ENDOGENOUS DISINVESTMENT ACTIVITIES AND THE TRANSFORMATION TO A NEW EQUILIBRIUM

A COMPUTABLE GENERAL EQUILIBRIUM APPROACH

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by
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Preface

In the past three decades we have seen a rapid development in applied equilibrium economics. In particular, the area of the computable general equilibrium (CGE) model has been very progressive. The sectoral allocation of business investment of fixed capital is very important of the CGE model, as well as any equilibrium model, to our understanding of economic activity.

However, the change of the capital stock is a dynamic process in a dual sense dismantling of old investments subject to physical or economic deterioration, and investment in new and more efficient machines brought into production. Both components of this process must be taken into consideration when the effects of long-term policy measures are under discussion.

The contribution in this book is the explicit recognitation of the importance of endogenous disinvestment activities to a new equilibrium. This is embodied in the condition specifying the economic life of capital to account for obsolescence. Thus, the transformation process will be endogenously specified in the model.

After the introduction, the two first chapters of this book provides a review of the linear activity model and its further development in the CGE model. The three last chapters develops the disinvestment process and its integration in the CGE model.

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CHAPTER 1

Introduction

A common characteristic in many economies is the the failure to meet the demands for structural change in the industrial sector of the economy. Economic disequilibrium will arise in both developed and underdeveloped economies. Often they are faced with changes in external conditions that will require major adjustments. The structural lack of equilibrium will accentuate the problems facing stabilisation policy (rising inflation and unemployment). In a longer view, the industrial sector contracts and the problem of external balance may become permanent. Moreover, the increased mobility of capital, skills and entrepreneurship, now as the core of the process of globalisation, has become even more important as a vehicle for international transactions. Increasing technological achievements, the adoption of investment liberalisation policies by many countries, privatisation, and the switch of emphasis by firms to geographical diversification, are some of the more important explanations to the strong expansion in structural change recorded in the past two decades. A natural question in this situation concerns the elaboration of an economic policy necessary to increase the adaptability of the industrial sector to meet the demand for structural change.

For a country where international trade represents a significant proportion of the economic activity the equilibrium of the domestic economy, is to a great extent determined by the conditions given abroad. Against this background, a crucial factor for each individual country is to the extent the industry sector can adjust to changes in foreign market conditions. To provide the formal link between changes in foreign market conditions and changes in domestic production capacity the adjustment process must also include economic transformation, i.e transferring resources from uncompetitive to more expansive sectors of the economy.

The contribution in this book is the explicit recognitation of the importance of endogenous disinvestment activities to a new equilibrium. This is embodied in the condition specifying the economic life of capital to account for obsolescence. As is discussed in greater detail later, this specification provides the formal link between capital formation and production capacity. Thus, the transformation process will be endogenously specified in the model.

The aim is here to present an economic structure what is representative for the process of structural transformation in an open economy. In technical terms, our economic structure is illustrated by the help of a computable general equilibrium (CGE) model. The model will be simple enough to be presented in a few pages, and yet complicated enough to demonstrate the key parts of the methodology.

1. 1 *Statement of the Problem*

If two countries engage in trade, each is assumed to have incentives to increase domestic production, and reduce consumption, of commodities in which it has the lower relative marginal cost prior to trade than the other.[1] In a free trade equilibrium, each country will export such commodities. In the theory of international trade, free trade raises the level of potential welfare (measured in terms of commodities) for a country above the level reached in autarchy. The increase in potential welfare can be subdivided into the gains from exchange that will result then commodities are obtained at lower prices from abroad, and the gains in domestic production from specialisation in the commodities in which the country has a comparative advantage.[2] Technically, this problem involves the choice between domestic production and imports, and between production for the domestic market or exports in different sectors of the economy. Only by evaluation of the economic efficiency of the industrial choices using the opportunity cost of resources can an

[1] We make the usual assumption that the agents are countries. This is a fiction. Except in centrally planned economies, trade is conducted by individual actors rather than by governments.

[2] Ricardo (1817) developed the doctrine of comparative advantage which showed that all nations can benefit from trade whatever their cost structure.

economic choice be made. From a formal point of view, CGE models is capable of handling this type of problem.

In close connection to the problem mentioned above, is the problem of structural change. In fact, structural change is more or less ubiquitous in an economy with free trade, and possibility to domestic specialisation. The problem of structural change has two interrelated aspects. One is the need to close down uncompetitive capacity. The other is the lack of expansion in potentially competitive parts of industry, to be solved only by transferring resources from uncompetitive to more expansive sectors of the economy.[3] However, under the conditions of structural disequilibrium, existing prices form an imperfect guide to resource allocation. Strictly speaking, the existing price structure must be either modified or discarded as a tool of resource allocation.

The core around which the CGE is applied is usually the Leontief input-output model. The essence of the Leontief input-output model is that it captures the crucial element of the interrelatedness of production arising through the flow of intermediate commodities among sectors. The essence of the CGE model is that it incorporate the fundamental equilibrium links among production structure, incomes of various groups and the pattern of demand. Moreover, the endogenous price and quantity variables are allowed to interact so as to simulate the workings of decentralised markets and autonomous economic decision makers. This implies, that we have possibility to specify substitution in production, foreign trade and demand.

However, economic adjustment does not imply economic transformation and long-term growth effects, if the model does not incorporate the specification of an endogenous response in the change of the capital stock. The change of the capital stock is a dynamic process in a dual sense dismantling of old investments subject to physical or economic deterioration, and investment in new and more efficient machines brought into production. Needless to say, both components of

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[3] Resistance to structural transformation is, by a study of Krantz and Schön (1983), often matched by a modernisation of the uncompetitive part of the industry, or in a competing industry. The result will be an increase in capacity despite stagnating demand. In this way the structural transformation of the economy as a whole is held back and the general economic growth is slowed down. Hence, it is important to distinguish and also consider the inherent conflict between the two often used concepts of structural change, i.e. transformation and rationalisation.

this process must be taken into consideration when the effects of long-term policy measures are under discussion.

The exchange rate, factor prices, and the value of output are in the context of the transformation process important variables. For example, an undervalued currency (perhaps through a devaluation) increases competitiveness, raises the profit rates, and thus, there is a risk that necessary cost reductions will not be realised. Hence, the incentives to dismantling old investments on obsolescence diminish. On the other hand, an overvaluation of the domestic currency can imply, due to decreasing competitiveness and falling profit rates, a risk of exaggregated cost cuts. Logically, the incentives to dismantling old investments on obsolescence increase. These two examples are simple but provide a strong argument for acknowledge the disinvestment (dismantling of capital stock) process in the economic analysis. Indeed, this leads to the question of finding the appropriate balance between competitiveness and an efficient transformation in the economy to sustain a desirable growth path in the economy.

As now is well known to the reader, the contribution in this book is the explicit recognitation of the importance of endogenous disinvestment activities to a new equilibrium. In technical terms, to add the transformation process to the CGE model. Given the specification of a vintage model, the key concept of the transformation process is the domestic rate of domestic capital rent, endogenously determined by the exchange rate, labour costs, and value added in each sector, respectively. The transformation process, constituting the necessary transformation pressure, is then stated to be in equilibrium when capital equipment (machines) scrapped (physical deterioration and obsolescence) releases enough labour to operate the new and more efficient machines brought into production. Consequently, economic transformation will, according to the principles described above, be endogenously specified in the equilibrium model.

The version of the model that finally will be developed in this study is myopic because the level and structure of investment are determined only by current period outcomes. The model can run forward over a number of periods by updating the capital stock according to the last solution´s investment pattern, and finding a new comparative solution. Thus, the investment stream is the result of myopic decisions.

The static framework implies that the equilibrium values of the endogenous variables depend only on the levels of the exogenous variables in the present solution. However, the static model is also used in a temporary equilibrium approach, in which the solution for each period is used to create the next period´s model parameters.[4] It should be clear that the model cannot be used for the analysis of short-run cyclical variations around basic trends. The model that will be developed in this study is best suited to analyse medium- to long-term tendencies, i.e. a periodisation that is long enough for relative prices to adjust to markets and to make individual decisions mutually consistent. Considered in isolation, i.e., in treating the concept of a period as the ultimate nature of capital, the long-run orientation implies that capital stocks can be fully adjusted to desired levels. In our specification, we will assume that individuals are price takers and behave competitively. Finally, although the model has some macroeconomic features, all variables in the model are real, and there are no financial assets or money markets. Thus, money plays a neutral role in this model. This implies that it is inappropriate to employ this type of model for analysing monetary phenomena such as inflation and international exchange rates.

1. 2 *Outline of Chapters*

This book, organised in 6 chapters, is designed as a textbook and a research publication in combination. In rough outline, Chapter 2 and 3 is a pure textbook representation, and Chapter 4, 5 and 6 are representative chapters of the research publication.

To start, Chapter 2 presents the theoretical framework and develops the equilibrium model in a mathematical programming formulation. The model in this chapter is essentially a Leontief type of input-output model, extended with foreign trade activities and and resource constraints. To provide the link to economic theory, the concept of welfare optimum (pareto efficiency) and its logical relation to competitive equilibrium is used as a connecting thread between the concept of economic equilibrium and the mathematical programming formulation. The role of shadow prices and their relation to market prices in a competitive market is described.

In Chapter 3 the nonlinear, price endogenous computable general equilibrium (CGE) model is presented. Alternative to the standard linear programming model, where the central planner is the only maximising actor, the CGE model have been developed to capture the

[4] However, the model do not take into account future markets despite the fact it explicitly consider time.

endogenous role of prices and the workings of the market system. In the CGE model the essence of the general equilibrium problem is the reconciliation of maximising decisions made separately and independently by various actors, specified in terms of optimisation or market simulation. The general overview of the features of such a model is given in the the chapter. Since the possibility to specify substitution in production, foreign trade and demand is very essential in the CGE modelling approach, the technique is in this chapter presented more closely.

Chapter 4 adds the transformation process to the equilibrium model of the open economy. Given the specification of a vintage model, the key concept of the transformation process is the domestic capital rent endogenously determined by the exchange rate, labour costs, and value added in each sector, respectively. In the equilibrium context, the domestic capital rent coordinates investment and the process of deterioration (obsolescence) of the capital stock, and thus, the structure of the transformation process. However, despite the fact that this neoclassical model is static, the approach nonetheless yields a view on economic transformation. Thus, the neoclassical adjustment results in transformations being seen as jumps from one equilibrium to another.

In Chapter 5 a CGE model is presented where the transformation process, formulated in the preceding chapter, will be an integrated part. To be more precise, the numerical example of the transformation model will take its departure in a CGE model, with the addition of the variables and equations of the transformation process developed in Chapter 4. In short, the focus of this chapter is to provide examples of structural transformation in an open economy. The numerical applications of this chapter will be an examination of the sensitivity of the model to systematic variation in key variables of the transformation process, and the variations that may appear through changes in domestic and international conditions.

The experiments in this chapter are divided into two sections. The first section emphasise changes (government intervention) in the fixed rate of real exchange. The second section extends the analysis of the first section by examining economic growth, i.e., the adjustment of temporary equilibria. Throughout, experiments are chosen to make the issue of disinvestment activities (economic obsolescence) explicit.

The final chapter, Chapter 6, start the discussion of the necessary improvements. The discussion is focused on the CGE model, neceesary empirical research, how to go further, and for the subject important policy questions. As the reader will see, the analytical potential of the

CGE model is great, but a great deal of scientific work is placed on the researcher.

CHAPTER 2

The Outlook of the Sovereign Planner - The Linear Activity Model

The purpose of this chapter is to formulate a linear numerical general equilibrium model. The model is essentially a Leontief type of input-output model, extended with foreign trade activities and and resource constraints. In this chapter the equilibrium model is developed and analysed under conditions of competitive market behaviour. To provide the reader with an understanding of the nature of this model and its link to economic theory, the concept of welfare optimum (pareto efficiency) and its logical relation to competitive equilibrium is used as a connecting thread between the concept of economic equilibrium and the mathematical programming formulation. The following sections will highlight the major features of the model. At the same time, the assumptions necessary to operationalise the model are made explicit.

2. 1 *Commodities and Activities*

In this study we shall be considering an economy where there exists a finite number of commodities (commodity groups)[5] subject to production, consumption, or both. The commodity concept also includes services. A commodity is characterised by the property that two equal quantities of it are completely equivalent for each consumer and each producer. The commodities are here divided into two groups, according

[5] Generally, a commodity is defined by its physical characteristics, its location, and the date of its delivery. Commodities differing in any of these characteristics will be regarded as different. However, in this model a commodity is synonymous with the industry supplying the commodity (sector classification principle).

to whether they are produced within the production system or not. Commodities in the former group are called *produced* commodities, in the latter group, *primary* commodities.[6]

This model is extended to include imports.[7] Thus, total supply within the economic system specified in this study, is partly a result of the activity within the domestic production system, and partly the result of importation from abroad. In terms of the model, imports are regarded as primary commodities.

At each given point of time, there exists a given technology which makes it possible to use different production methods. Each such production method represents a *process,* which converts certain commodities into certain others at given ratios of inputs to outputs, and is capable of being operated at any nonnegative activity level.[8] The commodities are aggregated into a fixed number of sectors and there is for each process an a_{ij} unit activity, i.e. a vector $a_{ij} \neq 0$, for each produced commodity i and each sector j. In order to produce each unit from sector j, the input need for the i:th commodity must be a fixed amount, which we denote a_{ij}. Hence, we define the intermediate requirements of commodity i per unit of output of sector j, or the input coefficients a_{ij} as the number of input units of commodity i necessary to produce one unit of output from sector j.[9] Positive valued coefficients a_{ij} indicate that the commodity involved is produced, negative valued coefficients that the commodity is used up by the process, and zero valued coefficients indicate that the commodity is not involved in the process. The input coefficients correspond to Walras´s technological coefficients, the only difference being that in the original Walrasian system only primary inputs were considered.

To simplify the presentation of the model it is assumed that each process leads to the production of only one commodity (no joint production), and that each commodity can be produced by one fixed-

[6] Thus, there is only use of primary commodities, not production of them.

[7] A detailed specification of foreign trade will be presented in section 2.5.

[8] Following Koopmans (1951) we may use the term *basic activity* for any activity a_{ij} (different from zero). There is a one-to-one correspondence between basic activities and sectors in the stipulated economy.

[9] The order of the subscripts in a_{ij} is easy to remember. The first subscript refers to the input, and the second to the output.

coefficients process only. Thus, the model is defined in such a way that the process (industry) is synonymous with the commodity. The assumption that the input coefficients a_{ij} are fixed leads to L-shaped isoquants, and signify that there is no substitution between inputs in the production of a given commodity. Consequently, with an input-output model the choice-of-techniques question does not arise. There is only one technique of production available in each industry for producing each of the commodities in the system.

In this context, two fundamental assumptions are frequently adopted. The first assumption is called *additivity*, and the second is called *proportionality*. The two assumptions are concerned with ways in which additional processes can be obtained from those in the basis. The additivity assumption implies that the processes can be utilised jointly for the production of several commodities, one for each process, and that the resulting commodity bundle is equal to the sum of the net produced amounts in the utilisation of the separate processes. This means that the production methods used to produce a given commodity are independent of whether other commodities are produced at the same time or not. Hence, the additivity assumption means that there is free enty, i.e. no institutional or other barrier to entry, and rules out external economics and diseconomies.

The proportionality (divisibility) assumption implies that each process can be realised on a continuous proportional expansion. Thus, the input of each separate commodity in the production of a given commodity is proportional to the produced amount Z_j. Generally, the proportionality assumption stipulates what is known as constant returns to scale in production. The set of all nonnegative multiples Z_j states the produced (gross) amount, and at the same time the level at which the process is utilised.[10]

From the conditions given above, let us extend the defined processes to include primary commodities and sectoral capital stocks (capacities). Similar input coefficients as for produced commodities are defined for primary commodities, denoted b_{hj} and capacities, denoted c_{kj}. Thus, a_{ij}, b_{hj} and c_{kj} refer to the input of a produced commodity *i,* a primary commodity *h,* and a capital commodity *k* respectively in the production of a unit of the commodity in sector *j*. The following

[10] According to Chenery and Clark (1959) the proportionality assumption is less valied the greater the degree of aggregation, and the additivity assumption is more valid the larger the aggregates.

expression (column vector) is obtained for the utilisation of an arbitrary process:

$$\{ -a_{1j}, .. , 1 - a_{jj}, .. , - a_{nj}, \; b_{1j}, .. , b_{mj}, \; c_{1j}, .. , c_{nj} \}' \, Z_j \qquad (2.1)$$

By this specification, any possible state of production can be represented by a nonnegative linear combination of separate processes with nonnegative multiples Z_j of a_{ij}, b_{hj} and c_{kj}. The term activity will be used as a synonym for production activity. Technically, any activity within the production system can be expressed by the vectors (2.1) which state the *n* processes together with the values of Z_j for the actually produced amount. Thus, an activity is composed of a nonnegative linear combination of the *n* separate processes.

2. 2 *Producers*

The *n* producers (industries) execute the production programs represented by the *n* nonnegative multiples Z_j of a_{ij}. The extent to which the activity is utilised must be feasible, i.e. to say the produced amount Z_j must be an element of the production set Y_j.

For any producer *j* there exists a given quantity of capital commodities, previously produced commodities, and in the short run specific for each produced commodity, and hence, each producer. In other words, capacities are assumed immobile. For the producer each activity implies a given transformation of primary commodities into produced commodities, and to make this transformation possible, a given quantity of capacities available. By this specification, the capacities are considered as primary commodities. Hence, the primary commodities can in the short run be partioned in two kind of commodities. One one hand, capacites, which in the current point of time are fixed to the existent establishments and on the other hand resources, which the different producers (industries) are competing for in the market.

Closely related to the assumptions given above is the assumption of irreversibility of production, i.e. the production process cannot reversed, thus, excluding negative activity levels from the solution. Further, free disposal is assumed, i.e. it is possible for all producers together to dispose of all commodities. Finally the assumption of free disposal together with the assumption of irreversibility implies the impossibility of free production, i.e., it requires inputs to produce outputs.[11]

2. 3 *Consumers*

The s consumers are the only owners and final users of commodities. Each consumer, denoted i owns the supplied quantity r_{ih} of the primary commodity, denoted h, and a share, denoted θ_{ij}, of the industry j. By this specification a special economy is then considered, namely the *private ownership economy* where consumers own the resources and control the producers. The rents may be assumed to be distributed following a certain rule, such as a fixed proportion. It should be noted that no matter how the rents are distributed, all the rents must be paid to consumers.

The set of consumption which enables consumer i to survive is his attainable set X_i, defined for all combinations of demand of desired commodities x_{ij}, and supplies of his initial endowment of primary commodities (labour service) r_{ih}, which he can sell to obtain income. Thus, each consumer is assumed to have an endowment of leisure, a portion which can be sold as labour service, and the leisure remaining is a component (nonnegative) in his attainable set.

The consumer´s preferences among different vectors x_{ij} and r_{ih} are represented by a utility function $S_i(x_{ij},-r_{ih})$ defined for all nonnegative quantities of desired commodities x_{ij} and quantities of primary commodities r_{ih}, represented as a nonpositive quantity. The utility function $S_i(x_{ij},-r_{ih})$, is continuous and increasing, twice continously differentiable, strictly quasi-concave and its first derivatives are not all simultaneously equal to zero.

Under the conditions of a private ownership economy, where primary commodities and capital commodities are owned by individual consumers, the i:th consumer´s income R_i will be the sum of the value of the supplied quantities of primary commodities and the shares θ_{ij} of the rents (returns of capital as a factor of production) of the producers.

[11] See further Debreu, G., (1959), p. 42.

2.4 *Foreign Trade*

Most commodities can be supplied not only by domestic production, but also by importation. A standard approach is to specify imports as an alternative source of supply of commodities classified by the input-output sectors. A different approach is to specify imports as a primary input that is not produced in the economy.

In the first approach, imports are specified as competitive, here denoted M_j, commodities which can be produced within the country but which are, as an alternative to domestic production, also imported. The imported commodity is here viewed as a perfect substitute for the domestically produced commodity. Consequently, those imported commodities which the agents is free to select for domestic production are classified as competitive imports. In this context, any particular commodity classified as competitive imports is assumed to be tradable in the international market, and has identical characteristics, whether it is produced at home or abroad. Formally, competitive imports are treated as if they were delivered to the corresponding domestic industries and then distributed by these industries together with the domestically produced amounts. Thus, the inputs $a_{ij}Z_j$ state the sums of produced and imported amounts, and not merely the produced amounts.[12]

In the second approach imports are specified as noncompetitive, here denoted $m_{qj}Z_j$, and instead of perfect substitues for domestic production, imports are treated as a complementary input, completely different from domestically produced commodities. This type of imports consists of commodities which cannot be produced whithin the country. Non-competitive imports including predominantly those commodities which are technically infeasible, and commodities whose production is economically unviable because of the present market situation compared with their minimum scale of production. In our notation, m_{ij} denotes the input coefficient of noncompetitive imports and Z_j the extent of which the process j is utilised.

When a commodity is imported there is an outlay of foreign currency per unit of imported amount M_j respective $m_{ij}Z_j$. If PW denotes the world market price in foreign currency, $-PW_jM_j$ and $-PW_jm_{ij}Z_j$ express the outlay of foreign currency. On the other hand, when a com-

[12] The exposition in this section is based on and similar to that of Werin (1965).

modity is exported, denoted E_j, there is a receipt, expressed by PW_jE_j, of foreign currency earned per unit of exported amount E_j. Consequently, foreign currency is here an intermediate commodity, where the import process requires foreign currency as input, and foreign currency is the output of the export process. Thus, in this context there are also given resources, but of foreign currency only. These resources are made up of net export earnings plus net foreign capital inflow, denoted F. In this model the amount of net foreign capital inflow is assumed exogenous. Given the exchange rate, it follows that foreign trade can be described as to be carried out by means of processes with fixed relations. Compatible with the assumption made for domestic production, it will be assumed that an import process involves importation of one single commodity. This assumption replaces, as for domestic production, an optimisation requirement.[13] Consequently, we also assume that an export process leads to the export of one commodity only.

The effects of transportation costs and tariffs are taken into consideration by including transport costs and tariffs into import prices (tariff augumented world market prices). Hence, the currency spent on importing a unit of a commodity is generally somewhat larger than the amount earned by exporting it.[14] If it were smaller, this would mean that the price in the exporting country would exceed the price in the importing country, which is not compatible with interregional general equilibrium.

In this model world market prices of traded commodities are assumed to be given. The assumption of given world market prices (the small country assumption) implies that the country is confronted with infinitely elastic demand for its exports and supply of its imports, so what the level as well as the pattern of imports and exports may be endogenously determined only subject to the foreign exchange restriction.

Considering the assumptions made, the production system is represented by an input-output model extended to include foreign trade

[13] Optimisation implies that the import process, given the smallest currency outlay, as well as the production process, given the best technique available, is choosen.

[14] Statistically, imports are calculated in *c.i.f.* prices and exports in *f.o.b.* prices. Given this specification, the currency outlay for imports will not be proportional to the existing world market prices. This implies that the foreign exchange constraint will not correctly reflect the conditions prevaliling on the world market.

as an alternative to domestic production. Each commodity can now in principle be supplied by two different activities. One of them is the production activity, the other the import activity, which is the result of the outlay of foreign currency. This means substitution possibilites between input for the supply of various commodities. A linear activity model which takes foreign trade into account is, in certain respects, quite similar to a neoclassical model.[15]

2. 5 *The Market - Feasible Activities*

For each process actually carried out within the economic system outlined above, the variables Z_j, M_j and E_j will take specific values. This seems agreeable to common sense. Any feasible state of supply, i.e the ability of the economy to achieve an allocation within the limits of its resources, may be stated more formally. Thus, the commodity balance constraint (equation 2.2 below) states that each feasible allocation must contain at least one import or production activity. Note, that in this model imports will be treated both as an alternative source of supply of commodities M_i and as another input analogous to capital and labor, denoted m_{ij}, the input coefficient of the imported amount of commodity *i* per unit of output of sector *j*.

Final supply is made up of the total supply of a commodity minus the amount of the commodity used within the production system (intermediate demand), where a_{ij} denote the intermediate requirements of commodity *i* per unit of output of sector *j*. On the other hand, use outside of the production system is called final demand. Since the demand for exports is considered on the left-hand side of equation (2.2), the right-hand side, here denoted D_{ij}, represents *domestic* final demand (assuming free disposal of commodities), i.e. the sum of private consumption, investment and government expenditures.

[15] However, if the model does not include any further restrictions on exports and imports, the assumption of constant returns of scale in production together with endogenous choice in trade may lead to an unrealistic specialisation in either trade or domestic production.

$$Z_j + M_j - E_j - \Sigma_{j}, a_{ij} Z_j \geq D_j \tag{2.2}$$

$$Z_j \geq 0, \quad M_j \geq 0, \quad E_j \geq 0, \quad D_j \geq 0$$

Equation (2.3), the primary commodity constraint, further restricts the feasible set. The primary commodity constraint represents here labour, supplied by the households. In this specification, equation (2.19) distinguishs different skill categories of labour, where b_{hj} denote the input coefficient of each primary commodity *h*. in each sector *j*. Despite different individuals will be of different productivities, the labour input in each sector is assumed to be an aggregation of labour of different skill categories. Hence, there is only one aggregate, and homogenous, primary commodity supplied by the households. This implies that labour is assumed perfectly mobile across sectors.

$$\Sigma_{j}, b_{hj} Z_j \leq \Sigma_{i}, r_{ih} \tag{2.3}$$

$$r_{ih} \geq 0$$

Empirically, *labour* is measured in unit wage costs, which refer to all wage payments including collective payroll charges. This implies that factor payments data is used as observations on physical quantities of factors for use in the determination of parametes for the model. The total supply of *labour resources* is given exogenously, calculated on the basis of total labour force (minus employed in the government sector) and we measure it in terms of wages (and salaries). Thus, the labour balance requirement is stated in value terms and not in physical terms. In all experiments, the labour resource constraint will be binding, i.e. our model solutions requiring full employment of labour. However, it is necessary to note that a computed market equilibrium (model solution) may, in principle, permit unemployment of labour.

Equation (2.4) represents the sectoral capital stocks. At each point of time it is assumed that the supply of these commodities is given and specific for each production unit. With these characteristics we must have a restriction for each capital commodity *i* and each sector *j*.[16] This

[16] This forms a matrix with capacity input coefficients in its principal diagonal and zero elements everywhere else. Hence, *i=j* for all c_{ij}.

is also the reason for classsifying these commodities as primary commodities in the short run.

$$c_{ij}\, Z_j \quad \leq \quad K_{ij} \qquad (2.4)$$

$$K_{ij} \;\; \geq 0$$

The real *capital stock* is a composite commodity and the commodity composition of capital differs across sectors. Consequently, the real capital stock is impossible to measure with any real precision. In this model the capital stock in each sector is aggregated into a single commodity and no difference is made between the two definitions, the real and the utilised.

The foreign exchange constraint (equation 2.5) restricts the amount of foreign currency that can be spent on imports. The supply of foreign currency is generated through exports and net capital inflows. PW_j denote the world market price of each commodity classified by the input-output sectors. In this model, *imports* will be treated both as an alternative (and identical) source of supply of commodities classified by the input-output sectors and as another input (composite) that is not produced in the economy, analogous to capital and labour. Technically, competitive imports are placed outside the interindustry part of the input-output table, specified by sector of origin, and noncompetitive imports are kept within the interindustry part of the input-output table, specified by sector of destination.

$$\Sigma_j\,,\Sigma_j\,,PW_j m_{ij} Z_j \; + \; \Sigma_j\,,PW_j M_j \quad \leq \quad \Sigma_j\,,PW_j E_j \; + \; F \qquad (2.5)$$

Recapitulating, the total supply of commodities in the economic system is partly a result of the activity within the domestic production system and partly a result of supplies from abroad. Since each process implies use of primary commodities, and production and use of produced commodities, the possibility to carry on these processes are therefore dependent on the given quantities of primary commodities, the produced amount of produced commodities, and the availability of foreign currency.

2. 6 *The Mathematical Formulation*

The point of departure for the programming model presented below is an economic system where an excess demand for any commodity implies an increase of the corresponding commodity price whithout any upper limit, and an excess supply of any commodity that the corresponding commodity prices decreases, given the restriction that the price will not take any negative value. Thus, while we would never accept a situation with positive excess demand in some market as an equilibrium, an excess supply in a market where the price is zero is quite consistent with our notion of an equilibrium. An economic system with these characteristics is compatible with a market economy. A state of equilibrium in this market economy is a situation where no individual. given the price system and the actions of the other individuals, has any incentive to choose a different allocation of commodities.

Stated more formaly, the equilibrium conditions state that there will be no excess demand for any commodity and market pricing of each commodity. Thus, the equilibrium conditions state that each commodity has only one price throughout the economy, and specifies that when the market equilibrium price for the commodity is positive, there is no excess supply or demand. Since the consumers in spite of the positive commodity prices demand all supplied quantities of Z_j and M_j, and supplies the sum of r_{ih} up to the quantity demanded by the producers, commodities with a positive price are regarded as *desired* commodities.[17]

The objective of our allocation problem is to find the set of supply activites that results in a bundle of desired commodities, in the sense that given the specified resources (resource constraints) it is impossible to increase the net amount of any desired commodity without decreasing the net amount of some other desired commodity. Such a bundle is called an efficient final commodity point, and the collection of all such efficient points traces the efficient supply frontier where each point is a possible efficient (Pareto efficient) state of allocation. In this framework the well known concept of Pareto optimality, i.e. a state in which no one´s satisfaction can be raised without lowering someone

[17] A commodity is *desirable* if any increase in its consumption, ceteris paribus, increases utility.

else´s, is translated to efficiency, and a term like 'allocation efficiency' is a more accurately descriptive of the concept.[18] A state of Pareto efficiency thus defined expresses a concept of allocative efficiency in converting resources into satisfactions. By the use of the concept of allocation efficiency, we can formulate the equilibrium model specified above within a mathematical programming format. Given the objective function and the constraint set as specified in section 2.6 the problem takes the following form, i.e. maximise:

$$W(x_i;r_h) \;+\; \Sigma_i\, S_i\,(x_{ij},\, -r_{ih}) \qquad (2.6)$$

subject to

$$Z_j + M_j - E_j - \Sigma_j\, a_{ij}\, Z_j \;\geq\; D_j \qquad (2.7)$$

$$\Sigma_j\, b_{hj}\, Z_j \;\leq\; \Sigma_i\, r_{ih} \qquad (2.8)$$

$$c_{ij}\, Z_j \;\leq\; K_{ij} \qquad (2.9)$$

$$\Sigma_j\, \Sigma_j\, PW_j m_{ij} Z_j + \Sigma_j\, PW_j M_j \;\leq\; \Sigma_j\, PW_j E_j + F \qquad (2.10)$$

$$Z_j \geq 0, \quad M_j \geq 0, \quad E_j \geq 0, \quad D_j \geq 0, \quad r_{ih} \geq 0, \quad K_{ij} \geq 0$$

This is a typical programming problem and we use the Kuhn-Tucker theorem[19] to derive the optimality conditions. If the assumptions regarding the objective function and the constraint set are satisfied, then a necessary and sufficient condition that (x_q^o, r_h^o) is the optimum solution to (x_i, r_h), is that there exists $p_j^o \geq 0$, $w_h^o \geq 0$, $v_{ij}^o \geq 0$, $ER^o \geq 0$ such that the Lagrangean:

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[18] Koopmans, T.C., (1957), p. 84.

[19] Kuhn, H. W. and A. W. Tucker, (1950). The Kuhn-Tucker theorem for constrained optimisation tells us that the necessary conditions for the solution of the primal are equivalent to finding the solution of the dual. It does not in itself provide us with a practical solution method for the problem.

$$L\{x_{ij}, r_{ih}, Z_j, M_j, p_j, w_h, v_{ij}, \varphi\} = \Sigma_i , S_i\ (x_{ij}, -r_{il}) +$$

$$+ p_j\ (Z_j + M_j - E_j - \Sigma_j , a_{ij}\ Z_j - D_j) +$$

$$+ w_h\ (\Sigma_i , r_{ih} - \Sigma_j , b_{hj}\ Z_j) + v_{ij}\ (K_{ij} - c_{ij}\ Z_j) +$$

$$+ ER(\Sigma_j , PW_j E_j + F - \Sigma_j , \Sigma_j , PW_j m_{ij} Z_j + \Sigma_j , PW_j M_j)$$

forms a saddle point at $\{x_{ij}^o, r_{ih}^o, Z_j^o, M_j^o, p_j^o, w_h^o, v_{ij}^o, ER^o\}$.

We identify the Lagrangean multipliers p_j^o, w_h^o, v_{ij}^o, and ER^o, associated with the commodity constraints, as efficiency prices and rents. These efficiency prices or shadow prices of the mathematical program incorporate the effect of the constraints upon the activity level in the model, so that resources are allocated most efficiently. Supply choices open to this model are to supply each commodity by domestic production, by both domestic production and importing, or by exclusively importing the commodity.

For any given objective function the *i*:th shadow price measures the opportunity cost of the the last unit of the *i*:th resource or commodity employed in a binding constraint. The fact that the shadow prices are computed and measured in terms of the objective function (all efficiency concepts in our model is measured in terms of the objective function) implies that the objective function is crucial in determining and interpreting the shadow price system.[20] If the constraint is not binding, i.e. carries the < or > sign at the optimum, the shadow price will be zero implying that the resource or commodity is free. In this context, it is worth mentioning that any resource omitted from the specification of the model is considered as free and having an opportunity cost of zero. Given this behaviour, it is natural to interpret the Lagrangean multipliers as equilibrium prices.

In the closed economy the basic technological and demand variables determine the domestic shadow price system.[21] However, the

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[20] The shadow prices of the model cannot be considered as "ideal", because this interpretation would be valied only if the specification of the objective function quantitatively embodied all goals of the economy.

[21] The discussion that follows, is based on Dervis, et al., (1982).

situation is quite different in a free trade economy where the domestic market is small in relation to the world market. Given the assumption of perfect substitutability between imported and domestically produced commodities, the small-country assumption implies that the individual country becomes a price taker facing exogenous world market prices. The theory of international trade suggests that, as far as some commodities are actually imported or exported, the domestic shadow prices among them tend to converge to their relative world market prices.[22] Consequently, world market prices determine the domestic shadow prices of tradables, and a given commodity has (at equilibrium) the same price whether it is imported or produced domestically. Hence, whereas supply and demand determine domestic shadow prices in a closed economy, they will adjust to world market prices in the small open economy.

In order to establish conditions compatible with the characteristics of a competitive equilibrium, equilibrium must prevail, not only on the market, but also for each producer and each consumer. For each producer in the sense that they cannot increase their profits by a change in the structure of production, and for each consumer in the sense that they cannot increase their utility by choosing a new combination of commodities specified in the utility function. Thus, a market equilibrium satisfying the system constraints consistent with the assumptions of competitive equilibrium must be characterised by the existence of a set of prices[23] such that profit maximising producers and utility maximising consumers, subject to their constraints, will generate production and consumption decisions such that the choices together constitute a balanced allocation of commodities, i.e. excess demands are nonpositive.

The *producer equilibrium* stipulates that each producer (industry) is assumed to maximise its profits at given prices p_j^o, w_h^o and exchange rate subject to the technological and institutional constraints. The producer´s profit is the difference between the total revenue from the sale of its commodity i and the expenditure upon all inputs

[22] Differences may exist due to transportation costs and tariff rates.

[23] These prices carries to each producer and each consumer a summary of information about the supply possibilities, resource availabilities and preferences of all other decision makers.

Thus, the programming solution gurantees zero profits, equality of supply and demand for every commodity with non-zero prices, and equality of price and marginal costs for every producer in every commodity he actually produces. Consequently, it is clear that a decentralised decision-making process would lead to the same aggregate production pattern identical to the one which is provided by the solution of the programming, provided that each producer faces the same set of prices and strives to maximise profits.

In a parallel way, *consumer equilibrium* is equivalent to the problem that each consumer maximises his utility $S_i(x_{ij},-r_{ih})$ subject to his income constraint. Given this specification, the consumer derives utility from the consumed quantities of the desired commodities and the quantities of the primary factors he retains. When the consumer has an initial endowment of primary commodities, rather than a fixed income, he may be willing to supply his endowment in the competitive market, and then choose a bundle of desired commodities to maximise his preferences in the budget set, defined by the income he receives from his sale of labour plus his profit earnings. Since a producer optimum is attained, the p_j^o, w_h^o respective v_{ij}^o are known constants, and consequently the individual´s income is fixed at R_i, where R_i is the maximum income attainable to him evaluated at the equilibrium point. Thus, the *i:*th consumer´s income R_i will be the sum of the values $w_h^o r_{ih}$ of the supplied quantities of r_{ih} and the shares θ_{ij} of the rents v_{ij}^o of the producers.

$$\Sigma_j , p_j^o x_{ij} \leq \Sigma_h , w_h^o r_{ih} + \Sigma_k , \Sigma_j , \theta_{ij} v_{ij}^o \equiv R_i \qquad (2.11)$$

The condition, which specifies that each individual spends all of his income to purchase x_q seems to be trivial. However, the consumer efficiency condition does not stipulate that R_i must be equal to the sum of $p_j x_i$, i.e. the expenditures of each household exhaust its income, but from a general competitive equilibrium point of view income and expenditures must balance.[24]

Thus, market equilibrium would be a more precise concept here. If such a market equilibrium is consistent with profit maximisation and

[24] Assuming that each consumer is on his budget constraint, the system as a whole must satisfy Walras´s Law, i.e. the value of market demands must equal the value of market endowments at all prices.

utility maximisation on the part of each producer and each consumer, then market equilibrium and competitive equilibrium are consistent. Clearly, a competitive equilibrium is a special case of a market equilibrium and the programming problem whose solution if it exists is a competitive equilibrium for the economy stipulated by this model.

2. 7 *Concluding Notes*

The *linear programming* formulation of the Leontief input-output model, established as the linear activity analysis model, represents an advancement in the construction of applied general equilibrium models, because it introduces a great deal of flexibility into the basic linear input-output structure. The lack of price-induced substitution and the absence of a criteria of economic efficiency, were overcome by the development of the linear activity model. By allowing inequality constraints and the introduction of an endogenous mechanism of choice among alternative feasible solutions, the effects of sector capacity constraints and primary input availabilities may be investigated in the model. Consequently, a linear activity model, extended to include foreign trade, can allow endogenous choice of domestic capacity utilisation and endogenous determination of trade, i.e. in that amount a specific commodity will be supplied from domestic production or imported, and the production for domestic market or exports.

However, the linear programming formulation retains the assumptions of horisontal supply functions (up to the point where capacity is reached) and vertical final demand functions for each sector as well as fixed proportion production functions. Hence, the demand for commodities and supply of factors are assumed to remain constant no matter what happens to prices. Thus, by using a linear programming formulation, without representing a realistic price system in which endogenous price and quantity variables are allowed to interact, the interplay of market forces cannot be described properly. These are simplifying assumptions which severely restrict the usefulness of the linear programming formulation of the input-output model.

In linear programming problems, the solution is guaranteed to occur at one (or more) of the vertices, of the feasible set. This implies that the optimal solutions are always to be found at one of the extreme points of the feasible set, and the solution will constitute a basic feasible solution of the linear programming problem. Consequently, all we need is a method of determining the set of all extreme points, from which we an optimum solution can be selected. However, this constitutes a significant drawback of the applicability of the model because the linear programming specification restricts the field of choice to the set of extreme points. Unlike the points of tangency in differential calculus, the extreme points are insensitive to small changes in the parameters of the model. This reduces the attractiveness of the model for comparative static experiments. In order to include some elements of flexibility within the system and make the linear programming model more realistic, it is desirable to allow for the inclusion of several resource constraints and to work on a highly disaggregate level. On the other hand, this will substantially increase the amount of data required to implement the model.

Finally, it seems reasonable to compare this model with models developed within the tradition of computable general equilibrium (CGE) modelling. In such a comparison this model seem to be based on overly restrictive assumptions. For example, while most standard CGE-models incorporate technology descriptions that allow for factor substitution, there are fixed coefficients in this model. Moreover, while most CGE-models incorporate complete systems of final demand functions, usually derived from explicit utility functions, the demand representation in this model is based on linear demand functions with no explicit relation to utility maximisation under a budget constraint. In addition, it is advisable to restrict the model to a level of aggregation which is consistent with an interpretation of comparative advantage in terms of defined activities. Operationally, the production sectors are defined in accordance with relative factor intensities, and the number of tradable sectors is set equal to the number of scarce factors. This will produce a more transparent link between the economy´s factor endowments and pattern of specialisation at given world market prices. Hence, no *ad hoc* assumptions in order to avoid unrealistic solutions will be needed.

CHAPTER 3

The Market Economy - Features of the CGE Model

Alternative to the standard linear programming model in the previous chapter, where the central planner is the maximising actor, economic models have been developed that attempt to capture the endogenous role of prices and the workings of the market system, where the essence of the general equilibrium problem is the reconciliation of maximising decisions made separately and independently by various actors. The objective of this literature is to convert the Walrasian general equilibrium structure, from an abstract representation of an ideal economy (Arrow and Debreu model, 1954) into numerical estimates of actual economies. In the construction of applied general equilibrium models two different approaches must be emphasised[25]. On one hand, the *computable general equilibrium* (CGE) models introduced by Adelman and Robinson (1978), extending the approach of Johansen (1960),[26] which, given a set of excess demand equations, simulate the behaviour of producers and consumers to study the competitive adjustment mechanism of a system of interdependent markets. One the other hand, the *activity analysis general equilibrium* (AGE) models introduced by Ginsburgh and Waelbroeck (1975) and Manne (1977), which are characterised by inequality constraints and specified as a mathematical programming problem to examine the optimisation solutions of which

[25] See Bergman (1990) for a survey of the development of the computable general equilibrium model. See also Borges (1986).

[26] The first successful implementation of an applied general equilibrium model is due to the pathbreaking study by Johansen (1960) of the Norwegian economy. Johansen retained the fixed-coefficients assumption in modeling intermediate demand, but employed Cobb-Douglas production functions in modeling the substitution between capital and labour services and technical change.

are competitive equilibria. The linear programming model, based on the traditional Koopmans activity model, was presented in the previous chapter. Now, we will present the basic features of the CGE-model.

3. 1 *The Basic Structure*

Rather than being a single maximisation problem, the competitive general equilibrium model involves the interaction and mutual consistency of a number of maximisation problems separately pursued by a varity of economic actors. The problem involves the reconciliation of distinct objectives and not only the maximisation of a single indicator of social preference[27]. As we know from the previous chapter, the duality theorem ensures that the objective function of the dual will equal, at optimum, the objective function of the primal. Thus, an overall budget constraint is satisfied. Nothing guarantees, however, that the budget constraints of the individual actors in the economy are satisfied. The essence of the general equilibrium problem is the reconciliation of maximising decisions made separately and independently by various actors in an economic system. In that sense, this problem is absent from the standard linear programming model, where the central planner is the only maximising actor. That is to say, the problem arises when one attempts to go from the shadow prices of linear programming model to the market-clearing prices of general equilibrium theory.[28] Theoretically, market equilibrium prices are prices at which the demand and supply decisions of many independent economic actors maximising their profits and utilities given initial endowments are reconciled.

The CGE model incorporate the fundamental general equilibrium links representing the decentralised interaction of various actors in a market economy. Thus, prices in the CGE model must adjust until the decisions by the producers are consistent with the decisions made by the various actors representing final demand. This implies that the model includes a general feedback mechanism that would require an adjustment in prices, i.e, the workings of market-clearing processes. In addition, the CGE model can accommodate different types of distor-

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[27] A presentation of the theoretical structures underlying the CGE models and there relationship to economic theory, see: Dervis, de Melo and Robinson (1982).

[28] Taylor (1975).

tions, such as taxes and tariffs or monopolistically fixed factor prices. Thus, the CGE model seems to address issues we recognise from macroeconometric models.

But that are then the differences between the traditional macroeconometric models and the CGE models? In short, the macroeconometric models have a very high content of statistics, but almost no content based on economic theory. In other words, one tries to find a pattern in the data, i.e., subsequently explained by economic phenomena. The macroeconometric models are located somewhere in between, drawing both on classical statistical methods as well as some economic theory. The macroeconometric models usually address macro issues such as the role of inflation or Keynesian unemployment. In this respect, the empirical content is crucial in the macroeconometric model but the connection to economic theory (optimisation behaviour) is small.

With CGE modeling, however, one starts with a theoretical model, i.e maximisation behaviour of the individual actors in the economy, and then finds data that fits the model. The used data are estimated independently and which are reported in the literature and are then calibrated to a represent a situation close to general equilibrium. The CGE model cannot address macro issues such as the role of inflation or Keynesian unemployment but market-clearing prices, and thus, questions of economic efficiency, is important. Consequently, the content of economic theory is crucial but the weakness is the lack of empirical validation of the model.

It was in the early 1970s that a major breakthrough made possible the development of detailed and complex general equilibrium models, which could be solved computationally. The breakthrough was the introduction of an algorithm for the solution of the general equilibrium problem, i.e., for the computation of equilibrium prices - which was developed by Herbert Scarf (1967). The most striking aspect of this algorithm was its general nature. In fact, it was guaranteed to converge, i.e., find the equilibrium vector of prices, under most general conditions. Since the algorithm is based on the proof of existence of equilibrium prices, and actually follows the steps used in that proof, it is guaranteed to work without any constraints on the specification of the model, apart from the general requirement that excess demand functions be continuous and that Walras´s law be observed.[29]

There is no precise definition of a CGE model. The group of related numerical multisectoral economic models usually referred to as

[29] For a generall discussion, see Shoven and Whalley (1992) pp 37-68.

CGE models has a set of common features. One of these is that both quantities and prices are endogenously determined within the models. In this respect CGE models differ to a great extent from input-output and programming models. Another feature is that CGE models in general can be numerically solved for market clearing prices for all product and factor markets. CGE models are generally focused on the real side of the economy, although financial instruments and financial markets are included in some models.

The CGE approach descends directly from the work of Arrow and Debreu (1954) and uses the Walrasian general equilibrium framework calibrated by real-world data to ensures consistency with observed empirical facts. CGE models can also be seen as a logical culmination of a trend in the literature on planning models to add more and more substitutability and nonlinearity to the basic input-output model.

Nevertheless, existing CGE models have often retained the assumptions of fixed coefficients for intermediate technology and the compositions for capital commodities. In contrast, the production technology for primary factors is described by a neoclassical production function that allows smooth substitution among several factor inputs. The degree of substitution is governed by the elasticities of substitution specified. Intermediate inputs are required according to fixed input-output coefficients, aggregated labour and capital are combined to create value added according to a specified production (Cobb-Douglas or CES) function. Aggregate labour is a aggregation of labour of different types, and the aggregate capital used in each sector is a linear aggregation of capital commodities from different sectors. Sectors are assumed to maximise profits, and labour demand functions come from the first order conditions equating the wage with the marginal revenue product of labour of each category.

For each sector, the production function describes the technology available. Given the level of sectoral demand, producers minimise costs by using optimal quantities of primary factors and intermediate commodities as a function of their relative prices. Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply conditions in all markets. Since each sector supplies inputs to other sectors, output prices and the optimal combination of input are determined simultaneously for all sectors. The assumption of perfect competition in commodity markets amounts to assuming that firms take commodity price as given. Under these circumstances one can treat each sector as one large price-taking firm.

Domestic supply of each sector is given by a constant-returns Cobb-Douglas or CES production function with labour of different skill categories and sector-specific capital stocks, which is assumed fixed within each period, subject to depreciation. This implies that current investment will add to capacity only in future periods. Hence the production function (ex post) will exhibit decreasing returns to scale in labour, the only variable. Unit production costs will be a function of the level of output, and a given sector can always maintain international competitiveness by a suitable change in the scale of operation. Thus, complete specialisation is avoided.

We often assume that exports and domestic sold commodities are perfect substitutes. This specification of export supply, however, overstates both the links between exports and domestic prices and the responsiveness of exports to demand shifts on world markets. By the possibility to specify foreign trade as, not only as perfect substitutes as in the linear model, but as close substitute to domestic production, and a substitution that can vary according to specification, the CGE model offers a more close relation to empirical evidence. As a result, export prices for any commodity may differ from world market prices as well as from prices paid on the domestic market, and a country may export and import commodities in a given sector. In this way the model captures the phenomen of intra-industry trade. This represents a significant departure from the "small country assumption" of traditional trade theory in which countries can export any amount of a given commodity at a given price and nothing at a higher price. Since the possibility to specify substitution (in production, foreign trade and demand) is very essential in the CGE modelling approach, the technique is presented more closely in the next section. We choose the just discussed, and most frequent, example - foreign trade.

3. 2 *Foreign Trade - the CES and CET Specification*

In the closed economy the basic technological and demand variables determine the domestic shadow price system. However, the situation is quite different in a free trade economy where the domestic market is small in relation to the world market. Given the assumption of perfect substitutability between imported and domestically produced commodities, the small-country assumption implies that the individual country becomes a price taker facing exogenous world market prices. The theory of international trade suggests that, as far as some commodities are actually imported or exported, the domestic shadow prices among them tend to converge to their relative world market prices. Consequently, world market prices determine the domestic shadow prices of tradables, and a given commodity has (at equilibrium) the same price whether it is imported or produced domestically. Hence, whereas supply and demand determine domestic shadow prices in a closed economy, they will adjust to world market prices in the small open economy.

Needless to say, extreme specialisation in production and trade conflicts with empirical evidence, which on the contrary, shows a relatively little specialisation on the sectoral level. However, the observed combination of domestic production and trade may be in complete accordance with the theoretical model. First, the country under study consists of many regions, which implies that a commodity may be imported to one region and exported from another, but never be both imported to and exported from one single region. Second, the same argument is applicable to the fact that the model is specified to cover a period of some length. Hence, a commodity may be both produced and traded at different points of time during the period of specification. Finally, the commodities of the model are aggregates of different commodity categories. For each of these commodities the theoretical requirement may be fulfilled.

In the standard small-country assumption, often made in international trade theory, a traded commodity is assumed to be one for which the single country is a price-taker and the domestically produced commodity is a perfect substitute for that sold in the world market. The discussion in Chapter 2 has already stressed that the small-country assumption leads to the result that the domestic price of a traded commodity is equal[30] to its world price (PW_i). Moreower, we also stressed that assuming perfect substitutability implies that there is no product differentiation between imports and domestic products and that a commodity will either be exported or imported but never both (intra-trade is eliminated). This impies that changes in world market prices, exchange rates and tariff rates, are entirely translated into changes in domestic prices, and hence, exaggregate the effects of trade policy over the domestic price system and the domestic economic structure. Furthermore, the small country assumption together with an assumption of constant returns to scale in production, leads to a tendency toward extreme specialisation in production that is not always desirable.[31] In the discussion above we have repeatedly stressed that extreme specialisa-tion in production and trade conflicts with empirical evidence (Flam 1981, Lundberg 1988), which on the contrary shows a considerable amount of intra-industry trade even within rather disaggregated pro-duction sectors.

At a level of high aggregation, each sector represents a bundle of different commodities. In this model[32], we solve this problem by relaxing the perfect substitutability assumption. Instead, we stipulate that for any traded commodity, imports M_j (perfecly elastic in supply) and domestically produced commodities x_j^Z are not perfect but relatively close substitutes. Thus, we relay on the Armington (1969) assumption that commodities of different origin are qualitatively different commodities. Formally, we define for each tradable commodity category a composite (aggregate) commodity x_j, which is a CES utility function of commodities produced abroad (imports, M_j) and commodities produced domestically, x_j^Z. We have:

$$x_j = AC_j \left[\delta_j M_j^{-\rho_j} + (1 - \delta_j) x_j^{Z\ -\rho_j} \right]^{-1/\rho_j} \qquad (3.1)$$

[30] Differences may exist due to transportation costs and tariff rates.

[31] Samuelson (1952)

[32] The computable general equilibrium (CGE) model to be described is a variant of the model developed by Dervis, de Melo and Robinson (1982). This section is, in certain parts, based on Condon, Dahl and Deverajan (1987).

where AC_j is the CES function shift parameter, δ_j, the value shares of imports in total domestic expenditure, is a constant, and σ_j, the elasticity of substitution between the two sources of supply in all domestic uses, is given by $\sigma_j = 1/(1+\rho_j)$.

This formulation implies that consumers (at home as well as abroad) will choose a mix of M_j and x_j^Z (inputs in the CES utility function "producing" the composite output x_j) depending on their relative prices.[33] Minimising the cost of obtaining a unit of utility (the composite commodity x_j):

$$p_j x_j = p_j^Z x_j^Z + p_j^M M_j \qquad (3.2)$$

subject to (3.1) yields:

$$\frac{M_j}{x_j^Z} = \left(\frac{p_j^Z}{p_j^M}\right)^{\sigma_j} \left(\frac{\delta_j}{1-\delta_j}\right)^{\sigma_j} \qquad (3.3)$$

where p_j^Z denote the domestic commodity price and p_j^M denote the domestic currency price of imports (domestic currency outlay of imports). Thus, the solution is to find a ratio of inputs (M_j to x_j^Z) so that the marginal rate of substitution equals the ratio of the price of the domestically produced commodity to the price of the imported commodity. In standard trade theory the trade substitution elasticity is infinity so that $p_j^Z = p_j^M$. If p_j^Z exceedes p_j^M, x_j^Z would have to be zero. Equation (3,3) allows for a richer set of responses,[34] but as σ_j gets larger, the responsiveness of M_j/x_j^Z to changes in p_j^Z/p_j^M rises. In that case p_j^Z/p_j^M will stay close to its base value and we approximate the case where p_j^Z, at the equilibrium, will stay fix to p_j^M. On the other hand, if σ_j is very low, large changes in p_j^Z/p_j^M may take place.[35] Thus, as a result of this specification, p_j^Z is no longer fixed to p_j^M, it is

[33] Consequently, there can be both import and export of each catergory of tradable commodities in equilibrium.

[34] If the trade substitution elasticity equal unity, the CES utility function reduces to a Cobb-Douglas utility function.

[35] In the extreme case where sigma is zero, M_j/x_j^Z would be fixed, and imports become perfect complements of domestic products.

endogenously determined in the model. The variable p_j^M, however, is linked to the exogenously fixed world market price, p_j^W by:

$$p_j^M = p_j^W ER \qquad (3.4)$$

where ER is the exchange rate (fixed initially in the model). This implies that we maintain the assumption of exogenously fixed world market prices of imports.

Turning to *export demand* standard trade theory assumes that a small country faces a perfectly elastic demand for its exports. This implies that any balance of payment problem can be solved by an indefinite expansion of exports at constant world market prices of the most profitable commodities. This profile of trade may not be realistic for many countries. While they may not be able to affect the world market prices with their exports, the countries may register a declining market share as their domestic prices rise. In addition, increasing selling costs will normally reduce the net return from exports as the quantity is increased. The most satisfying way to reflect this situation would be a specification were export demand E_j is a decreasing function of the domestic export costs (prices) in foreign currency. If we let p_j^E denote the domestic currency price of exports (domestic currency receipts of exports)[36] and p_j^W, as above, the world market price in foreign currency (exogenously fixed), we would have:

$$p_j^E = p_j^W ER \qquad (3.5)$$

Given the assumptions of standard trade theory, the variable p_j^E is linked to the exogenously fixed world market price p_j^W. However, assuming product differentiation leads to less than infinitely elastic demand functions for exports. The individual country is still regarded as a small country in the world market, hence, p_j^W is assumed exogenously fixed. But the foreign currency price of a particular country´s exports, denoted p_j^{WE}, is endogenously determined by its domestic production costs p_j^Z (average output price), and exchange rate policy ER. We get:

[36] Foreign currency is here regarded as an intermediate commodity (not desired in itself), where the import process requires foreign currency as input, and foreign currency is the output of the export process.

$$p_j^{WE} = \frac{p_j^Z}{ER} \qquad (3.6)$$

Consequently, we consider the following constant elasticity export demand function:

$$E_j = E_j^o\left(\frac{p_j^W}{p_j^{WE}}\right)^{n_j} \qquad (3.7)$$

where n_j is the price elasticity of export demand and E_j^o is a constant term reflecting total world demand for each commodity category and the country´s market share when, at equilibrium, $p_j^W = p_j^{WE}$. Logically, the domestic currency price of exports is:

$$p_j^E = p_j^{WE}\,ER \qquad (3.8)$$

Given the fact that our country is small, changes in p_j^{WE} will not affect p_j^W, but it will have effects on our country´s market share for aggregate commodity category j. For example, a devalutation of the exchange rate leads to a fall in p_j^{WE} and hence, with constant p_j^W, an increase in its market share. Conversly, an increase in domestic production costs, p_j^Z, leads to an increase in p_j^{WE}, and with constant p_j^W, its market share will decline. This implies that export prices p_j^E (or p_j^{WE}) are no longer fixed to the world market price in foreign currency p_j^W. The small-country assumption, requiring fixed terms of trade, will not longer hold. Consequently, the small country assumption is retained only in the sense that world market prices p_j^W on international traded commodities is to be regarded as given.

On the *supply side* exports is usually derived residually by subtracting domestic demand from total domestic production. Given the standard small-country assumption, domestic production will expand until domestic production costs rise to the world market price level. As long as domestic production costs are lower than existing world market prices, it will be profitable to expand domestic production for exports.[37] As a result, export supply may exhibit an excessively strong response to changes in domestic prices. When a domestic price rises, producers

[37] On the other hand, if the domestic price is greater than the world market price, the commodity will not be produced.

are induced to increase supply and domestic consumers to reduce their demand. The net result is a dramatic increase in exports. However, in reality, exports may not rise this fast, because the domestically consumed and exported commodities in the same sector may be quite different. Thus, the small-country assumption together with the assumption that the supply of exports is simply the difference between total domestic production and domestic absorption may in several cases greatly overestimate the responsiveness of export supply, and again, the problem increases with the degree of aggregation. Hence, we postulate a constant elasticity of the transformation (CET) function between domestically consumed x_j^Z and exported E_j commodities:

$$Z_j = \mathrm{AT}_j \left[\gamma_j E_j^{\phi_j} + (1 - \gamma_j) x_j^{Z\,\phi_j} \right]^{1/\phi_j} \tag{3.9}$$

Z_j is domestic output, AT_j is the CET function shift parameter, γ_j is a constant, and the elasticity of transformation τ_j is given by: $\tau_j = 1/(1 - \phi_j)$.

Maximising the revenue from a given output:

$$p_j^Z Z_j = p_j^Z x_j^Z + p_j^E E_j \tag{3.10}$$

subject to (3.9) yields the following allocation of supply between domestic sales and exports:

$$\frac{E_i}{x_i^Z} = \left(\frac{p_i^E}{p_i^Z}\right)^{\tau_i} \left(\frac{1-\gamma_i}{\gamma_i}\right)^{\tau_i} \tag{3.11}$$

This leads to the export price p_j^E (or p_j^{WE}) diverging from the domestic price p_j^Z.

The supply of exports by sector is a function of the ratio of the price in domestic currency of exports. This treatment partially segments the export and the domestic markets. Prices in the two market are linked together but need not be identical. Imports and domestic products are assumed to be imperfect substitutes. Imports and domestic commodities are combined according to a CES trade aggregation function, with consumers demanding the composite commodity. The trade substitution elasticity determines the extent to which import shares adjust in response to changes in relative prices. For both exports and imports, the word price in foregin currency is assumed to be constant - the small country assumption.

3. 3 *Concluding Notes*

The model is Walrasian in that only relative prices matter. This proposition reflects the well-known fact that if all prices increase in the same proportion, but relative prices are unaltered, the relationships in the economy remain unchanged. The order so solve the model to find the equilibrium prices, we arbitrarily set one price equal to one, and then solve the system for all other prices. The commodity with price set equal to unity is known as the numeraire commodity, and the prices of all other commodities are determined in terms of the numeraire. However, in applied models it is convenient to use a price-normalisation rule that provide a no-inflation benchmark against which all price changes are relative price changes.[38]

According to Walras´s law, there cannot be a situation of aggregate excess demand or supply. In other words, if one market has positive excess demand, another must have excess supply, to such an extent that in value terms they cancel out. To see that Walras´s law always hold, it is sufficient that, the total value of output, and the total value of expenditures balances. This result will always be true if all economic agents meet their budget constraints. Because each spending unit´s demand are subject to a budget constraint which says that outlay must equal income, it is clear that such a budget constraint also hold in the aggregate and will hold not only at equilibrium, but for all allowable price vectors.

The static model as presented above has no formal link between capital formation and production capacity. Capital commodities are assumed exogenous without any correspondence to the effect that is created by the supply of investment from sectors producing capital commodities (investment in final demand). The contribution in the next chapter is to add the transformation process to the computable general equilibrium model of an open economy. In equilibrium context, the model coordinates investment and the process of deterioration (obsolescence) of the capital stock, and thus, the structure of the transformation process.

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[38] See Dervis, et al., (1982), p 150.

With these requirements in mind, the next chapter provides a framework around which the solution for each period is used to create the next period´s model parameters. In other words, it will solve the market for equilibrium prices and quantities for one period and then add the solution obtained to the predetermined variables that are needed to obtain a market equilibrium for the next period. The model will be of temporary equilibrium type.

CHAPTER 4

Endogenous Disinvestment Activities to a New Equilibrium

The model presented in Chapter 3 provides a framework around which the two subsequent chapters are organised. In this chapter, Chapter 4, the transformation process will be presented. In the next chapter, Chapter 5, the transformation process will be an integral part of a traditional CGE model of an open economy. That model will be designed as a tool for the numerical experiments to outline the basic adjustment mechanisms that will determine the direction, and hence, the fundamental structure of the transformation process.

With this requirement in mind, we will now add the transformation process to the computable general equilibrium model of the open economy. Given the specification of a vintage model, the key concept of the transformation process is the rate of capital rent by sector endogenously determined by the exchange rate, labour costs, and value added in each sector, respectively. Technically, the necessary transformation pressure, in order to remain in a continuous state of full employment, is derivable from the rate of domestic capital rent. In the equilibrium context, the rate of domestic capital rent coordinates investment and the process of deterioration (obsolescence) of the capital stock, and thus, the structure of the transformation process.

As is well known, structural change is a continuous process, in which commodities and methods of production are renewed or replaced all the time.[39] For a country where international trade represents a significant proportion of the economic activity the equilibrium of the

[39] Here, the term *structural change* refers primarily to arrangements affecting the use of resources, and the patterns of domestic production and trade resulting from their allocation (structural transformation) in different sectors of the economy.

domestic economy is to a great extent determined by the conditions given abroad. Most countries are sufficiently small to take foreign demand as given. Against this background, a crucial factor is the extent to which the industry sector can adjust to changes in foreign market conditions.

Stated in the preceding discussion, the problem of structural change has two interrelated aspects. One is the need to close down uncompetitive capacity. The other is the lack of expansion in potentially competitive parts of industry, to be solved only by transferring resources from uncompetitive to more expansive sectors of the economy. However, under the conditions of structural disequilibrium, existing prices form a very imperfect guide to resource allocation. Strictly speaking, the existing price structure must be either modified or discarded as a tool of resource allocation. As repeatedly stressed, the CGE model is capable of handling this type of problem.

4. 1 *Setting of the Problem*

Structural change, adjustment problems, and policy measures directed to overcome these problems are the most active areas of research in the field of computable general equilibrium modeling. Modeling the "small open economy", the Heckscher-Ohlin model of international trade theory is, as has been presented in the preceding chapter, a natural point of departure for the design of a CGE model. However, the treatment of foreign trade in most open economy CGE models rests on the so-called "Armington assumption," i.e., the economy is assumed to have some market power rather than being a price-taker on international markets for tradeables. Technically, foreign and domestic commodities are assumed to be imperfect substitutes - an assumption widely used in CGE models of trade. This framework, is traditionally used to analyse open economy industrial adjustment (market or policy) to changes on international markets.

However, industrial adjustment does not imply industrial transformation and long-term growth effects, if the model does not incorporate the specification of an endogenous response in the change of the capital stock. The change of the capital stock is a dynamic process in a dual sense dismantling of old investments subject to physical or economic deterioration, and investment in new and more efficient machines brought into production. Needless to say, both components of this process must be taken into consideration when the effects of long-term policy measures are under discussion.

The exchange rate, factor prices, and the value of output are in the context of the transformation process important variables. An undervalued currency (perhaps through a devaluation) increases competitiveness, raises the profit rates, and thus, there is a risk that necessary cost reductions will not be realised. Hence, the incentives to dismantling old investments on obsolescence diminish. On the other hand, an overvaluation of the domestic currency can imply, due to decreasing competitiveness and falling profit rates, a risk of exaggregated cost cuts. Logically, the incentives to dismantling old investments on obsolescence increase. These two examples are simple but provide a strong argument for recognising the disinvestment (dismantling of capital stock) process in the economic analysis. Indeed, this leads to the question of finding the appropriate balance between competitive-ness and an efficient transformation in the industry sector to sustain a desirable growth path in the economy.[40]

It is easy to see that the value of the exchange rate has a strategic significance: (1) to support a favourable development in exports and thus increase the demand for domestic investments; and (2) to create the necessary incentives to scrap the amount of machines on obsolescence to release labour to operate new machines.[41] Consequently, the economic life of a machine of a given vintage becomes a variable to be determined.

As now is well known to the reader, the contribution in this book is the explicit recognitation of the importance of endogenous disinvestment activities to a new equilibrium. Or, in terms of the modeling approach that will be discussed in this chapter, to add the transformation process to the CGE model of the open economy. Given the specification of a vintage model, the key concept of the transformation process is the rate of domestic capital rent, endogenously determined by the exchange rate, labour costs, and value added in each sector,

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[40] The influence from the Swedish economist Dahmén is evident here. Dahméns contribution to the economic analysis of industrial dynamics has greatly influenced much research, both in Swedish economic history and in economic policy. For a survey, see Carlsson and Henriksson (1991).

[41] An extension designed to provide a framework for analysing the effects of currency devalutation on investment (structural and aggregate) by incorporationg two-period optimisation into a computable general equilibrium model is developed by Benjamin (1990).

respectively. The endogenous transformation process, constituting the necessary transformation pressure, is then stated to be in equilibrium when capital equipment (machines) scrapped (physical deterioration and obsolescence) releases enough labour to operate the new and more efficient machines brought into production. Hence, industrial transformation will now be endogenously specified in the equilibrium model.[42]

4. 2 *Outline of Disinvestment Activities.*

The mechanism discussed above illustrates a visible image of the principles of the industrial transformation process in the open economy. The objective is now to develop, in the framework of the computable general equilibrium model, one approach that incorporates Salter´s notion (Salter, 1960) of the vintage structure of industry sectors in the transformation process.[43] Within this framework, the individual country is regarded as small in the world market, hence, the world market rate of return (the foreign rate of capital rent) on production (r_j^{w}), for any industry and time period, is assumed exogenously fixed, that is:

$$r_j^{\mathrm{w}} = r_j^{\mathrm{wo}} \tag{4.1}$$

However, the rate of capital rent by domestic sector, denoted p_j^{K}, is endogenously determined for the industry sector in question by the rate of capital rent[44] (value added, VA_j , reduced by wage costs, p_j^{L}) to the value added of each industry respectively, and the exchange rate ER. We get:

$$p_j^{\mathrm{K}} = \frac{(VA_j - p_j^{\mathrm{L}})}{VA_j} \; ER \tag{4.2}$$

Within the competitive framework of the small open economy, it is here assumed that financial resources are free to flow between different countries. Given this specification, the rate of capital rent by sector

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[42] See Feldstein and Rothschild (1974), Auerbach (1979), Schworm (1979), Abel (1981), and Coates (1991) for theoretical analyses of endogenous depreciation.

[43] This section is based on Norén (1998).

[44] Given perfect competition, the share of marginal product of capital.

between the home country and the foreign countries in question will become crucial for the producer´s decision to expand production capacity, and likewise for financial circles to invest, domestically as well as abroad.[45] Or, to state the matter otherwise, in high-profit-rate countries investment will increase, and thence, attract funds from low-profit-rate countries.

One way to manage this problem computationally, we assume on the demand side a formulation of the constant-elasticity type that separately specifies two investment demand functions; the demand for investment abroad (I_j^{w}) and the domestic (I_j^{D}) market. On the supply side, we postulate a constant elasticity transformation (CET) function determining the ratio of funds invested domestically to funds invested abroad. First, however, we specify the investment demand functions as follows:

$$I_i^{D} = I_i^{Do}\left(\frac{p_j^K}{r_j^W}\right)^{\pi_j} + ß_i^{Do}(Z^{D}_{j\,t} - Z^{D}_{j\,t-1}) + \chi_i^{Do}K_i^{Do} \qquad (4.3)$$

Where π_j represents the rate of capital rent elasticity of investment demand for each sector respectively and I_j^{o} is a constant term reflecting investment demand when, at equilibrium, $r_j^{w} = p_j^{K}$. Given the world market rate of capital rent, changes in p_j^{K} will not affect r_j^{w}, but it will have effects on the demand for investment in the domestic country. For example, a decrease in the domestic labour costs or a devalutation of the domestic currency leads to an increase in p_j^{K} and hence, with constant r_j^{w}, will increase the demand for investment in the domestic country. Given the small-country assumption, domestic investment will expand until domestic labour costs rise, and hence, decrease p_j^{K} to the level of world market rate of capital rent r_j^{w}.

However, investment demand is affected by variables other than the relative rate of capital rent by sector. The change in total activity level, the change here denoted by ($Z_{j\ t}$ - $Z_{j\ t-1}$), of each country respectively and the need to replace the capital stock (K_j^{o}) due to physical deterioration (the proportion $ß_j^{o}$ and χ_j^{o} is set exogenously), are two important variables. Hence, these two variables are included in equation (4.3) above.

[45] This implies that households and firms can borrow and lend at the going interest rate on world capital markets.

Turning to the supply of funds available for investment to the particular sector, industries in countries with relatively increased rate of capital rents by sectors can be assumed to gain share at the expense of industries in other countries. Thus, compatible with the specification of the investment demand functions above, the sectoral allocation of funds, here denoted S_j, will respond to capital rent differentials in different countries.[46] The most satisfying way to reflect this situation computationally is to use a constant elasticity transformation (CET) function[47] between funds domestically invested (I_j^D) and funds invested abroad (I_j^w). Mathematically:

$$S_j = BT_j[\delta_j I_j^{w\ \varepsilon_j} + (1 - \delta_j) I_j^{D\ \varepsilon_j}]^{1/\varepsilon_j} \tag{4.4}$$

where S_j is total funds specified for each industry sector respectively,[48] BT_j is the CET function shift parameter, and the parameter δ_j, the distribution parameter, measures the relative investment shares of the funds allocated in the investment process. The elasticity of transformation ξ_j is given by $\xi_j = 1/(1-\varepsilon_j)$.

Maximising the revenue of available funds of a given sectoral investment allocation:

$$p_j^K S_j = p_j^K I_j^D + r_j^w I_j^w \tag{4.5}$$

subject to (equation 4.4) yields the following allocation of supply of funds available for investment to the particular sector between domestic and foreign investment markets:

[46] The mechanism by which saving is determined is in this chapter left unspecified. However, a specification will be included in the model in the next chapter.

[47] As noted by an observant reader, the standard theoretical specification of trade-focused CGE models, is applied to the formulation of sectoral allocation of funds. See further Kendrick (1990).

[48] Total funds is here a composite commodity, which is a blend of domestic and foreign savings.

$$\frac{I_j^{\mathrm{w}}}{I_j^{\mathrm{D}}} = \left(\frac{r_j^{w}}{p_j^{K}}\right)^{\xi_j} \left(\frac{1-\delta_j}{\delta_j}\right)^{\xi_j} \qquad (4.6)$$

Thus, the solution is to find a ratio of inputs (I_j^{w} to I_j^{D}) so that the marginal rate of transformation equals the ratio of the rate of capital rent by domestic sector to the rate of capital rent by foreign sector. Equation 4.6 allows for a rich set of responses. As ξ_j gets larger, the responsiveness of $I_j^{\mathrm{w}}/I_j^{\mathrm{D}}$ to changes in $r_j^{\mathrm{w}}/p_j^{\mathrm{K}}$ rises. In that case $r_j^{\mathrm{w}}/p_j^{\mathrm{K}}$ will stay close to its base value and we approximate the case where r_j^{w}, at the equilibrium, will stay fix to p_j^{K}. On the other hand, if ξ_j is very low, large changes in $r_j^{\mathrm{w}}/p_j^{\mathrm{K}}$ may take place.[49] Thus, as a result of this specification, p_j^{K} may, at the equilibrium, differ from r_j^{w}. The variable r_j^{w}, however, is linked to the exogenously fixed world market capital rent by sector, r_j^{wo}.

After determining the structure of investment demand (and supply of funds) we should note in passing that the flow of investment commodities must be specified in pratical applications. In quantitative terms, the request for capital commodities by sector of destination I_j^{D} (the sectoral capital accumulation) is translated into a demand for investment commodities by sector of origin I_i^{S} (producing sectors of capital commodities). Thus we have:

$$I_i^{\mathrm{S}} = \Sigma_i\, ,c_{ij}\, I_j^{\mathrm{D}} \qquad (4.\ 7)$$

where c_{ij} denotes the the capital composition matrix [50] of sectoral investment allocation shares, i.e., the proportion of capital stock in sector *j* originating in sector *i*.

The discussion above has already stressed that the capital stock is subject to physical as well as economic deterioration (obsolescence). In the latter case, as the capital stock gets older, the quasi-rent in the Marshallian sense falls and eventually becomes zero. The economic decision is then taken to scrap the capital object as obsolescent despite

[49] In the extreme case where ξ_j is zero, $I_j^{\mathrm{W}}/I_j^{\mathrm{D}}$ would be fixed and foreign investment activities become perfect complements of domestic investments.

[50] Note that $\Sigma_i \kappa_{ij} = 1$ for all *j* (Note that summation is taken over *i*).

its continuing physical durability. Hence, in technical terms, the model incorporates a condition that determines the economic life of a capital unit. This can be shown by using the following equation:

$$DEPR_j^{D} = DEPR_j^{Do}\left(\frac{r_j^{W}}{p_j^{K}}\right)^{\mu_j} \quad (4.8)$$

where μ_j represents the rate of capital rent by sector elasticity of sectoral obsolescence of capital equipment (machines) for each sector respectively and $DEPR^{o}_j$ is a constant term reflecting scrapping of sectoral capital equipment on obsolescence. Thus, the sectoral obsolescence of capital is here uniquely determined by the rate of capital rent by sector.

Stipulated in this way a proposition of structural equilibrium emerges. Labour is released from all old machines; this release and the growth in the total labour force is what provides the labour resources to operate the new vintage of machines brought into production.[51] Given the assumption of full employment, the transformation process is stated to be in equilibrium (structural equilibrium condition) when machines scrapped (physical deterioration and obsolescence) releases enough labour to operate the new and more efficient machines brought into production. Hence, the dual effect of variations in the rate of capital rent, the key variable of the transformation process, now appears.

Within the framework, the capital stock in use comprises machines of different vintages. The more recent vintages will have lower labour costs per unit of output, because they embody technical progress, i.e., machines of successive vintages become more efficient with technical progress.[52]

For instance, a devaluation of the domestic currency leads to an increase in p_j^{K} and hence, with constant r_j^{w}, will increase the demand for investment in the domestic country. In addition, the incentives to dismantling old investments on obsolescence diminish. As a consequence, the aggregated capital stock is increasing. Given structural

[51] The reader should note that the equilibrium condition is here stated for the economy as a whole.

[52] The analysis envisaged here is base on the assumption of substitutability between capital and labour before the installation of new capital equipments but fixed labour requirements after installation.

equilibrium, the domestic labour costs will rise, and thus decrease p_j^K, due to a beginning scarcity of labour to operate the new machines brought into production. Finally, a new equilibrium will be established. However, different sectors adjust differently, and a structural transformation between sectors will take place. The outcome of this transformation is a new structural profile of the economy (industry sectors). Technically, the necessary transformation pressure is derivable from the p_j^K equilibrium values.

4. 3 *Concluding Notes*

The problem of structural transformation has two interrelated aspects. One is the need to close down uncompetitive capacity. The other is the lack of expansion in potentially competitive parts of industry, to be solved only by transferring resources from no longer viable to more expansive sectors of the economy.

Within the competitive framework of the small open economy, it is assumed here that real as well as financial resources are free to flow, not only between different sectors of the economy, but also between different countries. This ability to incorporate the linkages between domestic and foreign investment markets is of particular importance. Hence, the model presented in this chapter is flexible and can, qualified and expanded in numerical applications, be used to analyse the consequences of a wide range of policy changes and external shocks.

The essence of the model stipulated in this chapter is that it captures the crucial element of structural transformation, and the transformation process is endogenously determined in the model. Given the specification of a vintage model, the key concept of the transformation process is the rate of domestic capital rent, endogenously determined by the exchange rate, labour costs and value added in each sector respectively. Technically, the necessary transformation pressure, in order to remain in a continuous state of full employment, is derivable from the the rate of domestic capital rent. In the multisector equilibrium context, the rate of capital rent coordinates investment and the process of deterioration (obsolescence) of the capital stock, and thus, the structure of the transformation process. Although the model outlined here may be a good point of departure, it is clear that a more realistic specification of the transformation process still represents a major challenge. This is not to say that we are not entiteled to expect a interesting performance if some of the specification above will be an integral part of a traditional CGE model. On the contrary, that will be our modeling experiment in the next chapter; the CGE transformation model.

CHAPTER 5

The Presentation of and Experiments with the CGE Transformation Model

In this chapter a numerical general equilibrium model is to be presented where the transformation process, formulated in the preceding chapter, will be an integral part. To be more precise, the numerical example of the transformation model will take its departure in the CGE mini-model[53] (included in the GAMS model library which is distributed with the GAMS system)[54] that is used to illustrate the basic use of CGE models, with the addition of the variables and equations of the transformation process developed in Chapter 4. As emphasised in Chapter 1, the CGE mini equilibrium model is simple enough to be presented in a few pages and yet complicated enough to demonstrate the application of the comming, in some sense, extended model. In short, the focus of this chapter is to provide examples of structural transformation in an open economy, issues that can be usefully investigated with a CGE model. The numerical applications of this chapter will be an examination of the sensitivity of the model to systematic variation in key variables of the transformation process, and the variations that may appear through changes in domestic and international conditions.

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[53] The CGE mini-model is a minor version of an equilibrium model that orginally come from Chenery, Lewis, de Melo, and Robinson in their work to designing an equilibrium development model of Korea. The model illustrate the basic use of CGE models. See further: Chenery, Robinson and Syrquin (eds.), 1986, pp 311-347.

[54] Brooke, Kendrick and Meeraus, (1988). The GAMS system internet address: http://www.gams.com/.

5. 1 *The Basic Structure of the CGE Transformation Model*

The behaviour of economic agents in this model is designed according to neoclassical microeconomic theory with relative prices playing a major role in the determination of economic activities. Producers minimise costs subject to a given production technology, and consumers maximase utility given their total expenditure determined as a constant fraction of their income. The model assumes perfect competition in all markets and domestic and foreign commodites are treated as imperfect substitutes according to Armingtons (1969) specification. Exports are determined by an exogenous foreign demand and the relative export price is measured in foreign currency.[55] Prices in the foreign markets are linked but need not to be identical to the domestic market. However, the world price in foreign currency (dollars) is assumed to be constant, i.e., the small country assumption[56].

Thus, the CGE model simulates the working of a market economy. In each period, it solves for wages and prices that clear the markets for labour and commodities. The model is Walrasian in that only relative prices matter. The numeraire against which all relative prices are measured is defined as an index of domestic prices. The model satisfies Walras´s law, which implies that there cannot be a situation of aggregate excess supply or demand. However, the model also comprises nontradable commodities. Nontradable commodities are commodities that are not subject to international trade. Government service as well as housing fit this category. It is very important to stress that according to the discussion in Chapter 3, we have no clear distinction between tradables and nontradables commodities in this model.

Intermediate inputs are required according to fixed input-output coefficients, aggregate labour and capital are combined to create value added according to a Cobb-Douglas production function. The labour market is segmented in distinct categories. Sectors are assumed to maximise profits, and labour demand functions come from the first

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[55] Note, that the export demand function (Equation 3.7) is not included in the CGE mini model.

[56] The reader have to note, that price incentive policy such as taxes, subsides, and tariffs are now explicity incorporated. Domestic prices can be altered by the government by changes in price incentive policy, and hence, affect the economic structure.

order conditions equating the wage with the marginal revenue product of labour of each category. These general characteristics of the CGE model was stipulated in Chapter 3.

The model in this chapter is of the temporary equilibrium type. It will solve the market for equilibrium prices and quantities for one period and then add the solution obtained to the predetermined variables that are needed to obtain the market equilibrium solution for the next period. As stipulated in Chapter 4, the rate of capital rent by sector coordinates investment and the process of deterioration (obsolescence) of the capital stock, and thus, the structure of the transformation process, the process that drive the CGE model forward in time.

Applications of theoretical models will often involve a number of compromises in order to make the model more realistic and more usefull in an applied setting. Here, the compromise is to make the structure of the transformation process to be an integral part of the CGE mini-model. We start with the price of capital commodities, i.e., the following definition from the CGE mini-model:

$$p_j^{\mathrm{K}} = \Sigma_j , (p_i \, c_{ij}) \tag{5.1}$$

p_j^{K} is the rate of capital rent by sector, p_i is the price of composite goods, and c_{ij} is the assumed fixed capital composition matrix.

We now have to rewrite equation (4. 1) of economic obsolescence to the following equation:

$$OBS_j = OBSO^{\mathrm{o}}(r_j^{\mathrm{w}} / p_j^{\mathrm{K}} \, (1/ER))^{\mu_j} \tag{5.2}$$

OBS_j is economic obsolescence, $OBSO^{\mathrm{o}}$ is a constant term reflecting scrapping of sectoral capital equipment on economic obsolescence when, at equilibrium, $r_j^{\mathrm{w}}\ _i = p_j^{\mathrm{K}}$ and ER, the real exchange rate, is unity. r_j^{w} is the assumed exogenously fixed international surplus ratio, and μ_j is the elasticity of sectoral obsolescence of capital equipment.

As the capital stock gets older, the quasi-rent in the Marshallian sense falls and eventually becomes zero. Following the preceding chapter, the economic decision is then taken to scrap the capital object as obsolescent despite its continuing physical durability. Thus, the sectoral economic obsolescence of capital is here uniquely determined by the rate of capital rent by sector. Sectoral economic obsolescence and physical deterioration constitute the total depreciation expenditure:

$$DEPRECIA = \Sigma_{j}, (DEPR_j \; p_j^{K} K_j) + \Sigma_{j}, OBS_j \qquad (5.3)$$

$DEPRECIA$ is the total depreciation expenditure, $DEPR_j$ are the depreciation rates, K_j is the capital stock by sector, p_j^{K} is, as before, the rate of capital rent by sector, and OBS_j is, as presented earlier, economic obsolenscence. We continue to total savings, thus

$$SAVINGS = HSAV + GOVSAV + DEPRECIA + FSAV \times ER \qquad (5.4)$$

where *SAVINGS* are total savings, *HSAV* are total household savings, *GOVSAV* are government savings, and *FSAV* are foreign savings. Note, that *DEPRECIA* now includes economic obsolenscence.

The owners of capital receive the residual value added, minus total depreciation expenditure, but plus net flow of foreign borrowing and the total premium income. Thus, total income accruing to capital is:

$$YH_h = \Sigma_{j}, (PVA_j Z_j) - DEPRECIA - \Sigma_{lc}, (P_{lc}^{L} L_{lc}) + FBOR \times ER + YPR \qquad (5.5)$$

YH_h is the total income by household type, PVA_j is value added price by sector, Z_j is the domestic output by sector, P_{lc}^{L} is the average wage rate by labor category, L_{lc} is the labor supply by labor category, *FBOR* is the net flow of foreign borrowing, *ER* is, as before, the real exchange rate, and *YPR* is total premium income accruing to capitalists.

As a consequense of these changes, the theoretical content of the traditional CGE model is enhanced by the direct incorporation of the transformation mechanism in the model. A change have here been done by adding one equation (Equation 5.2), three exogenous variables (r_j^{w}, $OBSO^{o}$ and μ_j) and one endogenous variable OBS_j to the CGE mini-model used in this study. A small but significant change.

The sectoral capital stocks K_j are fixed within periods. However, they change over time given aggregate growth of the capital stock and the sectoral allocation of investment. Sectoral share parameters of investment KIO_j are assumed to be fixed. The sectoral allocation of investment is here assumed to be adjusted over time (endogenously) to equate rental rates p_j^{K} in the industrial sectors by the terminal year.

In general terms, adjustment to structural equilibrium is a process where profitability (rental rates) in the different sectors will adjust to a "normal" level of profitability for the economy as a whole. For sectors where profitability is high relative to this normal level, the adjustment to equilibrium implies an increase in domestic production relative to other sectors. On the other hand, sectors where profitability is low relative to the normal level, an adjustment to equilibrium implies a decrease in domestic production relative to other sectors. Thus, a development which implies that a country adjusts to its comparative advantages are characterised as an adjustment towards equalising the relative profitability between sectors. The results of this adjustment are reflected in the direction of domestic production.

The exogenous sectoral capital stocks K_j in any year depend on investment allocation, economic obsolescence OBS_j, and the depreciation rates $DEPR_j$. The relative price of capital commodities p_j^K will determine the real investment I_j^D resulting from total investment $ITOT$[57]. Total investment is equal to the sum of domestic and foreign savings in domestic currency. Domestic savings is made up of government GR and private savings $HSAV$. In other words, a function of real GDP.

In the CGE mini-model domestic investment by sector of destination is given by:

$$p_j^K \, I_j^D = KIO_j \, ITOT - KI^o{}_j \, \Sigma_j \, , (DST_j \, p_j) \tag{5.6}$$

DST_j is inventory investment by sector, and p_i is, as before, the price of composite goods. The request for the volume of investment by sector of destination I_j^D (the sectoral capital accumulation) are translated into a demand for investment commodities by sector of origin I_i^S (producing sectors of capital commodities), thus investment by sector of origin:

$$I_i^S = \Sigma_j \, , c_{ij} \, I_j^D \tag{5.7}$$

In accordance with the production structure, as represented by the input-output model, the investment by sector of origin I_i^S is also known as final demand for productive investment. The summation of c_{ij}, summation by rows, is equal to one.

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[57] The level of total investment is determined endogenously by savings behavior. Generally, investment is made up of two parts, replacement investment and net investment. Replacement investment is that portion of the total which exactly maintains the capital stocks while net investment is that portion which depends on the level of demand. Another component of capital formation is inventories.

Given this structure of the equilibrium model, the temporary equilibrium specification endogenises investment and extends the requirement of consistency in the model. In equilibrium terms, investment is allocated endogenously to make sectoral rental rates (relative price of capital commodities) approximately equal by the terminal year. The period output of the capital stock requirement is inserted as a predetermined variable for the next period optimisation. Once capital stock requirement by sector of destination is established, its sectoral allocation into a demand for investment commodities by sector of origin must be specified. This specification provides the formal link between capital formation and production capacity.

However, the model do not take into account future markets despite the fact it explicitly consider time. There is no intertemporal optimisation[58] and the agents have no expectations about future prices. Given this formulation, the model do not embody the true concept of a dynamic model but rather is akin to comparative statics, which analyses periods as number of discrete moments, using a static model for each of these moments. Our study is focused on structural adjustment (transformation) in pure market variables only. This implies for instance that improvements in technology and technological substitution in the process of production, one important source of industrial innovation and structural renewal,[59] is omitted as an endogenous variable in the analysis.

Moreover, all investments are in established industries and hence, according to the specification of the model, directed to the production of a given set of commodities. In the real world, investments made to increase the total capacity as well as the replacement and scrapping of old production units, change the production characteristics. Investments in new capacity embodying best-practice techniques will decrease the sector´s input coefficient at full capacity. Thus, new capacity have in general input-output proportions different from those of existing production units due to changed relative prices and technical progress, which may be embodied or disembodied (learning by doing). Investments introduce new input-output combinations, and in the long

[58] In intertemporal models, agents have rational expectations and future markets are considered when optimising. Endogenous variables follow an optimal path over time and there are no incentives to deviate from this path at any point of time.

[59] See Freeman, (1974).

run, production of commodities which cannot be found within the initial production possibility set.

As the reader will recall, the numeraire against wich all prices are measured is defined as an index of domestic prices. Thus, variations in the nominal exchange rate in the model directly affect the ratio of the price - in domestic currency - of imports and exports to the price of domestic sales and in that way represent a change in in the real exchange rate. A devaluation increases the domestic price of imports and exports relative domestic sales, and thus, encourages exports and import substitution.[60] With the price normalisation, the formal presentation of the core equations of our extended CGE model is complete.

The description above sketches only the particular characteristics of our model. A detailed description of all mathematical equations is presented in the appendix to this chapter.

5. 2 *The Numerical Experiments*

Given the specification above, we are now equipped with a numerically general equilibrium model designed as a tool to determine the optimum resource allocation and, given the numerical results, the significance of equilibrium. The equilibrium conditions in the model include a supply-demand balance in three different typ of market: labour, commodity, and foregin exchange. A fourth macroeconomic equilibrium condition is the balance between saving and investment, i.e., the macro closure of the model.

With reference to Dervis, de Melo and Robinson (1982)[61] the model can easily degenerate into a magic black box that yields quantitative results but do not really add to our understanding of the mechanisms governing the model. Considering this comment, the experiments are designed to outline the basic adjustment mechanisms that will determine the direction, and hence, the fundamental structure of our solutions.

Following Chenery, Lewis, de Melo, and Robinson (1986) the model contain three institutions, namely production sectors, factors of production, and household types. The production system comprises

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[60] For a discussion, see Dervis, et al., (1982), pp. 192-197.

[61] Dervis, et al., (1982), p.183.

three production sectors. The production sectors; agriculture, industry, and service, represents the whole economy. The production sectors are associated with a specific labour category, namely agricultural labour, industrial labour, and service labour.[62] Each household category is characterised by a single type of factor it owns and supplies. Here, there will be two categories of households; labour household and capitalist household. The labour household supplying the three different kind of labour and receive the wage rate of value added, and the capitalist household being the owners of capital and receive the residual value added.[63]

Given the assumptions of the model the economy is assumed to be in equilibrium, a so called benchmark equilibrium. A benchmark equilibrium data set is a collection of data in which equilibrium conditions of an assumed underlying model are satisfied. Since we do not accomplish an empirical comprehensive study, but only use the model as an illustration, we shall use the data supplied with the CGE mini-model and make appropiate assumptions of the necessary data input related to the extended part of the model.[64] As anyone who deals with empirical studies knows, obtaining adequate and reliable data for the model is the most time-consuming task faced in the study. Therefore the data collection in this numerical study is reduced to a minimum.

The first task is to present table 5.1 that represent the benchmark equilibrium data. The variables in this table together with the computations in each experiment will make table 5.1 to table 5.7 self-contained.

As by now well known to the reader, the capital stock in this model is subject to physical as well as economic deterioration (obsolescence). The physical deterioration, depreciation rates, is assumed to be two percent of the capital stock in each sector. The assumed initial values of economic deterioration, obsolenscence by each sector,

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[62] Alternatively, the sectors can be defined in terms of input characteristics; labour-intensive, capital-intensive, and knowledge-intensive commodities.

[63] Note, that in equilibrium the expenditures of each household exhaust its income (formula 2.11 in Chapter 2). However, in this chapter we consider saving. In any case, total income generated in the system always equals total national product at market prices.

[64] As noted, the mini-equilibrium-model is included in the GAMS model library, which is distributed with the GAMS system. Readers who have access to the GAMS program can thus take an active part of the model developed here.

is here added. This initial values will be five percent of each sector respectively. However, the elasticity of sectoral obsolescence of capital equipment is assumed to be different for the three sectors. The value is assumed to be 2.0 for the agriculture sector, 2.5 for industry, and 1.0 for services. All figures of elasticity variabels are percentages. Since we only use this model as an illustration, the assumed values are without empirical significance. In all experiments, the computations of the economy is assumed to start from the computed benchmark equilibrium presented in table 5.1 below.

Table 5. 1: *Computed Benchmark Equilibrium*

	Agriculture	*Industry*	*Services*
Domestic prices	0.924	1.064	0.993
Rate of capital rent	1.053	1.053	1.053
Value added price	0.667	0.347	0.647
Composite commodity supply	688.600	1024.420	486.654
Domestic output	647.939	915.659	503.199
Domestic sales	630.266	889.625	481.058
Exports	17.578	25.943	22.156
Imports	58.688	134.936	4.797
Capital stock	657.575	338.708	1548.519
Intermediate uses	270.274	487.736	163.787
Private consumption	415.503	249.157	174.420
Government consumption	2.823	9.881	128.448
Investment by origin	-	277.646	20.000
Economic obsolescence	**29.668**	**14.878**	**73.548**
Investment by destination	38.699	86.290	172.656
Domestic price of imports	1.000	1.000	1.000
Domestic price of exports	1.000	1.000	1.000
Average output price	0.926	1.064	0.993
Price of composite commodities	0.931	1.057	0.991

Real exchange rate 1.000, General price level 1.000, Government revenue 185.975, Tariff revenue 30.703, Indirect tax revenue 69.174, Total household savings 56.949, Government savings 45.577, Total depreciation expenditure 171.677, Total savings 313.377, Total investment 313.377, Foreign savings 39.174, Net flow of foreign borrowing 62.866, Household tax revenue 86.097, and Private GDP 966.296.

Note, that the value of marginal product of capital (rate of capital rent) is everywere the same. Real exchange rate, general price level, and foreign savings are fixed. Since the CGE mini model is applied for a particular country, Korea, the computations are in billion won. Exchange rate is defined as won per dollar. Foreign savings, net remittanes from abroad, and net flow of foreign borrowing is, however, expressed in billion dollars.

We are now prepared to draw attention to the elaboration of the experiments, and in this context, evaluate the results of the computations. As is well known, the choice of endogenous variables are crucial then illustrating the equilibrium mechanism of the model, and hence implicitly, the specification of numerical experiments.[65] In all experiments we assume that the exchange rate is fixed and the balance of trade is endogenous, so that foreign capital inflow adjusts. This redefines the balance of payments constraint. As a consequence, the value of imports no longer has to be exactly equal to the value of exports. Further, the foreign capital inflow (net flow of foreign borrowing) constitutes an addition to the income generated within the economy, and is also incorporated in the capital income equation.

The experiments are divided in two sections. The first section emphasise changes (government intervention) in the fixed rate of real exchange. The second section extends the analysis of the first section by examining economic growth, i.e., the adjustment of temporary equilibrium. Throughout, experiments are chosen to make the issue of disinvestment activities (economic obsolescence) explicit.

5. 2. 1 *Change in Foreign Currency*

The exchange rate, factor prices, and the value of output are in the context of the transformation process important variables. An undervalued currency increases competitiveness, raises the profit rates, and thus, there is a risk that necessary cost reductions will not be realised. Hence, the incentives to dismantling old investments on obsolescence diminish. On the other hand, an overvaluation of the domestic currency can imply, due to decreasing competitiveness and falling profit rates, a risk of exaggregated cost cuts. The incentives to dismantling old investments on obsolescence increase.

In the first experiment we start with an increase in the real exchange rate, i.e., a devaluation of domestic currency. We assume arbitrarily a devaluation by 20 percent. Recall, we start from the computed benchmark equilibrium data (Table 5.1). Table 5.2 present the results obtained.

[65] The model is solved by the GAMS program. A describtion of how the system of equations can be implemented in GAMS, see Condon, Dahl and Deverajan (1987).

Table 5. 2: *Devaluation of Domestic Currency*

	Agriculture	*Industry*	*Services*
Domestic prices	0.916	1.043	0.971
Rate of capital rent	1.056	1.056	1.056
Value added price	0.665	0.332	0.639
Composite commodity supply	658.491	980.100	476.448
Domestic output	649.416	904.610	505.299
Domestic sales	622.345	865.972	471.375
Exports	25.426	37.965	32.650
Imports	39.561	114.813	4.332
Capital stock	657.575	338.708	1548.519
Intermediate uses	268.298	484.362	162.715
Private consumption	387.370	232.947	167.066
Government consumption	2.823	9.881	128.448
Investment by origin	-	252.910	18.218
Economic obsolescence	**20.476**	**9.356**	**61.102**
Investment by destination	35.253	78.594	157.281
Domestic price of imports	1.200	1.200	1.200
Domestic price of exports	1.200	1.200	1.200
Average output price	0.925	1.049	0.984
Price of composite commodities	0.938	1.062	0.972

Real exchange rate 1.200, General price level 1.000, Government revenue 179.169, Tariff revenue 30.240, Indirect tax revenue 68.059, Total household savings 53.491, Government savings 41.169, Total depreciation expenditure 144.683, Total savings 286.352, Total investment 286.352, Foreign savings 39.174, Net flow of foreign borrowing -1.710, Household tax revenue 80.870, and Private GDP 970.631.

First, we have to consider the decrease in economic obsolescence. As expected, the incentives to dismantling old investments on obsolescence diminish. Thus, a devaluation policy have a substantial impact on economic obsolescence. That will be the consequences? The general answer is that the process of structural renewal will be hampered and in the long run a slowdown in economic growth because of the decrease in investment. However, to get a more specific answer, we must carry out a more detailed empirical study under a longer period of time.

Second, we have to consider the activities in foreign trade. The devaluation affects exports and import prices uniformly. This is confirmed in Table 5.2. In quantitative terms, the devaluation expand the production of exportables. For exports to expand, their dollar price must decline on foreign markets. With fixed import prices, this decline leads to a deterioation in the terms of trade. Moreover, the increased import prices in domestic currency implies a fall in imports and an increased import substitution. Thus, adjustment by devaluation affects both exports and imports in each sector. Finally, note the change in net flow of foreign borrowing. The negative value indicate a net outflow of foreign currency.

In the next experiment (Table 5.3) we have a decrease in real exchange rate, i.e., an appreciation of domestic currency by 20 percent. Again, we start from the computed benchmark equilibrium data.

Table 5. 3: *Appreciation of Domestic Currency*

	Agriculture	*Industry*	*Services*
Domestic prices	0.919	1.100	1.030
Rate of capital rent	1.056	1.056	1.056
Value added price	0.659	0.376	0.671
Composite commodity supply	722.428	1077.568	492.724
Domestic output	644.520	934.927	500.814
Domestic sales	632.864	917.073	486.592
Exports	11.439	16.057	13.332
Imports	90.928	164.602	5.383
Capital stock	657.575	338.708	1548.519
Intermediate uses	273.631	493.775	165.742
Private consumption	445.973	259.645	175.896
Government consumption	2.823	9.881	128.448
Investment by origin	-	314.268	22.638
Economic obsolescence	**46.033**	**25.778**	**91.614**
Investment by destination	43.800	97.687	195.417
Domestic price of imports	0.800	0.800	0.800
Domestic price of exports	0.800	0.800	0.800
Average output price	0.916	1.093	1.022
Price of composite commodities	0.905	1.059	1.026

Real exchange rate 0.800, General price level 1.000, Government revenue 192.734, Tariff revenue 31.341, Indirect tax revenue 71.552, Total household savings 59.425, Government savings 47.975, Total depreciation expenditure 217.194, Total savings 355.933, Total investment 355.973, Foreign savings 39.174, Net flow of foreign borrowing 141.734, Household tax revenue 89.841, and Private GDP 1008.312.

As expected, the reverse to the experiment above is the case, i.e., all of the features from the earlier experiment are preserved but in opposite direction. For example, the incentives to dismantling old investments on obsolescence now increase.

The experiments in the first section have illustrated an important trade-off in the open economy, namly the trade-off between competitiveness (increased import substitution and export expansion) and structural renewal. The change in the real exchange rate have a considerable influence on that balance. Logically, this leads to the question of finding the appropriate balance between competitiveness and an efficient transformation to sustain a desirable growth path in the economy.

5. 2. 2 *Temporary Equilibrium Adjustment - A Scenario*

As stipulated above, the model in this section works step-wise from period to period, and solves the market for prices and quantities. The solution for each period, with each static solution depending only on current and past variables, is used to create the next period´s variables in the model. The model is solved as a sequence of static equilibria, with no intertemporal optimisation. Dynamics appear through changes in domestic and international conditions.[66]

For each period the sectorally capital stocks are adjusted. Given the computed data of investment by destination minus physical deterioration and sectoral obsolescence, added to the current capital stocks, will become the next period´s sectoral capital stocks. In addition, the assumed initial variables of sector obsolescence is added. Thus, the capital stock and the variable of economic obsolescence are inserted as predetermined variables for the next period equilibrium computation. Recall, physical deterioration is assumed to be two percent of current sectoral capital stock. The initial variables of sectoral obsolescence is assumed to be five percent of next period´s sectoral capital stocks. These are the predetermined variables.

The first period, the starting point of the temporary equilibrium computations, is represented by the computed benchmark equilibrium presented in Table 5.1.

Next period (Period 2) is presented in Table 5.4. Most of the features in the solution below are preserved in all subsequent experiments. Note, the decrease of the capital stock in the agriculture sector. That is a request from period 1. A development that will continue in the next period.

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[66] The temporary equilibrium approach used in this chapter, does not imply that the underlying economic system is viewed as discrete. Instead, the discrete moments are simply approximations (artificial to some extent) of the essentially continuous system being modeled.

Table 5. 4: *Temporary Equilibrium - Period 2*

	Agriculture	*Industry*	*Services*
Domestic prices	0.963	1.030	1.002
Rate of capital rent	1.024	1.024	1.024
Value added price	0.702	0.316	0.660
Supply of composite commodities	695.193	1086.333	498.998
Domestic output	647.754	975.660	515.538
Domestic sales	631.502	946.088	493.242
Exports	16.223	29.561	22.312
Imports	63.778	140.267	4.936
Capital stock	653.454	403.346	1616.667
Intermediate uses	282.325	511.370	171.782
Private consumption	410.045	262.929	177.003
Government consumption	2.823	9.881	128.448
Investment by origin	-	302.152	21.765
Economic obsolescence	**31.156**	**18.995**	**78.934**
Investment by destination	42.111	93.924	187.882
Domestic price of imports	1.000	1.000	1.000
Domestic price of exports	1.000	1.000	1.000
Average output price	0.964	1.029	1.002
Price of composite commodities	0.966	1.026	1.000

Real exchange rate 1.000, General price level 1.000, Government revenue 191.725, Tariff revenue 32.165, Indirect tax revenue 71.407, Total household savings 58.309 Government savings 50.401, Total depreciation expenditure 183.842, Total savings 331.726, Total investment 331.726, Foreign savings 39.174, Net flow of foreign borrowing 69.530, Household tax revenue 88.153, and Private GDP 989.371.

Turning to the next period (Period 3). The calculations of capital stock and variables of economic obsolescence, based on equilibrium data from the preceding period, are inserted as predetermined variables. In addition, it is assumed that financial resources are free to flow between different countries. Hence, the rate of capital rent by sector between the home country and the foreign countries in question will become crucial for the producer´s decision to expand production capacity, domestically as well as abroad. To state the matter otherwise, in high-profit-rate countries investment will increase, and thence, attract funds from low-profit-rate countries. In quantitative terms we assume an increase in foregin capital rent by 10 percent in agriculture and 20 percent in industry. The results of the equilibrium computation is presented in Table 5.5 below.

The increase in foreign capital rent in agriculture and industry imply a decrease in the relative value of the domestic capital rent in corresponding domestic sectors. The result is a an increase in economic obsolescence. If the increase in foreign capital rent will not become transitory, industrial growth may be reduced because of a fall in future investment. According to an equilibrium computation without the assumed increase in foreign capital rent, economic obsolescence had been 32.488 in agriculture, and 23.440 in industry.

Table 5. 5: *Temporary Equilibrium - Period 3*

	Agriculture	*Industry*	*Services*
Domestic prices	0.988	1.008	1.005
Rate of capital rent	1.007	1.007	1.007
Value added price	0.726	0.298	0.665
Supply of composite commodities	699.046	1155.815	509.919
Domestic output	647.274	1041.283	526.679
Domestic sales	631.852	1008.404	504.031
Exports	15.428	32.892	22.664
Imports	67.203	147.401	5.050
Capital stock	651.340	470.208	1693.272
Intermediate uses	295.437	536.744	180.323
Private consumption	400.786	268.060	176.575
Government consumption	2.823	9.881	128.448
Investment by origin	-	341.130	24.573
Economic obsolescence	**38.899**	**36.487**	**84.117**
Investment by destination	47.542	106.052	212.109
Domestic price of imports	1.000	1.000	1.000
Domestic price of exports	1.000	1.000	1.000
Average output price	0.988	1.008	1.005
Price of composite commodities	0.989	1.007	1.003

Real exchange rate 1.000, General price level 1.000, Government revenue 195.985, Tariff revenue 33.807, Indirect tax revenue 73.976, Total household savings 58.341, Government savings 54.403, Total depreciation expenditure 216.165, Total savings 368.084, Total investment 368.084, Foreign savings 39.174, Net flow of foreign borrowing 75.688, Household tax revenue 88.202, and Private GDP 989.917.

Considering the situation above, it is assumed that the government will act by economic policy in the next period (Period 4). The economic policy is here a large devaluation by 20 percent.

The devaluation, as we allready know from Table 5.2, affects exports and import prices uniformly. Exports increase and we can note a fall in imports and an increased import substitution. As we also known, the consequences on economic obsolescence is smaller, compared to the situation there no devaluation had been carried out. To be more precisely, an equilibrium computation without devaluation shows 39.868 for agriculture, 42.808 for industry, and 90.197 for services. Due to increased economic activity, the request for decrease of the capital stock in the agriculture sector have ceased.

Table 5. 6: *Temporary Equilibrium - Period 4*

	Agriculture	*Industry*	*Services*
Domestic prices	1.012	0.965	0.972
Rate of capital rent	0.992	0.992	0.992
Value added price	0.752	0.267	0.651
Supply of composite commodities	673.279	1146.363	511.122
Domestic output	647.811	1074.228	541.988
Domestic sales	626.266	1019.828	505.678
Exports	20.990	52.198	34.958
Imports	48.526	128.476	4.649
Capital stock	646.956	530.369	1787.399
Intermediate uses	302.254	551.405	185.445
Private consumption	368.202	259.343	173.766
Government consumption	2.823	9.881	128.448
Investment by origin	-	325.734	23.464
Economic obsolescence	**27.627**	**27.053**	**75.083**
Investment by destination	45.398	101.257	202.543
Domestic price of imports	1.200	1.200	1.200
Domestic price of exports	1.200	1.200	1.200
Average output price	1.017	0.975	0.985
Price of composite commodities	1.028	0.993	0.973

Real exchange rate 1.200, General price level 1.000, Government revenue 192.801, Tariff revenue 34.286, Indirect tax revenue 74.321, Total household savings 55.690, Government savings 55.108, Total depreciation expenditure 188.578, Total savings 346.386, Total investment 346.386, Foreign savings 39.174, Net flow of foreign borrowing 5.760, Household tax revenue 84.194, and Private GDP 944.939.

Needless to say, if the increase in foreign capital rent is to be regarded as permanent, a devaluation policy to be more competitive is not a sufficient policy to restore long run equilibrium. In a case like this, the request for domestic change in production structure will become more radical. Whatever the measures, to restore a long run equilibrium, we are coming back to the question of finding the appropriate balance between competitiveness and an efficient transformation to sustain a desirable growth path in the economy.

Next period, Period 5, is the last equilibrium computation. The equilibrium solution is presented in Table 5.7 below.

Fourtunatly, the increase in foreign capital rent was only transitory, and is now going back to its original level. This is to say that the relative value of the domestic capital rent have increased, and our production structure will become more competitive for future investment. That imply a decrese in economic obsolescence. However, we also assume a currency change by the government. More precisely, an appreciation of domestic currency by 20 percent, i.e., the currency value before the assumed devaluation. This is a rather logical assumption, since the competitive situation in domestic production now have increased. Anyhow, the sum of these economic changes turn out to be an increase in economic obsolescence. Compared to a situation where no change in foreign conditions and no domestic policy change have taken place, the economic obsolescence had been 23.821 in agriculture, 18.052 in industry, and 80.345 in services.

Table 5. 7: *Temporary Equilibrium - Period 5*

	Agriculture	*Industry*	*Services*
Domestic prices	1.050	0.966	0.993
Rate of capital rent	0.972	0.972	0.972
Value added price	0.783	0.262	0.662
Supply of composite commodities	713.557	1245.733	535.148
Domestic output	650.880	1129.494	553.351
Domestic sales	637.098	1090.738	528.994
Exports	13.758	38.727	24.373
Imports	76.618	155.035	5.274
Capital stock	651.788	593.966	1879.111
Intermediate uses	313.762	573.509	192.886
Private consumption	396.972	291.178	187.078
Government consumption	2.823	9.881	128.448
Investment by origin	-	371.165	26.736
Economic obsolescence	**34.520**	**28.701**	**96.700**
Investment by destination	51.725	115.403	230.772
Domestic price of imports	1.000	1.000	1.000
Domestic price of exports	1.000	1.000	1.000
Average output price	1.046	0.967	0.993
Price of composite commodities	1.045	0.970	0.991

Real exchange rate 1.000, General price level 1.000, Government revenue 205.542, Tariff revenue 36.094, Indirect tax revenue 77.120, Total household savings 61.070, Government savings 65.708, Total depreciation expenditure 220.642, Total savings 386.595, Total investment 386.595, Foreign savings 39.174, Net flow of foreign borrowing 84.800, Household tax revenue 92.328, and Private GDP 1036.228.

5. 3 *Concluding Remarks*

There are of course possibilities for making alternative experiments with the model. But although we cannot present an exhaustive set of experiments, the workings of the model has been clarified, and at the same time, indicated how future empirical applications might be implemented. Thus, we have been able to examine the importance of different initial conditions and the economic structure within a framework that imposes intersectoral consistency. However, the numerical experiments in this study would need to be justified by empirical analysis.

The model stipulated in this chapter do not exactly follow the specification in Chapter 4, but captures the crucial element of structural transformation, and thus the transformation process is endogenously determined in the model. The key concept of the transformation process is the foreign capital surplus by sector, the rate of domestic capital rent by sector, and the exchange rate. These values determines the transformation process. In other words, the structure of the transformation process is here an integral part of the CGE mini-model; the CGE transformation model. In this equilibrium model, the rate of domestic capital rent by sector coordinates investment and the process of economic obsolescence of the capital stock. The model outlined here is a good point of departure. It is clear, however, that a more developed and realistic specification of the transformation process represents a major challenge. A challenge that in some sense start in the next, and final, chapter.

APPENDIX: *The Mathematical Equations of the Model*

- PRICES

Definition of domestic import prices.

$$p_j^M = p_j^{WM} ER(1 + tm_j + pr_j) \qquad \text{(A5.1)}$$

p_j^{WM} is the world market price of imports, ER is the real exchange rate, tm_j is the tariff rate on imports, and pr_j is the import premium rate.

Definition of domestic export prices.

$$p_j^E = p_j^{WE}(1 + te_j) ER \qquad \text{(A5.2)}$$

p_j^E is the domestic price of exports, p_j^{WE} is the world market price of exports, te_j are the export duty rates, and ER is the real exchange rate.

Value of domestic sales.

$$p_i x_i = p_j^Z x_j^Z + p_j^M M_j \qquad \text{(A5.3)}$$

p_i is the price of composite commodites, x_i is the composite commodity supply, p_j^Z is the domestic price, x_j^Z are the domestic sales, p_j^M is the domestic price of imports, and M_j is imports by sector.

Value of domestic output.

$$p_j^Z Z_j = p_j^Z x_j^Z + p_j^E E_j \qquad \text{(A5.4)}$$

p_j^Z is the average output price by sector, Z_j is the domestic output by sector, x_j^Z are domestic sales, p_j^E is the domestic price of exports, and E_j is exports by sector.

Definition of activity prices.

$$p_j^Z(1\text{-}ITAX_j) = PVA_j + \Sigma\, a_{ij}\, p_i \qquad \text{(A5.5)}$$

p_j^Z is the average output price by sector, $ITAX_j$ is the indirect tax rate, PVA_j is the value added price by sector, a_{ij} are the input-output coefficients, and p_i is the price of composite commodities.

Definition of capital commodity price.

$$p_j^K = \Sigma_i\,, (p_i\, c_{ij}) \qquad \text{(A5.6)}$$

p_j^K is the rate of capital rent by sector, p_i is the price of composite commodities, and c_{ij} is the capital composition matrix.

Definition of general price level.

$$p_{\text{index}} = \Sigma_j\,, (pwts_i\, p_i) \qquad \text{(A5.7)}$$

p_{index} is the general price level, $pwts_i$ are the CPI weights, and p_i is the price of composite commodity.

- OUTPUT AND THE FACTORS OF PRODUCTION

Production function (Cobb-Douglas).

$$Z_j = \mathrm{AD}_j\, \Pi_{lc} L_{j,lc}^{\alpha_{j,lc}}\, K_j^{(1\, -\, \Sigma_{lc}\,,\, \alpha_{j,lc})} \qquad \text{(A5.8)}$$

Z_j is the domestic output by sector, AD_j is the production function shift parameter, $\alpha_{j,lc}$ is the labor share parameter, $L_{j,lc}$ is the employment by sector and labor category (lc), and K_j is the capital stock by sector.

First order condition for profit maximum.

$$P_{lc}^{L}\, W_{dist}\, L_{j,lc} = x_j^{Z}\ PVA_j\ \alpha_{j,lc} \qquad \text{(A5.9)}$$

p_{lc}^{L} is the average wage rate by labor category (lc), W_{dist} are the wage proportionality factors, $L_{j,lc}$ denote the employment by sector and labor category, and PVA_j is the value added price by sector.

Labour market equilibrium.

$$\Sigma_j\, ,\, L_{j,lc} \leq L_{lc} \qquad \text{(A5.10)}$$

$L_{j,lc}$ denote the employment by sector and labor category, and L_{lc} is the labour supply by labor category (lc).

CET function - Exports (domestic output).

$$Z_j = AT_j[\gamma_j\, E_j^{\ \phi_j} + (1 - \gamma_j) x_j^{Z\ \phi_j}]^{\ 1/\phi_j} \qquad \text{(A5.11)}$$

Z_j is the domestic output by sector, AT_j is the CET function shift parameter, GAMMA is the CET function share parameter, E_j is exports by sector, RHOT is the CET function exponent, and x_j^Z are the domestic sales.

Export supply.

$$E_j/x_j^Z = (p_j^E/p_j^Z\, (1 - \gamma_j)\, /_{\gamma_j}\, {}^{(1/(\phi_j - 1)\,)} \qquad \text{(A5.12)}$$

p_j^E is the domestic price of exports, and p_j^Z is the domestic price.

CES function - composite commodity aggregation function.

$$x_i = AC_j\,[\delta_j\, M_j^{\;-\rho_j} + (1 - \delta_j)x_j^{Z\;\;-\rho_j}\,]^{-1/\rho_j} \qquad \text{(A5.13)}$$

x_i is the composite commodity supply, AC_j is the armington function shift parameter, δ_j is the armington function share parameter, M_j is imports, ρ_j is the armington function exponent, and x_j^Z are the domestic sales

Cost minimisation of composite good.

$$M_j/x_j^Z = (p_j^Z/p_j^M\,\delta_j)\,/_{(1\,-\,\delta_j)}{}^{(1/(\phi_j\,-1))} \qquad \text{(A5.14)}$$

p_j^Z is the domestic prices, and p_j^M is the domestic price of imports.

Domestic sales for nontraded sectors.

A first step toward more realism has been taken by introducing non-tradable commodities. Nontradable commodities are commodities that are not subject to international trade. In general, most service as well as housing and construction fit this category.

$$x_j^Z = Z_j \qquad \text{(A5.15)}$$

x_j^Z are the domestic sales, and Z_j is the domestic output by sector.

Composite commodity aggregation for nontraded sectors.

$$x_i = x_j^Z \qquad \text{(A5.16)}$$

x_i is the composite commodity supply, and x_j^Z are domestic sales.

- DEMAND

Total intermediate uses.

$$x_{ij} = \Sigma_j , a_{ij} \, Z_j) \qquad \text{(A5.17)}$$

x_{ij} are the intermediate uses, a_{ij} is the input-output coefficients, and Z_j is the domestic output by sector.

The sector balances of intermediate inputs (interindustry matrix) form the basis of the input-output table. The input-output matrix is derived from the interindustry matrix, by dividing each element in a column by the row sum of the corresponding row. The *Leontief* matrix is obtained from the input-output matrix by subtracting it from an *n* by *n* identity matrix. This changes the sign of all off-diagonal elements and makes all diagonal elements into their complements to one. Theoretically, the input coefficients are in physical terms. Empirically, the coefficients are in monetary terms. As long as we assume that prices are constant, the input coefficients should be the same either in physical or monetary terms.

The transactions may be valued at either the price received by the producer, *producer´s value,* or at the price paid by the consumer, *purchaser´s value.* The difference between these values is that transport margins, net indirect commodity taxes, i.e., indirect taxes less subsidies, and trade margins are added to the basic producer´s values in the national accounts. Since the demand components are computed at purchaser´s values, production and imports are converted to these values too.

Inventory investment.

$$DST_j = DSTR_j \, Z_j \qquad \text{(A5.18)}$$

DST_j is inventory investment by sector, $DSTR_j$ is the ratio of inventory investment to gross output, and Z_j is the domestic output by sector.

Private consumption behavior.

$$p_j CD_j = \Sigma_h , (CLES_{j,h}(1\text{-}MPS_h)YH_h (1\text{-}HTAX_h)) \qquad \text{(A5.19)}$$

p_j are the price of composite commodites, CD_j is the final demand for private consumption, $CLES_{j,h}$ are the private consumption shares, MPS_h is the marginal propensity to save by household type, YH_h is the total income by household type, and $HTAX_h$ is the income tax rate by household type

Private GDP.

$$Y = \Sigma_h YH_h \qquad \text{(A5.20)}$$

Y is private *GDP*, YH_h is the total income by household type.

Total income accruing to labour.

$$YH_h = \Sigma_{lc} , (P_{lc}^{L} L_{lc}) + REMIT \times ER \qquad \text{(A5.21)}$$

YH_h is the total income by household type, P_{lc}^{L} is the average wage rate by labour category, L_{lc} is the labour supply by labor category, $REMIT$ is the net remittances from abroad, and ER is the real exchange rate.

Total income accruing to capital.

(A5.22)

$$YH_h = \Sigma_j , (PVA_j Z_j) - DEPRECIA - \Sigma_{lc} (P_{lc}^{L} * L_{lc}) + FBOR \times ER + YPR$$

YH_h is the total income by household type, PVA_j is value added price by sector, Z_j is the domestic output by sector, $DEPRECIA$ is total depreciation expenditure, P_{lc}^{L} is the average wage rate by labor category, L_{lc} is the labor supply by labor category, $FBOR$ is the net flow of foreign borrowing, ER is the real exchange rate, and YPR is total premium income accruing to capitalists.

- SAVING AND INCOME

Household savings.

$$HSAV = \Sigma_h , (MPS_h \, YH_h \, (1 - HTAX_h)) \qquad \text{(A5.23)}$$

$HSAV$ are the total household savings, MPS_h is the marginal propensity to save by household type h, YH_h is the total income by household type, and $HTAX_h$ is the income tax rate by household type.

Government revenue.

$$GR = TARIFF - NETSUB + INDTAX + TOTHTAX \qquad \text{(A5.24)}$$

GR is the government revenue, $TARIFF$ is the tariff revenue, $NETSUB$ is the export duty revenue, $INDTAX$ is the indirect tax revenue, $TOTHTAX$ is the household tax revenue.

Government savings.

$$GR = \Sigma_j \, (p_j \, GD_j) + GOVSAV \qquad \text{(A5.25)}$$

GR is the government revenue, p_j are the price of composite commodites, GD_j is the final demand for government consumption, and $GOVSAV$ are government savings. It is an essential assumption for a real equilibrium model that the government must balance its budget.

Government consumption shares.

$$GD_j = GLES_j \, GDTOT \qquad \text{(A5.26)}$$

GD_j is the final demand for government consumption, $GLES_j$ is the government consumption shares, and $GDTOT$ is the total volume of government consumption.

Tariff revenue.

$$TARIFF = \Sigma_j ,(TM_j\, M_j\ \ p_j{}^{WM})ER \qquad \text{(A5.27)}$$

$TARIFF$ is the tariff revenue, TM_j are the tariff rates on imports, M_j are imports, $p_j{}^{WM}$ are world market price of imports, ER is the real exchange rate.

Indirect taxes on domestic production.

$$INDTAX = \Sigma_j ,(ITAX_j\, p_j{}^{Z}\, Z_j) \qquad \text{(A5.28)}$$

$INDTAX$ is the indirect tax revenue, $ITAX_j$ is the indirect tax rates, $p_j{}^{Z}$ is the average output price by sector, and Z_j is the domestic output by sector.

Export duties.

$$NETSUB = \Sigma_j ,(te_j\, E_j\ \ p_j{}^{WE})ER \qquad \text{(A5.29)}$$

$NETSUB$ is export duty revenue, te_j are export duty rates, E_j are exports by sector, $p_j{}^{WE}$ is the world market price of exports, ER is the real exchange rate.

Total import premium income.

$$YPR = \Sigma_j ,(p_j{}^{WM}\, M_j)ER \times pr \qquad \text{(A5.30)}$$

YPR is the total premium income accruing to capitalists, $p_j{}^{WM}$ is the world market price of imports, M_j are imports, ER is the real exchange rate, and pr is import premium.

Total household taxes collected by government.

$$TOTHTAX = \Sigma_h ,(HTAX_h \; YH_h) \qquad \text{(A5.31)}$$

$TOTHTAX$ is the household tax revenue, $HTAX_h$ is the income tax rate by household type h, YH_h is the total income by household type h.

* CAPITAL FORMATION

Depreciation expenditure.

$$DEPRECIA = \Sigma_j ,(DEPR_j \; p_j^K K_j) + \Sigma_j OBS_j \qquad \text{(A5.32)}$$

$DEPRECIA$ is total depreciation expenditure, $DEPR_j$ are the depreciation rates, K_j is the capital stock by sector, p_j^K is the rate of capital rent by sector, and OBS_j is economic obsolenscence.

Economic obsolescence.

$$OBS_j = OBSO^o(r_j^w / p_j^K (1/ER))^{\mu_j} \qquad \text{(A5.33)}$$

OBS_j is economic obsolescence, $OBSO^o$ is a constant term reflecting scrapping of sectoral capital equipment on obsolescence when, at equilibrium, $r_j^w = p_j^K$, and ER is the exchange rate, r_j^w is the international surplus ratio, p_j^K is the rate of capital rent by sector, and μ_j is the elasticity of sectoral obsolescence of capital equipment.

Total savings.

$$SAVINGS = HSAV + GOVSAV + DEPRECIA + FSAV \times ER \qquad \text{(A5.34)}$$

$SAVINGS$ are total savings, $HSAV$ are total household savings, $GOVSAV$ are government savings, $DEPRECIA$ is total depreciation expenditure, FSAV are foreign savings.

Domestic investment by sector of destination.

$$p_j^{K}\ I_j^{D} = KIO_j\ ITOT - KI^{o}_j\ \Sigma_j\ (DST_j\ {}^{*}p_j) \qquad \text{(A5.35)}$$

p_j^{K} is rate of capital rent by sector, r_j^{w} is the international surplus ratio, I_j^{D} is volume of investment by sector of destination, KI^{o}_j are the shares of investment by sector of destination, $ITOT$ is the total investment, DST_j is inventory investment by sector, p_j is the price of composite goods. The sectoral share parameters for investment are assumed to be fixed. The total level of investment is determined endogenously. Total investment is determined by savings in the economy (savings-determined investment).

Investment by sector of origin.

$$I_i^{S} = \Sigma_j\ ,\ c_{ij}\ I_j^{D} \qquad \text{(A5.36)}$$

I_i^{S} is the final demand for productive investment, c_{ij} is the capital composition matrix, and I_j^{D} is the volume of domestic investment by sector of destination.

Current account balance.

$$\Sigma_j\ ,\ p_j^{WM}\ M_j = \Sigma_j\ (p_j^{WE}\ E_j) + FSAV + REMIT + FBOR \qquad \text{(A5.37)}$$

p_j^{WM} is the world market price of imports, M_j are imports, p_j^{WE} is the world market price of exports, E_j are exports by sector, $FSAV$ are foreign savings, $REMIT$ are net remittances from abroad, and $FBOR$ is the net flow of foreign borrowing.

- MARKET EQUILIBRIUM

Commodity market equilibrium.

$$x_i = x_{ij} + CD_j + GD_j + I_i^S + DST_j \qquad \text{(A5.38)}$$

x_i are the composite commodity supply, x_{ij} are intermediates uses, CD_j is the final demand for private consumption, GD_j is the final demand for government consumption, I_i^S is the final demand for productive investment, and DST_j is the inventory investment by sector.

Objective function.

$$OMEGA = \Pi_j \, CD_j^{\,CLESj,h} \qquad \text{(A5.39)}$$

$OMEGA$ is the objective function variable, $CLES_{j,h}$ is the private consumption shares, and CD_j is the final demand for private consumption.

CHAPTER 6

Searching for Reality - The Empirical Challenge

The contribution in this book is the explicit recognitation of the importance of endogenous disinvestment activities to a new equilibrium. This is embodied in the condition specifying the economic life of capital to account for obsolescence. This specification provides the formal link between capital formation and production capacity. Thus, the transformation process is endogenously specified in the model. The economic structure is representative for the process of economic transformation in an open economy. In technical terms, the economic structure is illustrated by the help of a computable general equilibrium (CGE) model to capture the role of prices and the workings of the market system.

Operationally, the objective in this study is to apply the model to a number of situations in order to demonstrate its capabilities. Experiments, exploring the equilibrium mechanism of the model, and applications, designed as a series of temporary equilibria, with numerical data were reported in this study. The specification of the experiments has been analysed in detail in order to stimulate criticism and further discussion of the model as a tool of empirical analysis. At this stage of development, there are many improvments which remain to be made. This chapter will start the discussion of the necessary improvements. The discussion is focused on the CGE model, necessary empirical research, and for the subject important policy questions. As the reader will see, the analytical potential of the equilibrium model is great, but a great deal of scientific work is placed on the researcher.

6. 1 *Necessary Steps to Reality*

The general equilibrium model discussed in the previous chapter contains several variables that are of empirical, and thus of statistical interest. We have been given special attention to the variable of economic obsolescence. However, this variable has only been used as a concept in our model, in other words, the variable has not been derived from any empirical observation. The same is applied to the elasticity of sectoral obsolescence. The entities of the model should be given numerically estimated values. Unfortunately, the possibilities are limited by the actual access to empirical observations. However, in an empirical study it would be preferable. Anyhow, to carry out empirical observations representing economic obsolescence we have to choose a variable to measure.

In principle, two variables are possible. The first is statistics of bankruptcies, the second is statistics of employees who had received notice of dismissal or lay off. However, both variables have their weakness as a measure of economic obsolescence.

Bankruptcies is a legal concept, comprising only a part of the process of economic obsolescence. In most cases, it is not the whole company or the whole industrial activity that is economic obsolete. For example, it can be an economic necessity to terminate some production or change the method of the manufacturing process. But this request for change does not in necessarily implies bankruptcy. On the contrary, in the integrated open economy the request for change in the process of production is an important element of the growth process.

Employees who had received notice of dismissal or lay off is more closely linked, in statistic sense, to the change in the process of production. But, even this variable have its weakness. For example, if one part of the company becoming economic obsolete, the labour force will be moved to another activity in the same company. Thus, the economic obsolescence, that have ocurred in the company, will not be found in the statistics of laid off employees. The same situation will arise if the employees would give up work at the company by a retirement plan instead of having a notice of dismissal.

In the CGE mini model the commodities are classified according to characteristics in use rather than production. The reverse would be preferable, In other words, the commodities would be classified according to input characteristics rather than by using standard industrial classifications, As an example, a classification in labour-intensive, capital-intensive, and knowledge-intensive commodities would be applied. International trade is of course essential in an open economy, and the theory of international trade (comparative advantage) relay on a definition of commodities in terms of input characteristics. It is a theory of the division of labour across different types of production activities.

Given this classification, and in order to look into economic transformation in general, certain characteristics may be helpful. From the discussion of the structural development in Sweden,[67] but it is valied for the most industrial countries.

In the knowledge-intensive manufacturing sector new technology, new products, and the possibility to establish new markets, are not only the driving forces, but also strategical for the competitive situation. Thus, a continuosly reneval of the process of production is necessary. To work with the latest technology is here important. As a consequence, the lifetime of capital will become short. The frequent investment in new technology implies that the request for economic obsolescence in this sector is relative high.

The companies in the labour-intensive manufacturing sector is characterised by a relative strong concentration on import substitution. In the labour-intensive manufacturing sector the request on renewal of the process of production, and hence economic obsolescence, is probably low. The explanation is a low growth level in the labour-intensive manufacturing sector, and thence, low requirements of new capacity. Due to the relative low capital costs, increased need of capital is probably combined by a longer life time in the existing establishments. In other words, economic obsolescence in this sector is relative low.

On the other hand, the capital costs are considerable in the capital-intensive manufacturing sector. Exports from this sector is considerable in most industrialised countries. Long-term investment decisions characterise the sector. Structural rationalisation and economics of scale have induced a concentration of establishments, and thus, the number of production units have been reduced. Hence, economic obsolescence will increase by increased investments in the capital-intensive manufacturing sector.

In order to make an assessement of economic transformation, it is essential to consider the economic situation in general. An economic situation could be dominated by opportunities. Or in other words, of

[67] See Lundberg (1992) and Norén (1995).

new fields of activities. An economic situation could also be dominated by a necessity of adjustment and adaptions. The first situation will give rise to a positive transformation pressure. The second situation, unfortunately, a negative transformation pressure.[68] These two concepts of structural transformation is the key to understand the importance of personel and collective motivations, and thereby provide the framework for the entrepreneur in economic analysis.[69] From an evolutionary theoretical point of view (Schumpeter[70] is among the classics in the field) the equilibrium model - and theory - outlined in this study is inadequate to capture the specification of the mechanisms that creates incentives for the entrepreneur to enforce new transformation activities (disinvest- and investment activities) to maintain the capacity for growth

6. 2 *To Go Further*

More variables, endogenous and exogenous, can be added, and more complex functional relationships can be used to develop numerical examples. CGE models of a small open economies are numerous, and one should think that there is little insight to be gained from presenting another model. However, the aim in this study is not to comprise all type of adjustment problems that can be open for formulation in an equilibrium model, but rather to study a specific problem designed for the specific model.

Wheras the rate of industrial transformation in the advanced economies in general has mainly been restricted by a failure to absorbe labour in expanding sectors, structural adjustment in other has been prevented by the unresponsiveness of the stagnating sectors to relase labour. Thus, we must ask to that extent has the labour market restricted the expansive parts of industry. Obviously, the lack of

[68] Positive and negative transformation pressure and their importance of the general transformation process has attracted much attention by Dahmén, who is also the founder of the concept in economic analysis. Dahméns total contribution is documented by Carlsson and Henriksson (1991).

[69] The perfect competition theory defines the equilibrium state and not the process of adjustment. (Kirzner, 1973).

[70] Schumpeter, 1942 and 1976.

transformation in the labour market, not only affect, but also to a great extent determine the conditions for industry in the long run.

Research is needed to develop better data related transformation activities as well as to determine the appropriateness of the concept. Also, it might be advantageous to distinguishing different levels of skill in the labour force. Availability of labour and skills plays a crucial role in the growth process. In the beginning of this decade, there is an increased shortage of skilled labour in several countries. Labour market, divided in separate skill categories, must be integrated in the analysis. The question is thus quite clear, to that extent will general tendency for an increased shortage of skilled labour affect economic structure and growth, in aggregate and in different industry sectors? The question will not be answered in this study, but in a model with a specified transformation structure, this question vill become logical.

The numerical results of the experiments indicate that equilibrium changes in economic obsolescence does not have a substantial impact on investments. The explanation is the treatment of capacity expansion, i.e., investments, in the model. Investment and the process of deterioration (obsolescence) of the capital stock, and thus, the structure of the transformation process must be seen in a total (one) context. In this connection, the addition of a more realistic approach in the investment allocation process must be considered. The two concepts of transformation pressure - positive and negative - must be taken into consideration, and in some way or another be integrated in the investment scenario. Strictly speaking, the change in the total activity level must also affect the volume of investment, whether the situation in the economy is dominated by opportunities or by necessity of adjustments. However, we have not to forget, the aim of the model is crucial for the chosen method.

Finally, a CGE model can accommodate different types of distortions, such as taxes and tariffs or monopolistically fixed factor prices. Consequently, the model used here incorporate price-incentive variables that represents tools of policy makers. These tools have not been used in the numerical experiments. However, in empirical applications the situation will become somewhat different.

6. 3 *Concluding Notes*

We have tried in this last chapter of the book to suggest some ways in which the model can be improved. As noted at the beginning of this chapter, there are many improvements which remain to be made. The improvements include model specification and statistical estimation of the coefficients in the model as well as an outline of interesting scenarios for which the model may be used.

CGE models do have an extremely useful role to play in the analysis of economic transformation and thereby structural change, in that they provide a consistent and empirically rigorous framework for policy analysis. This is a promising development since it adapts the general equilibrium tools to a whole new range of issues which are, and in particular will be, of major concern to policy makers for some time to come. Economic policy to support capacity expansion must comprise both investment as well as disinvestment. A new variable, disinvestment (economic obsolescence), must be taken into consideration. How this variable responds to changes of other variables of the economy, and how disinvestment activities can be influenced by economic policy, is here important knowledge. However, we must keep in mind that only the future will show how far the response will become from policy makers.

The discussion has now come to an end and all we can establish here is that the explicit recognition of the importance of endogenous disinvestment activities in transition to a new equilibrium seems to be an interesting, and perhaps an important, contribution.

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