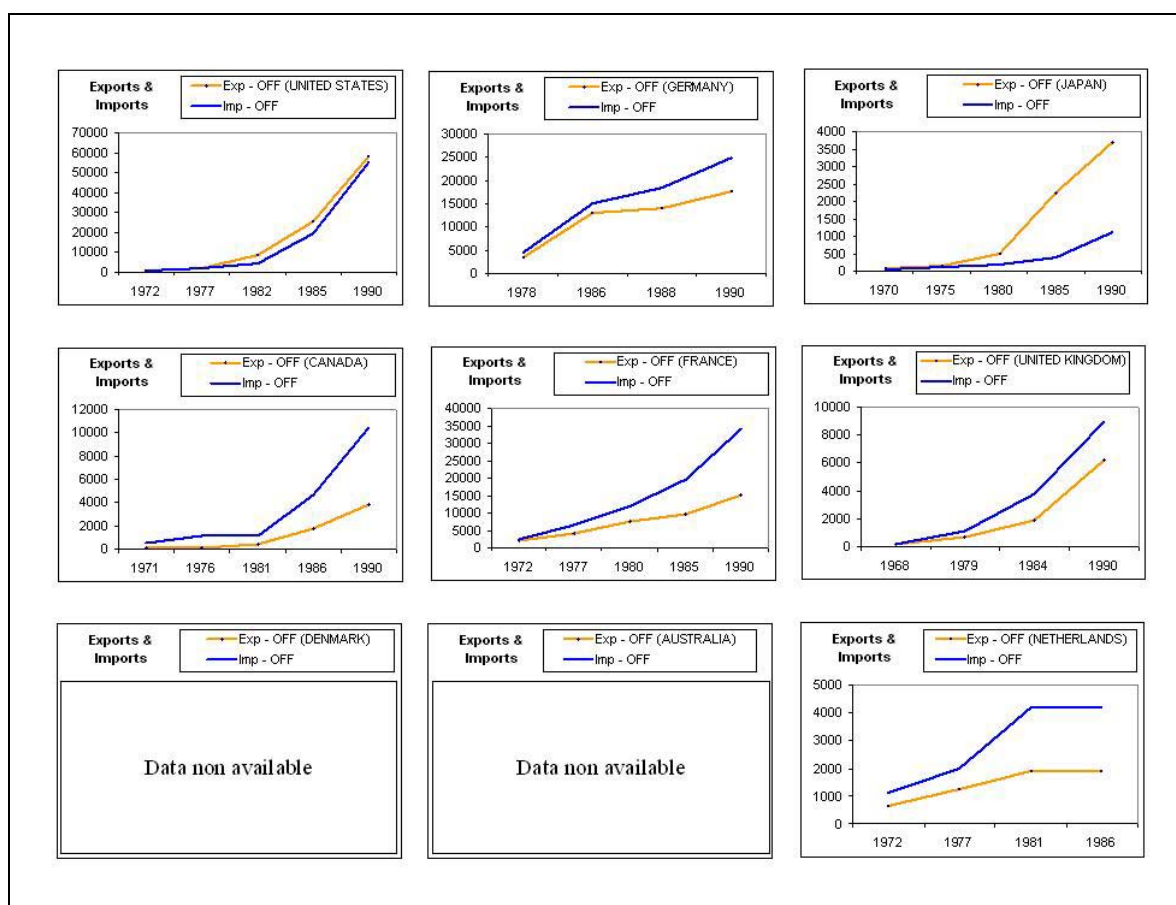


Figure A-8 Exports and Imports: Office & computing machinery

A.2.5 Motor vehicles (VEH)

Figure A-9 shows the final demand (FD) and gross output (GO) for motor vehicles. Broadly speaking, this sector was rising during the period studied in all countries (only the United Kingdom's GO declined somewhat). This sector is perhaps the one that shows more variety when comparing GO and FD shapes. Almost each country shows a particular relationship between its two magnitudes.

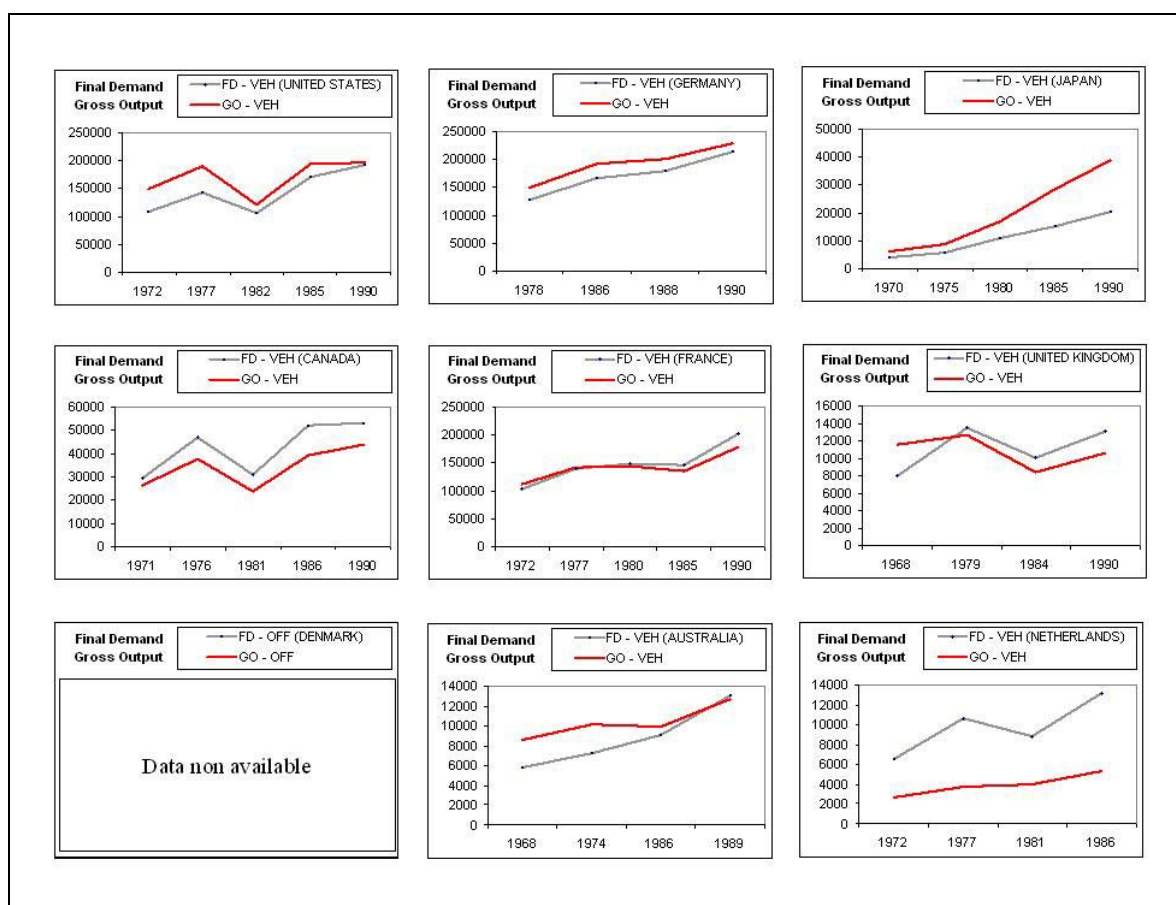


Figure A-9 Final Demand and Gross Output: Motor vehicles

Figure A-10 shows exports (Exp) and imports (Imp) for VEH sector. More or less, as it was indicated for FD and GO, we observe trends showing different shapes for all countries. Three countries were net exporters (Japan, France and Germany) and three countries were net importers (the United States, Australia and the Netherlands). The United Kingdom turned from net exporter to net importer.

No data is available for Denmark in the sense that the respective columns in its I-O matrices are all zero. For that reason no graphic is showed in Figure A-10.

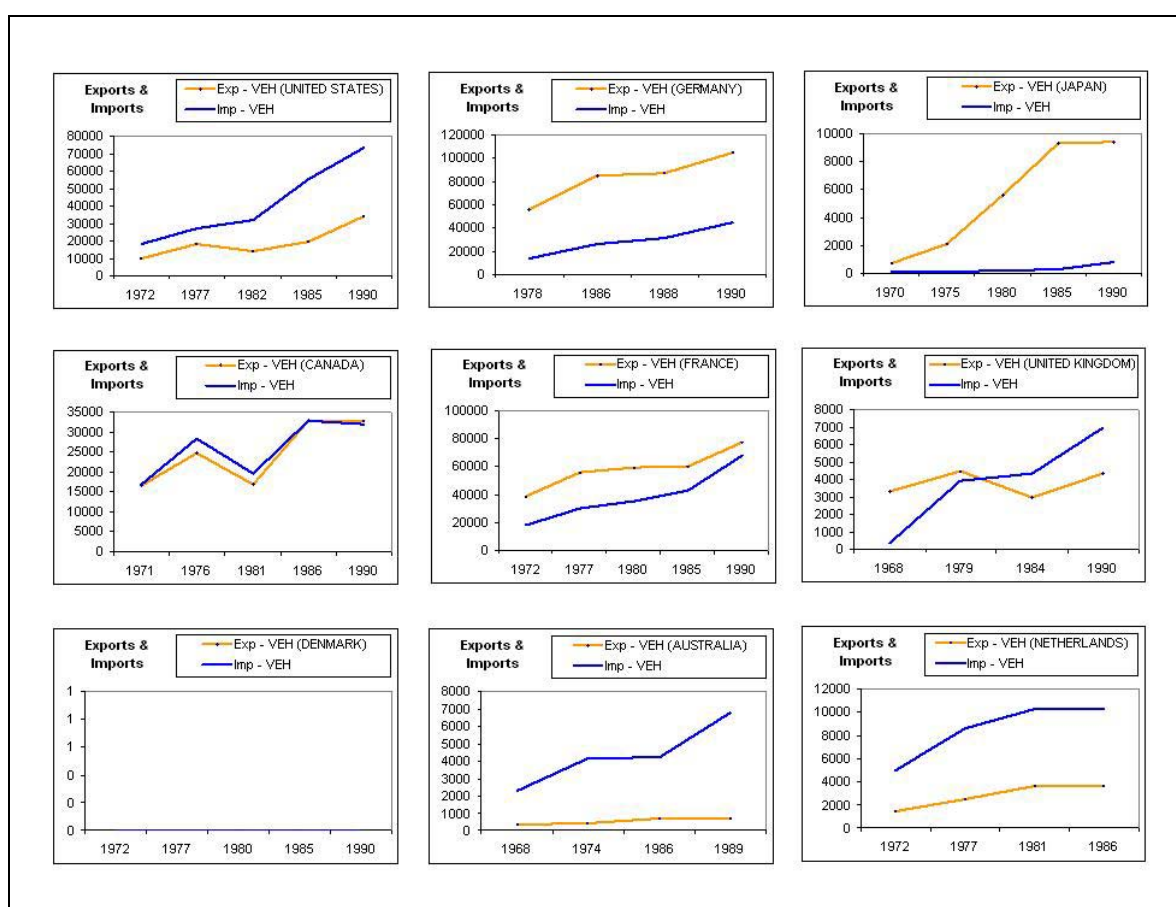


Figure A-10 Exports and Imports: Motor vehicles

A.2.6 Construction (CON)

Figure A-11 shows the final demand (FD) and gross output (GO) for construction. This sector shows in quite a remarkably way how each curve follows the other in all countries. CON rose in Japan, France, the United Kingdom and Australia. It remained more or less stable in the United States, Germany and the Netherlands. It declined in Denmark and Canada. As it is intuitively expected, for all countries GO was always bigger than FD.

This sector shows clearly how in each country FD and GO follow a similarly shaped curve. Clearly, in all countries, GO is bigger than FD as is to be expected, because the difference is used as inter-industry inputs.

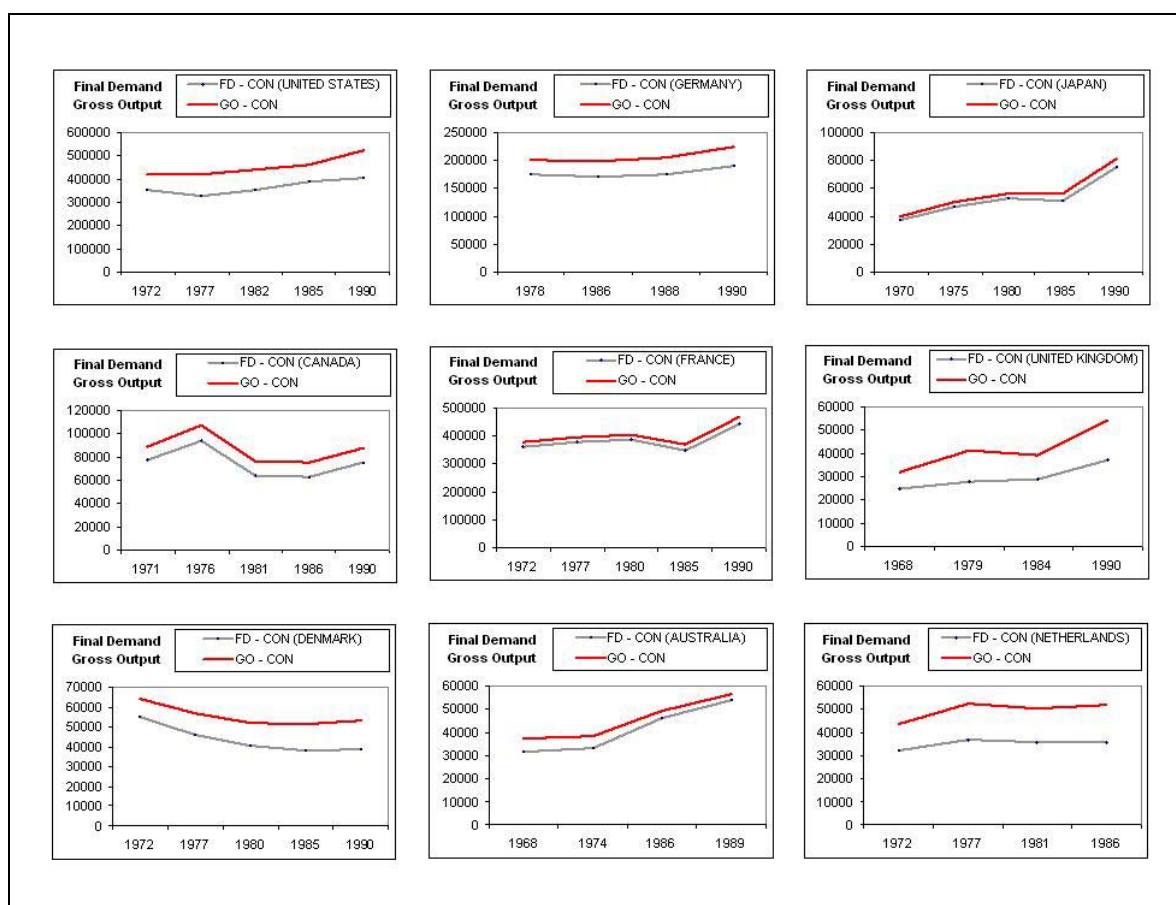


Figure A-11 Final Demand and Gross Output: Construction

Figure A-12 shows exports (Exp) and imports (Imp) for construction sector. As expected, CON is a sector that does not rely on international trade. The amount of imports and exports (when it was the case) were relatively insignificant comparing with FD and GO in all countries.

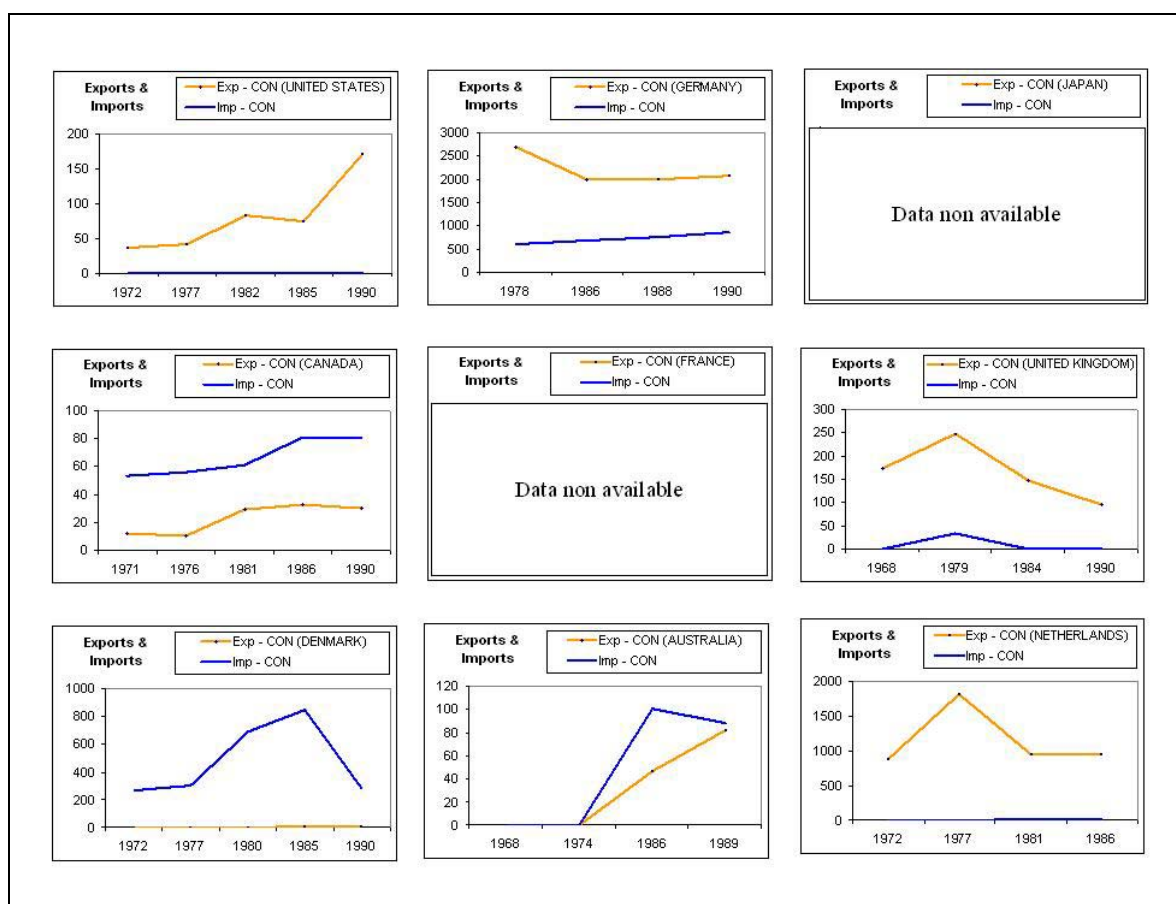


Figure A-12 Exports and Imports: Construction

A.2.7 Finance & insurance (FIN)

Figure A-13 shows the final demand (FD) and gross output (GO) for finance & insurance. GO for all the countries was bigger than FD, which is clearly reasonable because this kind of service is primarily offered at home. The trend is upward in almost all curves, except in France, in which it experienced a considerable downturn.

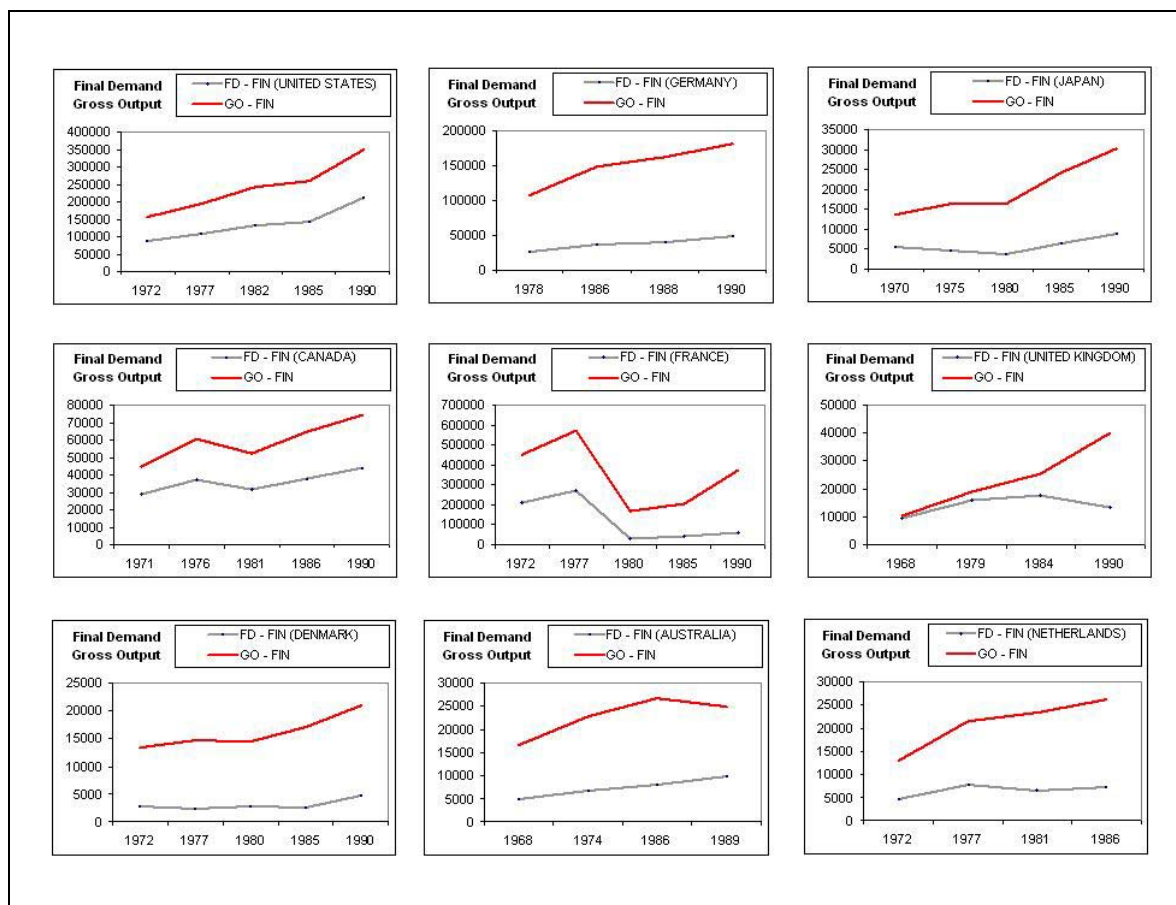


Figure A-13 Final Demand and Gross Output: Finance & insurance

Figure A-14 shows Exp and Imp for FIN sector. Certainly, the amounts of imports and exports relative with GO are very small. Thus, as in the CON sector case, business was strong at home. In any case, both curves show a variety of shapes, almost one for each country. The role of net exporter was reserved for the United States, Denmark, the United Kingdom and the Netherlands, and the role of net importer was assigned to Canada and Germany. Japan and Australia changed their role and clearly in the late 1980s they became net importers. France was a net exporter during the 1970s and, after that, it has more or less balanced its terms of trade in this sector.

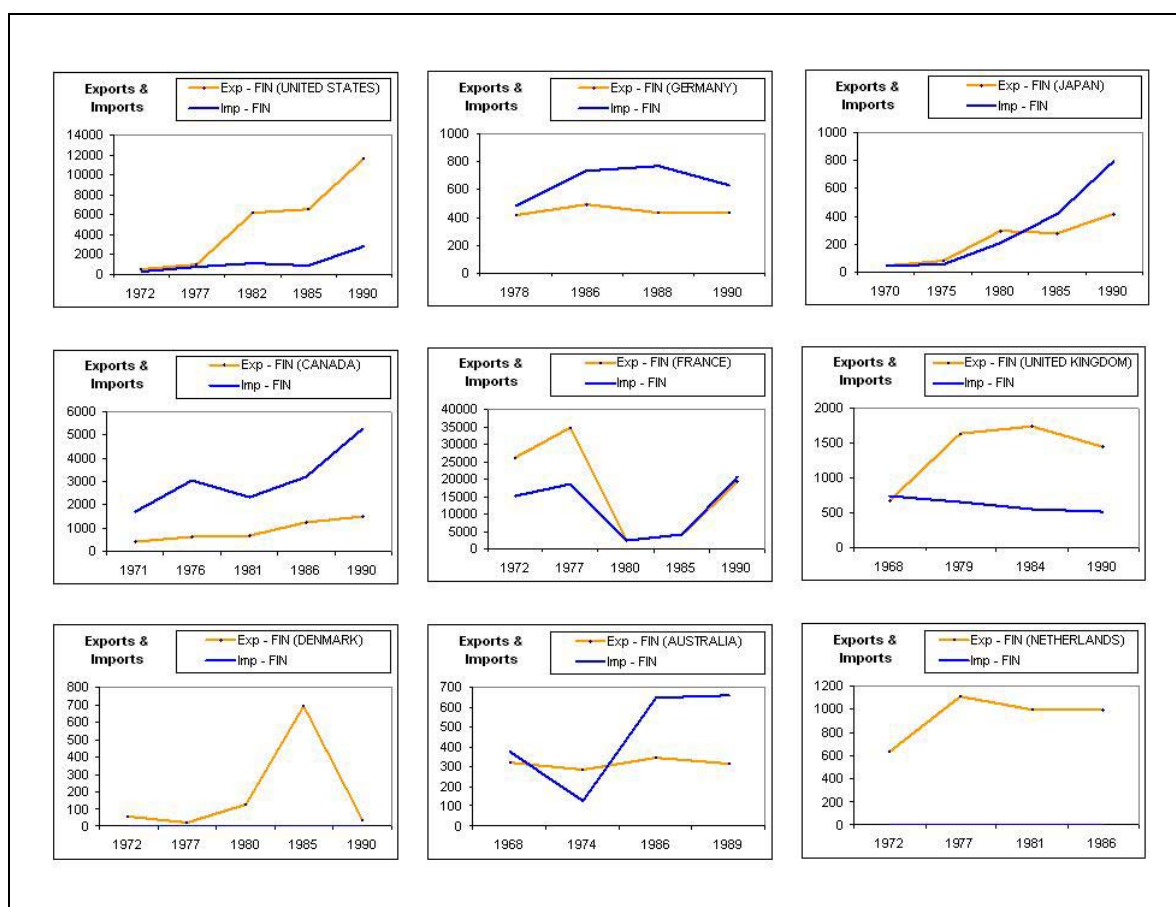


Figure A-14 Exports and Imports: Finance & insurance

A.3 Input-Output coefficients

Perhaps, analysing the I-O coefficients is a more difficult task. Each I-O matrix represents in some way a country's 'photograph' of its production system for a particular year. A collection of matrices over time may give a general idea of how this production system has changed. But change implies changes in processes (for instance, improvement on more efficient ways of producing a commodity, which may imply using different proportion of other sector output in the production of a good in a particular sector) and also changes in technologies (for instance, the invention of new -not always more useful- products and the elimination of others, which also changes sectors' interdependence inside an economy). But, we cannot forget that I-O is a method of aggregation of diverse commodities, even though the production of many differentiated commodities at a micro level may belong to the same aggregated sector. So, changes in processes and technology are observed only through these coefficients. All this information is captured in these coefficients. I-O records the interdependence among sectors in a country during a period of time, but it does not tell us about the dynamics of the emergence of new products or, perhaps, that others may be no longer produced. I-O is a very elegant way of representing an economic system, but it is limited to dealing with micro-structural changes. However, we can observe the way those coefficients have changed over time, which allows us to gain insights on how to simulate their trends. That is precisely the aim of this section. The OECD database covers a period of 22 years with 4 or 5 years in-between the available matrices (although, not always that regularity is presented).

Working with macro models, an evident weakness is the assumption of overall change in the aggregation. It is not so easy to observe the creation of new products or how other products are no longer made in the economic system.

In order to observe the evolution of the technical coefficients, we graph the coefficients for a particular sector (e.g. AGR-AGR, CON-AGR, MNI-AGR and so on) to observe what was going on and highlight trends (if any) among them. This allows observing technological changes in a country through the period under investigation. Then, we compare a particular coefficient (e.g. from AGR to CON) between all countries in the same figure, to observe technological changes in the same sector across countries.

Another important task is to calculate the rate of variation of each coefficient through time. We can identify a range of variation of those coefficients. This could be used as a proxy for variation of technology for each simulated country. This was developed by means of an Excel worksheet but not reported here.

Examples are given for the following sectors: AGR, CON, VEH and OFF in Figure A-15, Figure A-16, Figure A-17 and Figure A-18. Each figure includes 9 subfigures, one for each sector. Each subfigure shows data for 5 years. The years may differ from country to country; however, they are all in the years between 1968 and 1990 (to make the representation easier, we drew it as 1970 to 1990). The name of the sector appears on the top of the subfigures; the year in the x axe and the technical coefficient in the y axe. Each coefficient is plotted for all countries in the same figure to facilitate a visual comparison of their trends.

A.3.1 Agriculture, forestry & fishing (AGR)

Figure A-15 shows the I-O coefficients of the agriculture sector (the flows of each sector to AGR sector). The reduction of some coefficients is noticeable in almost all countries. In particular, PET and CON have decreased and the tendency is to a convergence. On the other hand, VEH, OFF and FIN have increased their participation as inputs for the AGR sector. Perhaps, this pinpoints, in part, a process of globalisation in agricultural production.

A.3.2 Office and computing machinery (OFF)

Figure A-16 shows the I-O coefficients of the office & computing machinery sector (the flows of each sector to OFF sector). This sector shows, in a quite remarkably way, the technological changes that occurred during the period under investigation. All the coefficients, for all the countries, show a convergence in the sense that fewer inputs of those sectors have been used in the production of OFF commodities.

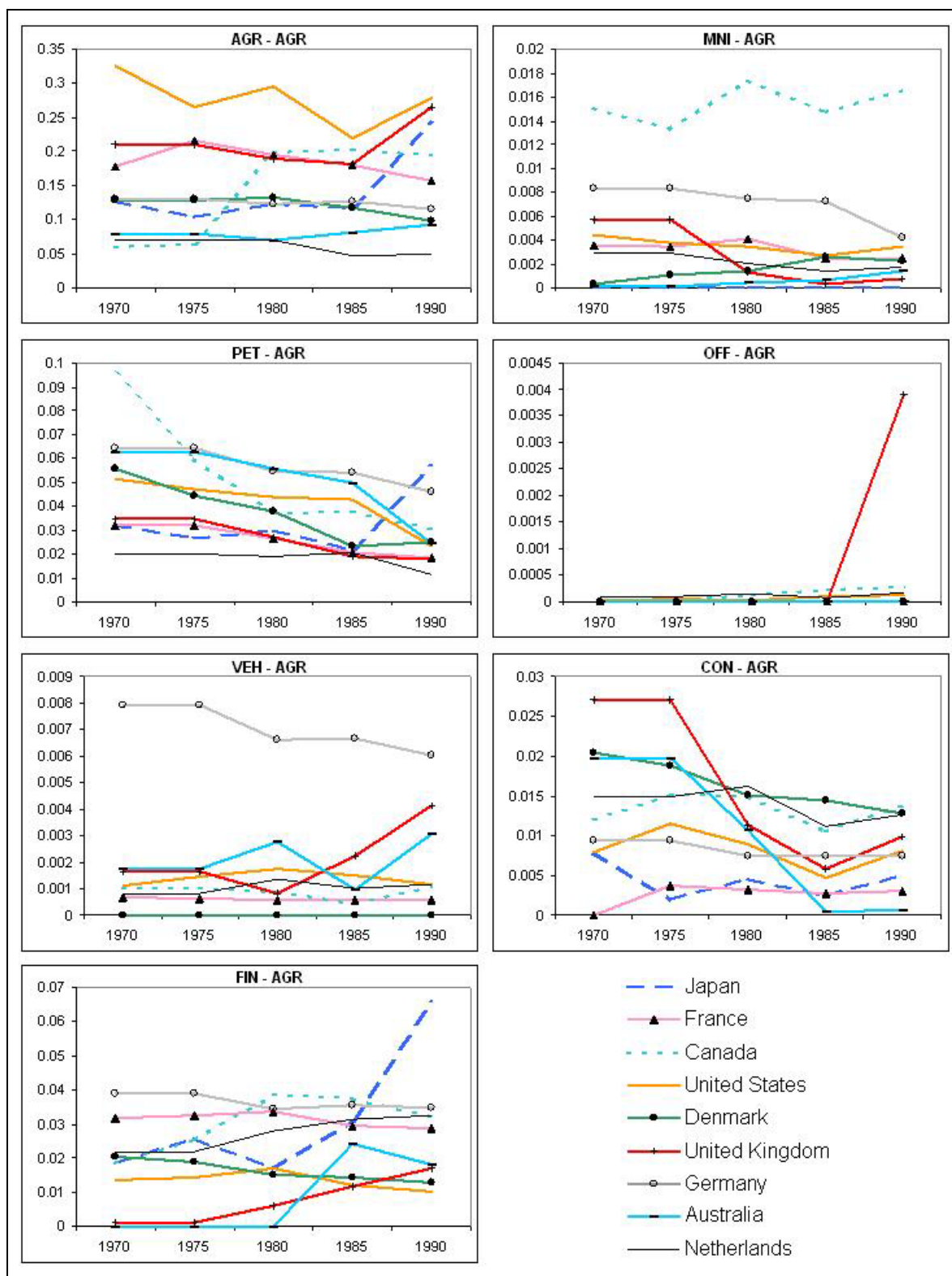


Figure A-15 Technical coefficients: Agriculture, forestry & fishing

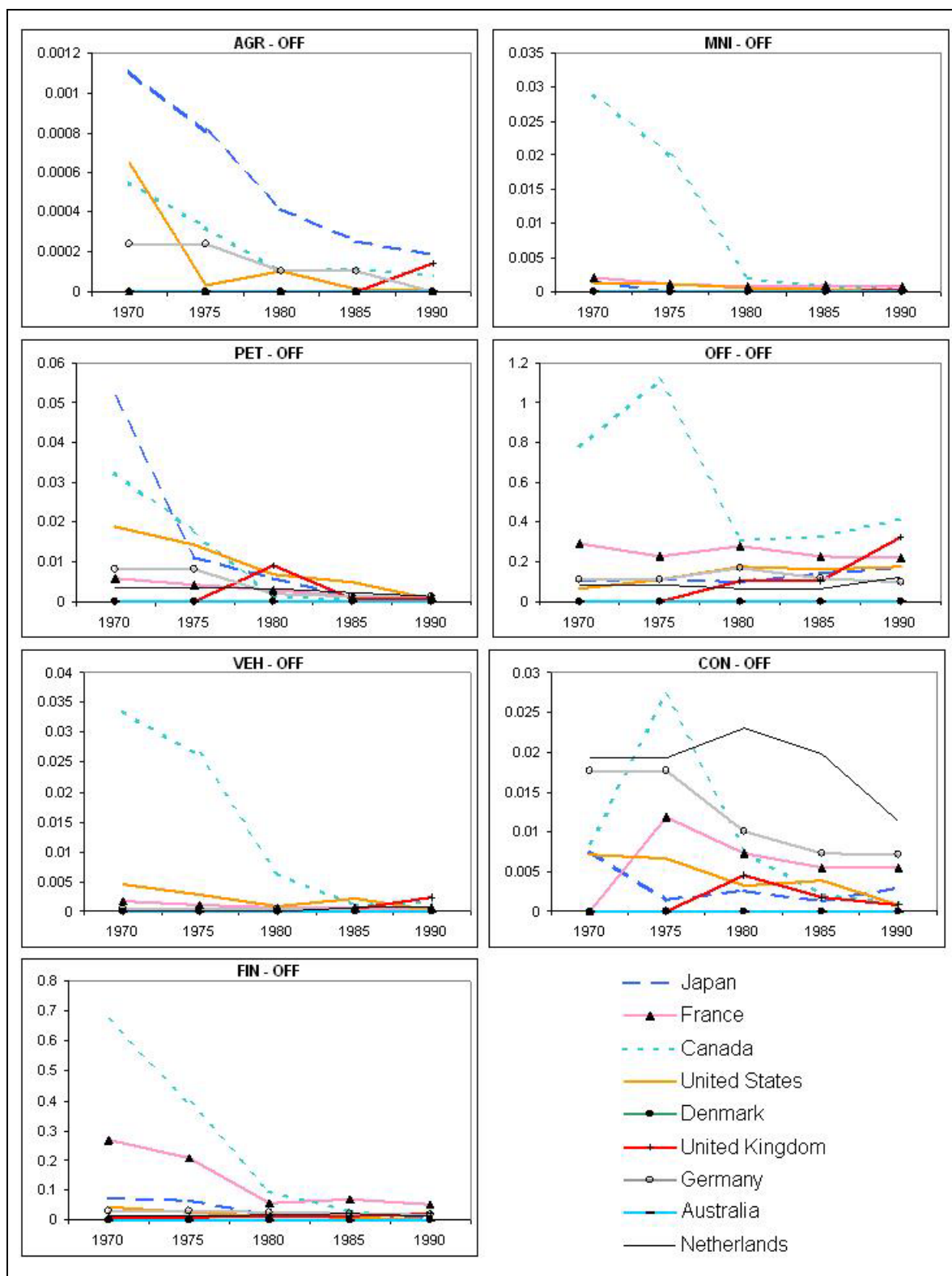


Figure A-16 Technical coefficients: Office & computing machinery

A.3.3 Motor vehicles (VEH)

Figure A-17 shows the I-O coefficients of the motor vehicles sector (the flows of each sector to VEH sector). The technology used for building motor vehicles shows a convergence trend to use less AGR, MNI and PET as inputs for VEH production. This may be observed in almost all countries. An opposite trend is observed in the case of OFF as input, which started to increase in the middle 1980s. The other sectors' coefficients show less regular patterns.

A.3.4 Construction (CON)

Figure A-18 shows the I-O coefficients of the construction sector (the flows of each sector to CON sector). In general, these coefficients have varied little. The major tendency is to decrease. Only the contribution of OFF has risen in all countries.

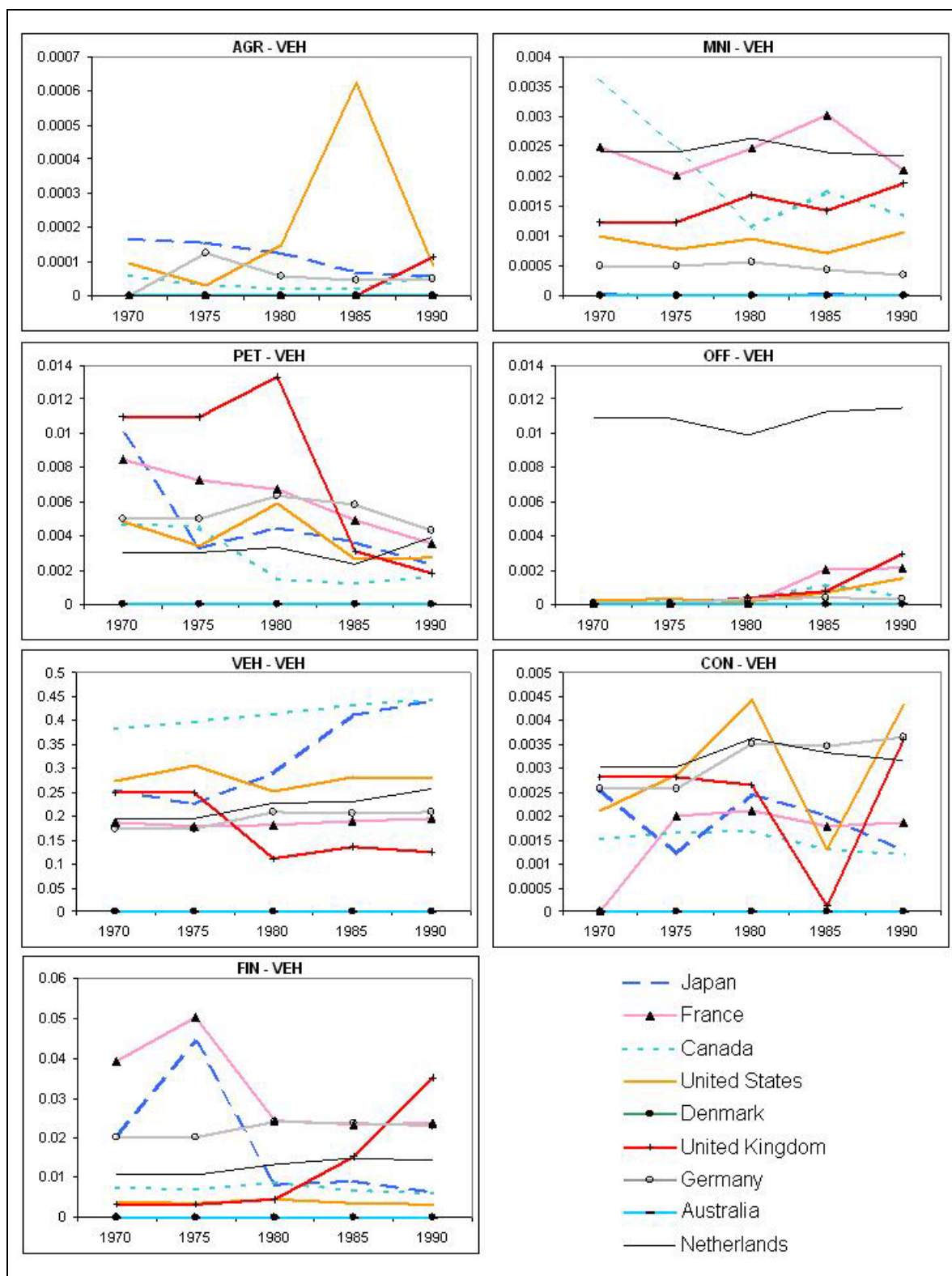


Figure A-17 Technical coefficients: Motor vehicles

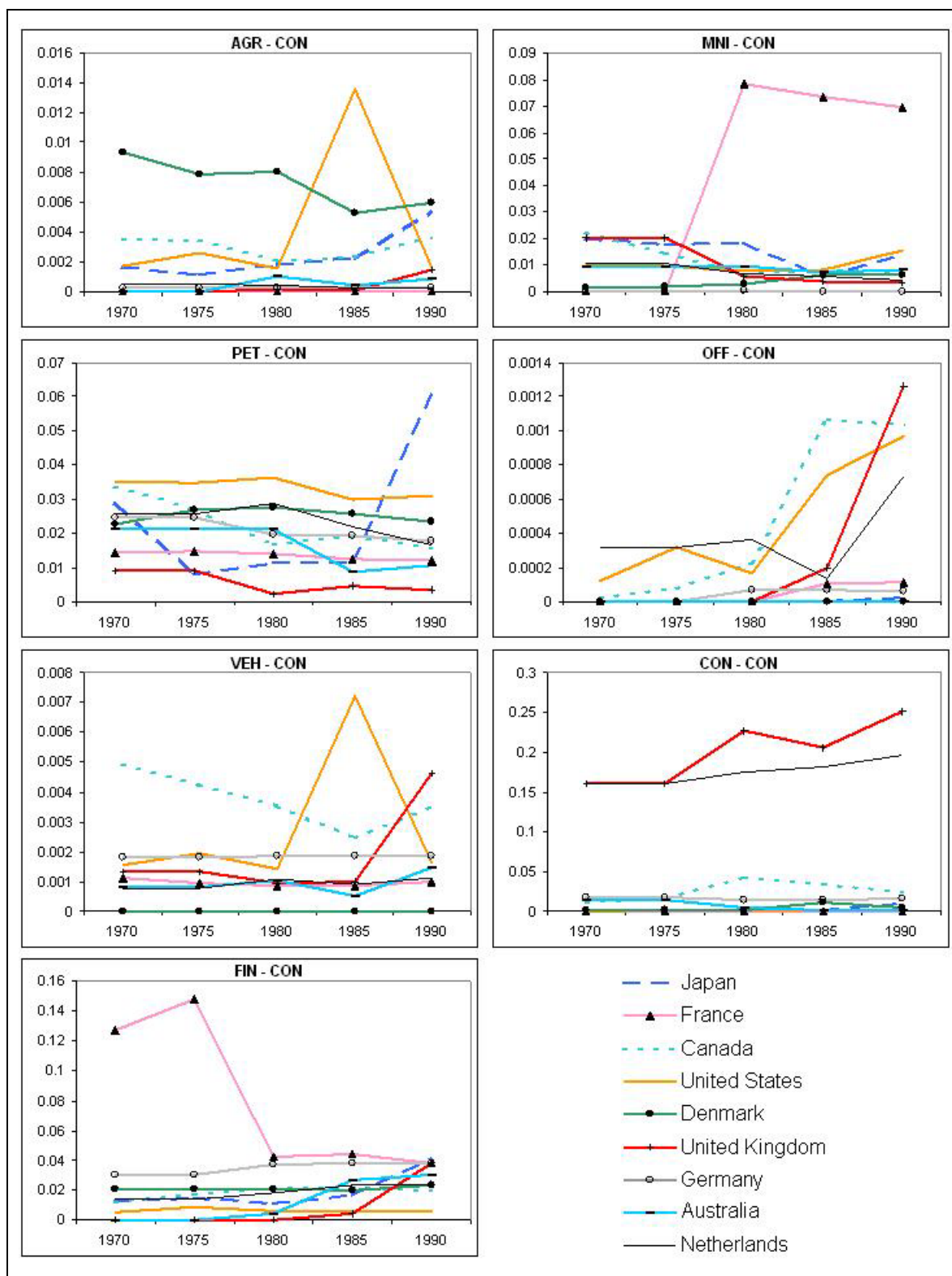


Figure A-18 Technical coefficients: Construction

A.4 Population trends

Figure A-19 shows the trends in country population. Population and income per capita trends could help us understand the relationship between these variables and Final Demand, Gross Output, Exports and Imports trends.

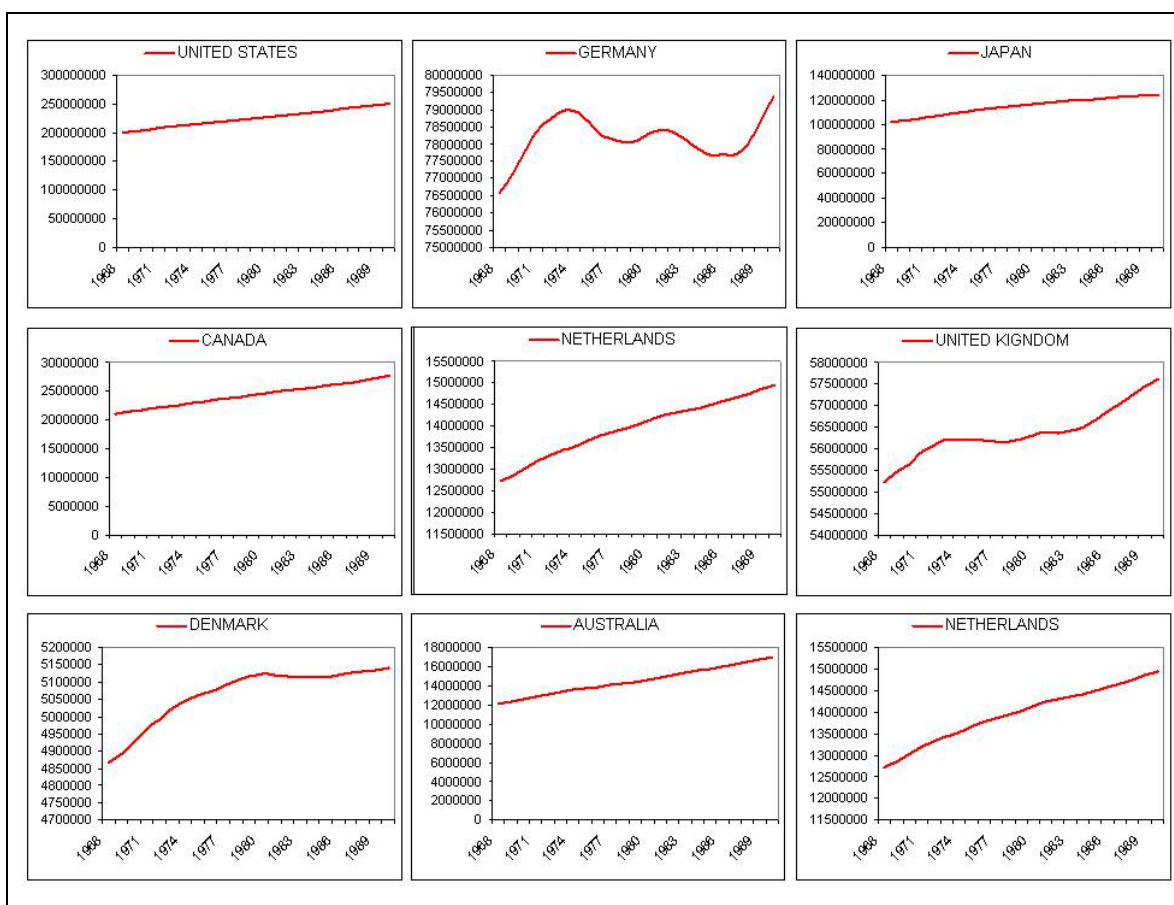


Figure A-19 Population

A.5 Conclusions

The graphical observation of the dynamics in Final Demand, Gross Output, Imports and Exports might be a first step to represent, from a simulation viewpoint, the Leontief Input-Output model. To analyse the dynamics of the above variables, it is important to consider the trends of population and income per capita growth, as they are the main determinant of final demand, and consequently gross output. This could allow a

complete representation of an entire economic system using simulation techniques. Changes in population levels as well as disposable income per capita may change the composition of final demand, which induces change in the gross output, exports and imports of an economic system. These are clear bottom-up processes that may also affect the international trade system. The international trade system, through linkages between countries, might also constrain the export capacities and import requirements, and therefore, the production of a country via the sector-interdependencies. Technological change might change technical coefficients, as it is observed in the figures discussed in this appendix. For these reasons, it is important to study a way of capture the Input-Output dynamic that allows representing countries' economies in the model presented in this thesis. Some preliminary results, not presented here, have been obtained that encourage the use of computer based simulation model to represent the inter-sectoral interdependencies.

Appendix B

WTO and major Regional Trading Blocs

B.1 The World Trade Organisation

The World Trade Organisation is defined [WTO 2001] as the only global international organisation dealing with the rules of trade between nations. At its heart are the WTO agreements, negotiated and signed by the bulk of the world's trading nations and ratified in their parliaments. The goal is to help producers of goods and services, exporters, and importers to conduct their business. It is formed by 142 country members (as of 26 July 2001). Its main functions are:

- To administer WTO trade agreements
- To provide a forum for trade negotiations
- To handle trade disputes
- To monitor national trade policies
- To provide technical assistance and training for developing countries
- To co-operate with other international organisations

B.2 Selected major Regional Trading Blocs

Table B-1 shows the membership of selected major Regional Trading Blocs (also known as Regional Integration Agreements [World Bank 2000]) with the date of formation.

European Union (EU) - 1995: formerly European Community (EC), 1957: Belgium, France, Germany, Italy, Luxembourg, The Netherlands; 1973: Denmark, Ireland, United Kingdom; 1981: Greece; 1986: Portugal, Spain; 1995: Austria, Finland, Sweden.

European Economic Area - 1994: EU, Iceland, Liechtenstein, Norway.

Euro-Mediterranean Economic Area (Euro-Maghreb). Bilateral agreements, 1995: EU and Tunisia; 1996: EU and Morocco.

EU bilateral agreements with Eastern Europe - 1994: EC and Hungary, Poland; 1995: EU and Bulgaria, Romania, Estonia, Latvia, Lithuania, Czech Republic, Slovak Republic, Slovenia.

European Free Trade Association (EFTA) - 1960: Iceland, Liechtenstein, Norway, Switzerland.

Canada-United States Free Trade Area (CUFTA) - 1988: Canada, United States.

North America Free Trade Area (NAFTA) - 1994: Canada, Mexico, United States.

Asia Pacific Economic Cooperation (APEC) - 1989: Australia, Brunei Darussalam, Canada, Indonesia, Japan, Malaysia, New Zealand, Philippines, the Republic of Korea, Singapore, Thailand, United States; 1991: China, Hong Kong, Taiwan; 1993: Mexico Papua New Guinea; 1994: Chile; 1998: Peru, Russia, Vietnam.

Andean Pact - 1969: Bolivia, Colombia, Ecuador, Peru, Venezuela.

Central American Common Market (CACM) - 1960: El Salvador, Guatemala, Honduras, Nicaragua; 1962: Costa Rica.

Southern Cone Common Market (Mercado Común del Sur MERCOSUR) - 1991: Argentina, Brazil, Paraguay, Uruguay.

Group of Three - 1995. Colombia, Mexico, Venezuela.

Latin American Integration Association (LAIA) - formerly Latin America Free Trade Area 1960: revived 1980, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay, Venezuela.

Caribbean Community and Common Market (CARICOM) - 1973: Antigua and Barbuda, Barbados, Jamaica, St. Kitts and Nevis, Trinidad and Tobago; 1994: Belize, Dominica, Grenada, Monserrat, St. Lucia, St. Vincent and the Grenadines; 1983: The Bahamas (part of the Caribbean Community but not of the Common Market).

Cross-Border Initiative - 1992: Burundi, Comoros, Kenya, Madagascar, Malawi, Mauritius, Namibia, Rwanda, Seychelles, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe.

East African Co-operation - 1967: formerly East African Community, broke up in 1977 and recently revived, Kenya, Tanzania, Uganda.

Economic and Monetary Community of Central Africa: 1994: Cameroon, Central African Republic, Chad, Congo, Gabon; 1989: Equatorial Guinea.

Economic Community of West African States (ECOWAS) - 1975: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo.
Common Market for Eastern and Southern Africa: 1993: Angola, Burundi, Comoros, Djibouti, Egypt, Ethiopia, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Rwanda, Somalia, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe.
Indian Ocean Commission - 1984: Comoros, Madagascar, Mauritius, Seychelles.
Southern African Development Community (SADC) - 1980: formerly known as the Southern African Development Co-ordination Conference, Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia, Zimbabwe; 1990: Namibia; 1994 South Africa; 1995: Mauritius; 1998: Democratic Republic of Congo, Seychelles.
Economic Community of West Africa - 1973: revived in 1994 as West African Economic and Monetary Union: 1994: Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal, Togo; 1997: Guinea-Bissau.
Southern African Customs Union (SACU) - 1910: Botswana, Lesotho, Namibia, South Africa, Swaziland.
Economic Community of the Countries of the Great lakes - 1976: Burundi, Rwanda, Democratic Republic of Congo.
Association of Southeast Asian Nations (ASEAN) - 1967: ASEAN Free Trade Area was created in 1992: Indonesia, Malaysia, Philippines, Singapore, Thailand; 1984: Brunei Darussalam; 1995: Vietnam; 1997: Myanmar, Lao People Democratic Republic; 1999: Cambodia.
Gulf Co-operation Council (GCC) - 1981: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates.
South Asian Association for Regional Co-operation - 1985: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka.

Table B-1 Membership of selected major Regional Integration Agreements.
Source: WTO data [World Bank 2000].

Appendix C

Patterns of trade

C.1 Introduction

This appendix presents an algorithm that determines the ‘best pattern’ of trade among all the possible combinations of patterns between countries. The algorithm starts with import requirements, export capacities, prices and tariffs by sector for each country, and transport costs between countries. Its basic idea is that a country buys a quantity of commodities from the country that offers the best price. If that is not possible, it looks for the next one until all its import requirements are satisfied. In order to select the “best pattern” the algorithm includes a clearing condition (the minimum between the maximum import requirements and the maximum export capacities traded) and an optimisation condition (minimising the total amount of monetary expenditures on world trade by sector). It is then possible to find a solution of the ‘best’ pattern of trade by sector chosen from all the possibilities.

As stated in Chapter 7, the algorithm was generalised by giving to the user the possibility to decide between the following cases: (i) countries buy the maximum amount available at the best price of the market; (ii) countries buy a proportion, set by user, of the maximum amount available at the best price of the market. The process is repeated k times until the countries fulfil their import requirements. The first case (the only one presented in this appendix) supposes that countries buy only once per period; for example, once a year if the period of time is the year. The second case simulates the buying process as a discrete one that occurs in k times during a time period; for example, once a week. Experiments were carried out with both cases. Preliminary results of the second case are similar to the results of the first one. For this reason, in this appendix as

in chapter 8, only the results of the first case are presented. However, the idea of case two is worth to further research.

C.2 The algorithm¹

C.2.1 Description

We suppose nc countries (nc = number of countries). A buyer (importer) country is represented by r and a seller (exporter) country is represented by c . Each country has s aggregated sectors. In this appendix the algorithm is presented using an example with 6 countries ($nc = 6$) and the following five sectors ($s = 5$): AGR for agricultural products, MNI for mining products, CON for construction, MAN for manufactures, and SER for services². For each sector we know the import requirements (the amounts every country wishes or requires to buy in the international markets) and the export capacities (the amounts it is willing to sell). Let us represent these quantities as:

$$x[r, j] \quad r = 1, 2, \dots, 6; j = \text{AGR, MNI, } \dots, \text{SER}$$

$$m[c, j] \quad c = 1, 2, \dots, 6; j = \text{AGR, MNI, } \dots, \text{OTH}$$

where $x[r, j]$ is the quantity of commodity j country r will try to export in the international market and $m[c, j]$ is the quantity of commodity j country c will try to import from the international market. Perfect competition is assumed among products of the same sector. This means, each country c will buy indifferently from any of the remaining countries taking into consideration only prices.

Additionally, we know the sectors' selling prices. The tariffs each country fixes for importing commodities are equally known. $P[r, j]$ is the price country r asks for commodity j and $ta[c, j]$ is the tariff country c imposes when importing commodity j .

¹ The algorithm was programmed using GLIDER simulation language [Domingo et al. 1993].

² We decided to use 6 countries and 5 sectors in order to reduce the amount of data in the presentation. The algorithm works well with larger number; experiments were done using many more sectors and countries.

$tr[r, c]$ is the transport cost of one unit of any commodity from country r to country c .

It is assumed that

$$tr[c, r] = tr[r, c] \quad \text{Equation 1}$$

which means that the cost of transport from country r to country c is equal to the cost of transport from country c to country r ; and that

$$tr[c, c] = 0 \quad \forall c \quad \text{Equation 2}$$

which means that there is no cost of transport for a country c with itself, because there is no international trade with itself.

Each country calculates how much it must pay for a unit of commodity if it decides to buy that commodity from a particular country. In fact, the country does this for all other countries. P_c is the total price country c must pay to country r if it decides to buy a unit of commodity j , as indicated in Equation 3³:

$$P_c[r, j] = (P[r, j] + tr[r, c]) * (1 + ta[c, j]) \quad \text{Equation 3}$$

which indicates the effective price a country c pays for the commodity (sector) j produced by country r , obtained by the sum of sector price, transport costs and tariffs.

At this point, country c is in a position to rank the other countries ($cn - 1$, excluding itself) in ascending order of seller. For example, a particular order of countries for country 1 in agriculture (AGR) sector might be

$$3 \quad 6 \quad 2 \quad 4 \quad 5$$

which can be interpreted as

$$P_1[3, AGR] < P_1[6, AGR] < P_1[2, AGR] < P_1[4, AGR] < P_1[5, AGR] \quad \text{Equation 4}$$

or in other words, in the AGR sector, country 1 prefers to buy its import requirements first from country 3, second from country 6, and so on.

³ This is a reduced form of the more general calculation of commodity prices. See for example Woznick [2000, p.58].

Additionally, country c tries to buy the maximum of imports on a particular sector from that country which is ranked first as seller (minimum P_c) as explained above. However, it can be constrained by the quantity of exports the counterpart has available for exporting.

If $x[r, j] \geq m[c, j]$, then c buys the amount m to country r and completely satisfies its demand on j . At the same time, country r decreases the amount x by m , so now it has less to offer ($x - m$) to new buyers.

On the contrary, if $x[r, j] < m[c, j]$, then c buys the quantity x from r and tries to cover the difference ($m - x$) by trying to buy from the next country according to the P_c order and so on.

Country c will do this repeatedly until it has satisfied its import requirements.

The above algorithm is executed for all the countries. One of them must begin the ‘negotiation’, meaning it has the opportunity to satisfy its import requirements at minimum cost P_c according to the order given by its respective Equation 4.

Clearly, the pattern of trade the algorithm yields is biased in favour of the countries that have decided at first how much and from whom to buy what commodity, because they take advantage of buying from their better sellers. In order to prevent this bias, it might be convenient to calculate all the patterns generated for the different combinations of countries' orders as buyers.

In particular, if there are only two countries (1 and 2), the orders are necessarily:

$$\begin{array}{cc} 1 & 2 \\ 2 & 1 \end{array}$$

or, in other words, in the first order country 1 is the first to buy and country 2 the second, in the second order country 2 is the first to buy and country 1 the second.

Alternatively, if there are 3 countries (1, 2 and 3), then it is necessary to try the pattern of trade generated by the following orders:

1	2	3
2	1	3
3	2	1
2	3	1
1	3	2
3	1	2

which shows that we are considering a combinatorial number of possibilities equal to $nc!$ (nc factorial)

If $nc = 2$, the number of possible trials will be $2! = 2$

If $nc = 3$, the number of possible trials will be $3! = 6$

If $nc = 6$, the number of possible trials will be $6! = 720$

The algorithm is run for each order of countries (720 times in the numerical example that is shown in section C.3 below). Each run gives the pattern of trade for the particular order in a specific sector.

A particular order of countries could represent which country has the advantage of ‘arriving first’ in the negotiation. So, it can satisfy its imports requirements completely at least cost.

C.2.2 Clearing condition

Only those patterns of trade which guarantee any country to sell all its export capacities or to buy all its import requirements are valid. This is a constraint that is called here a clearing condition over the patterns of trade. At a world level, the maximum import requirements and/or the maximum export capacities are traded. It will depend on which one is the smallest. By doing so, each country will be better-off because it manages to reach its international trade objectives (expressed by its export capacities and import requirements). This may be thought as a measure of effectiveness of markets in the sense that all the desired transactions are satisfied if possible.

The clearing condition may be written as:

$$\text{Max } (x[r, j]) \text{ is traded } \quad \forall r \text{ in sector } j \quad \text{Equation 5}$$

or

$$\text{Max } (m[r, j]) \text{ is traded } \quad \forall r \text{ in sector } j \quad \text{Equation 6}$$

C.2.3 The trade matrix by sector

It is possible to record the quantities of products by sector a country exports to others. Let us define $Strade[j, r, c]$ as the quantity (units of commodities) in sector j , country r exports to country c (or, alternatively, country c imports from country r). Let us also define $trade[j, r, c]$ as:

$$trade[j, r, c] = Strade[j, r, c] * P_c[r, j] \quad \text{Equation 7}$$

which gives the amount of trade in currency units, say \$ (where P_c is the price as defined in Equation 3). Each pattern of trade has associated a particular *trade* matrix, which is the result of a particular combination of trade priority (which country started trading).

C.2.4 Optimisation condition

It may be possible to find many sequential purchase orders for which the above clearing condition holds. This gives us a subset of feasible patterns. We know interchanges take place in reality only in one way. So, the question is which one of those previously found alternatives could serve as a proxy of the parallel interchanges? We propose to choose the sequential purchase order that reduces the total costs of world trade. Countries agree to spend collectively as little money as possible on trade. In other words, we are choosing the more efficient sequential order.

C.2.5 Total trade matrix

The algorithm described above is run for all sectors. This means that for each sector a particular pattern of trade is found. Having all the export values a country r sells to a counterpart country c (in all sectors), we can add them together to find the total value

of exports, and write it as $Ttrade[r,c]$, where $Ttrade[r,c]=0$ if $r = c$, which means a country does not trade with itself.

It is important to emphasise that $Ttrade[r,c]$ amounts are in monetary units. So we can calculate the total world trade value using Equation 8:

$$Ttrade[r,c] = \sum_j trade[j,r,c] \quad \forall j \quad \text{Equation 8}$$

C.3 A numerical example

Table C-1 shows the export capacities and the import requirements in manufacture sector for countries C1, C2, .. C6 respectively. These are the quantities (in units of products) each country wants to exchange in the international market.

	C1	C2	C3	C4	C5	C6
Export capacities	883	220	378	283	1230	157
Imports requirements	1103	283	315	473	757	220

Table C-1 Export capacities and import requirements in manufactures

Table C-2 shows the prices in manufacture sector each country C1, C2, .. C6 asks others.

C1	C2	C3	C4	C5	C6
4.0	6.0	5.5	4.0	2.1	3.5

Table C-2 Prices in manufactures

Table C-3 shows the transport costs between countries. This matrix is symmetrical because we are assuming that the cost of transportation from a country to another is the same the other way around.

	C1	C2	C3	C4	C5	C6
C1	0.00	0.17	0.28	0.31	0.36	0.41
C2	0.17	0.00	0.16	0.38	0.33	0.35
C3	0.28	0.16	0.00	0.42	0.39	0.32
C4	0.31	0.38	0.42	0.00	0.12	0.29
C5	0.36	0.33	0.39	0.12	0.00	0.11
C6	0.41	0.35	0.32	0.29	0.11	0.00

Table C-3 Transport costs between countries

Table C-4 shows the tariffs between countries. For the purpose of this example, we are assumed that the tariff is the same for all countries (100% of the total price P_c). Thus, only transport cost and prices determine the pattern of trade in this example.

	C1	C2	C3	C4	C5	C6
C1	0%	100%	100%	100%	100%	100%
C2	100%	0%	100%	100%	100%	100%
C3	100%	100%	0%	100%	100%	100%
C4	100%	100%	100%	0%	100%	100%
C5	100%	100%	100%	100%	0%	100%
C6	100%	100%	100%	100%	100%	0%

Table C-4 Tariffs between countries

The application of the algorithm with the above data produces the following results.:

- i. The clearing condition finds 274 out of 720 (total permutations) feasible patterns.
- ii. The optimisation condition finds order #420 as the best order. However, orders #415, #416, #417, #418 and #419 also give the same pattern of trade. This is because the pattern is the same whatever order C4, C5 and C6 buy in first place and C1, C2 and C3 buy successively in that specific order.
- iii. Best order of countries:

#420: C6 C4 C5 C1 C2 C3; trade in MAN: \$23810.8

However these orders also give the same patterns of trade:

#415: C4 C5 C6 C1 C2 C3; trade in MAN: \$23810.8
 #416: C5 C4 C6 C1 C2 C3; trade in MAN: \$23810.8
 #417: C6 C5 C4 C1 C2 C3; trade in MAN: \$23810.8
 #418: C5 C6 C4 C1 C2 C3; trade in MAN: \$23810.8
 #419: C4 C6 C5 C1 C2 C3; trade in MAN: \$23810.8

iv. Pattern of trade:

Table C-5 shows the pattern of trade for sector MAN given by the best order (#420). For example: using rows, it is possible to see that country C1 exports 283 units of MAN to country C2, 283 to C3 and 317 to C5. This allows C1 to sell all its export capacity (883 units of MAN).). Similarly, using columns, it is possible to see for example that country C1 imports 188 units from C2, 378 units from C3, and 537 units from C5. This allows C1 to buy all its import requirements (1103 units of MAN). In this example, all countries have reached their intentional trade objectives (expressed by their export capacities and import requirements). If this is not the case, as indicated in Chapter 7, part of the amount not satisfied is transfer to the next period of time.

	C1	C2	C3	C4	C5	C6	Total
C1	0	283	283	0	317	0	883
C2	188	0	32	0	0	0	220
C3	378	0	0	0	0	0	378
C4	0	0	0	0	283	0	283
C5	537	0	0	473	0	220	1230
C6	0	0	0	0	157	0	157
Total	1103	283	315	473	757	220	

Table C-5 Strade (units of products) in sector MAN given by order #420

v. Trade in monetary units:

Moreover, Table C-6 shows the amount of trade in monetary units (\$) in sector MAN. Adding up all the values shown in Table C-6 gives the amount of world trade in sector MAN, which is the minimum according with the optimisation condition described in subsection C.2.4.

	C1	C2	C3	C4	C5	C6
C1	0	2360.2	2422.5	0	2764.2	0
C2	2319.9	0	394.2	0	0	0
C3	4369.7	0	0	0	0	0
C4	0	0	0	0	2331.9	0
C5	2642	0	0	2100.1	0	972.4
C6	0	0	0	0	1133.5	0

Table C-6 Trade (\$) in sector MAN given by order #420

All the amounts of world trade given by the 274 feasible orders are plotted in Figure C-1. Each pair of points represents the amount of world trade in monetary units (y axe) obtained by one of the 274 feasible orders (x axe). In Figure C-2, the same pair of points are plotted in ascending order to present better which gives the min. amount of world trade. In both figures, we have highlighted the group of best orders (#415, #416, #417, #418, #419 and #420) that give the minimum amount of trade at the world level of \$23810.8.

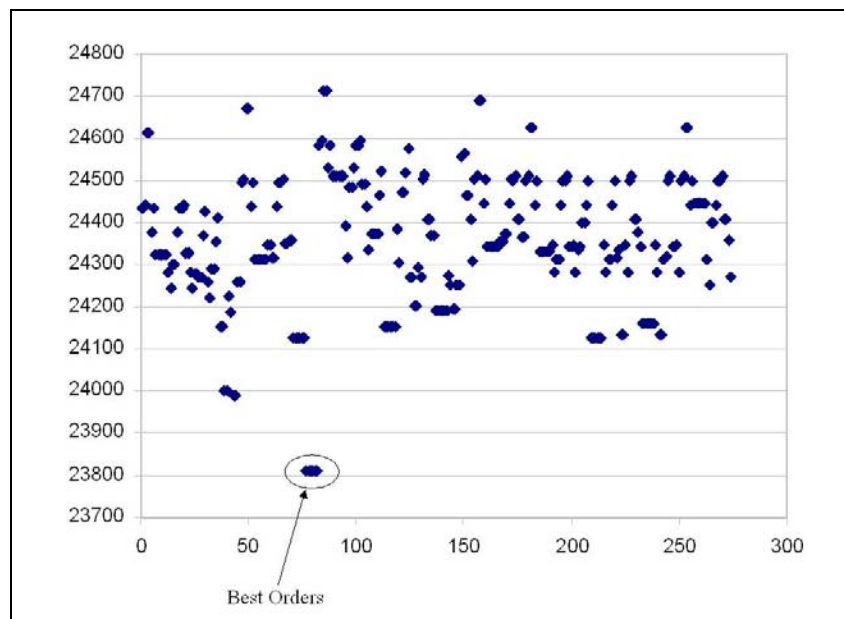


Figure C-1 Scatter of the amount of trade (\$) in sector MAN, given by the 274 feasible orders

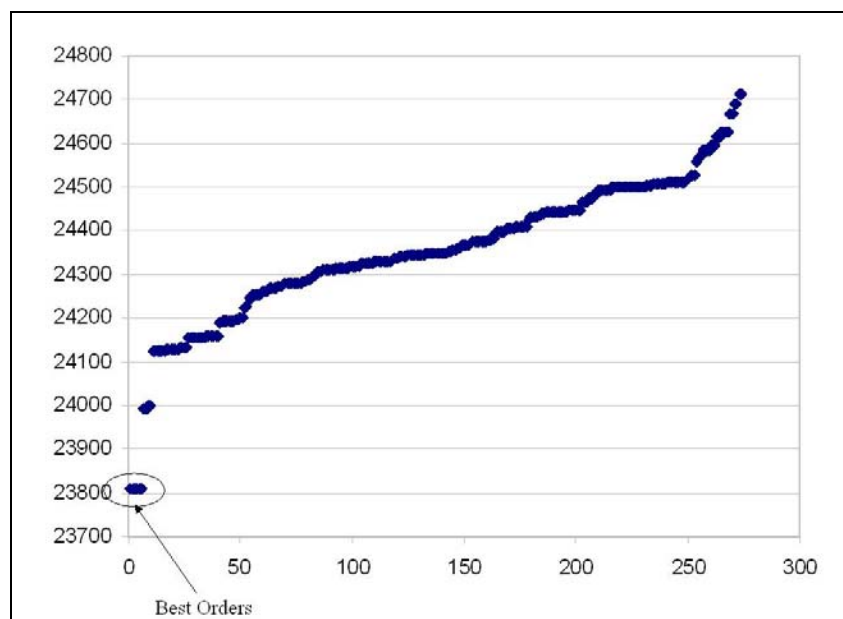


Figure C-2 Ascending arrangement of the amount of trade (\$) in sector MAN, given by the 274 feasible orders

C.4 Conclusions and further research

The algorithm, presented in this appendix, produces results that are acceptable. It was used in the experiments of Chapter 8 with the developed model. However, further research, is worth exploring among other the following possible extensions:

- To verify what happens to each country's 'welfare'. A country is better off if it pays the minimum value for its imports requirements and receives the maximum value for its exports. It is interesting to compare the patterns of trade that satisfy these welfare conditions instead of the pattern obtained by the optimization condition chosen (for example the pattern that minimises $Ttrade$). It might be interesting to ask: is there a criterion that allows us to establish the best pattern of trade for all countries collectively to improve their terms of trade? For example, it may be possible to maximise the difference between total value of exports minus total value of imports. The interesting point is that this opens a door to policy analysis and interdependence.
- To probe further into the algorithm, to see what happens if besides the best price order, each country knows an international quality ranking of countries by sector, which means, they can choose between quality ranking as well as price ranking, or

maybe a trade-off in between. Clearly, this would increase the range of possibilities, if we want to maintain the deterministic way of finding the patterns of trade.

- To experiment further with the generalised algorithm (subsection C.1) by giving the possibility to all countries to buy some amount to their best sellers.

Of course, in the real world one does not explicitly work all the involved calculations before deciding whom to buy from and how much. Moreover, many other variables are used when countries take such decisions. Nevertheless, the above algorithm might lead us to explore the complexity we observe inside a network of transactions such as that emerging in international trade.

Appendix D

Results of the basic simulation run

D.1 Introduction

In this appendix we present graphically the results obtained with the basic simulation run for the following sectors: mining products (Figure D-1), manufactures (Figure D-2) and services (Figure D-3). This serves to compare the results obtained through the selected experiments presented in Chapter 8. We also present the trends of prices as they were used in the simulation (prices are presented by country, Figure D-4, and by sector, Figure D-5). Finally, Figure D-6 presents the patterns of trade obtained.

D.2 Sector: Mining Products

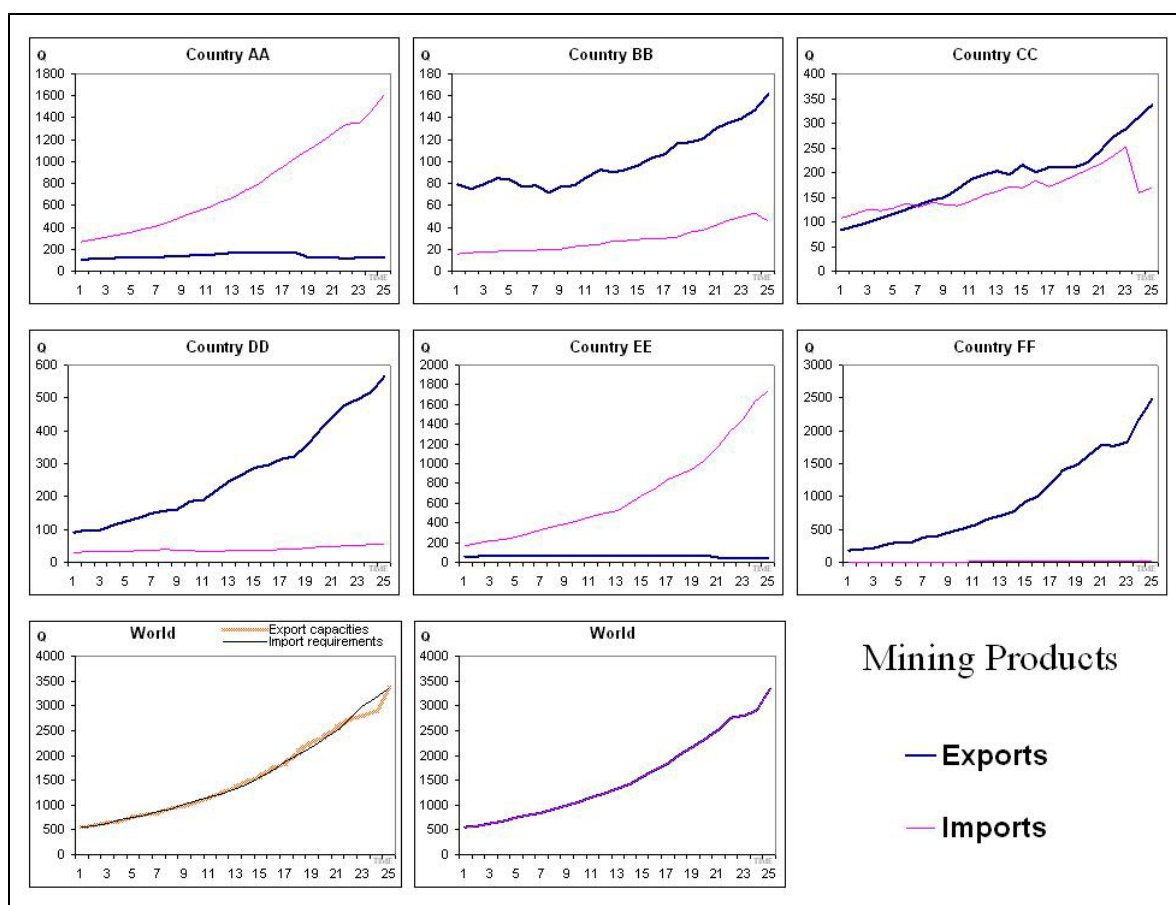


Figure D-1 Mining products: Exports and Imports

D.3 Sector: Manufactures

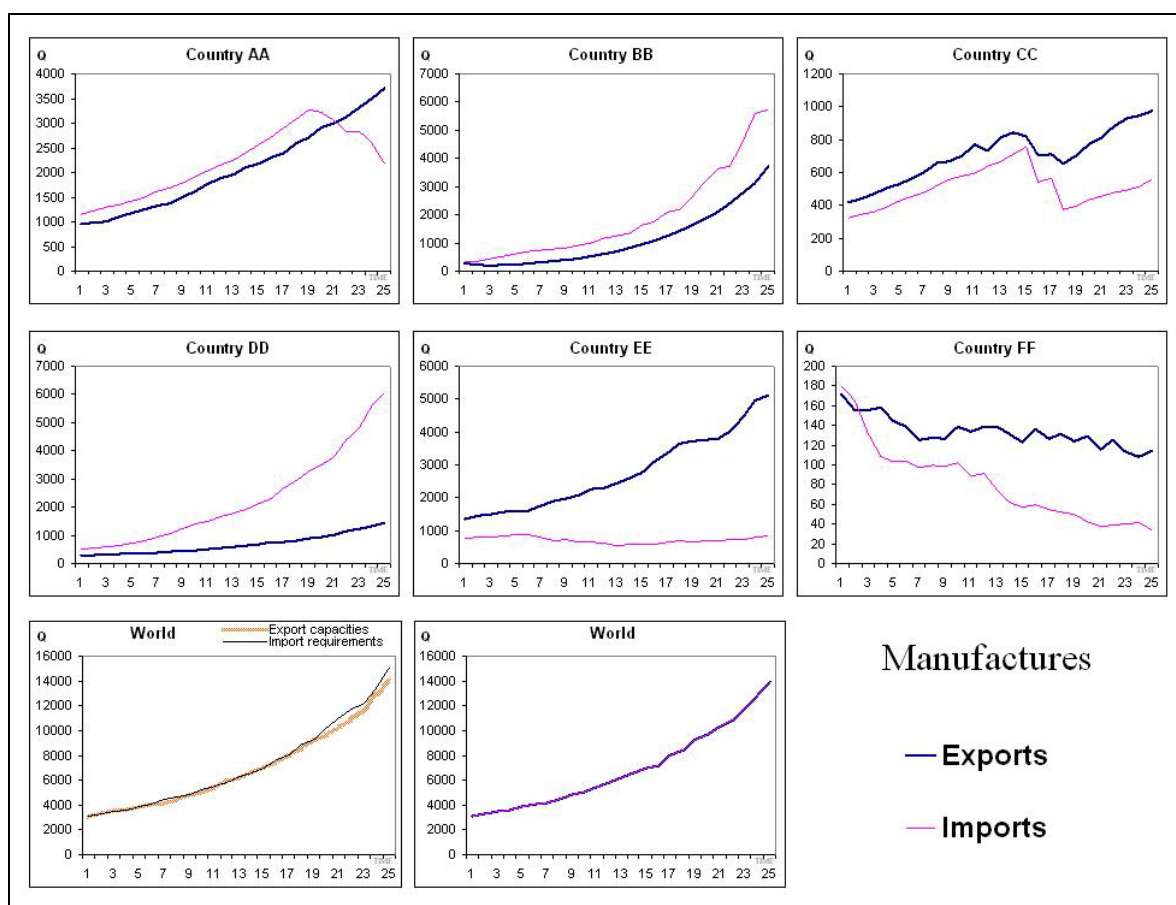


Figure D-2 Manufactures: Exports and Imports

D.4 Sector: Services

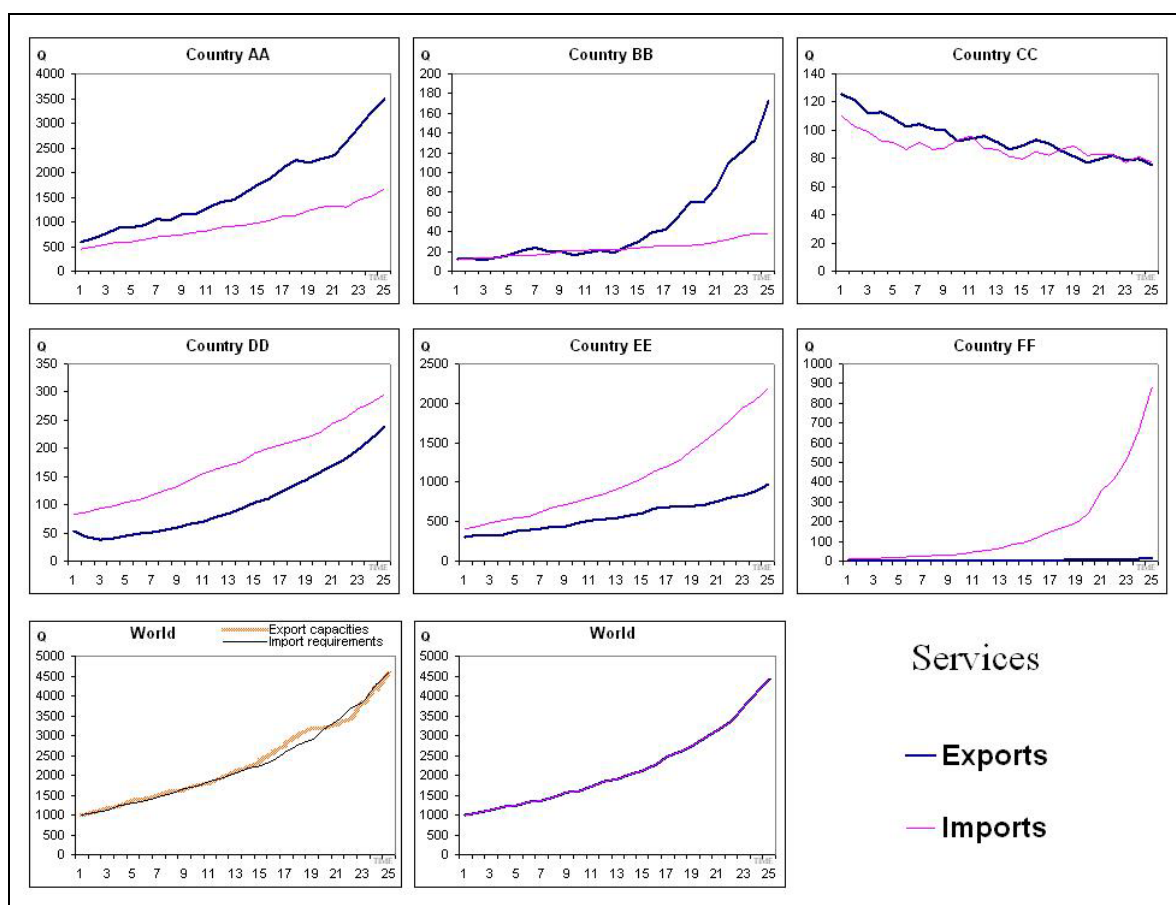


Figure D-3 Services: Exports and Imports

D.5 Prices by country

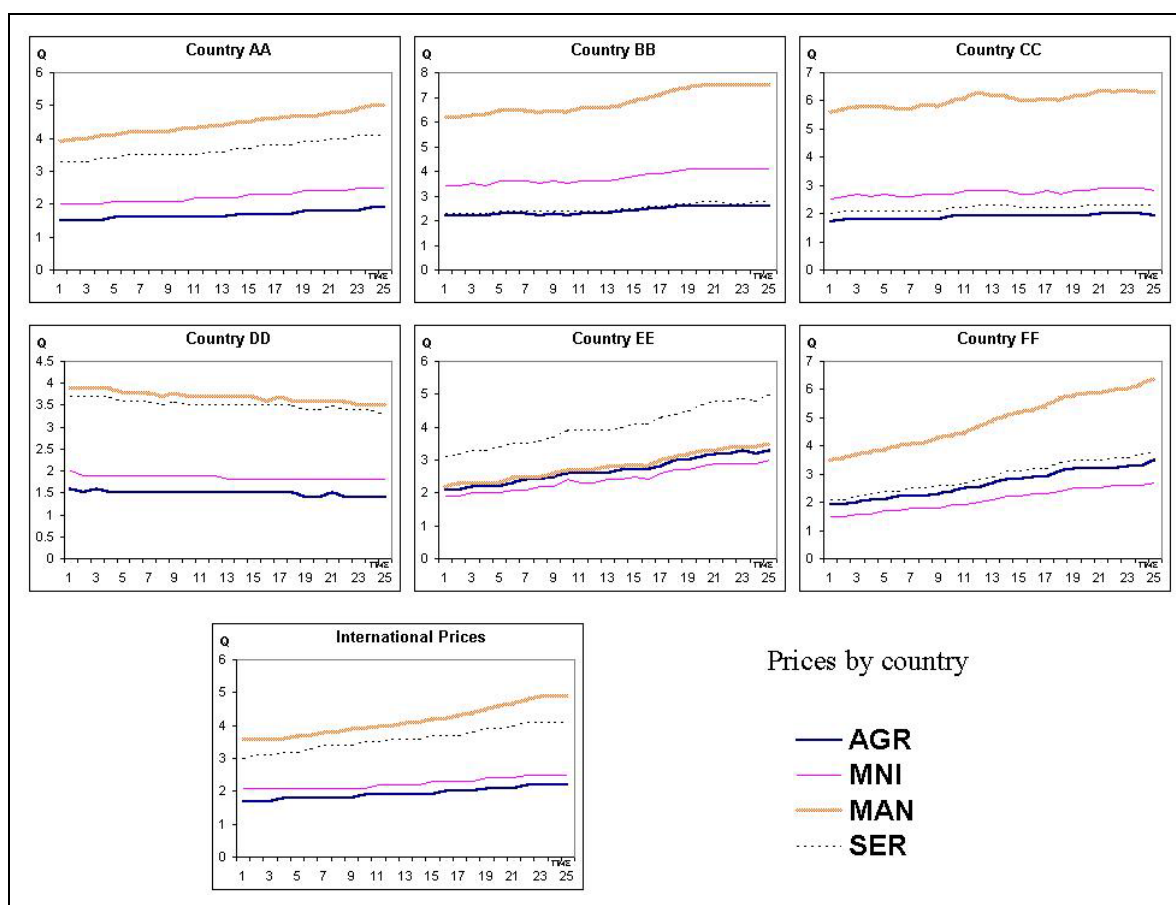


Figure D-4 Prices by country

D.6 Prices by sector

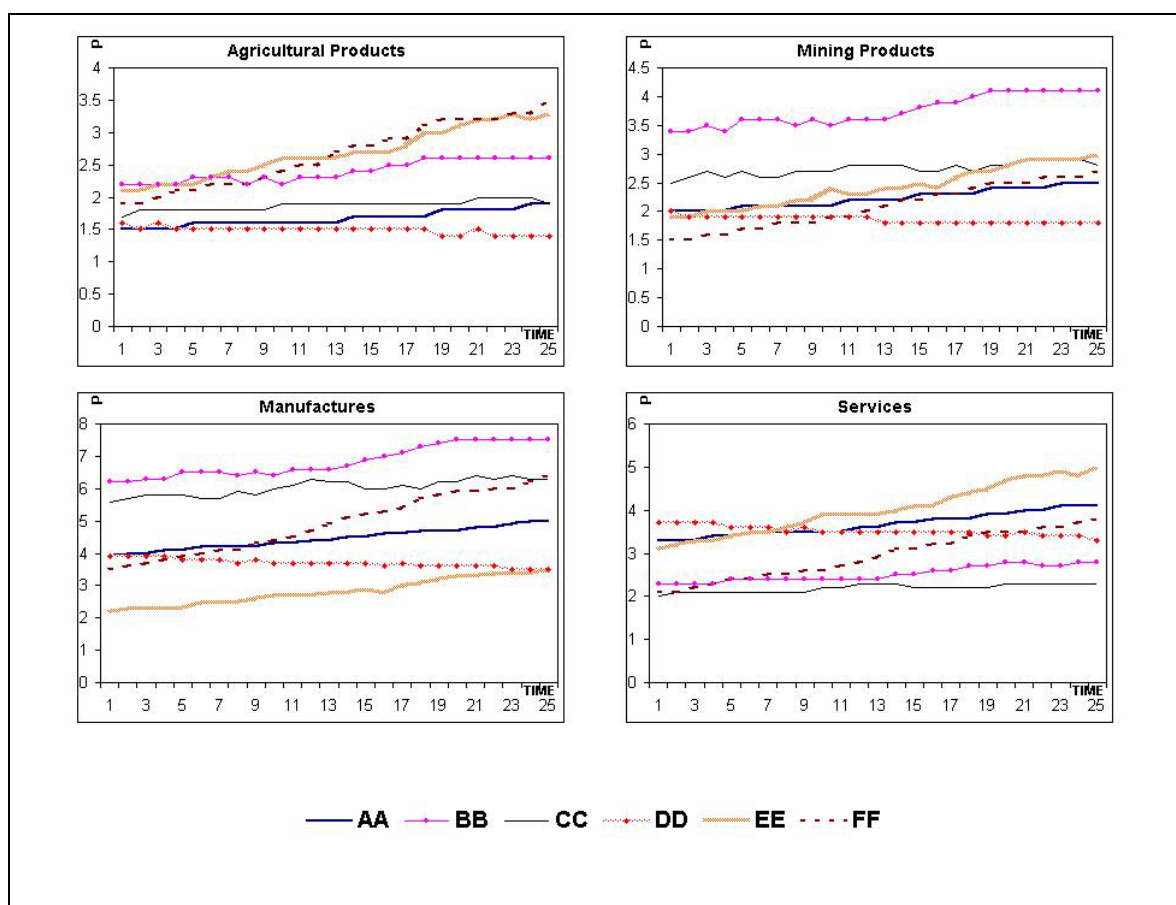


Figure D-5 Prices by sector

D.7 Terms of trade

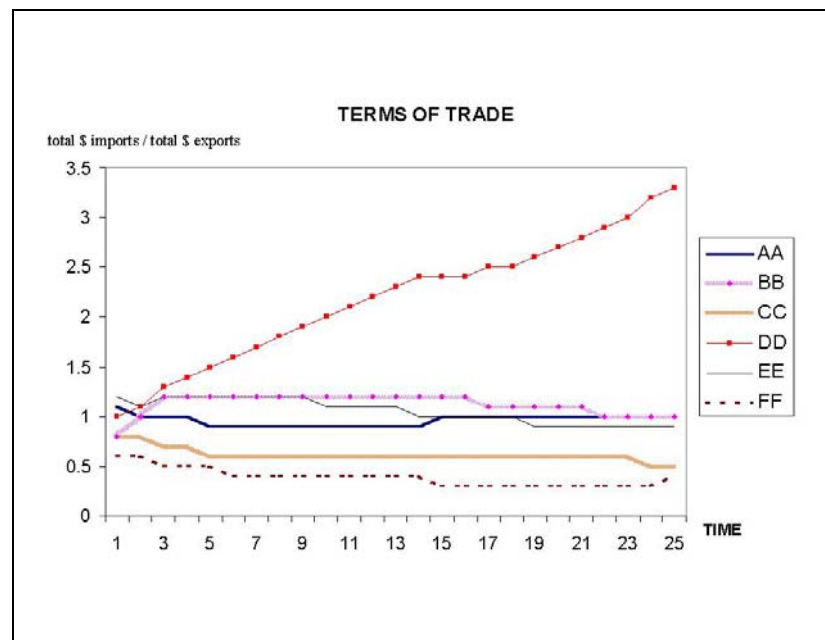


Figure D-6 Terms of trade

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