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THE ECONOMICS OF INTERNATIONAL MIGRATION:

A SIMULATION STUDY

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ABSTRACT

This dissertation develops a simulation model for exploring the implications of the integration of economic activity and demographic behaviour and for evaluating the consequences of changes in population variables in different economic and demographic situations. A two-country macro-model is specified using different assumptions regarding the conditions of the two nations. The effects of given population changes, especially the fertility and migration propensities, in one country on the demographic and macroeconomic variables in both countries are given emphasis in the analysis.

The analysis is built around a simulation model that uses actual demographic data to create two hypothetical countries having economic and demographic relations. The model then conducts experiments with these two countries by tracing the effects of specific changes in the economic and demographic variables on the overall economic and demographic characteristics of each country over time. In this way, the model provides valuable insights into the patterns of economic-demographic relationships as well as the construction of economic-demographic models for particular countries.

The study is conducted in two parts. The first part consists of a survey of recent developments in trade theory and experience with economic-demographic modelling, and outlines the theoretical approach to the construction of the dynamic economic-demographic model to be used in the second part of the study. The second part then employs the

model in the analysis of the effects of changes in population and economic variables on the two-country trading system.

The basic results of the analysis provide insights regarding the effects of changes in fertility-rates, international migration propensities, production patterns, factor-endowments, the distributions of labour skills, and several other characteristics on such variables as per-capita income, the supplies of labour and capital, the total population, wage rates, imports and exports, and net migration rates, as well as the differences in the behaviour of these variables between the two countries over long periods of time.

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In the process of completing the tremendous amount of work involved in a doctoral dissertation, one often incurs a large amount of indebtedness to various people in the immediate research environment as well as to some who are only indirectly connected with the work. In my case, the debts are obviously too numerous to list here but some of the people who have helped me deserve special thanks and I hope this medium will suffice to show my profound appreciation of their assistance and encouragement.

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CHAPTER 1

INTRODUCTION

1.1 Research Objective, Methodology, and Technique

It has long been realized that population growth has an important impact on a country's development. In economic literature, the analysis of the relationship between population growth and economic welfare dates back to Thomas Malthus and David Ricardo whose pessimistic growth theories stressed the possibility of ultimate economic stagnation as a result of excessive population growth. Although subsequent events proved the Malthusian doctrine wrong in that the mass starvation he predicted failed to occur, it did provide a powerful analytical framework. Since the Second World War, economists have become interested in the theory of balanced exponential growth and have attempted to examine the extent to which neoclassical growth models help to explain the optimal relationship between the growth of national income and capital stock and the growth of population.[1] It is also true that concern about population development has become one of the most important issues in the world today. In particular, questions about the economic and social consequences of the changes in the rates of population growth and the policies for influencing these rates are central ones. Above all, there is also the forward-looking approach in which the optimal rate of population growth is related to the anticipated long-term economic development.

From a developing country's point of view, an increasing population could be a fundamental burden in the process of economic development, especially when the growth rate of population exceeds that of national income. Given this difficulty of economic growth in developing countries, investigators in the area of population and economic development have emphasized the economic effects of reducing population growth rates and have recommended policies by which these rates could be affected. Examples of such studies include the works of Coale and Hoover (1958), Holland and Gillespie (1968), and Enke and Zind (1968), among others.

The population problem is however not limited to developing countries. Demographic analysis is equally relevant in developed countries where, with decreasing fertility rates, technological change and natural resource development, the potential exists for population or labour shortage. This phenomenon has been experienced in Canada, the United States, Australia, and other developed countries.[2] Demographic analysis is also fast becoming the basis for policy planning, especially with regard to manpower and immigration policies. For a long time, immigration has been the quickest method of population growth in population-scarce countries. Canadian experience indicates that more than half of the growth in the labour force in the last three decades is directly attributable to gross immigration (Parai 1974; Richmond 1974) while 22 per-cent of the post-war increase in population resulted directly from net immigration.

Studies of the relationship of economic growth and international migration are numerous. Examples of these include studies by Thomas (1954), Easterlin (1968), and Marr (1972), all of whom discovered that international migration is sensitive to fluctuations in levels of unemployment and rates of growth among countries. Parai (1974) found that immigration has a large impact on a country's economic growth and per capita income. Mishan and Needleman (1968), Davies (1972, 1974), and Marr (1972), however, observed that increase in immigration would worsen a country's rate of unemployment and its per capita income in the short run. The essential implication of all these studies is that the economic effects of immigration are numerous and complex, depending on the patterns of demographic and economic relationships, both domestically as well as through international trade.

Demographic variables have many direct and indirect effects on various aspects of an economy, especially its growth, savings and the age-sex-skill composition of its labour force. Changes in fertility, mortality, and migration have many important long-term economic, social, and political consequences. Thus an effort to incorporate demographic factors into economic planning considerations may improve allocative efficiency greatly.

The primary purpose of this dissertation is to develop a theoretical framework for the analysis of the economic effects of demographic changes, with an emphasis on the effects of international migration. It is hoped that the macroeconomic-demographic model used in this investigation will not only serve as a guide to our analysis, but will also suggest some new techniques for economic-demographic research.

Analysis of the interrelationships between demographic and economic variables is rather new, with most investigation limited to cases of closed economies. Given the great importance of trade in the world economy today, it seems desirable that the study of the dynamic interrelationships between demographic and economic variables should be broadened to encompass international systems. With this in mind, the present study develops a two country economic-demographic model with special allowances made for international demographic and economic interactions. Thus, we are able to explore patterns of both migration and international commodity trade.

In most literature on economic growth or development, commodity output is aggregated into a single production function. However, an aggregate production function is not suitable for international trade analysis. To overcome this problem, an extended version of Uzawa's two-sector model and a modified Vanek approach to the Heckscher-Ohlin theorem[3] on the direction of trade are developed and used in the analysis of international trade and in the construction of the simulation model. Since the conventional 2-input, 2-output trade model cannot explain the changes of migration propensities under the assumption of wage differences, the model is enlarged to a 3-input case in which labour is split into two catagories -- skilled and unskilled labour. The wage rates play a major role in determining changes in the levels of migration and changes in the skill composition of the population.

In our economic sub-model, the 3-input, 2-output production function is defined within the traditional neoclassical framework. This means that both factor markets and product markets are assumed to be in simultaneous equilibrium at all times. Therefore the model is appropriate for analysing long-run effects on the economy and is specifically designed to analyse the long-run effects of demographic changes. In particular, we specify changes in fertility rates or in propensities to migrate, and study their effects on the levels and time paths of income, consumption, capital stock, and the labour force in both countries.

The demographic sub-model is basically an adaption of the Denton-Spencer (1975) theoretical framework, which incorporates age-sex disaggregation of the population. Our model includes skill-type population categories. It determines the levels of migration according to age-sex-skill-specific population characteristics and the corresponding migration propensities, with allowance for the possibility of government restrictions on immigration. Skill-type sub-populations are influenced by school enrollment rates at ages 15 to 19, and these in turn are affected by the wage differentials between skilled and unskilled labour within a country. Migration propensities are affected by the wage rate differentials between countries. Feed-back effects are thus generated from the economic sector to the demographic sector.

Since our model is hypothetical, in the sense that it does not relate to any particular country, parameter values are assigned arbitrarily, but with particular attention given to making them as representative of a real economy as possible. Canadian data have been used in a number of instances as a basis for choosing values. Production functions are of the Cobb-Douglas type and are specified so that production of each commodity reflects a specific degree of factor intensity, thus enhancing the opportunities for applying international trade theory which predicts the direction of trade according to factor intensities. Although a standard set of parameter values has been assigned, sensitivity analyses are carried out to assess the effects of alternative choices of parameter values.

Despite the model's conceptual simplicity, it involves a large number of variables and structural equations. The overall size of the model necessitates the use of computer simulation techniques to investigate experimentally the behaviour of the complex system. With given initial conditions, parameter values, and exogenous variables, we can derive specific simulation results. By comparison of simulation results, we can determine the effects of particular exogenous changes. Since the equations are not empirically determined, the model cannot be viewed as a forecasting model, and the use of it is concerned only with the analysis of interactions between economic and demographic systems in a general sense.

The model is represented by a system of non-linear simultaneous equations. These include four production functions, six factor-market equilibrium equations, two world goods-market equilibrium equations and a world price equation. The system must be solved for both countries in each year of a simulation period; Newton's method[5] is used for this purpose.

The simulation results lead to a number of conclusions of general interest. The impact of fertility changes on economic variables occurs with a lag of roughly two decades, whereas the impact of immigration is immediate. With migration permitted but no trade, both countries grow at the same rates in the final equilibrium state. If trade is permitted, population changes may affect the volume of trade. The results indicate that the Vanek approach to the Heckscher-Ohlin theorem regarding the direction of trade in commodity space is correct in most circumstances, but a strong abundance of a particular factor has to be specified in some cases. Furthermore, it is found that changes in the parameter values of production functions may not only change the direction of trade, but also the levels of production and patterns of income distribution.

1.2 Dissertation Organization and Synopsis

The dissertation is an attempt to apply simulation techniques to analyse the effects of population change on demographic and economic variables with a 2-country economic-demographic model. In chapter 2, the literature is reviewed, with the focus on approaches to modelling in the field of economic-demographic analysis and a review of studies relating to the economics of international migration. The chapter opens with a discussion of the problems involved in constructing an economic-demographic model with special reference to the Denton-Spencer model. This is followed by a survey of the literature in terms of purposes, approaches, and significant contributions to modelling.

Chapter 3 contains a discussion of those international trade theories that are of relevance to the economic-demographic model embodied in the study. A basic 2-country, 2-input, and 2-output model is constructed and numerical examples are provided to demonstrate the applicability of traditional trade theorems. These theorems include the Heckscher-Ohlin theorem, the factor-price equalization theorem, the Stolper-Samuelson theorem, and the Rybzynski theorem. It is argued that the conditions of factor abundance and factor intensiveness of production are the main determinants of trade in the neoclassical model. Without these conditions, patterns of international trade will be indeterminate. After the illustration of these theorems, a dynamic process of economic change is presented in order to give guidelines for incorporating demographic and economic changes within a simple growth model.

The economic-demographic model is presented and described in Chapter 4. We start with a discussion of the theoretical problems involved when there are more than two factor inputs or more than two commodities. Then we provide an overview of the model and a discussion of how the economic and demographic variables are linked within a general equilibrium framework. The latter part of the chapter presents a detailed sector-by-sector description of the model. Attention is given to the interpretation of the demographic and economic relations and to possible migration and trade restrictions.

Chapter 5 consists of a detailed analysis of the simulation results obtained with the model under various assumptions regarding the values of exogenous variables and international trading conditions. The procedures for specifying parameter values are described in the first section. We then present the simulation results for each of the following cases: (1) no trade in goods but population is internationally mobile; (2) only goods can move internationally; and (3) both goods and population move internationally. We consider the effects of shocks through changes in the total fertility rate for all cases but the shocks are introduced for changes in migration rates in case (1) only. Some alternative sets of parameter values are also introduced for sensitivity tests. In particular, we emphasize the values of migration elasticities and the parameters of the school enrollment equations.

In the next section of the chapter, we discuss the conditions under which the Vanek approach to the Heckscher-Ohlin theorem is applicable. An extension of the Williams theoretical analysis of the direction of trade is undertaken with hypotheses regarding the direction of trade and the corresponding parameters of production functions derived and experimented with. Finally, we discuss the economic consequences of the change in the total fertility rate under various assumptions about the production functions.

Chapter 6 provides a summary of the results and comments on the outlook for further research. There is a cross-classification of results by type of variable and experiment, and this is discussed. The possible application of the model in policy making is discussed. The basic conclusions of the study and the scope for further research are outlined at the end of the chapter.

FOOTNOTES TO CHAPTER 1

1. A review of growth theories is presented in Growth Economics, edited by Amartya Sen, Penguin Modern Economics Readings, 1970.
2. See Berelson (1973).
3. See Uzawa (1961, 1963), Vanek (1968), and Williams (1971, 1977). For discussion, see Chapter 3 and Chapter 5 of this dissertation.
4. This method solves the system of equations by iterative application of Taylor-series expansions and Cramer's rule to achieve convergence. See Conte and Boor (1972) and Evans (1968).

CHAPTER 2

REVIEW OF LITERATURE ON ECONOMIC-DEMOGRAPHIC MODELS

2.1 Introduction

The literature on the linkages between economic and demographic factors, and the influences of any changes in these factors on both population growth and economic development, is extensive. Generally, the studies are organized around an appropriate economic-demographic model, often accompanied by simulation experiments under alternative assumption about parameter values. Even though the studies reviewed here have rarely considered the international interactions among sectors, they still help us to understand the approaches to the construction of economic-demographic models.

This chapter surveys some of the literature, reviews the techniques of economic-demographic modelling employed in different studies, and assesses the basic contributions of the studies themselves. In particular, in section 2.2, we spell out some problems involved in modelling for simulation, based on a model developed by F. T. Denton and B. G. Spencer, and use the Denton-Spencer model to illustrate the process of model construction. Section 2.3 provides a review of other literature on economic-demographic models and of studies of the economic effects of international migration. Section 2.4 is the conclusion of the chapter.

2.2 Economic-Demographic Modelling and the Denton-Spencer Model in Brief

A basic reason for constructing an economic-demographic simulation model is to understand the dynamic structure of a system in which there are formal linkages between the population and the economy. The approach to modelling often depends on the purpose for which the model is being designed. The important question is how well the model can represent the actual system. Problems arise in most cases because of the difficulties of finding sufficient historical data for all of the variables that should be included in the model. The problems of estimating parameter values can become especially formidable when formulating a dynamic nonlinear model. In this case, as Holland and Gillespie (1963, p. 208) point out, one may be forced to sacrifice some aspects of realism. This is true especially in the estimation of capital stock and in the formulation of aggregate production functions. Basically, data on capital inputs or rates of return are available only for a small number of countries and industries, and even when such data are available, they may not be suitable for use in estimation.[1] In particular, if a neo-classical production function is employed, the 'value' of capital becomes meaningless as it is 'physical' units that are required. In order to have the capital in physical terms, one may simply assume initial capital-output ratios in different countries[2], or provide an equilibrium capital stock based on the rate of return on capital[3], or estimate it with a saving function.[4] The aggregate production function must also be specified. The usual choice ranges from the Cobb-Douglas type with unitary elasticity of substitution to the Walras-Leontief type with constant input coefficients; in addition, the intermediate two-factor CES production function may also be used. As a matter of fact, the two-factor CES production function has become the most widely discussed function in the literature. It has all the properties of the neoclassical production function and includes the Cobb-Douglas and the Walras-Leontief functions as special cases. The problem, however, is that the parameters of the production function are often difficult to identify. This problem is related to the effect of variations in factor supply upon relative factor prices and the variability of the rate of technical change over time.[5] One may thus be forced to specify a model which incorporates a simple hypothetical form of production function in its theoretical structure.

Among the various approaches to economic-demographic modelling (which will be noted in a later section), the most common incorporate a neoclassical model of production. The neoclassical model assumes that output is determined by capital, labour and the technology of the economy. All markets, including those for factors and goods, are assumed to be in equilibrium at all times. Without showing the process of equilibrium adjustment, the model is of limited use in showing long-run impacts on the economy.

The Denton-Spencer (1975) model incorporates a standard neo-classical model of an economy in which the growth of capital is a consequence of savings which depend solely on income. With the given structure of effective capital input and the form of production function, the initial stationary state capital stock (K) is determined as[6]:

$$K = \frac{\gamma}{\delta} Q$$

where γ is the propensity to save, δ the depreciation rate, and Q the total output. In stationary state, output is constant, as are capital and labour. A Cobb-Douglas type production function, $Q = \alpha K^{\beta} E^{1-\beta}$, implies that the initial equilibrium capital stock is a function of the effective labour input (E) alone, such that:

$$K = \left(\frac{\gamma \cdot \alpha}{\delta}\right)^{\frac{1}{1-\beta}} \cdot E$$

Even though the production functions in most of the Denton-Spencer simulation experiments are specialized to the standard Cobb-Douglas form, the basic production function is still of the CES form.

Since it is a one-good economy, the real national income is determined by total output within the year, which is in turn determined by the effective labour input and the effective capital input. The effective labour input is calculated on the basis of age-sex-specific productivity weights which reflect differences in marginal products, by sex and age, whereas the effective capital input is based on weights which reflect the marginal products of different capital vintages. Allowance is made for both embodied and disembodied technical progress.

It is important to understand the interactions between demographic and economic variables. These include the influences on total savings of the age composition of the population, the patterns of change in income or education levels in response to changes in fertility rates and population growth, and so on. In most cases, the Denton-Spencer model is uni-directional since these relationships run only one way -- from the demographic sector to the economic sector without any feedback to the population through changes in per capita income, education, or other variables. In their closed economy model, only in two chapters are there specific allowances for feedback effects. (The positive effect of male wage rates on the current age-specific fertility rates on the one hand, and the negative effect of female wage rates on both the female labour participation rates and fertility rates, on the other.) There are no strong reasons against such simple economic-demographic linkages since, as we have mentioned above, models are formed for the type of policy or the purpose of investigation in question. A simple form may permit easier understanding.

Although its economic and demographic linkages are relatively simple, the Denton-Spencer model is detailed in its specification of the demographic sector. It includes eleven basic equations to specify the age-sex composition of population according to given age patterns of fertility rates and the age-sex-specific mortality rates and immigration rates. In most cases, their basic model serves to highlight the importance of age-specific disaggregation of the population and is designed for investigating the economic implications of exogenously determined demographic trends, including demographic changes through fertility rate changes and changes in immigration rates. In their analysis, the influence of demographic change on economic variables has a far-ranging impact, which might be diluted over time, but goes from labour force to output, then to capital stock, and back to output. However, the timing of effects is uniformly faster for immigration changes than for fertility changes. This is because immigration changes have an immediate effect on the labour force while fertility changes have direct effects on the labour force only after 15 or 20 years.

The basic Denton-Spencer model described above has been applied in several of their studies. They assign a realistic set of initial values to the variables and assign alternative values to the parameters in order to explore the consequences of exogenously determined shocks through computer simulations with the model. The subjects investigated include the economic consequences of changes in fertility, the effects of family size on household consumption and saving, the implications of changing rates of population growth for aggregate education and health care costs, and the effects of changes in population growth rates on the burden of a national pension.

An extention of their model involves the exploration of the consequences of labour migration in a model with two countries. In this extension, they determine the age-sex-specific probabilities of migration between countries x and y by means of the equation:

$$m_{ij(xy)} = m^*_{ij(xy)} \left(\frac{\overline{W}_{(y)}}{\overline{W}_{(x)}} \right)^{\tau_x} \qquad \left(\begin{matrix} i = \text{male, female;} \\ j = \text{ages } 0,1,\ldots,109 \end{matrix} \right)$$

where m is the probability of emigration from x to y, m* the probability of emigration in equilibrium, $\overline{W}$ the average wage rate, and τ an elasticity parameter. Simulation experiments are conducted to investigate effects on demographic variables and income per capita of four different types of shocks: fertility change, change in migration propensities, a war, and the opening of a new country. Even though this two-country economic-demographic model is kept simple in its framework, the two countries being assumed to be identical and no commodity trade being allowed, it provides a methodology for investigating not only domestic effects but international ones as well.

2.3 Review of Literature on Other Economic-Demographic Models and on Economic Effects of Interantional Migration

In this section we survey other literature on the effects of demographic changes, including the effects of changes in international migration on economic variables. The studies covered here are reviewed in terms of their approaches to modelling and also their significant contributions. To this extent, emphasis is placed mostly on the more prominent features of the models. The studies are discussed below in chronological order, by date of publication.

Thomas (1954) in his *Migration and Economic Growth: Study of Great Britain and the Atlantic Economy*, provides a significant contribution to the study of the relationship between migration and economic variables. He hypothesizes that the cycle in international migration is closely related to the cycles in economic activity in corresponding countries or areas. Referring to data for the United Kingdom and the United States, and for Europe and North America in the nineteenth and early twentieth centuries, he finds that troughs in economic activity in the United Kingdom correspond with peaks in the United States, and vice versa. Peaks and troughs in migration from the U.K. to the U.S. are also found to correspond to the peaks and troughs in economic activity in the U.S.. Throughout the period 1845-1913, immigration preceded American building activity and, especially in the period 1878-98, immigration to the U.S. was determined by the course of American investment in railways. These findings are also true for migration from Europe to North America.

The study *Population Growth and Economic Development in Low-Income Countries* by Coale and Hoover (1958) is one of the earliest and most important studies of the linkages between demographic and economic systems. The authors provide a full account of the demographic and economic characteristics of the Indian economy and a brief study of the Mexican economy. They find that the main factors which obstruct economic development in low-income countries are those arising from rapid population growth and the lack of capital formation. In order to determine the possible economic effects of fertility control in India from 1956-1986, the authors assume that a prime determinant of the rate of development is the allocation of national output to the combined category of public and private investment (F). This hypothesis is specified in the form:

$$F = aY - \left(\frac{aY_0 - F_0}{C_0}\right) C$$

where Y is the national income and C the number of equivalent adult consumers, and the subscript denotes the base year. The productive effects of the various types of investment outlays are denoted by the symbol G, which depends on total output (current and lagged up to fifteen years) and on the population of equivalent consumers. The production function for the projection from 1956 to 1986 is of the form:

$$Y_{t+2.5} = Y_t + \frac{2.5\ G}{R}$$

where R is a trend term which increases at a constant rate per annum. Coale and Hoover use three different hypotheses regarding fertility: unchanged; reduced by 50% from 1966 to 1981; and reduced by 50% from 1956 to 1981. They find that in 1986, with low fertility, there is a

40% higher income per consumer and higher welfare expenditure per consumer than with high fertility. Output effects from 1986 to 2011 are determined by a logarithmic version of a Cobb-Douglas production function, permitting substitution of labour for capital. They conclude that, at any stage in the foreseeable future of the low-income countries with high fertility, a reduction in fertility would produce important economic advantages.

The book Experiments on a Simulated Underdeveloped Economy: Development Plans and Balance of Payment Policies by Holland and Gillespie (1963) includes three parts -- "A Development Planning Study", by Holland; "The Balance of Payments of a Growing Economy", by Gillespie; and the last part entitled "Improved Models and Additional Uses of Simulation", by Holland. Part one deals with the model setting, development planning and simulated results of internal controls, whereas part two extends the model to the implications and the consequences of foreign policies. Part three provides a criticism and discussion of the appropriateness of the use of a simulation model. The model used in these studies is a complex input-output model. Population is assumed to grow at a constant and exogenously determined rate, so that changes in age composition or labour force participation rates do not influence the productive capacity of the economy. But the size of the total population determines consumption, and hence savings and the denominator of the per capita income ratio. The only variable which affects the level of production is capital, so that capital-output ratios in various sectors act as constraints on output. Holland finds that, for the Indian economy in the first study mentioned above, the reduction in investment will not reduce the rate of inflation but will cause a significant loss in growth of output. The use of anti-inflation policy leads to a reduction in the balance of payments deficit through a reduction of capital imports. A higher population growth rate tends to increase the rate of inflation, and hence reduce the level of investment and the growth of real national product. Gillespie, using various assumptions about consumers' demand elasticities, finds that the successful application of devaluation for balance of payments adjustment should consider the foreign demand elasticity. Tariffs, as a revenue earning source, depend on the elasticity of foreign demand. Quota policy is used only on imports of consumer goods. The effects of a multiple exchange rate policy are not much altered by inflation but are significantly altered by changes in the domestic consumers' demand elasticity.

T. M. Brown (1965), in his Canadian Economic Growth provides three projections for Canadian GNP from 1962 through 1991, under various assumptions. The first two projections employ a very simple model with a simple linear production function. Results for GNP and other demographic and economic variables are based on the assumptions that population growth follows a historical trend, with net immigration of 50,000 per annum. Participation rates are projected only for the total male and female populations in the first projection, whereas separate rates are specified by sex and 5-year age groups in projection number two. An econometric model based on data from 1926 to 1961 is designed and estimated for use in projection three. It consists of 29 equations, including 6 demand equations, 1 supply equation, 6 other behavioural equations, and 16 identities. The supply of labour is treated as exogenous. Population variables appear in the private consumption and government gross investment equations. The linear production function contains two inputs -- labour and capital. The basic conclusion of this study is that Canadian economic growth, as a result of technical progress and capital investment, will stimulate the demand for goods but displace labour.

A study by Friedlander (1965), Labour Migration and Economic Growth: A Case Study of Puerto Rico, attempts to measure the effects of emigration on Puerto Rican economic growth. In his theoretical analysis, Friedlander uses three variables to explain the growth of output, population, and net capital formation. These variables are the birth rate, the saving rate, and a variable to represent the occupational composition of the migrants. The first two variables are determined by the level of income per capita while the third is determined by the difference in income per capita between two areas. Output is a function of capital alone which, through the operation of a saving function, can be expressed as a function of per capita income. Friedlander finds that, for most of the periods 1940-1962, emigration is significant in determining the higher capital-labour and skilled labour-unskilled labour ratios which have a favourable effect on labour productivity in all sectors of the economy. This result indicates not only that the size and growth of the Puerto Rican population and labour force are reduced, but also that there are increases in its income per capita and the standard of living.

A paper concerning the economic effects of immigration is one by Mishan and Needleman (1968), "Immigration: Some Long Term Economic Consequences". This paper consists of two parts, the first dealing with long-term effects of immigrant-induced changes in the capital-labour ratio and the second with allocative aspects of large-scale immigration. In the first part, Mishan and Needleman attempt to assess the long run economic effects of immigration under various assumptions about production and import demand functions for the U.K. economy. They employ a traditional neoclassical framework, assuming that the production function is of the CES type, with capital and labour as its inputs. They also assume that capital increases annually by a fixed proportion of aggregate income, whereas labour grows at a constant rate. Over a time period of 30 years, Mishan and Needleman find that with a net immigrant inflow of half a million per annum, the U.K. would suffer a decreasing per capita income in most cases. Per capita income would rise only when production is characterized by increasing returns to scale and a low elasticity of factor subsititution. Wage rates would fall gradually but the decline would slow down with high elasticity of substitution. The increasing returns to capital provide gains to the indigenous population. However these gains would become negative when capital transfers occur irrespective of the method of international adjustment adopted or the foreign trade elasticities. The second part of this paper concerns mainly the social and economic consequences of a large scale immigration.

In his article, "Demographic Change and Economic Growth: Australia 1861-1911", Kelley (1968) uses a detailed cohort distribution of the total population together with data on immigrants to Australia to estimate a series of actual work force additions including migration, ΔL, and a labour force series (with migration), holding the age-composition constant at 1861 values, $\Delta L'$. The difference between ΔL and $\Delta L'$ is then used to measure the percentage of labour-force growth resulting from the changes in the age composition of the population. By the same token, Kelley also measures a series of $(\Delta L)'$ and $(\Delta L')'$ with migration excluded. The comparison of $[\Delta L - \Delta L']$ (including migration) with $[(\Delta L)' - (\Delta L')']$

(excluding migration) measures the effects on the age composition of the work force due solely to immigration over the period. The effects of net migration on savings and on residential construction are also estimated in his paper. He assumes that the average saving ratio varies inversely with the burden of dependency which is defined as the ratio of dependents to the total population. For the purpose of this estimation, he constructs the consumption function (C) and production (Y) identity in the form:

$$C = N a + b Y$$

$$Y = (Y/W)\ (N)\ (W/N)$$

where N is the total population; a, the intercept; b, the marginal propensity to consume; Y/W, the average labour force productivity; and W/N, the work force-population ratio. Since saving is the difference between Y and C, it has a specific relationship to the work-force population ratio. Two other alternative saving models are also used and the results compared. In particular he adopts the Modigliani-Brumberg life cycle formulation to highlight the influences of demographic change on aggregate savings. One particular aggregate average saving ratio is taken as the sum of age-specific saving ratios, each weighted by the proportion of total income earned at the age in that year. Aside from the effects of immigration on savings, no mention is made in this paper of the effects of immigration on income and production.

Enke and Zind (1969), in their article, "Effect of Fewer Births On Average Income", use a dynamic theoretical model with parameter values specified so as to characterize a less developed economy, in order to suggest the effect of a gradual reduction in age-specific fertility rates.

The model employed uses age-specific death, fertility, and consumption rates for an annually changing age distribution of population. The national production function is a logarithmic version of a modified Cobb-Douglas type:

$$\log Y = a_1 \log K + a_2 \log L + t \log a_3 + \log a_4$$

where the a's are parameters. Saving propensities are assumed to vary with disposable income and productive innovation. However, since no mathematical specification of the equation in the model is provided, the linkage between demographic and economic variables is not apparent.

In Population, Labor Force, and Long Swings in Economic Growth, Easterlin (1968) uses methods developed by Kuznets and by others to show the linkage between U.S. economic activity and changes in immigration, fertility rates and the labour force participation rates, especially in the analysis of the nature of demographic swings and their interrelations with economic conditions. He argues that past swings in immigration and the more recent swings in fertility, labour force participation, and household headship rates, have been primarily induced by cyclical variations in income and employment opportunities in the labour market. But a demographic swing may also have important feedback effects on the level of economic activity; he shows that the change of U.S. total population between 1870 and 1950 was due primarily to variations in the rate of net immigration and both changes are closely correlated with changes in industrial conditions which in turn stimulate additional internal and external demographic movements. Easterlin's main conclusion is that in the United States, 'fluctuations in demographic variables have typically arisen from movements in immigration or the "rate" components of change rather than from an echo effect of a surge in births, operating through the aging and mortality components. Such demographic fluctuations were induced rather than initiated by changes in economic activity, although they had important feedback effects'.[7] In part III, which focusses on labour force analysis, he notes that the labour force is determined by the structure of the working age population together with net migration and participation rate changes. He finds that the contribution of participation rate change to labour force growth since 1940 appears to be explicitly caused by the variations in labour market tightness operating via the unemployment rate and a reduction of labour supply sources due to legislative and other impediments to immigration. The change in sex-age participation rates are caused by several factors, including school enrollment, marital and child-dependency status.

In "The Economic Effects of Malaria Eradication", Barlow (1969) provides an economic-demographic model for comparing the economic effects of malaria eradication with the situation without eradication in Ceylon from 1947 to 1966 and the projected effects from 1967 to 1977. Four categories of equations were specified and used in describing the effects of eradication on per capita income: (i) The growth of population is determined by standard population cohorts, excluding the possibility of external migration but including the effect of malaria eradication on birth and death rates. (ii) Gross domestic product (GDP) is determined by a Cobb-Douglas production function with labour disaggregated into two skill-types in the form:

$$GDP_t = A\ (qa_t)\ (LS_t qs_t)^{es_t} (LU_t qu_t)^{eu_t} (K_t qk_t)^{ek_t}\ V_t$$

where LS, LU, and K are the stocks of skilled labour, unskilled labour and capital, respectively, and qs, qu, and qk are quality indices applying respectively to the three factors; es, eu, and ek are the elasticities of output with respect to the corresponding factors. The term qa represents disembodied technical change and V is an error term. (3) Two labour categories are classified by the level of education and the labour force of each group is determined by their participation rates. (4) The size of the capital stock is equal to the aggregation of past net investments and is the consequence of private, government and foreign saving. Because prices are assumed to be exogenous and are used only to convert real values, Barlow does not specify the demand function and monetary equation in his model. For these reasons, his specification of the foreign saving equation, which includes both current account and capital account, seems somewhat misleading.

The study by Davies (1972) entitled An Economic-Demographic Simulation Model Designed to Test the Effects of Changes in the Rate of Skill Composition of Net Immigration on the Canadian Economy from 1952 to 1968, employs a modified version of the TRACE econometric model of the Canadian economy for demographic simulation analysis. The modification to the TRACE model involves some 440 new equations describing age-sex-skill-specific population cohorts, labour force participation rates, and human capital formation. Population is classified into three skill types -- unskilled, skilled, and professional -- according to their level of educational attainment. Hence the production function for the potential output in the non-agriculture business sector of the TRACE model is changed to a four-factor Cobb-Douglas production function. Assuming the skill composition of net immigration to be unchanged, Davies compares the simulation results for per capita income, the consumer price index and unemployment rates for Canada from 1952 to 1968 under three assumptions about the net migration rate: the standard case assumes the actual net migration rate while the two other cases assume a fifty percent increase or reduction in the net migration rate. The study also conducts additional simulation experiments and sensitivity analyses. Davies concludes that an increase in immigration could lead to a reduction in the price level and also to a worsening in the rate of unemployment and the level of per capita income. At the same time, after isolating age structure effects, the improvement in the skill composition of net immigration increases the economy's productive capacity.

Marr (1972) in his dissertation The Economic Impact of Canadian Inward and Outward Migration and Their Determinants, 1950-1967 specifies an econometric model for the analysis of the determinants of total annual migration to and from Canada and the impact of the net migration on the Canadian economy for the period 1950 to 1967. The major empirical finding is that only the relative real per capita incomes of the foreign and domestic economies and the domestic unemployment rate are significant in determining the inward migration rate. With his fifty-eight equation econometric model, he compares the simulation results for a case in which the net inward migration is one hundred thousand persons greater than the case in which actual historical values are used. The additional population appears to increase the labour force and employment as well as per capita consumption and investment while, at the same time, increasing the unemployment rate and decreasing per capita income.

In a paper entitled "Macroeconomic Effects of Immigration: Evidence from CANDIDE Model 1.0", Davies (1974) extends his earlier analysis by using the CANDIDE 1.0 model. In this study, population is introduced to the CANDIDE 1.0 model complete with age-sex-education classification. Some demographic variables, including the level of gross immigration, are endogenously determined in the model. Labour force participation rates are endogenous for some age-sex-specific groups, and depend on the change in per capita disposable income and previous unemployment rates. Davies' major conclusion is that immigration should be discouraged because it depresses per capita income and increases unemployment rates.

Barlow and Davies (1974) in their "Policy Analysis With a Disaggregated Economic-Demographic Model" designed a simulation model for testing the economic effects of various policies, including malaria eradication, birth control, and disarmament, on the growth of income per equivalent consumer, the growth of labour inputs and the growth of investment in developing countries. The population of equivalent consumers in the model is disaggregated by age, sex, and education. A four-input CES production function is included among the fifty sets of equations in the model. These inputs include capital and three varieties of labour distinguished by educational attainment. Each of the four factors in the function is characterized by a quality index. Overall labour quality is determined by the weighted average of the quality indexes according to the average education, the amount of on-the-job training, and debility. Capital quality is determined by depreciation rate, the fraction of imported capital goods and the rate of embodied technical progress.

Applying the theory of duality and assuming general equilibrium in the output and factor markets, Epstein (1974), in his study entitled "Some Economic Effects of Immigration: A General Equilibrium Analysis", derives the immigrant-induced changes in the wage rate, in the return to capital, and in real income. Capital is assumed to be homogeneous but labour is classified into two types according to skill level. Using the framework of a closed economy and a constant returns to scale production function, the comparative static results show that immigration depresses wages in a one-commodity model. However, in the two-commodity case, the immigrant-induced changes in wage rates are found to be very sensitive to the consumption patterns of the immigrant and indigenous workers.

The book Population, Public Policy, and Economic Development, edited by Michael C. Keeley (1976), consists of two parts, one dealing with the economic consequences of demographic change, and one with policies to affect fertility. We concentrate on the first part. Part one includes two chapters and two papers in each chapter. We summarize them as below:

Stephen Enke, "Economic-Demographic Modelling":

This paper is a synthesis of Enke's earlier studies as well as the results of studies included in the General Electric-TEMPO model.[8] Enke stresses the importance of declines in the fertility rate for the economic growth and development of the less-developed countries (LDC's). He first outlines the essentials of a basic macroeconomic-demographic simulation model and then presents some illustrative simulations of an idealized LDC. In the model, he employs a Cobb-Douglas production function in which the output elasticities of labour and capital sum to less than unity. Saving is positively related to GNP but is inversely related to population. With this formulation, he finds that GNP is not significantly affected by the decline in fertility since capital is increasing according to the saving function. However, per capita income is higher even with changes in the parameters of the basic model. Finally he points out that low fertility will improve LDC's economic condition on the ground that it increases the confidence of repayment of loans to foreign lenders, and improves the trade belance and terms of trade.

Michael C. Keeley, "A Neoclassical Analysis of Economic-Demographic Simulation Models":

Keeley draws our attention to the relevance of the fraction of dependents in the analysis of the relationship between fertility reduction and economic development. His theoretical analysis is basically neoclassical, focussing on the changes in per capita income due to the various consequences of fertility reduction. Per capita income is shown to be sensitive to the incorporation of human capital into the model. The rate of change of the capital-labour ratio when fertility changes is shown to depend on the rate of capital depreciation, the responsiveness of labour supply to the real wage, the responsiveness of savings to the dependency rate, and the output elasticities of capital and labour in production. A major conclusion of Keeley's study is to note that a decline in the fertility rate must lead to an increase in per capita income in the short run because of the smaller fraction of children in the population. After some 15 to 20 years, however, the first cohort born under the regime of low fertility enters the labour force; eventually the decline in the young dependency ratio is negated by the rise in the old age dependency ratio. In a context such as this, Keeley argues that per capita income is not a good proxy for economic development. He concludes that without a measure of the benefits or utility of children or of possible externalities, no indication of any change in societal welfare is possible.

Bruce H. Herrick, "Economic Effects of Chilean Fertility Decline":

Herrick developed an economic-demographic projection model similar to Enke's, but with greater detail relating to the formation of human capital and with specific reference to Chile. He believes that negative effects of changes in the population growth rates on the per capita income are possible, as a result of the positive change of dependency ratio and negative change of saving rates due to the change of the population growth rate. In order to test for these effects, Herrick makes several assumptions regarding different fertility patterns and the time pattern of social service expenditures in the areas of education and health. In particular, he assumes that government expenditures on education are affected by changes in human fertility while labour force productivity is reinforced by the level of human capital formation. Given the level of education, Herrick formulates the disaggregated constant returns to scale production function as:

$$Y = Z\ (1+T)^t\ K^{\alpha}\ L_1^{\beta_1}\ L_2^{\beta_2}\ L_3^{\beta_3}\ L_4^{\beta_4}$$

where Y is national income, Z is the constant term and T is the technical change parameter; α and β's are output elasticities with respect to capital (K), and labour categories (L's), respectively; labour is classified into four groups according to the number of years of education. It is found that lower fertility enables the government to expand the educational system more easily, even if the percentage of GNP spent on education is constant. Finally, there are substantial independent effects on national income and per capita income whenever there is an increase in the supply of educational facilities per child due to the low fertility rates.

Douglas L. Maxwell and Richard Brown, "Developed and Developing Countries: Closing the Gap":

Like Keeley and Herrick above, Maxwell and Brown also emphasize the importance of human capital formation in the process of economic development. They extend the traditional neoclassical model to the two-country, one-commodity case. The Cobb-Douglas production function used in the study includes a third independent input -- the total stock of education embodied in the labour force. Assuming that international migration is the least significant, in Maxwell and Brown's formulation, the important interactions between the two countries depend on the amount of official assistance, investment, and trade. The two countries are depicted to represent the developed world and the less-developed world. In particular, the flow of investment from the developed world to the less-developed world is assumed to depend not only on the comparison of the relative marginal products of capital but also on the risk element which is defined as the residual of the difference between these two returns in equilibrium. This risk element is assumed to be predictable. Given this formulation and the age structure of the two worlds, they find that the widely divergent rates of population growth between the developed and less-developed worlds have important implications for trade between the two. Increases in saving rates are shown to be much more costly as compared to other methods as a way of increasing GNP per capita. The high return to capital resulting from the high labour-capital ratio in the less-developed world induces investors from the developed world to increase the amount of their investment in the less-developed world. While private investment from the developed world is an important factor in the economic development of the less-developed world, it may be that in the short run official assistance from rich nations would prove a much faster method of raising consumption per capita in the less-developed countries. This model also indicates that an increase in human capital in the less-developed world would raise income substantially and also increase the incentives for the developed world's investment in the less-developed world. They conclude that the best policy for the less-developed world seems to be a mutually reinforcing combination of increasing school enrollments and directly promoting fertility reductions.

Casetti (1977), in his paper "Economic Growth and the Population Explosion: Simulation Experiments using a Growth Model with Population Endogenous", reports simulation results concerning some demographic and economic variables under various assumptions regarding the values of the growth parameters for less-developed country. The model involves one population equation and one economy equation. The equation for population is a function of time and an endogenously generated level of income per capita; in the economy equation, GNP is a Cobb-Douglas function of capital and labour. He concludes that a target growth rate of GNP is essential for both the reduction of population growth and the improvement of economic development of a typical less-developed country.

In his recent paper "Macroeconomic Effects of Immigration: Evidence from CANDIDE, TRACE and RDX2", Davies (1977) compares the effects of different levels of net immigration on the Canadian economy based on three different macro-econometric models. Simulation experiments with each of the three models lead to the conclusion that increased immigration lowers real GNP per capita, raises the unemployment rate and reduces the rate of inflation.

2.4 Conclusion

It can be seen from the studies reviewed above that there are different approaches to economic-demographic modelling. The approach chosen in any particular study depends on the purposes for which the study is being conducted and the type of data that are available. Although most of the models reviewed have involved the linkage of demographic and economic factors in a macro-economic model, some have focussed on simulation analysis. The common theme in all those studies remains a concern about the effect of demographic change on economic variables.

Many of the models reviewed here can be distinguished according to their approach to labour supply. While some of the earliest studies treated labour as a homogeneous factor of production, more recent studies have classified labour according to skill-types. As a result of this disaggregation of labour, education, which determines the level of labour skill, has become an important aspect of economic-demographic modelling.

The structures of the models reviewed have also been found to vary depending on the type of assumptions made. Generally, they employ neoclassical production functions of the Cobb-Douglas type, although some have been based on Harrod-Domar growth models or even Leontief fixed-coefficient production functions. Almost all of them are concerned with only the one-commodity, closed economy case and none of them has dealt with a two-commodity trading situation. As we have stated, we hope to show that the interactions between demographic and economic variables can be examined in a framework with two open economies. Since the linkage of the two open economies would take place only through trade and migration, the next chapter is devoted to a review of those theories of international trade that are considered relevant to this study.

FOOTNOTES TO CHAPTER 2

1. The 'capital in value' concept has led to the so-called Cambridge controversies on capital aggregation. However, the discussion of these controversies is not within the scope of this study. For a good review of this topic, see Harcourt, G. C., "Some Cambridge Controversies in the Theory of Capital", J. Econ. Lit., June, 1969.
2. Maxwell and Brown (1976) use this assumption for both developed and developing countries.
3. Arrow, Chenery, Minhas and Solow (1961), for example, use the estimated rate of return on capital (r) for the capital stock estimation, such that $K = (V-wL)/r$, where K is the capital stock, V the value added, and wL the total labour outlay.
4. For instance, Herrick (1976) and Denton and Spencer (1975). Actually, this is equivalent to assuming a fixed capital output ratio if the saving coefficients are fixed in relation to the national income.
5. It is seldom possible to distinguish between embodied and disembodied technical change as long as old capital remains productive and new investment is being undertaken. See Nadiri (1970) for a review of this topic.
6. Since in their basic structure, capital formation (I) is constant at a given marginal propensity to save and is reduced only by a constant depreciation rate, δ, the total capital stock at time t is equivalent to the form $K_t = (1-\delta)\ K_{t-1} + \gamma Q_t$, which gives the equation above.

7. See Easterlin (1968), page 66.

8. These papers include DeVany, A. and S. Enke, (1968), Population Growth and Development: Background and Guide (Santa Barbara: Tempo #19); McFarland, W. E. (1968), Description of the Economic Demographic Model (Santa Barbara: General Electric-TEMPO, #52); and Enke, S. (1972), "High Fertility Impairs Credit Worthiness of Developing Nations", in Spatial, Regional, and Population Economics: Eassays in Honor of Edgar M. Hoover, ed. by Mark Perlman, C. J. Leven, and B. Chinitz (N.Y.: Gordon and Breach, 1972).

CHAPTER 3

A SYNTHETIC ANALYSIS OF INTERNATIONAL TRADE THEORY WITH A NUMERICAL ILLUSTRATION

3.1 Introduction

The real theory of international trade defines a standard model in which there are 2 countries, 2 commodities, and 2 factors of production. Associated with this model are a set of assumptions from which some important theorems of the real theory of international trade are derived. These assumption are:

(1) perfect competition in both product and factor markets;

(2) identical production functions for each good in all countries; each function is linearly homogeneous and quasi-concave in such the way that commodities can be classified according to factor intensities;

(3) fixed endowments of homogeneous factors in each country with differences in the relative endowments of these factors between countries;

(4) perfect factor mobility intra-nationally and complete factor immobility internationally;

(5) identical preferences in each country with homothetic and concave indifference curves;

(6) no trade barriers or costs;

(7) absence of complete specialization; and

(8) no factor intensive reversal.

From this model, four propositions may be derived. These propositions are:[1]

(1) The Heckscher-Ohlin Theorem, whereby a country exports that commodity which uses intensively that factor which is relatively abundant.

(2) The Factor-Price Equalization Theorem, which suggests that the prices of factors of production will be equal in the two countries engaging in free trade even if factors are immobile among countries.

(3) According to the Stolper-Samuelson Theorem, a tariff on the domestic price of the imported good will increase relative to that of the exported good and will increase the price of the factor which is relatively scarce in that country.

(4) The Rybczynski Theorem, whereby an increase in the quantity of one factor will lead to a worsening in the terms of trade -- that is, to a decrease in the relative price of the commodity using relatively more of the factor. If the relative price of the goods is held constant, the absolute output of the good which uses the increased factor relatively most intensively should increase and the other commodity will decline absolutely.

The behaviour of the model is dominated by differences in relative factor endowments. Except for the differences in factor endowments, and, in (3) of tariffs, all conditions are assumed to be the same in both countries.

In the following sections, we develop a version of the theorems listed above within the context of general equilibrium with demographic features. We start in section 3.2 with a specification of the traditional 2-input, 2-commodity, 2-country model, and in section 3.3, we provide numerical examples to explore the validity of the four basic propositions noted above. In section 3.4, the basic model is converted into a simple growth model in order to illustrate the relationships between changes in population and changes in economic variables within the context of international trade theory. Section 3.5 is the conclusion of this chapter.

3.2 A Simple 2-input, 2-output Macro Model

The purpose of this section is to present a simple macro-model relating to the case of two countries, two commodities, and two factors of production.[2] This model will be extended by the introduction of the demographic influences in the latter part of this chapter.

Consider an economy that is endowed with fixed amounts of factors -- capital (K) and labour (L) -- used in the production of two commodities, one for consumption (Q_C) and one for investment (Q_I).[3] The full-employment factor equilibrium condition requires that the amount of each factor employed in production is equal to its supply, such that:

$$(3.1) \qquad L_C + L_I = L$$

$$(3.2) \qquad K_C + K_I = K$$

where L_C and L_I denote the amounts of labour employed in consumption and investment goods production, respectively. Also K_C and K_I are the amounts of capital employed in the corresponding industries.

The production function for each good is assumed to be of the Cobb-Douglas type, and exhibiting constant returns to scale and diminishing marginal productivity to each of the factors. These functions can be represented as:

$$(3.3) \qquad Q_C = A\ (K_C)^{\alpha}\ (L_C)^{1-\alpha} \qquad (0< \alpha <1)$$

$$(3.4) \qquad Q_I = B\ (K_I)^{\beta}\ (L_I)^{1-\beta} \qquad (0< \beta <1)$$

where A, B, α, and β are parameters of the production function. Assuming perfect competition and adopting the marginal productivity conditions, in equilibrium the price of each factor must be the same in each industry, and must be equal to its marginal value product, as shown in equations

(3.5) to (3.8), where we take the price of the consumption goods as the numeraire ($P_C = 1$).

$$W = (1-\alpha)\ (Q_C/L_C)\ P_C \qquad (3.5)$$

$$W = (1-\beta)\ (Q_I/L_I)\ (P_I/P_C) \qquad (3.6)$$

$$R = \alpha\ (Q_C/K_C)\ P_C \qquad (3.7)$$

$$R = \beta\ (Q_I/K_I)\ (P_I/P_C) \qquad (3.8)$$

where W is the wage rate and R is the return to capital. Under conditions of perfect competition and linearly homogeneous production functions, the prices of commodities are equal to the marginal (and average) costs of production.

$$1 = P_C = (1/Q_C)\ (W\ L_C + R\ K_C) \qquad (3.9)$$

$$(P_I/P_C) = (1/Q_I)\ (W\ L_I + R\ K_I) \qquad (3.10)$$

Equation (3.11a) expresses national income as the value of output produced or alternatively, in equation (3.11b), as the total cost of factors in production.

$$Y = Q_C + (P_I/P_C)\ Q_I \qquad (3.11a)$$

$$Y = W\ L + R\ K \qquad (3.11b)$$

Consumption and saving are taken to be a constant fraction of income according to the size of marginal propensity to save, s, (equations 3.12 and 3.13).

$$C = (1-s)\ Y \qquad (3.12)$$

$$S = s\ Y \qquad (3.13)$$

Investment consists of real goods which are not consumed, that is, $I = Y - C$, and using (3.12) and (3.13), we can therefore obtain, (3.14) $I = S$

From equations (3.12) to (3.14), we can also derive the condition:

(3.15) $Y = C + S = C + I$

In a closed economy, we have the market equilibrium condition that, for each commodity, aggregate demand must be equal to aggregate supply. That is:

(3.16) $C = Q_C$

(3.17) $I = Q_I \ (P_I/P_C)$

However, only one of equation (3.16) or (3.17) is needed to solve the system. This is because we can obtain equation (3.17) by using (3.11a) and (3.15) to (3.16). For an open economy, equations (3.16) and (3.17) are then replaced by:

(3.18) $MC = C - Q_C$

(3.19) $MK = I \left[1/(P_I/P_C)\right] - Q_I$

where MC and MK are imports of consumption goods and investment goods, respectively, and are equal to their differences of demand and production. Rearranging (3.18) and (3.19), we have the balance of trade equation:

(3.20) $MC = - MK \ (P_I/P_C)$

Since total world supplies and demands of the goods must be equal in equilibrium, we have:

(3.21) $\Sigma_i \ C_i = \Sigma_i \ Q_{Ci}$ (i=country 1,2)

(3.22) $\Sigma_i \ I_i = \Sigma_i \ Q_{Ii} \ (P_I/P_C)_i$ (i=country 1,2)

In the standard closed economy model, there are 17 equations but only 13 unknowns. Equations (3.9) and (3.10) can be derived from Euler's theorem and the marginal productivity conditions (equations 3.5 to 3.8), thus explaining the redundancy of two equations. Since equation (3.15) is derived from (3.12) through (3.14), it does not represent on independent condition. Also, one of equations (3.16) or (3.17) is redundant by Walras' law.

In the world trading situation, there are 38 equations and 29 unknowns to solve for. The 29 unknowns in this case consist (for each nation) of the 13 as in the case of the closed economy which would make for 26 in all, except that there is only one price ratio to be determined and hence only 25 for the two nations. Additionally, we need to determine MC and MK for each nation making a total of 29.

The list of equations for each nation in the open economy case would include (3.1) to (3.15) plus (3.18) to (3.20) for a total 36 which,when equations (3.21) and (3.22) are added, constitutes a list of 38. The redundant equations are as before, (3.9), (3.10), (3.15), and (3.20), which when both countries are included,accounts for 8 equations. Finally, in the open economy case, equation (3.21) or (3.22) may be eliminated by Walras' law.

The above equations are not recursive; since, at least a subset must be solved simultaneously. The set of equations non-linear in form includes production functions, factor price equations, commodity market equilibrium equations, and factor market equilibrium equations. The system is solved using Newton's iteration method.[4]

3.3 Numerical Example

This section provides a munerical example of the theorems listed in 3.1. All assumptions needed for the illustration of the H-O theorem and factor-price equalization theorem are retained as stated in the introduction to this chapter. The free trade assumption is relaxed in order to illustrate the Stolper-Samuelson theorem while the assumption regarding the fixity of factor-supplies is relaxed in order to illustrate the Rybczynski theorem.

The model we employ here for the illustration of the theorems is the same as shown in section 3.2 above. The initial parameter values are arbitarily chosen with a given specification of factor abundance for countries and of factor intensities for commodities.

We assume that country 1 is relatively capital abundant with total labour supply equal to 10 units and total capital supply equal to 200 units, whereas country 2 is relatively labour abundant with total labour supply equal to 12 units and total capital supply equal to 170 units. Furthermore, we assume that the consumption goods (Q_C) are relatively labour intensive[5]. with production coefficients A = 1.75 and α = .33; investment goods (Q_I) are relatively capital intensive with production coefficients B = 1.75 and β = .67. Also, the saving parameter (s) is equal to 0.2, and is the same in both countries. This ensures that identical consumption preferences obtain in each country.

The H-O theorem and the factor-price equalization theorem are illustrated by comparing the autarkic and free trade situations in each country. The equilibrium values for the endogenous variables in the pre-trade and post-trade situations are presented in table 3.1. The price of consumption good is adopted as the numeraire. Since country 1 is capital

Table 3.1: Levels of Endogenous Variables under Autarky and Free Trade in Country 1, Capital Intensive, and Country 2, Labour Intensive

Variables	Country 1		Country 2	
	Before Trade	After Trade	Before Trade	After Trade
L	10.00	10.00	12.00	12.00
L_C	8.90	8.09	10.68	11.50
L_I	1.10	1.91	1.32	0.50
K	200.00	200.00	170.00	170.00
K_C	132.66	101.37	112.76	144.00
K_I	67.34	98.63	57.24	25.94
Q_C	38.00	32.61	40.69	46.34
Q_I	30.28	46.96	28.84	12.35
W	2.86	2.70	2.55	2.70
R	0.09	0.11	0.12	0.11
P_I/P_C	0.31	0.33	0.35	0.33
C	38.00	38.59	40.69	40.36
I	9.50	9.65	10.17	10.09
$I.(P_C/P_I)$	30.28	28.99	28.84	30.32
Y	47.50	48.20	50.87	50.45
Y/L	4.75	4.82	4.24	4.21
MC	0.00	5.98	0.00	-5.98
MK	0.00	-17.97	0.00	17.97

Key to Symbols:

L, total labour; L_C, labour employed in production of Q_C; L_I, labour employed in production of Q_I; K, total capital; K_C, capital employed in production of Q_C; K_I, capital employed in production of Q_C; Q_C, production of consumption goods; Q_I, production of investment goods; W, wage rate; R, return to capital; P_I/P_C, price ratio; C, total consumption; I, total investment; Y, total income; Y/L, income per labour; MC, import of Q_C; MK, import of Q_I.

Note: $I.(P_C/P_I)$ refers to the total investment in terms of Q_I.

abundant with capital intensive investment good production, it gives country 1 a relatively lower price ratio (P_I/P_C) and a relatively higher factor price ratio (W/R) than country 2 before trade. These conditions determine the pattern of trade according to the H-O theorem. The commodity price ratio resulting from trade falls between those in the two countries before trade. Country 1 is exporting capital goods which use the country's abundant factor, capital, intensively, and is importing consumption goods which use the country's scarce factor, labour, intensively. The reverse situation is also true for country 2 which confirms that the H-O theorem is valid in this case.

The factor-price equalization theorem is also confirmed in our example as shown in table 3.1. Each country's scarce factor has fallen in price relative to the abundant factor, resulting in both complete factor price and commodity price equalization.

The Stolper-Samuelson theorem and the Rybczynski theorem can be illustrated by imposing a tariff in the former case[6] and allowing a factor increase in the latter. Table 3.2 illustrates these situations. As indicated, country 1 imposes a 5% import tax in one case, and experiences a 5% increase in labour supply (by higher fertility, or by allowing immigration, for example), in the other. Since country 1 is the labour scarce country, it imports consumption goods under free trade as predicted by the H-O theorem above. A 5% import tax in country 1 causes P_I/P_C to fall and at the same time (because of equation 3.26) causes the wage rate to rise in terms of the return to capital, R. This result satisfies the prediction of the Stolper-Samuelson theorem that the price of the factor which is relatively scarce will increase in terms of the price of the other factor as a result of the imposition of an import tariff.

Table 3.2: Effects on Endogenous Variables in Country 1, the Capital Abundant Country, of an Increase in The Tariff and an Increase in Labour Supply Under Free Trade

Variables	Free Trade	5% Tariff	5% Labour Increase
L	10.00	10.00	10.50
L_C	8.09	8.77	8.75
L_I	1.91	1.23	1.75
K	200.00	200.00	200.00
K_C	101.37	126.89	109.64
K_I	98.63	73.11	90.36
Q_C	32.61	37.08	35.27
Q_I	46.96	33.00	43.02
W	2.70	2.83	2.70
R	0.11	0.10	0.11
P_I/P_C	0.33	0.32	0.33
C	38.59	38.08	39.67
I	9.65	9.52	9.92
$I.(P_C/P_I)$	28.99	29.84	29.80
Y	48.24	47.60	49.59
Y/L	4.82	4.76	4.72
MC	5.98	1.00	4.40
MK	-17.97	-3.16	-13.22

Key to Symbols:

L, total labour; L_C, labour employed in production of Q_C; L_I, labour employed in production of Q_I; K, total capital; K_C, capital employed in production of Q_C; K_I, capital employed in production of Q_C; Q_C, production of consumption goods; Q_I, production of investment goods; W, wage rate; R, return to capital; P_I/P_C, price ratio; C, total consumption; I, total investment; Y, total income; Y/L, income per labour; MC, import of Q_C; MK, import of Q_I.

Note: $I.(P_C/P_I)$ refers to the total investment in terms of Q_I.

As noted in section 3.1 above, the Rybczynski theorem asserts that an increase in the supply of one factor will increase the output of the commodity which uses the increased factor more intensively. Through this mechanism, the relative price of goods is kept constant. In our case, as reported in table 3.2, a 5% increase in labour supply results in an expansion of Q_C production and a decline in the output of Q_I. Since Q_C is labour intensive, our results confirm the theoretical prediction.

For comparison, two additional cases are illustrated. In the first case, the capital-scarce country, country 2, imposes a 5% import tax. In the second case, country 2 is allowed a 5% increase in its labour supply. The results from these experiments are presented in table 3.3. The Stolper-Samuelson and the Rybczynski theorems are again confirmed. Country 2 experiences an increase in the return to its capital when it imposes a tariff and experiences an increase in the output of Q_C when its labour supply increases. However, the results in table 3.3 and table 3.2 hold only for the case of a small economy; the changes in tariff and labour supply in such a country will not affect the world level.

Apart from the variables mentioned above, table 3.1, table 3.2, and table 3.3 also show the changes of consumption (C), investment (I), income (Y), and income per labour (Y/L). All values except capital and imports of capital are in terms of consumption goods. The results indicate that both countries are better off in terms of real income under free trade.[7] However, in both cases, increases in tariff and labour supply lead to a reduction of income per labour and in the volume of international trade when world prices are constant.

Table 3.3: Effects on Endogenous Variables in Country 2, the Labour Abundant Country, of an Increase in the Tariff and an Increase in Labour Supply under Free Trade

Variables	Free Trade	5% Tariff	5% Labour Increase
L	12.00	12.00	12.60
L_C	11.50	10.83	12.29
L_I	0.50	1.17	0.31
K	170.00	170.00	170.00
K_C	114.06	117.52	153.99
K_I	25.94	52.48	16.01
Q_C	46.34	41.62	49.53
Q_I	12.35	26.20	7.62
W	2.70	2.58	2.70
R	0.11	0.12	0.11
P_I/P_C	0.33	0.35	0.33
C	40.36	40.62	41.66
I	10.09	10.15	10.41
$I.(P_I/P_C)$	30.32	25.07	31.29
Y	50.45	50.77	52.07
Y/L	4.68	4.23	4.13
MC	-5.98	-1.00	-7.88
MK	17.97	2.87	23.67

Key to Symbols:
L, total labour; L_C, labour employed in production of Q_C; L_I, labour employed in production of Q_I; K, total capital; K_C, capital employed in production of Q_C; K_I, capital employed in production of Q_C; Q_C, production of consumption goods; Q_I, production of investment goods; W, wage rate; R, return to capital; P_I/P_C, price ratio; C, total consumption; I, total investment; Y, total income; Y/L, income per labour; MC, import of Q_C; MK, import of Q_I.

Note: $I.(P_C/P_I)$ refers to the total investment in terms of Q_I.

3.4 Introduction of Trade in An Economic-Demographic Model: A Two-Country Example

In this section we introduce some demographic variables into the above simple trade model. Our approach differs from that of Johnson (1958), Bhagwati (1958), and Rybczynski (1955) and others, in that these studies concentrated mainly on the comparative static analysis of the effects of labour growth, capital accumulation, and technical progress on the growing country's consumption, production, prices, and welfare. Comparative static models, however, cannot indicate the trend and the pattern of growth. Furthermore, in the model described below, the growth of factor endowments are endogenous whereas in previous models capital and labour are considered to be exogenous variables whose values, therefore, are assumed to be determined by factors which lie totally outside the scope of the economic system. In this section, we develop a simple dynamic model to show how the growth of population affects the capital stocks, the volume of trade, and other variables in both countries.

For simplicity, we retain all the equations of the preceding model but insert two basic demographic equations and a capital formation equation for each country.

(3.23) $$N_t = (b - d)\, N_{t-1} + NMIG_{t-1} + N_{t-1}$$

(3.24) $$L_t = pr\, N_t$$

(3.25) $$K_t = (1 - \delta)\, K_{t-1} + Q_{I,t-1} + MK_{t-1}$$

where N_t is the population at period t,

$NMIG_t$ is the net migration and equals the difference between the number of immigrants and emigrants in period t,

b is the crude birth rate,

d is the crude death rate,

pr is the labour force participation rate, and

δ is the depreciation rate.

This is a general equilibrium model; all equations except equations (3.23) and (3.25) are interdependent and are to be solved simultaneously. According to equation (3.25) the magnitude of variables Q_I and MK at time period t-1 become part of the capital stock for the next period, reduced by the amount of depreciation. Population in period t is determined, according to equation (3.23), by the population of the previous period augmented by the change due to births, deaths, and net migration. In equation (3.24), the labour force is equal to the proportion of the total population employed as determined by the labour participation rate (pr). Since this model is neoclassical, there is no under- or un-employment in either economy. The initial assumption is that all parameters remain fixed throughout the period so that we can trace the possible growth paths corresponding to different situations by varying these parameters systematically. Suppose the parameter values are as before and we set the labour participation rate (pr) equal to 0.4 and the depreciation rate (δ) equal to 0.05 and assume that these are the same in both countries. Capital stocks are initially fixed at 200 and 170 units for country 1 and 2, respectively. Three different cases are then examined on the basis of the following assumptions:

(i) Assume that both countries, which represent developed countries, have the same birth rate (b = 0.0160) and death rate (d = 0.0075) with initial population equal to 25 and 30 units for country 1 and country 2, respectively. Assume also that migration is not allowed in this case.

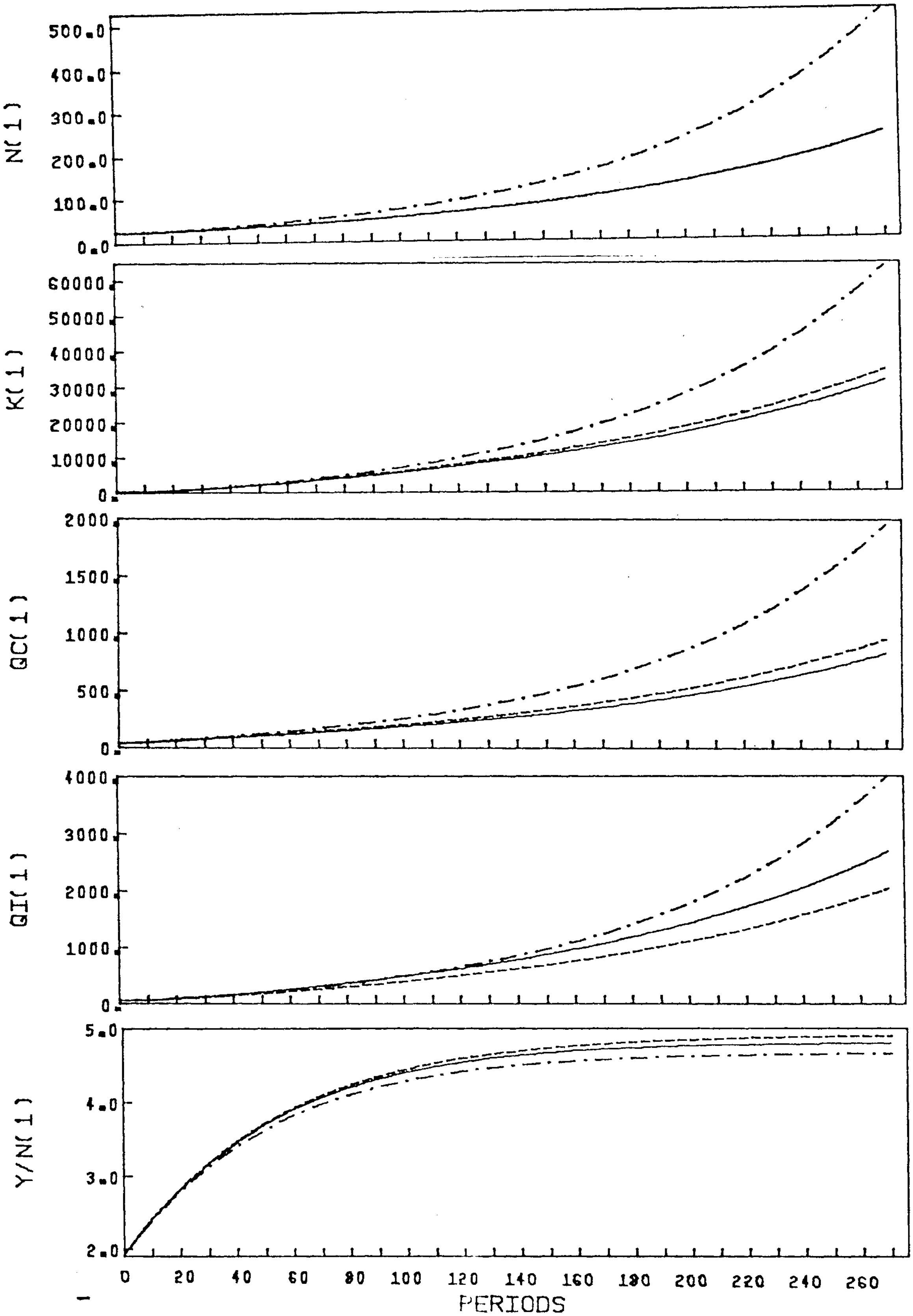
(ii) Continue with the no migration case but assume that country 2 has a higher birth rate ($b_2 = 0.034$) and a higher death rate ($d_2 = 0.020$). Country 2 represents the typical developing country in that it is labour abundant and has a higher rate of population increase.

(iii) Continue with the population assumption (ii) but introduce the possibility of migration. We assume that in each period 0.1% of the total population in country 1, the developed nation, migrates to country 2, but that 0.3% of the total population in country 2, the underdeveloped nation, migrates tc country 1.

In this model, the determination of growth proceeds from the demographic side to the economic side, so that population growth dominates the growth of other variables. Capital formation, on the other hand, has a secondary effect on the economy's growth. An increase in population in a country will increase its labour force via equation (3.24), which in turn will increase its total production through equations (3.3) and (3.4). The income of that country is also defined by equations (3.11a) or (3.11b). With this result, the country's consumption, investment, imports, and exports are also determined within the model. With equation (3.25), the capital stock for the next period is then determined. This, combined with the growth of population, provides a process of continuing economic development.

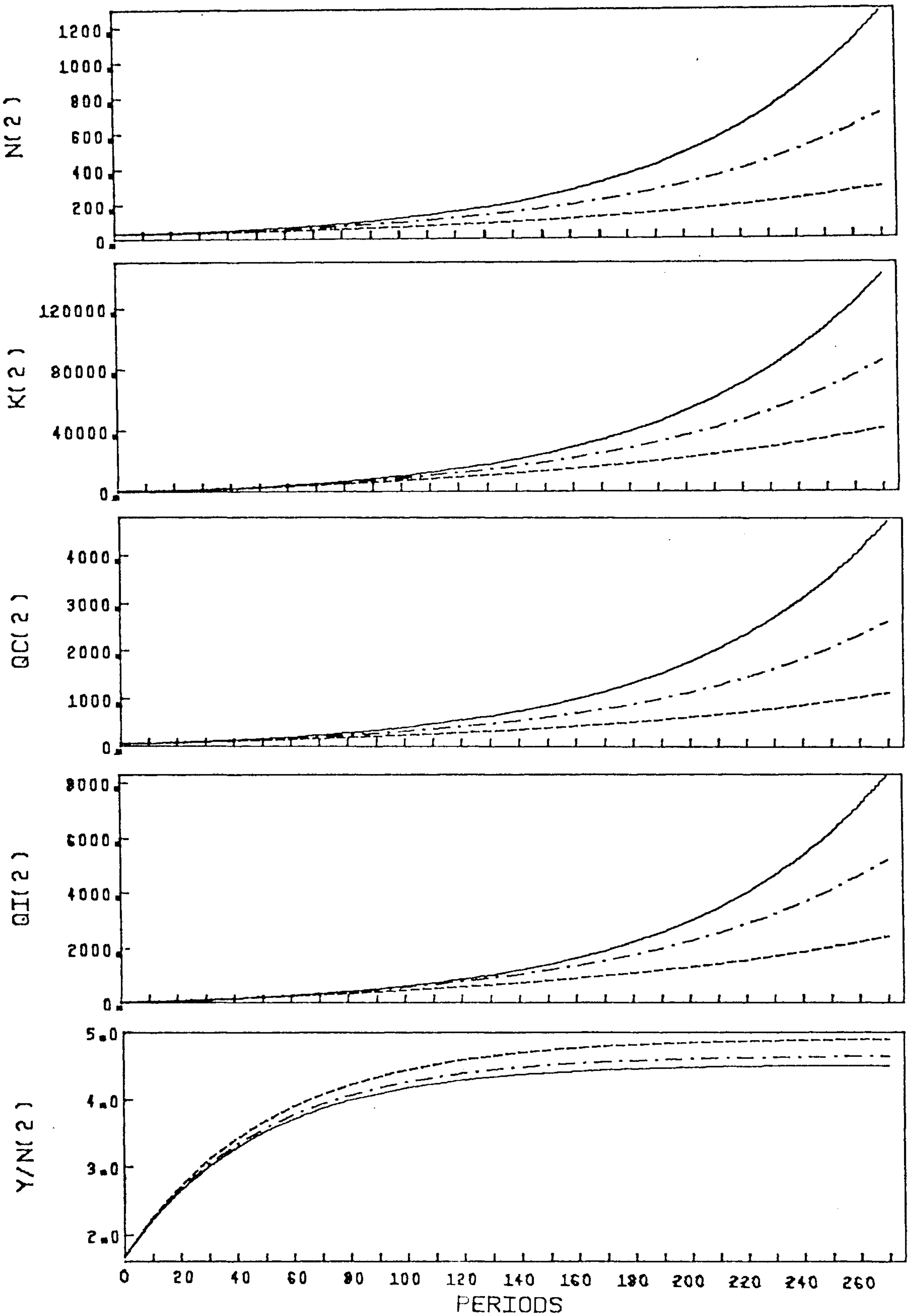
Starting from an initial trading equilibrium, figure 3.1 shows the differential rates of growth of capital stock, production levels, and other variables as they depend on the degree of population growth in both countries. Variables are changed and plotted from periods 1 to 250

Figure 3.1: Effects of Population Change on Some Selected Variables Under Various Assumptions of Birth-Rates, Death-Rates, and Migration-Rates



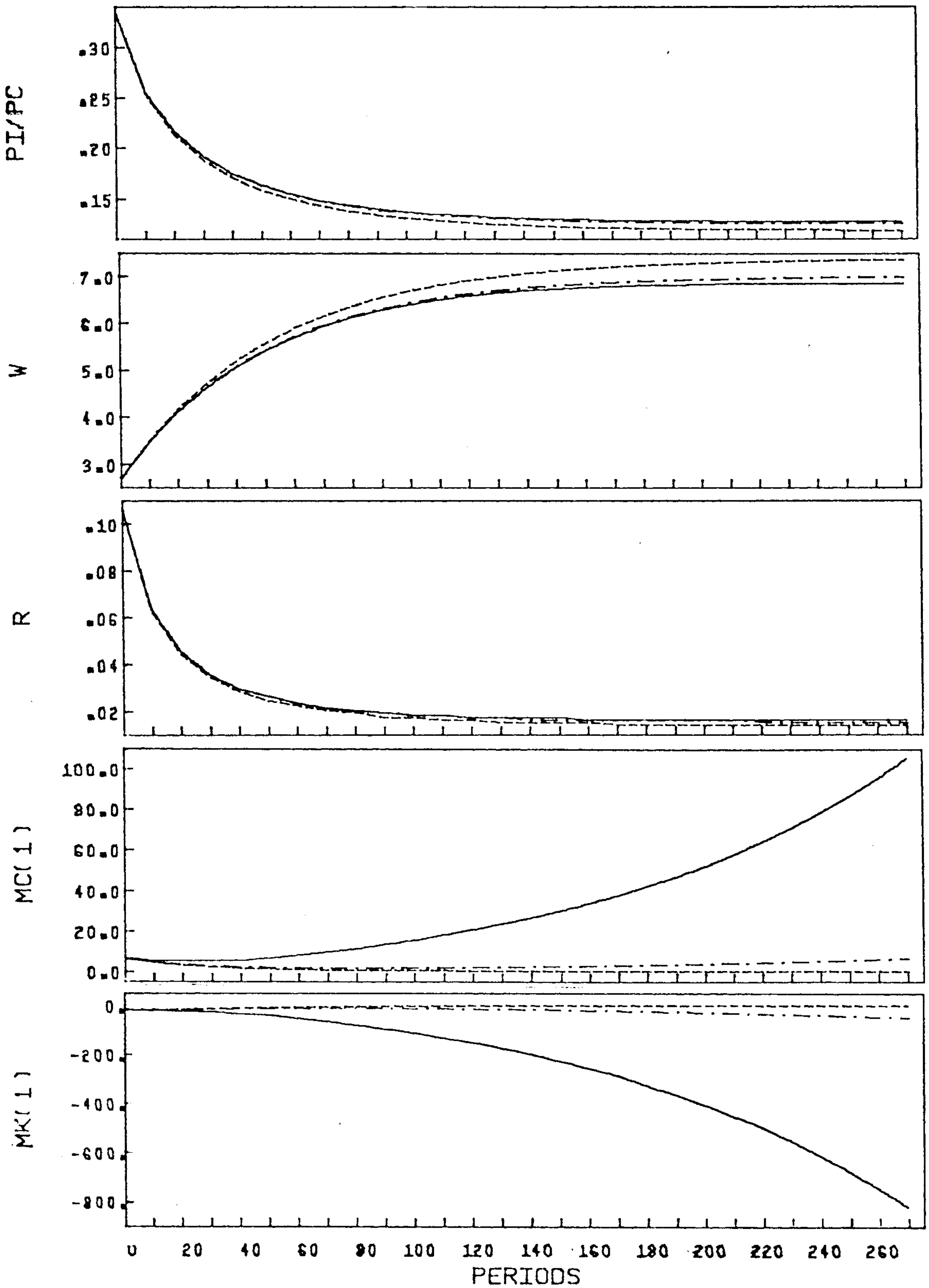
(i) Standard Case - - - - -
(ii) Higher Birth-Rate in Country 2 Case ————
(iii) Migration Case -•-•-•-•

Figure 3.1: (Contd.)



(i) Standard Case – – – – –
(ii) Higher Birth-Rate in Country 2 Case ———
(iii) Migration Case –•–•–•–•

Figure 3.1: (Contd.)



(i) Standard Case — — — —
(ii) Higher Birth-Rate in Country 2 Case ————
(iii) Migration Case —•—•—•—•

Figure 3.1: (Contd.)

Key to Symbols:

N(1), total population in country 1;

K(1), total capital stock in country 1;

QC(1), production of consumption goods in country 1;

QI(1), production of investment goods in country 1;

Y/N(1), income per capita in country 1;

N(2), total population in country 2;

K(2), total capital stock in country 2;

QC(2), production of consumption goods in country 2;

QI(2), production of investment goods in country 2;

Y/N(2), income per capita in country 2;

PI/PC, price ratio for both countries;

W, wage rate for both countries;

R, return to capital for both countries;

MC(1), import of consumption goods by country 1;

MK(1), import of investment goods by country 1.

in order to give a better insight of the changes in both demographic and economic variables over a long period.

As shown in figure 3.1, a higher population growth rate in country 2 causes country 1 to have a lower level of capital formation and a lower level of consumption goods production in the presence of trade, whereas country 2, with high population growth, experiences not only a higher level of capital formation, but also a higher level of production in both commodities after some periods. As a matter of fact, the Rybczynski theorem still holds when the rates of growth of labour and capital in country 2 are higher than those in country 1. Initial factor endowments determine the initial direction of trade and this is not reversed. Consequently, the nation with greater population growth has the greater capital formation and it eventually has a greater total income. All production activities in country 2 become very large compared to those in country 1.

The factor-price equalization theorem holds as long as the production functions and consumption preferences are the same and there is no trade barrier between these two countries. Because the growth of capital stock is higher (due to the high saving rate and a low initial depreciation) than the growth of population, the return to capital becomes lower whereas the wage rate becomes higher in both countries. At the same time, since the production of investment goods is relatively capital intensive, the rate of investment goods production relative to the production of consumption goods is higher in each nation, which further verifies the Rybczynski theorem in this more general two nation situation. As a result, the price ratio decreases in both nations. When the rate of growth of capital stock approaches the rate of growth of population in each country, the price ratio, wage rates, and return to capital become constant.

The H-O theorem is also illustrated. In the first case, country 1 (the capital abundant nation), imports consumption goods (the labour intensive commodity) and exports investment goods, as predicted by the H-O theorem. However, after some period, the differential rates of population and capital growth in the two nations is such as to make their capital-labour ratio the same and there is no basis for international transaction between them from then on. At this stage, the rates of population and capital growth are the same in both countries. In case (ii), because of a higher population growth, country 2 has a continuing lower capital-labour ratio as compared to country 1, and, over time, this results in a rapid increase in the amount of capital imports by country 2. However, international migration may slow down this process as shown in case (iii).

Note also that the income per capita becomes stable when all growth rates are the same but reduces gradually in both countries when one country has a higher population growth rate. Furthermore, migration from country 2, the labour abundant nation, to country 1 will increase per capita income in the former and reduce it in the latter.

3.5 Conclusion

The aim of this chapter has been to restate some basic real trade theories and to consider them in an explicit dynamic content. Using a simple two-country macro-model, we showed not only that four basic theorems (the H-O theorem, the factor-price equalization theorem, the Stolper-Samuelson theorem, and the Rybczynski theorem) can be obtained, but more importantly that demographic changes can be incorporated into the standard trade theory. The next chapter is concerned with the case where there are more factors than goods.

FOOTNOTES TO CHAPTER 3

1. The proof of these theorems are available in any advanced text. See, for example Kemp (1969), Chachloliades (1973), and Takayama (1972).

2. This model is basically similar to Uzawa's (1961, 1963) two sector model; however, we are concerned with the open economy rather than the closed economy.

3. The two sectors in international trade theory are natually the sector producing the importable goods and the sector producing the exportable goods. An alternative interpretation of the two sectors can be that they are two consumption good sectors or as one consumption good sector and one investment good sector. We use the latter interpretation only for convenience to facilitate the extension of the model to a dynamic economic-demographic model in our later exercise.

4. See footnote 4 of chapter 1.

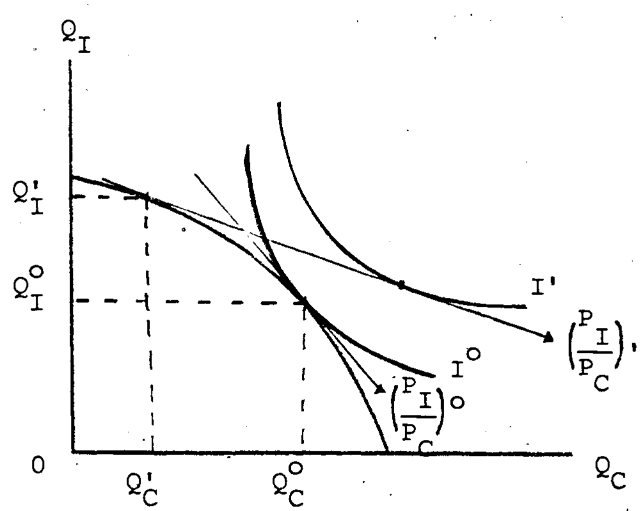
5. The relative factor intensity of a commodity is indicated by comparing α and β of our equations. Let $k_C = (K_C/L_C)$ and $k_I = (K_I/L_I)$ be the capital labour ratio for the production of consumption goods and investment goods, respectively. From equations (3.5) and (3.7), and from (3.6) and (3.8), we obtain $\frac{W}{R} = (\frac{1-\alpha}{\alpha} k_C) = (\frac{1-\beta}{\beta} k_I)$. When compared with $\frac{1-\alpha}{\alpha} \gtreqless \frac{1-\beta}{\beta}$, $k_I \gtreqless k_C$ indicates the relative factor intensity of commodities.

6. Since Stolper-Samuelson theorem deals primarily with the changes of factor income through trade taxes without the consideration of the redistribution of the tax revenue by the government, the total income and expenditure in this report are therefore excluded the tariff revenue for consistency. See Stolper-Samuelson (1941) and Chacholiades (1973, p. 434).

7. If we look at Samuelson's (1939, 1962) and Kemp's (1962, 1968, 1969) argument, we may obtain the result that free trade is better, since:

$$Q_C' + \left(\frac{P_I}{P_C}\right)' Q_I' > Q_C^o + \left(\frac{P_I}{P_C}\right)' Q_I^o$$

where the superscripts o and ' are the pre- and post- trade levels, respectively. This is illustrated in the diagram below:



Counter-arguments are discussed in Ford (1967) and Nash (1969).

CHAPTER 4

THE TWO-COUNTRY MODEL OF THE ECONOMIC-DEMOGRAPHIC SYSTEM

4.1 Introduction

We have reviewed some of the literature on economic-demographic modelling, in chapter 2, and discussed some important theorems from international trade, in chapter 3. As an extension, in chapter 3, we also provided a simple two-country model to relate the growth of population to various economic variables, followed by a numerical illustration of the model. The model assumed labour to be a homogeneous component of population. Labour and capital were assumed to be inputs in the production of both consumption and investment goods.

In this chapter, we extend our previous 2-input (labour and capital), 2-output (consumption goods and investment goods) model to a 3-input (skilled labour, unskilled labour, and capital), 2-commodity (consumption goods and investment goods) model; we also incorporate a more detailed treatment of the population conponents. This model is used later in the study for simulation analysis. In the next section of this chapter we present a brief discussion of the theoretical implications which arise when it is assumed that there are more factors than goods. The following section contains an overview of the model, indicates the general linkages between economic and demographic variables, and provides a general equilibrium framework for the economic sectors. The third section gives a more detailed sector-by-sector description of the model, and the final section offers some concluding remarks.

4.2 The Case of More Factors than Goods

So far, we have confined our discussion to the 2-factor, 2-good model of world trade. The extension to the case of many goods, factors, and nations is part of the extensive literature starting with Samuelson (1953), then followed by Vanek (1968), Williams (1970, 1977), Batra (1973), and Batra and Casas (1976), among others.[1] This section is based on the system described by Samuelson (1953) concerning how the general system can be partitioned so as to produce a set of n equations in which n factor prices depend only on n commodity prices -- the set being explicitly independent of factor supply and demand conditions.

In the case with more goods than factors $(n > r)$, the model appears to be overdetermined but market forces create circumstances in which some goods will not be produced at all and the prices of $(n - r)$ of the goods will have adjusted themselves to the prices of any r goods.[2] If both nations produce these r-goods in common, the assumptions listed on the first page of chapter 3 are sufficient to determine the prices of r factors of production, given the prices of r commodities.

On the other hand, in the case where there are more factors than goods $(r > n)$, Samuelson (1953) points out that the general equilibrium system cannot be solved in this manner. To the subsystem involving goods and factor prices, we must add the conditions requiring that the demand for each resource equals its supply.[3] These additional conditions contribute complicated factor substitution terms to the relationship between product prices and factor rewards, leading to the different factor price ratios between countries.[4]

Even if the model can be solved in these circumstances, the determination of trade according to the H-O theorem remains unpredictable if there are more than two factors in production, since the concept of factor intensity of commodities can become ambiguous. For example, a commodity Q can be intensive in X_1 as compared to X_2 but not intensive in X_1 as compared to X_3, where the X_j's are factors of production. The same problem applies with respect to the concept of factor abundance in a country. Thus, we cannot predict the direction of trade according to the H-O theorem outlined in Chapter 3 above.

In order to derive the direction of trade according to the H-O theorem, one alternative way is to treat exportables and importables in terms of the factor content, irrespective of the number of goods and factors. For example, in a world of two trading countries, each country has identical demand functions and, facing identical commodity prices, each country consumes goods in the same proportion. Suppose a production equilibrium exists on the price plane, the factor price ratio will be constant and invariant with changes in the proportions in which goods are produced. Each commodity will be produced using the same factor proportions in all countries. Given the demand conditions and factor endowments, there exists an equilibrium proportion of capital and labour which is embodied in the production of each of the traded commodities and the difference between consumption and supply of a resource must be traded. Thus, the pattern of trade in resources through commodities is established and the H-O theorem is still valid in this sense.

Williams (1970) assumes the existence of factor price equalization and the similarity of tastes in consumption. He redefines the concept of factor intensity in terms of absolute amounts of any resource used in the per unit output of any commodity and the definition of relative factor abundance according to the ratio of total amounts of resource to total income in the country. His concepts provide a theorem consistent with that proposed by Heckscher and Ohlin in terms of resource content of trade.

Alternatively, Vanek (1968) assumes the factor price equalization along with all other assumptions of the H-O model and redefines the relative factor abundance by ranking the comparative ratios of domestic (X's) to foreign (x's) units of productive factors measured in physical terms, such that:

$$\frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \ldots \geqq \frac{X_j}{x_j} \geqq \ldots \geqq \frac{X_n}{x_n}$$

Vanek shows that if X_j/x_j is equal to the ratios of their national incomes, the country will show net export of factor contents of X_1 to X_j and will show net import of factor contents of X_{j+1} to X_n. This can be easily seen by deriving the following equation in matrix notation as:

$$V = W\ (X + x)$$

where V is the vector of the factor contents of total world output and W a diagonal matrix (n x n) of the n factor prices. In the domestic country, the vector of the value content of national output is:

$$Y = W\ X$$

Assuming identical tastes and product prices, the value of the factor content of domestic consumption y is a constant fraction m ($0 < m < 1$) of the factor content of the world output, so that:

$$y = m\, V$$

The trade vector T reflecting the net factor content of trade is:

$$T = Y - y$$

and hence m is determined by the balance of trade equilibrium condition,

$$T' I = 0$$

where I is an unit vector. The jth element of the vector T can be written as:

$$T_j = W_j \left[X_j \ (1 - m) - m\, x_j \right]$$

Then T_j becomes function of m alone, with the prescribed values of W_j, X_j, and x_j. Since m is fixed, the relationships of m to X_j/x_j is obtained by setting $T_j = 0$, such that $\frac{X_j}{x_j} = \frac{m}{1 - m}$. If $T_i > 0$, it must be that $\frac{X_i}{x_i} > \frac{m}{1 - m}$, and this implies that $\frac{X_i}{x_i} > \frac{X_j}{x_j}$. The reverse is also true for $T_j < 0$ with $\frac{X_j}{x_j} > \frac{X_i}{x_i}$. Given the value of m from the equilibrium condition, we can easily obtain a benchmark at j and since the order of X's to x's is maintained throughout, we can uniquely determine trade flows in terms of factor contents according to relative factor abundance.

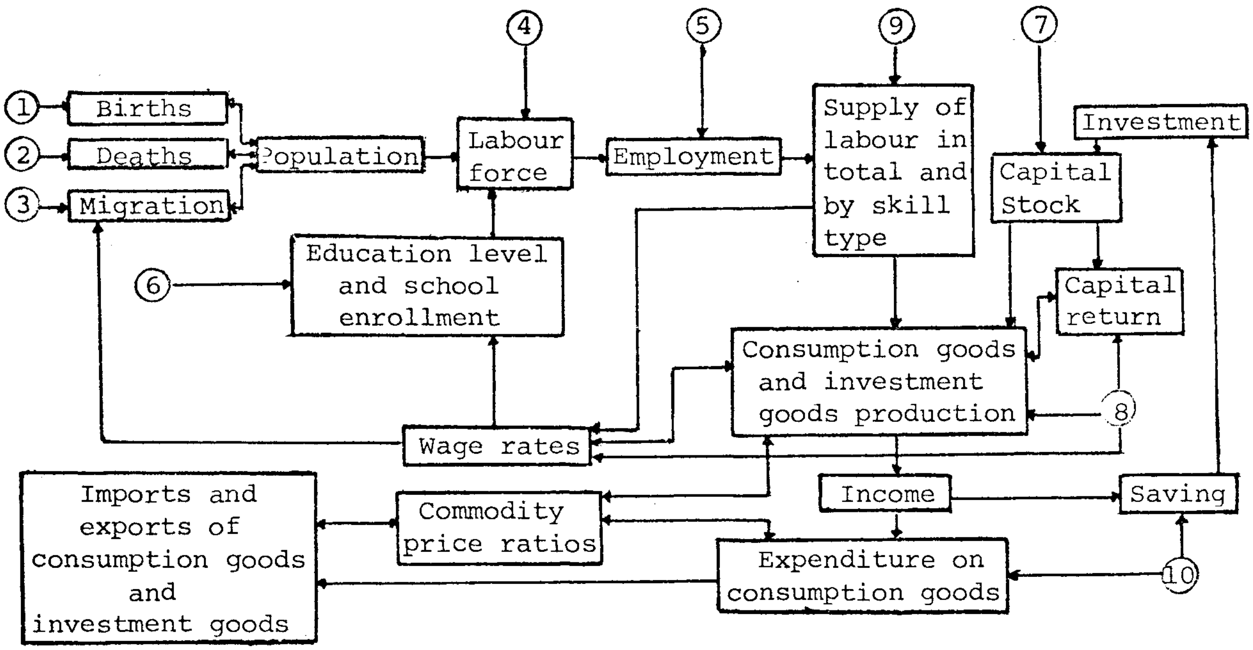
4.3 An Overview of the Economic-Demographic Model

Since we are interested in a two country case, the model is built with due consideration given to the interaction of economic and demographic variables both within and between countries. Within a country, the model tells how changes in the composition of population influence the economic situation, including production and income distribution; it also tells how the changing economy affects the labour catagories. In the international framework, the model describes how the changes in economic variables in one country influence the movements of both people and commodities in the other. In order to understand how the model works, it is necessary to consider the nature of the two countries of the model. Therefore, in this section, we concentrate on the discussion of the economic and demographic processes and their interactions which characterize the countries.

For simplicity, we assume that the two countries can be characterized by equations with identical structural forms. Thus, the description of one country will suffice for both. As mentioned above, the model consists of two parts. The economic side of the model represents the aggregate behaviour of the economy, including production, income generation, consumption, and the determination of capital stock. The demographic part represents the processes involved in the determination of population, human capital, and the labour force. The model is such that both the sex-age and educational level distributions of the population influence the supplies of different labour skills, and hence production, income, consumption, and investment. In turn, both the level and distribution of income affect school enrollment rates, migration rates, and hence the distribution of population by skill types.

The interrelationships of the model can be presented schematically as in figure 4.1, and its interpretation follows. For convenience, we use rectangles for the endogenous variables and circles for exogenous variables.

Figure 4.1 Schematic Representation of the Model



(1) Fertility rates
(2) Death rates
(3) Basic migration rates
(4) Labour force participation rates
(5) Employment rates
(6) Basic school enrollment rates
(7) Depreciation rate on capital stock
(8) Parameters of production functions
(9) Productivity weights for labour
(10) Parameter of consumption function

Starting with the demographic side of the model, the total population is disaggregated by 5-year age groups, sex, and skill-type. This disaggregation provides 56 population cohorts. The model moves ahead by 5-year intervals. Each cohort is aged by 5 years and adjusted for mortality and migration. The number of births in each 5-year interval is determined by applying age-specific fertility rates to the female population of child-bearing age, and the number of deaths is obtained by applying age-sex-specific mortality rates to the population in every age group. Migration is calculated in accordance with age, sex, and skill-specific migration rates, and these in turn are influenced by relative wage levels in the two countries.

The skill composition of the population is determined by the level of education in each cohort. Accordingly, the crucial variables in the determination of the skilled population are the school enrollment rates for the age group 15 to 19. These school enrollment rates are determined by the differences between the expected lifetime earnings of each labour type, based on current wage rates discounted for time preference. An individual who has enrolled for study at ages 15 to 19 becomes a unit of skilled labour at the age of 20, and remains in the skilled category thereafter.

Having classified the population by skill types, the labour force is then determined by the application of age, sex, and skill-specific participation rates to the population at ages 15 and over for unskilled labour, and at ages 20 and over for skilled labour. Assuming that unemployment rates are constant at the full-employment level, employment for each age-sex-skill labour category is computed by applying an age-sex-skill-specific employment rate to the labour force. In order to make the model more realistic, each labour type is weighted according to its relative productivity at each age. The total effective labour supply of each skill type is then obtained by aggregating the age groups.

The economic side of the model consists of three sectors: production (including the distribution of resources), consumption, and international trade. These three components, as shown in figure 4.1, are interrelated through the effects of the commodity price ratio. Supposing the country to be small, its price ratio is exogenously determined, being equal to the world price ratio. In this case, the price ratio determines not only the level of production, but also the level of consumption and the amount of trade. If the country is large enough to affect the world price ratio, the values of the variables in these three sectors and the commodity and factor price ratios would have to be solved for simultaneously, in order to determine the world equilibrium values of all commodity supplies and demands.

For the purposes of the analysis, let us first assume that the commodity price ratio is exogenously given. At any point in time, we have equilibrium stocks of capital, K, of skilled workers, L_S, and of unskilled workers, L_U. In a neoclassical framework, all these stocks of inputs go into the production of both consumption goods and investment goods. Let the production functions be represented as follows:

$$Q_C = f\ (K_C, L_{SC}, L_{UC})$$
$$Q_I = g\ (K_I, L_{SI}, L_{UI})$$

where Q_C and Q_I are consumption goods and investment goods, respectively.

Under conditions of full employment, we also have:

$$K_C + K_I = K$$
$$L_{SC} + L_{SI} = L_S$$
$$L_{UC} + L_{UI} = L_U$$

Assuming that production functions are well behaved such that, in equilibrium, the marginal rate of substitution (MRS) for any pair of inputs is the same in both industries, wage rates and the return to capital are determined by their marginal products:

$$W_i = P_C \cdot f_i = P_I \cdot g_i \qquad (i = L_S, L_U, K)$$

where $f_i = \partial f/\partial i$ and $g_i = \partial g/\partial i$ represent the marginal physical products of factor i (MPP_i) in the production of consumption and investment goods, respectively. It follows that:

$$\frac{W_i}{W_j} = \frac{f_i}{f_j} = MRS_{ij}^{Q_C} = MRS_{ij}^{Q_I} = \frac{g_i}{g_j} \qquad (i \neq j;\ i,j = L_S, L_U, K)$$

These are the conditions which guarantee that the economy will, in equilibrium, allocate its resources efficiently, the equilibrium points being located somewhere on the contract curve in the box diagram and production somewhere along the production-possibility frontier, as shown in figure 4.2.[5]

In figure 4.2, TABCT' in (a) is the production possibility frontier which is equivalent to $Q_C abc Q_I$ in (b), whereas $Q_C A'B'C'Q_I$ in (b), $Q_C A''B''C''Q_I$ in (c), and $Q_C A'''B'''C'''Q_I$ in (d) are contract curves for pairs of inputs. In our example, when the price ratio p_1 is given, production of Q_C and Q_I will be at A, and this determines the factor distribution in

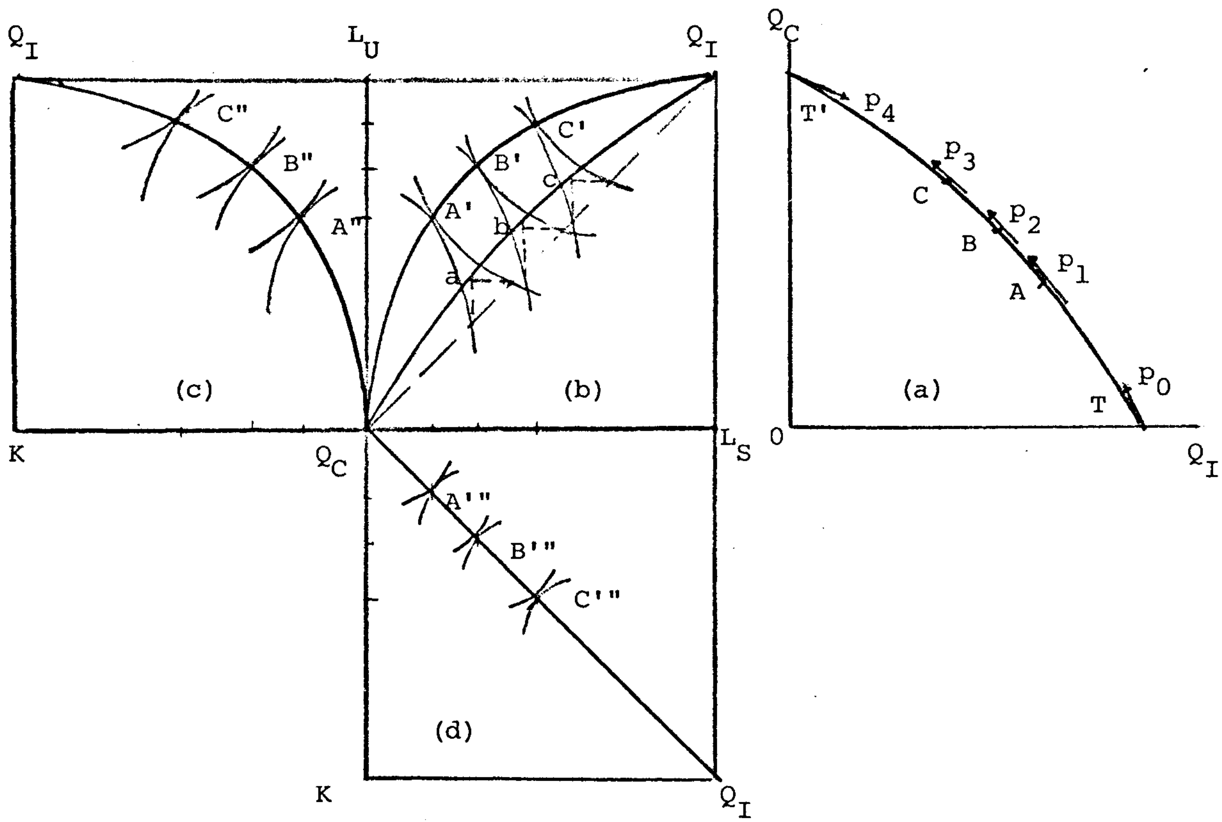


Figure 4.2 Contract Curves and the Production Possibility Frontier in a 3-Input, 2-Output Model

all production activities along their respective contract curves. Any change of the price ratio, for instance, from p_1 to p_2 or p_3, will lead to new equilibrium production and factor distributions along the production possibility and contract curves.[6]

Total outputs of Q_C and Q_I determine the size of income. The income is divided between total consumption and saving according to the parameters of the saving function, which is independent of the size and age composition of the population. Investment is obtained by setting it equal to saving with its value expressed in terms of consumption goods. The total amount of investment, minus the depreciation of capital stock, determines the net addition to the stock for the next period.

Given the parameter of the saving function, s, we derive the autarkic consumption and production point A with its equilibrium price

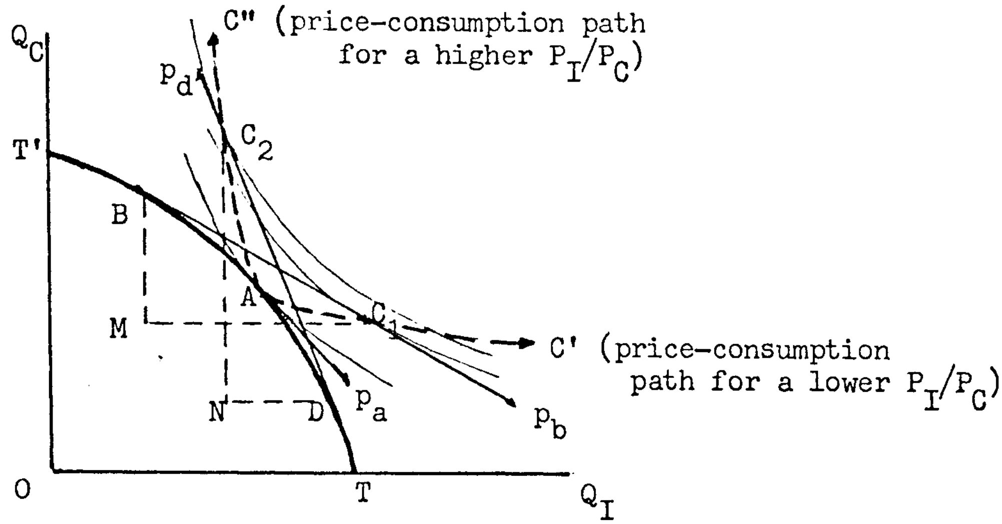


Figure 4.3 The Effect of Changes in the Price Ratio on the Level of Consumption and Production

ratio p_a in figure 4.3. Two price-consumption paths originating from A are obtained, one for decreases and the other for increases in the price ratio. The AC' path is obtained when the price ratio p_a is reduced, whereas AC" is the path for an increase in the price ratio.[7]

If two countries have the same price ratio when in autarky, there is no inducement to trade. But if the autarkic price ratio in country 1 is higher than that in country 2 ($p_a^1 > p_a^2$), country 1 will export consumption goods in exchange for investment goods, and the price ratio will be lowered in country 1. If p_b is the new price ratio, country 1 will produce at point B, in figure 4.3, and consume at point C_1, leaving an excess supply of consumption goods (=BM) and an excess demand for investment goods (=MC_1). On the other hand, the price ratio in country 2 will rise as a result of trade. It is assumed that the price ratio p_d leaves country 2 with an excess supply of investment goods (=ND) and an excess demand for consumption goods (=NC_2). The price ratios will not stabilize until equilibrium is reached. Figure 4.4 gives a simplified illustration of the process. The Marshall-Edgeworth type offer curves 01 for country 1 and 02 for country 2 are derived by transforming their excess supply or demand levels for commodities with the price ratio changes. Op_a^1 and Op_a^2 are original price ratios for countries 1 and 2, respectively, and Op_b and Op_d are their new price ratios with M and N indicating the

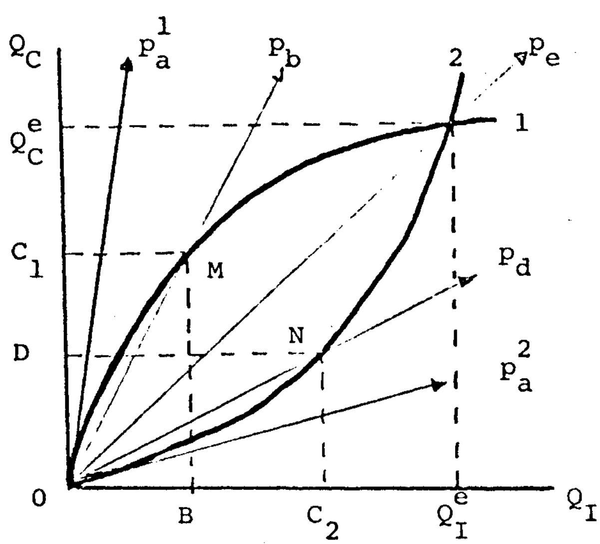


Figure 4.4 Marshall-Edgeworth Type Offer Curves

respective points at which the countries are willing to trade. Assuming that there is no barrier to trade between the two countries, the equilibrium price ratio will be p_e at which ratio all goods markets will be cleared. Country 1 will export OQ_C^e of consumption goods for OQ_I^e of investment goods and country 2 will export OQ_I^e of investment goods in exchange for OQ_C^e of consumption goods. With the price ratio determined, all other economic variables will be simultaneously determined.

4.4 Detailed Description of the Model

As stated earlier, the two countries are identical in terms of the structure of their economic-demographic systems and the equations used as a starting point. Table 4.1 shows the initial set of equations for a representative economy. It indicates not only the type of economic-demographic system that a country has, but also the relationship of this country to the other one. The equations are first presented in table 4.1 and then described in detail.

Table 4.1

Equations of the Two-Country Model
(five year intervals)

Fertility and Births

(1) $$f_{jt} = a_j F_t \qquad (j = 4,5,\ldots,10)$$

$$f_{jt} = 0 \qquad (j<4;\ j>10)$$

(2) $$B_t = 5 \Sigma_j \left[\tfrac{1}{2} (f_{j-1,t-1} + f_{jt})\right] \left[\tfrac{1}{2} (N_{2,j-1,t-1} + N_{2jt})\right] \qquad (j = 4,5,\ldots 10)$$

(3) $$B_{1t} = \frac{b}{1 + b} B_t$$

(4) $$B_{2t} = \frac{1}{1 + b} B_t$$

Migration

Supply of Migrants:

(5) $$m_{ijkt(x,y)} = m^*_{ijk(x,y)} \left(\frac{W^*_{k(y)}}{W^*_{k(x)}}\right)^{\tau_{kx}}_{t-1} \qquad (i=1,2;\ j=1,2,\ldots,14;\ k=S,U)$$

(6) $$m_{ijkt(y,x)} = m^*_{ijk(y,x)} \left(\frac{W^*_{k(x)}}{W^*_{k(y)}}\right)^{\tau_{ky}}_{t-1} \qquad (i=1,2;\ j=1,2,\ldots,14;\ k=S,U)$$

$$(7)\quad IM^S_{i1Ut(y)} = m_{i1Ut(x,y)}\ B_{it(x)} \qquad (i=1,2)$$

$$(8)\quad IM^S_{ijkt(y)} = m_{ijkt(x,y)}\ N_{i,j-1,k,t-1(x)} \qquad (i=1,2;\ j=2,\ldots,13;\ k=S,U)$$

$$(8a)\quad IM^S_{i,14,kt(y)} = m_{i,14,kt(x,y)}\ (N_{i,13,k,t-1} + N_{i,14,k,t-1})_{(x)}$$

$$(i=1,2;\ k=S,U)$$

$$(9)\quad EM^S_{i1Ut(y)} = m_{i1Ut(y,x)}\ B_{it(y)} \qquad (i=1,2)$$

$$(10)\quad EM^S_{ijkt(y)} = m_{ijkt(y,x)}\ N_{i,j-1,k,t-1(y)} \qquad (i=1,2;\ j=2,\ldots,13;\ k=S,U)$$

$$(10a)\quad EM^S_{i,14,kt(y)} = m_{i,14,kt(y,x)}\ (N_{i,13,k,t-1} + N_{i,14,k,t-1})_{(y)}$$

$$(i=1,2;\ k=S,U)$$

Demand for Migrants:

$$(11)\quad IM^D_{i1Ut(y)} = \bar{m}_{i1Ut(x,y)}\ B_{it(y)} \qquad (i=1,2)$$

$$(12)\quad IM^D_{ijkt(y)} = \bar{m}_{ijkt(x,y)}\ N_{i,j-1,k,t-1(y)} \qquad (i=1,2;\ j=2,\ldots,13;\ k=S,U)$$

$$(12a)\quad IM^D_{i,14,kt(y)} = \bar{m}_{i,14,kt(x,y)}\ (N_{i,13,k,t-1} + N_{i,14,k,t-1})_{(y)}$$

$$(i=1,2;\ k=S,U)$$

$$(13)\quad EM^D_{i1Ut(y)} = \bar{m}_{i1Ut(y,x)}\ B_{it(x)} \qquad (i=1,2)$$

$$(14)\quad EM^D_{ijkt(y)} = \bar{m}_{ijkt(y,x)}\ N_{i,j-1,k,t-1(x)} \qquad (i=1,2;\ j=2,\ldots,13;\ k=S,U)$$

$$(14a)\quad EM^D_{i,14,kt(y)} = \bar{m}_{i,14,kt(y,x)}\ (N_{i,13,k,t-1} + N_{i,14,k,t-1})_{(x)}$$

$$(i=1,2;\ k=S,U)$$

Migration Flows:

$$(15)\quad IM_{ijkt(y)} = IM^S_{ijkt(y)} \text{ if } IM^S_{ijkt(y)} \leqq IM^D_{ijkt(y)} \qquad (i=1,2;j=1,\ldots,14;k=S,U)$$

$$(16)\quad IM_{ijkt(y)} = IM^D_{ijkt(y)} \text{ if } IM^S_{ijkt(y)} > IM^D_{ijkt(y)} \qquad (i=1,2;j=1,\ldots,14;k=S,U)$$

$$(17)\quad EM_{ijkt(y)} = EM^S_{ijkt(y)} \text{ if } EM^S_{ijkt(y)} \leqq EM^D_{ijkt(y)} \qquad (i=1,2;j=1,\ldots,14;k=S,U)$$

$$(18)\quad EM_{ijkt(y)} = EM^D_{ijkt(y)} \text{ if } EM^S_{ijkt(y)} > EM^D_{ijkt(y)} \qquad (i=1,2;j=1,\ldots,14;k=S,U)$$

$$(19)\quad IM_{t(y)} = \Sigma_i \Sigma_j \Sigma_k\ IM_{ijkt(y)} \qquad (i=1,2;\ j=1,\ldots,14;\ k=S,U)$$

$$(20)\quad EM_{t(y)} = \Sigma_i \Sigma_j \Sigma_k\ EM_{ijkt(y)} \qquad (i=1,2;\ j=1,\ldots,14;\ k=S,U)$$

Population

(21) $N_{i1t} = B_{it} (1-d_{i0}) + (IM_{i1t} - EM_{i1t})$ (i = 1,2)

(22) $N_{ijt} = N_{i,j-1,t-1} (1-d_{i,j-1}) + \Sigma_k (IM_{ijkt} - EM_{ijkt})$

(i=1,2; j=2,...,13; k=S,U)

(23) $N_{i,14,t} = N_{i,13,t-1} (1-d_{i,13}) + N_{i,14,t-1} (1-d_{i,14})$

$+ \Sigma_k (IM_{i,14,kt} - EM_{i,14,kt})$ (i=1,2; k=S,U)

(24) $N_t = \Sigma_i \Sigma_j N_{ijt}$ (i=1,2; j=1,2,...,14)

Labour Supply and Employment

(25) $\bar{e}_{i4St} = \bar{e}^*_{i4S} \exp\{\gamma[\Sigma_{j=4}^{14} (1+\rho)^{-(j-4)} W_{ijS,t-1} - \Sigma_{j=4}^{14} (1+\rho)^{-(j-4)} W_{ijU,t-1}]\}$

(i=1,2; j=4,...,14)

where $W_{i4S} = 0$ (i=1,2)

$W_{ijS} = \ell_{ijS} W^*_S$ (i=1,2; j=5,...,14)

$W_{ijU} = \ell_{ijU} W^*_U$ (i=1,2; j=4,...,14)

(26) $N_{i4St} = \bar{e}_{i4St} N_{i4t}$ (i=1,2)

(27) $N_{i4Ut} = (1 - \bar{e}_{i4St}) N_{i4t}$ (i=1,2)

(28) $N_{ijkt} = (1-d_{i,j-1}) N_{i,j-1,k,t-1} + (IM_{ijkt} - EM_{ijkt})$

(i=1,2; j=5,...,13; k=S,U)

(29) $N_{i,14,kt} = (1-d_{i,13}) N_{i,13,k,t-1} + (1-d_{i,14}) N_{i,14,k,t-1}$

$+ (IM_{i,14,kt} - EM_{i,14,kt})$ (i=1,2; k=S,U)

(30) $L_{ijkt} = p_{ijk} N_{ijkt}$ (i=1,2; j=4,...,14; k=S,U)

(31) $L_{kt} = \Sigma_i \Sigma_j L_{ijkt}$ (i=1,2; j=4,...,14; k=S,U)

(32) $L_t = L_{St} + L_{Ut}$

(33) $E_{ijkt} = L_{ijkt} (1 - u_{ijk})$ (i=1,2; j=4,...,14; k=S,U)

(34) $E_{kt} = \Sigma_i \Sigma_j E_{ijkt}$ (i=1,2; j=4,...,14; k=S,U)

(35) $E^*_{kt} = \Sigma_i \Sigma_j \ell_{ijk} E_{ijkt}$ (i=1,2; j=4,...,14; k=S,U)

(36) $E^*_{kt} = E^*_{kCt} + E^*_{kIt}$ (k=S,U)

Capital Formation

(37) $K_t = K_{t-1}\,(1-\delta) + Q_{I,t-1} + MK_{t-1}$

(38) $K_t = K_{Ct} + K_{It}$

Production

(39) $Q_{Ct} = \alpha_0\,(K_{Ct})^{\alpha_1}\,(E^*_{SCt})^{\alpha_2}\,(E^*_{UCt})^{\alpha_3}$

(40) $Q_{It} = \beta_0\,(K_{It})^{\beta_1}\,(E^*_{SIt})^{\beta_2}\,(E^*_{UIt})^{\beta_3}$

Income

(41) $Y_t = W^*_{St}\,E^*_{St} + W^*_{Ut}\,E^*_{Ut} + R_t\,K_t$

(42)++ $Y_t = Q_{Ct} + \left(\frac{P_I}{P_C}\right)_t Q_{It}$

Wage Rates and Return to Capital

(43) $W^*_{St} = \alpha_2\left(\frac{Q_C}{E^*_{SC}}\right)_t$

(44) $W^*_{St} = \beta_2\left(\frac{Q_I}{E^*_{SI}}\right)_t\left(\frac{P_I}{P_C}\right)_t$

(45) $W^*_{Ut} = \alpha_3\left(\frac{Q_C}{E^*_{UC}}\right)_t$

(46) $W^*_{Ut} = \beta_3\left(\frac{Q_I}{E^*_{UI}}\right)_t\left(\frac{P_I}{P_C}\right)_t$

(47) $R_t = \alpha_1\left(\frac{Q_C}{K_C}\right)_t$

(48) $R_t = \beta_1\left(\frac{Q_I}{K_I}\right)_t\left(\frac{P_I}{P_C}\right)_t$

Consumption, Saving, and Investment

(49) $C_t = (1 - s)\,Y_t$

(50) $C_t = Q_{Ct} + MC_t$

(51) $S_t = s\,Y_t$

(52) $I_t = S_t$

(53) $I_t = (Q_{It} + MK_t)\left(\frac{P_I}{P_C}\right)_t$

(54)++ $Y_t \equiv C_t + I_t \equiv C_t + S_t$

(55)++ $MK_t \left(\frac{P_I}{P_C}\right)_t = - MC_t$

International Market Equilibrium

(56) $C_{(x)t} + C_{(y)t} = Q_{C(x)t} + Q_{C(y)t}$

(57)++ $I_{(x)t} + I_{(y)t} = Q_{I(x)t} \left(\frac{P_I}{P_C}\right)_{(x)t} + Q_{I(y)t} \left(\frac{P_I}{P_C}\right)_{(y)t}$

If tariff is imposed, we add

(58) $\left(\frac{P_I}{P_C}\right)_{(y)t} = (1 + tariff_{(x)})\ (1 + tariff_{(y)}) \left(\frac{P_I}{P_C}\right)_{(x)t}$ if $MK_{(y)} > 0$

(59) $\left(\frac{P_I}{P_C}\right)_{(y)t} = \frac{1}{(1 + tariff_{(x)})\ (1 + tariff_{(y)})} \left(\frac{P_I}{P_C}\right)_{(x)t}$ if $MC_{(y)} > 0$

otherwise

(60) $\left(\frac{P_I}{P_C}\right)_{(y)t} = \left(\frac{P_I}{P_C}\right)_{(x)t}$

For country (x), we reproduce the above equations except the migration equations, since

(61) $IM_{(x)t} = EM_{(y)t}$

(61) $EM_{(x)t} = IM_{(y)t}$

Endogenous Variables

1.	B:	total live births during 5-year interval
2.	B_1:	male live births during 5-year interval
3.	B_2:	female live births during 5-year interval
4.	C:	consumption during 5-year interval
5.	EM_U^S:	potential unskilled labour emigration during 5 years

6. EM_S^S: potential skilled labour emigration during 5 years

7. EM_U^D: restricted unskilled labour emigration during 5 years

8. EM_S^D: restricted skilled labour emigration during 5 years

9. EM_U: actual emigration of unskilled workers

10. EM_S: actual emigration of skilled workers

11. EM: actual total emigrants during 5-year interval

12. E_{ijk}: labour employment with sex-age-skill classification

13. E_S: total skilled labour at mid-interval

14. E_U: total unskilled labour at mid-interval

15. E_S^*: effective skilled labour input

16. E_U^*: effective unskilled labour input

17. E_{SC}^*: effective skilled labour employed in production of Q_C

18. E_{SI}^*: effective skilled labour employed in production of Q_I

19. E_{UC}^*: effective unskilled labour employed in production of Q_C

20. E_{UI}^*: effective unskilled labour employed in production of Q_I

21. $\bar{e}$: probability of continuing education at the ages of 15-19

22. f: annual age-specific fertility rate (births per woman)

23. IM_U^S: potential unskilled labour immigration during 5 years

24. IM_S^S: potential skilled labour immigration during 5 years

25. IM_U^D: restricted unskilled labour immigration during 5 years

26. IM_S^D: restricted skilled labour immigration during 5 years

27. IM_U: actual immigration of unskilled workers

28. IM_S: actual immigration of skilled workers

29. IM: actual total immigrants during 5-year interval

30. I: investment during 5-year interval

31. K: capital stock at the beginning of the 5-year interval

32. K_C: capital employed in production of Q_C

33. K_I: capital employed in production of Q_I

34. L_{ijk}: sex-age-skill type labour supply

35. L_S: total skilled labour supply at mid-interval

36. L_U: total unskilled labour supply at mid-interval

37. MK: net import (or export, if negative) of investment goods during 5-year interval

38. MC: net import (or export, if negative) of consumption goods during 5-year interval

39. $m_{U(x,y)}$: probability of migration of an unskilled worker from country x to country y

40. $m_{U(y,x)}$: probability of migration of an unskilled worker from country y to country x

41. $m_{S(x,y)}$: probability of migration of a skilled worker from country x to country y

42. $m_{S(y,x)}$: probability of migration of a skilled worker from country y to country x

43. N_{ij}: population cohort with sex-age specification at mid-interval

44. N: total population at mid-interval

45. N_{S4}: population in school of ages 15-19

46. N_{U4}: unskilled population of ages 15-19

47. N_{ijk}: population cohort with sex-age-skill specification

48. (P_I/P_C): ratio of investment goods price to consumption goods price

49. Q_C: production of consumption goods during 5-year interval

50. Q_I: production of investment goods during 5-year interval

51. R: rate of return to capital

52. S: saving during 5-year interval

53. Y: total income during 5-year interval

54. W_S^*: effective skilled labour wage rate

55. W_U^*: effective unskilled labour wage rate

56. W_{ijk}: labour wage rate with sex-age-skill classification

Parameters and Exogenous Variables

1. a: ratio of age-specific fertility rate to total fertility rate
2. b: ratio of male live births to female live births
3. d: proportion of persons who die during 5-year interval
4. $\bar{e}^*$: probability of education continuing in equilibrium at ages 15-19
5. F: total fertility rate (births per woman 15-49 years of age)
6. ℓ_{ijk}: labour productivity weight associated with sex, age, and skill
7. m*: probability of migration in equilibrium
8. $\bar{m}$: ratio of restricted immigration to domestic population
9. p: labour force participation rate
10. s: marginal propensity to save
11. u: unemployment rate
12. ρ: time preference discount rate
13. γ: parameter of education function (adjustment parameter)
14. δ: rate of depreciation of capital over five years
15. α, β: parameters of production functions
16. τ: parameter of migration functions

Subscripts

1. i: subscript referring to sex
2. j: subscript referring to age
3. k: subscript referring to skill type
4. x: subscript referring to country x

5. y: subscript referring to country y

6. t: subscript referring to time interval (t=1,2,...)

Note: the symbol ++ indicates a redundant equation, i.e., one that can be ignored in solving the model.

Fertility and births:

A set of simplified fertility and birth equations is designed for the computation of total births during the 5-year intervals. We assume the age-specific fertility rates to vary proportionately with the exogenously determined total fertility rate. Women are assumed to be fertile only from the ages 15 to 49 (age cohorts 4 to 10). These fertility rates, when applied to the appropriate female population cohorts, determine total live births and hence, the population in age cohort 1 (ages 0 to 4). In this instance, the number of births during the 5-year interval (B_t) is equal to the sum of the product of average age-specific fertility rates (average of f_{jt} and $f_{j-1,t-1}$) and the average female population of age cohorts j and j-1, multiplied by 5. The figure for total births is then split into male and female births according to a specified sex ratio.

Migration:

Equations describing migration are divided into two separate groups, relating to supply and demand. Equations (5) to (10) determine the supply of migrants whereas equations (11) to (14) determine the demand for immigration or emigration, by country. The key variables for migration levels in these equations are the intended emigration rates (m_{ijk}) and the restricted in migration rates ($\overline{m}_{ijk}$). The m_{ijk}'s are the age-sex-skill-specific probabilities of migration between the 'home' country (y) and the 'foreign' country (x). These emigration probabilities differ from their equilibrium values (m^*_{ijk}) in that the former are influenced by differences in relative wage levels at home and abroad. The parameter τ, in equations (5) and (6), interpreted as the elasticity of the migration rate with respect to relative wage rates, is assumed to be non-negative. With positive equilibrium migration probabilities, intended migration still exists even when there is no overall economic stimulus. Once the probabilities of migration have been determined in equations (5) and (6), the supplies of migrants of different ages, sexes, and skill levels are computed in equations (7) to (10).

The restricted migration rates are exogenously determined by the respective government's immigration policies. It is assumed that these rates accord with the desired ratios of immigrants to native population by age, sex, and skill. Given the restricted migration rates, the numbers of age-sex-skill-specific migration demands are determined in equations (11) to (14).

If neither country has any restrictions on migration, the number of immigrants or emigrants is the same as the number of migrants supplied, as indicated in equations (7) to (10). Migration restriction ensures that the number of migrants is determined depending on the supply of migrants or the restricted level, whichever is lower. These numbers are computed in equations (15) to (18). In equations (19) and (20), the total numbers of immigrants and emigrants are computed by summing over age, sex, and skill components.

Population:

The population is disaggregated by sex and by 5-year age groups. The male and female populations in each cohort are calculated by applying the fixed set of mortality rates to the population of the cohort 5-year earlier, and adding net immigration. This general form is exclusive of cohorts 1 (ages 0-4) and 14 (ages 65 and over). The population of males or females in cohort 1 is obtained by multiplying the number of male or female births by an infant survival rate and adding to this the net immigration of that age and sex during the given interval (equation 21). On the other hand, the population of males or females in cohort 14 (ages 65 and over) is measured by summing the surviving members of the male or female sex in cohort 13 (ages 60 to 64) and cohort 14 (ages 65 and over) present 5 years earlier together with the net immigration of that cohort during the interval (equation 23). The total population, in equation (24), is the sum of the population in all age-sex groups.

Labour supply and employment:

Without specifying the education enrollment equations, population cohorts can only be disaggregated by sex and age as above. The skill type population cohorts are classified according to the number of years of schooling and are determined by the school enrollment rates for ages 15 to 19. Whether labour is skilled or not depends on whether it has completed more than eight years of schooling. Thus the number of persons of ages 15 to 19 enrolled in school will become the skilled males and females. The probability of school enrollment for ages 15 to 19 is a function of the expected life-time earnings differential discounted by their rate of time preference; and the earnings differential is based on the last interval's wage rates weighted by age-sex productivities.[8] Suppose we let D be the discounted wage differential, the probability of school enrollment ($\bar{e}$) is then represented in semilog form as:

$$\log\ (\bar{e}) = \sigma + \gamma D \qquad \sigma > 0;\ 0 < \gamma < 1$$

so that $\bar{e} = \exp\ \{\sigma + \gamma D\}$

or $\bar{e} = \bar{e}^{*} \exp\ \{\gamma D\}$

with $\bar{e}^{*} = \exp\ (\sigma)$

as shown in equation (25). Note that the term $\bar{e}^*$ becomes the equilibrium school enrollment rate and the term γ is the adjustment parameter. Under these conditions, the probability of school enrollment is positive. Once this rate ($\bar{e}$) is defined, the distribution of the skill type population of cohort 4 (ages 15 to 19) by skill type is determined by equations (26) and (27). For simplicity, we assume that once an individual becomes skilled or unskilled he or she remains so for the rest of his or her life. Therefore, we may recompute the population in each cohort with regard to different sex, skill-level, and age categories at 5-year intervals in equations (28) and (29).

The labour force is calculated by applying participation rates to the population cohorts 4 to 14, by sex and by skill-type. Participation rates are assumed to be zero for skilled persons less than 20 and for unskilled persons less than 15, the boundary points for age cohorts 4 and 3, respectively. This is shown in equation (30); the results are aggregated in equation (31) to determine the supplies of skilled and unskilled labour. The total labour force in equation (32) is the sum of these two groups.

Employment for each age-sex-skill category is computed in equation (33) by applying a fixed employment rate (1 - u) to the labour force, where u is the age-sex-skill specific unemployment rate, and the results are summed in equation (34) to obtain the total employment of labour of the two skill-types. The unemployment rates involved are assumed to be constant at the full employment level, in accordance with the assumptions of the model.

The effective skilled and unskilled labour supplies are obtained by weighting employment by the productivity coefficients for each age, sex, and skill category. The productivity profiles for each cohort are derived from estimates of marginal productivity. The assumption is similar to that of Denton and Spencer (1975, Ch. 2) which includes age-sex effects and cohort effects (knowledge improvement through the educational system) on the variations in productivity. With this assumption, a cohort's productivity weight depends on its age only, classified by skill types for convenience. One way to measure the age productivity profiles is based on census earnings data. Given indexes of real average earnings of each skill-type for each cohort, the productivity weight of a cohort is taken by comparing its real average earnings ($\overline{W}^o_{ijk}$) to the average earnings ($\overline{W}^o_k$) of all cohorts for each skill group, such that,

$$\ell_{ijk} = \frac{MPP_{ijk}}{\frac{1}{n}\Sigma_i\Sigma_j\ MPP_{ijk}} = \frac{\overline{W}^o_{ijk}}{\overline{W}^o_k} \qquad (i=1,2;\ j=4,\ldots,14;\ k=S,U)$$

where n is the total number of cohorts (i.j) for both skill groups. For example, based on Canadian income groups for 1970,[9] the age-productivity weighted profiles for skilled and unskilled males and females as derived are shown in figure 4.5. The productivity weight for each skill group reaches a peak level near age 50, and weights for male are higher than that for female. Since weights are taken from the ratio of earnings to total average earnings for each skill group, age-productivity profiles for each skill group have a similar structure with weights for male being greater than unity ($\overline{W}^o_{ijk} > \overline{W}^o_k$) at peak levels. Assuming that weights are fixed, wages for each cohort can be calculated once overall wages are obtained.

The total effective labour supply for each skill category is split into two production sub-groups (for consumption goods and investment goods production) whose size is determined in the model by the condition that full employment for each skill category will be reached in equilibrium.

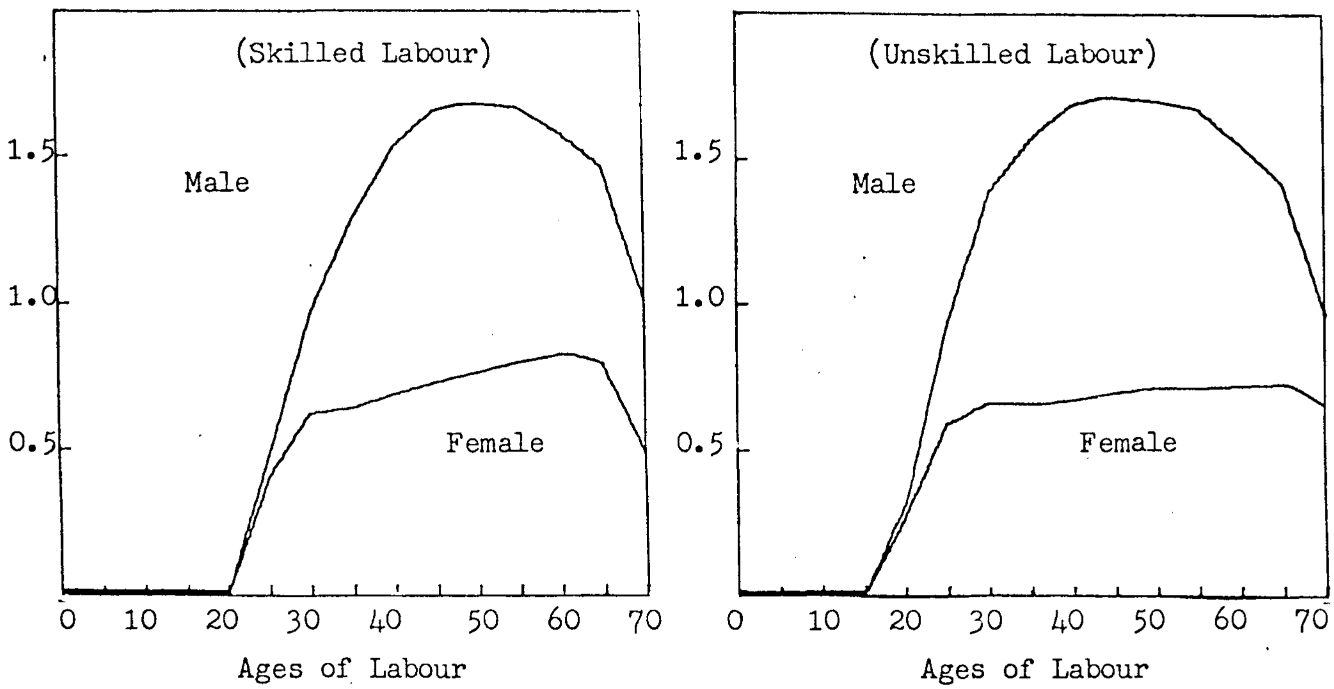


Figure 4.5: Age-Productivity Profiles

$$\left[\ell_{ijk} = \frac{\overline{W}^{o}_{ijk}}{\overline{W}^{o}_{k}} \right]$$

This implies that productivity will be the same for each sub-group in either skill category.

Capital formation:

The stock of capital in terms of physical units at the beginning of interval t is computed by depreciating previous capital stock at a constant rate δ and adding investment in the preceding interval. The latter, which includes total investment goods production and capital imports (exports, if negative), converted into its value in terms of consumption goods, is the net investment in the previous interval. For convenience, investment within the interval does not affect the capital stock until the beginning of the following interval, and does not start to depreciate until then. Furthermore, depreciation on capital stock is assumed to take place only at the end of each interval, in order to avoid the complications of calculation. The total capital stock, like effective labour, is employed in the production of both consumption goods and investment goods.

Production:

Production involves three inputs (capital, skilled labour, and unskilled labour) and two outputs (consumption goods and investment goods). The production functions in equations (39) and (40) are of standard Cobb-Douglas form with constant returns to scale. The α's and β's (except α_0 and β_0, which are constant coefficients) are the elasticities of output with respect to the corresponding inputs. Since these functions have unit elasticity of substitution for each input, each input has a constant share of total production.[10] These results may be seen in our wage equations below.

Income:

In our model, perfect competition is assumed; thus, the price of a commodity is equal to its unit cost. Income, therefore, can be measured either by the total cost of inputs (equation 41) or the total value of outputs (equation 42). Furthermore, all values of outputs and inputs are computed in terms of consumption goods, and the value of income is computed in terms of its consumption good equivalent.

Wage rates and return to capital:

Given a perfectly competitive factor market, factors are paid the value of their marginal products. The wage per unit of effective labour for each skill type is determined by equations (43) to (46), while the return to capital is calculated in equations (47) and (48). All wages and return to capital are measured in terms of consumption goods. Following from the assumption of perfect competition, wage rates and return to capital are the same in both industries, thus guaranteeing efficiency in production.

Consumption, saving, and investment:

Consumption and saving are taken to be a constant fraction of income. The value of investment in terms of consumption goods is set equal to saving, as shown in equation (52). We assume that consumption goods are produced only for consumption, and investment goods for investment, so that import (export) of consumption goods or investment goods is determined by the corresponding excess demand (supply), as indicated by equations (50) and (53). The determination of the value of investment goods is appropriately adjusted by the relative price ratio. The computation of all values in terms of consumption goods ensures that the income and balance of payments represented by equations (54) and (55) hold.

International market equilibrium:

Equations (56) and (57) represent the world market equilibrium conditions for both commodities at which no excess demands exist in the world market.

Tariffs:

Tariffs are the means by which a country could alter the relative price ratios between the two countries. Equation (58) shows the relative price relationship when both countries impose tariffs and country (y) imports capital, whereas equation (59) indicates the situation when country (y) imports consumption goods. These equations are easily derived by re-arrangement of the price relations: $P_{ij} = (1 + \text{tariff}_{(j)})\ P_{ik}$ ($i=C,I$; $j=x,y$; $k=y,x$; $j \neq k$). In the free trade situation, price ratios are the same in both countries as in equation (60). Of course, in an autarkic situation, it is possible to have $(P_I/P_C)_{(y)t} \gtreqless (P_I/P_C)_{(x)t}$.[11]

4.5 Conclusion

In this chapter, we have provided and described the economic-demographic model which is to be used for simulation analysis in the next chapter. As has been noted, the model allows for demographic variables to affect economic variables, through the changes in the labour force and hence in productive capacity; the changes in economic variables, in turn, influence the demographic variables through their effects on migration propensities and school enrollment rates. A general equilibrium analysis of the economic side of the model has also been provided, noting especially that the system of equations comprising the model has to be solved simultaneously to allow for the interaction of supplies, demands, and prices of goods and factors, both domestically and internationally.

Apart from the interactions of demographic and economic variables, the model also incorporates some policy variables, embodied specifically in migration and trade restriction equations. This allows us to obtain a better insight into how particular policies might affect the operation of the economy in both its domestic and international dimensions.

FOOTNOTES TO CHAPTER 4

1. Other studies include Melvin (1968), Bhagwati (1972), ane Warne (1973) which focus on the concepts of factor abundance and factor intensity, and Kemp (1969), Batra (1973), Batra and Casas (1976), Burgess (1976), Woodland (1977), and Hillman and Bullard III (1978) which emphasize the analysis of trade theory with the duality approach.

2. Let n the number of goods, r the number of factors, W_j and P_i prices of factor j and good i (Q_i), and X_{ij} the quantity of input j used in producing output i. So there are (rxn) marginality conditions, $W_j = P_i \ (\partial Q_i/\partial X_{ij})$, and n production functions, $Q_i \ (a_{ij}\text{'s}) = 1$. However, there are only n.r + r unknowns (the n.r a_{ij}'s and r W_j's). When n > r as in the above case, we have n - r redundant equations.

3. Since we have only n.r + n equations and n.r + r unknowns, we add the third set of condition: $\Sigma_i \ a_{ij} \ Q_i = X_j$ giving r.equations and n unknown output levels Q's, so that we have (n.r + r + n) equations and the same number of unknown thereby making the model fully determinate.

4. See Samuelson (1949). The methematical interpretation has been presented in Batra (1973), Batra and Casas (1976), Burgess (1976), and others.

5. This diagram is constructed by assuming $K = L_S = L_U = 100$ with the production functions of $Q_C = K_C^{.2} \ L_{SC}^{.2} \ L_{UC}^{.6}$ and $Q_I = K_I^{.4} \ L_{SI}^{.4} \ L_{UI}^{.2}$. Of course, different parameters of production functions yield different shapes for contract curves.

6. Of course, specialization is possible when price ratios are very high (p_0, eg.) or very low (p_4). In this paper, we rule out this possibility.

7. According to our assumptions, demands for consumption goods and investment goods are constant fractions of the total income represented by:

$$C_{Q_C} = C\left(\frac{1}{P_C}\right) = (1-s)Y\left(\frac{1}{P_C}\right) \text{ or } P_C C_{Q_C} = (1-s)Y$$

$$C_{Q_I} = I\left(\frac{P_C}{P_I}\right) = s\ Y\ \left(\frac{P_C}{P_I}\right) \text{ or } \left(\frac{P_I}{P_C}\right)\ C_{Q_I} = s\ Y$$

where C_{Q_C} and C_{Q_I} are demand for consumption goods and investment goods, respectively. Since $s \geqq 0, (1-s) \geqq 0$, and $s + (1-s) = 1$, it follows that the income-elasticity of demand for each goods is unity and the cross-elasticity is zero. The demand functions thus imply a utility function of the Cobb - Douglas form, i.e., $u = C_{Q_C}^{(1-s)}\ C_{Q_I}^{s}$ from which it follows that the utility function produces convex indifference curves with all goods normal. Ref. H.A. John Green's (1971) Consumer Theory (Penguin Books), sections 4.6 (pp.83 to 89) and 9.2 (pp.135 to 136) for the proof.

8. The weighted wage rates can be obtained directly from equations (35), (36), (39), and (40) where effective workers are substituted for by skill type labours. For instance, if

$$Q_C = \alpha_0 \, (K_C)^{\alpha_1} \, (\Sigma_i \Sigma_j \, \ell_{ijS} \, E_{ijSC})^{\alpha_2} \, (\Sigma_i \Sigma_j \, \ell_{ijU} \, E_{ijUC})^{\alpha_3},$$

then
$$W_{Sij} = \partial Q_C / \partial E_{ijSC} = \alpha_2 \cdot (Q_C / \Sigma_i \Sigma_j \, E_{ijSC}) \, \ell_{ijS}$$
$$= W_S^* \, \ell_{ijS}$$

and also
$$W_{Uij} = \partial Q_C / \partial E_{ijUC} = \alpha_3 \, (Q_C / \Sigma_i \Sigma_j \, E_{ijUC}) \, \ell_{ijU}$$
$$= W_u^* \, \ell_{ijU}$$

as indicated in equation (25).

9. It should be noted that the income data used in constructing the age-productivity weighted profiles include the effects of both age and technical change. However, since our model assumes no technical change, such effects have been ignored in the measurement of these profiles.

10. Since, as noted in Sámuelson (1968), a general form of the elasticity of substutition for factor i, X_i, in a n factor production function, $Q = F\,(X_1, \ldots, X_n)$, is:

$$\sigma_i = - \frac{F_i}{X_i \, F_{ii}} \left(1 - \frac{F_i \, X_i}{F}\right)$$
$$= - E_{X_i F_i} \, (1 - \alpha_i)$$

where $E_{X_i F_i}$ is the elasticity of the <u>ceteris paribus</u> marginal-product demand curve for the ith factor, α_i is the relative share of the ith factor. The change in relative share of factor i depends on its elasticity of substitution, such that:

$$\frac{\partial \alpha_i}{\partial X_i} \gtreqless 0 \quad \text{iff} \quad \sigma_i \gtreqless 1$$

See Samuelson (1968) for the proof.

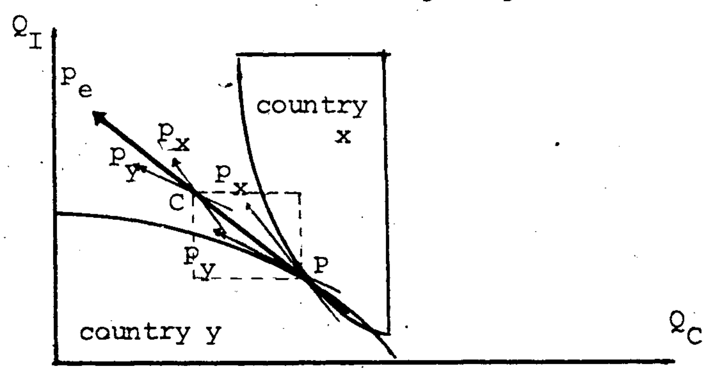
11. With the consideration of the transfer of the government tariff revenue to the private sector, equations (41) and (42) should be replaced by this form: $Y' = Y + TR$

where Y' is the total income including tariff revenue TR which is calculated from

$$TR_{(y)} = MC_{(y)} \cdot tariff_{(y)} \cdot (1 + tariff_{(y)}) \left(\frac{P_I}{P_C}\right)_{(y)} \quad \text{if } MC_{(y)} > 0$$

or $$TR_{(y)} = MK_{(y)} \cdot \left(\frac{tariff_{(y)}}{1 + tariff_{(y)}}\right) \left(\frac{P_I}{P_C}\right)_{(y)} \quad \text{if } MK_{(y)} > 0$$

This situation is shown in the following diagram:



Note that in the diagram, p_x, p_y, and p_e are price ratios $\left(\frac{P_I}{P_C}\right)$ for countries x and y and the international equilibrium price ratio respectively. Since $\left(\frac{P_I}{P_C}\right)_{(x)} = \left(\frac{1}{1 + tariff_{(x)}}\right) \left(\frac{P_I}{P_C}\right)_{(e)}$

and $\left(\frac{P_I}{P_C}\right)_{(y)} = (1 + tariff_{(y)}) \left(\frac{P_I}{P_C}\right)_{(e)}$

so that we have $\left(\frac{P_I}{P_C}\right)_{(y)} = (1 + tariff_{(y)})(1 + tariff_{(x)}) \left(\frac{P_I}{P_C}\right)_{(x)}$

as shown in equation (58).

CHAPTER 5

SIMULATION EXPERIMENTS WITH THE ECONOMIC-DEMOGRAPHIC MODEL

5.1 Introduction

This chapter contains a detailed presentation and discussion of the results of computer simulation experiments in which the model is used to study the effects of variations in fertility rates and migration probabilities on the future trends in both demographic and economic variables. The model is purely hypothetical and, as such, does not relate to any actual economic-demographic system. However, in order to make the model more realistic, many of the demographic and economic parameters were calculated from Canadian data, at least in a rough manner.

Since this is a 2-country model, we focus not only on the effects of migration itself but also on the consequences of international commodity flows. For simplicity, we assume that movements of labour and commodities are costless and free from restrictions so that commodity prices in equilibrium are the same in the two nations, irrespective of the existence of factor price inequality between the nations.[1] This inequality of factor prices is the main cause of labour migration. Commodity trade and population movements play important roles in the real world, especially by moderating the differences in demographic and economic structure between nations. Three different cases -- one with trade flows, another with only labour migration, and a third permitting both trade flows and labour migration -- are investigated in this study.

In section 5.2, we present the specification of the parameter values used in the experiments. In section 5.3, we present some computer simulation results in which a shock, either a change in fertility rates or in migration probabilities, to the three different cases are investigated. For convenience, we assume, in all cases, that the two countries are initially identical and are in stationary equilibrium. Then we introduce an exogenous shock to disturb this equilibrium so that the time paths of changes in some of the selected demographic and economic variables can be observed. Section 5.4 is devoted to an analysis of effects on the direction of trade and section 5.5 to the discussion of the consequences of variations in the production functions' parameters with a shock in fertility rates in the no-migration case. Section 5.6 gives some concluding remarks.

5.2 The Specification of Parameter Values

Since the two countries are assumed to be identical and initially in stationary equilibrium, their parameter values are the same. To approximate a real world situation, parameter values are based largely on Canadian data. However, a range of parameter values have been used in order to test the sensitivity of the model to changes in these parameters.

Starting with the demographic sector, the age pattern of fertility rates is based on the Canadian rates for 1973, and the birth rates for males and females are also calculated from 1973 data, taken from the United Nations Demographic Yearbook, 1974.

The 5-year mortality rates are calculated from the 1973 life table in the Demographic Yearbook, with the rates of death at the mid-interval for each cohort.[2]

The equilibrium values for the age-sex-skill-specific emigration probabilities are based on the estimation and projection of the age-sex composition of emigration through 1986, by Statistics Canada.[3] The migration probabilities for the two labour skills are set in such a way that the migration probabilities for skilled labour are higher, in keeping with the assumption of greater propensity to migrate among the skilled population. All these probabilities are weighted to conform with an assumed total migration rate.

The age-sex-skill-specific labour force participation rates and unemployment rates are measured from the 1971 Census of Canada, based on the labour force activity according to the level of schooling in particular age groups.

The age-sex-skill-specific productivity weights are calculated from Statistics Canada 1971 income data, taken as the ratio of average earnings to the total average earnings classified by levels of schooling.[4]

The equilibrium school enrollment rates for ages 15 to 19 are taken from the single-age school enrollment rate of 1966 reported by Statistics Canada, estimated by averaging the rates of ages 17 to 19, and adjusted according to the rates reported in the United Nations Statistical Yearbook for 1975.

The marginal propensity to save out of income is based on IMF International Financial Statistics, and is taken as the ratio of gross fixed capital formation to GNP in 1973.

Other parameters are set arbitrarily due to the lack of information. Some of these parameter values are summarized below:

(1) The elasticity parameter in the migration functions (τ) is assumed to be the same for skilled as well as unskilled labour. That is: $\tau = \tau_S = \tau_U = .5$

(2) School enrollment function:

(i) Equilibrium school enrollment rates: $(\bar{e}_1^*, \bar{e}_2^*) = (.446, .363)$

(ii) The rate of time preference (5 years): $\rho = .2$

(iii) Adjustment parameter: $\gamma = .01$

(3) Capital depreciation rate: $\delta = .225$ (.05 per annum)

(4) Production functions:

(i) For consumption goods: $(\alpha_0, \alpha_1, \alpha_2, \alpha_3) = (5., .6, .2, .2)$

(ii) For investment goods: $(\beta_0, \beta_1, \beta_2, \beta_3) = (5., .4, .4, .2)$

(5) Marginal propensity to save: $s = .22$

(6) Initial total emigration rate = 5% (1% per annum)

These values are used in all of the experiments, unless otherwise indicated.

5.3 Simulation Experiments Initiated by Demographic Changes

This section outlines some simulation experiments involving the consequences of an exogenous change in a demographic variable which take place in one of the two countries. For convenience, initial identical stationary population and stationary economy assumptions are implemented side by side such that the population growth, economic growth, net immigration, imports, and exports in each country are all zero. Each experiment begins with the relaxation of the identity assumption by the introduction of a shift in the level of fertility or the rate of emigration in a country in period 1 (5 years), which leads to changes in the growth paths of demographic and economic variables. The three different cases employed in the simulation exercise are:

(1) no trade in goods but population is internationally mobile,

(2) only goods can move internationally, and

(3) both goods and population move internationally.

In case (1), we consider simulation experiments with shocks introduced through changes in both fertility and migration rates, but in (2) and (3), only fertility rates are allowed to change.

A different set of parameter values is selected in each case in order to find out the response of the economy to shocks when these parameters are changed. Obviously, there would be hundreds of possible combinations of such parameters even if only two values were chosen for each parameter. However, only a few of such combinations are experimented with in the simulation exercise. Alternative parameter values chosen are indicated in each case below.

Case (1): Only population is mobile internationally

In this case we consider two different shocks: (A) a change in the total fertility rate in one country, and (B) a change in migration propensities in one country.

(A) A temporary rise in the total fertility rate

Suppose that a temporary doubling in the total fertility rate (F) occurs in country 1 during period 1 (5 years), and then the rate returns to its initial level afterwards. This change causes a disturbance to the initial equality of both demographic and economic variables in the two countries. For convenience, initial levels of population and all other economic variables are set at 100.0 and the aggregate rates of immigration and emigration are set at 5% in terms of native population, leaving the net immigration rates equal to 0.0%.

Three sets of experiments have been undertaken. With the values of parameters the same in both countries, three alternative parameter values for migration elasticities have been chosen. These values are $\tau = 0$, .5, and 1, respectively, but keeping $\tau = \tau_S = \tau_U$ in each case, for convenience.

Consider first the age composition of population. With the case of $\tau = .5$, table 5.1 shows the effects of the shock on these variables, including the level of population and the crude birth rate. Since population is allowed to move internationally, an increase in the level of fertility in one country clearly leads both countries to a continuing increase in population. The population will only settle down to a new stationary level several hundred years later. Immediately following the shock, there is a sharp rise in the crude birth rate in country 1, followed by a sharp decline when the total fertility rate reverts to its original level.

After a time, population in country 1 increases significantly as these young female cohorts enter the childbearing ages. This phenomenon reaches a peak some 25 or 30 years later when the most fertile childbearing age is reached, and then slows down until it reaches another peak in years 55 to 60. Population in country 2 grows at a similar pace as a result of an increase in the number of immigrants. As a matter of fact, since the growth of population in country 2 depends mainly on immigration, its adjustment is somewhat smoother than that experienced in country 1.

International migration has an important impact on the effects of the different rates of population growth in the two countries; these rates are shown in table 5.2 and figure 5.1. Since unskilled population includes individuals in cohorts 1 to 3 (ages 0 to 14), the aggregate emigration rate for unskilled population in country 1 is higher after the sudden drop in the first period following the shock, whereas aggregate immigration rates always remain lower due to the lag in immigration and the increment to the younger ages in that category. Migration rates for both skill categories are greatly affected when the younger population of these categories reach working age.

The increment of working population leads to lower wage rates in both countries; the wage rates are lower in country 1 than in country 2. The maximum wage differentials between country 1 and country 2 occur 30 years after the outset of the shock, as a result of the especially rapid rate of growth of the effective labour force which occurs in country 1 at that time. The differentials are narrowed by migration and the increment of the capital stock until they disappear. However, some 55 to 65 years after the shock, the wage differentials are reversed, with the wage rates in country 1 becoming higher than in country 2. The reason is that, by this time, capital has become a relatively abundant factor in country 1. Both wage rates rise sharply in both countries at about year 70 because those born during the shock drop out of the labour force at the age of 65 thus making the capital labour ratios higher; after the retirement of these cohorts, the wage rates gradually move back to their initial values.

Migration rates of both skill-type populations change following the track of the wage differentials, when τ is greater than 0. However, the bulk of the change in migration flows appears to be accounted for by the change in the age composition of the population, and is not induced by the wage differentials. Note that after year 70 the emigration rate in country 1 is lower than that in country 2 due to the age compositional effect as well as the relatively lower wage rates in country 2. Since wage rate differentials change rather smoothly after year 70, migration rates for both countries become relatively stable, and shift gradually back towards their initial levels.

Income per capita in country 2 falls steadily but by less than that in country 1 because of the lower increment in labour supply. In country 1, income per capita first falls by 5.7%, then increases by 1.3% in years 20 to 25 following the increment to the labour force. It then rises slowly up to years 50 to 55, after which it drops steadily until it reaches a trough in the 70th year. Subsequently, it rises steadily until a new stationary state is reached. The change in income per capita results from changes in the proportion of the population in the labour force and also from the wage-rate changes. Since labour force increases lead to decreases in productivity, wage-rate changes are opposite in direction to changes in the labour force.

Since the return to capital is one of the components of income, changes in it also lead to changes in per capita income. The rate of return to capital moves in a direction opposite to that of wage rate changes, with the amount of change depending on the change in the capital-labour ratios. However, as the new stationary state is approached, the return to capital as well as wage rates and per capita income move back toward their initial levels.

The capital stock, just like labour, increases relatively more in country 1, as a result of higher production, and hence income and saving. The increments to capital stocks in both countries start in year 25, when the production of investment goods is significantly affected by changes in the supply of effective labour. The increments are continuous until the populations in both countries reach their respective stationary states. At that time, the production of investment goods is just enough to cover the amount from depreciation.

The other two sets of experiments, using $\tau = 0$ and $\tau = 1$ respectively, have the same structural changes as those in the case with $\tau = .5$. But, as reported in figure 5.1, these two sets of results fall evenly on each side of the case with $\tau = .5$,without particular dispersion of the effects. Our finding, as shown in figure 5.1, is that not only migration rates are sensitive to elasticities of relative wage rates, but so also are the other variables, although the degree of senstivity for these other variables is not great. For instance, when $\tau = 0$, the change in migration rates is less, in comparison to the other two cases, and leads to larger disparities in all variables between countries some years after the initial shock. This means that the less sensitive the migration probabilities are to relative wage rates, the lower the growth rates of demographic and economic variables in country 1, and the less rapid the growth of these variables in country 2.

(B) A temporary change in migration propensities

We now consider a case in which, for a period of 5 years, migration propensities (m^*_{ijk}) double in country 1, then return to their initial values afterward, while those of country 2 remain constant. Three sets of experiments have also been considered, with the values of τ equal to 0, .5, and 1, respectively. The change disturbs the initial identity of the stationary state in the two countries, leading to a sudden decrease in the size of the population in country 1 with an offsetting increase in country 2. However, with the assumption of constant fertility and mortality rates, these changes in the size of population for both countries do not alter the total size of the population in the two countries.

The overall simulation results are shown in figure 5.2. The sudden reduction of country 1's population by 5.3%, and the corresponding increase in country 2's population by the same amount, is a result of the sudden increment in country 1's migration propensities. After period 1, population sizes of the countries moved steadily to their initial levels as a result of migration reversal. Population flows, of course, take place in response to differentials in relative wage rates between countries, and by the assumed value given to the elasticity parameters. In particular, the emigration rates in country 1 are lower in year 10 but increase gradually and, for some years, exceed the rates in country 2 as a result of the occurrence of lower relative wage rates in country 1.

Per capita income, on the other hand, responds to the population flows, with an indirect connection to factors of production and the returns to them. Higher per capita income and wages are observed in country 1, through increments in the relative shares per worker in production immediately after the shock is introduced. Also, there is a moderate reduction in per capita income and wage rates following the reduction of population and capital stock up to some levels which are even below those in country 2. The occurrence of lower W_S^* around year 30, and of lower W_U^* around year 50, is mainly because of the relative abundance of labour in production in country 1 as compared to country 2. On the other hand, the return to capital decreases in country 1 right after the shock because of the reduction in the total population which follows the decrease in the number of workers. But it increases afterward due to the decreases in the capital stock as the production of investment goods is insufficient to cover capital depreciation. Increasing net immigration in country 1, after year 5, leads to lower per capita income and wage rates and higher return to capital in country 1 as compared to country 2, up to about year 35, when there is a factor abundance reversal. The changes in these variables are not unbounded; in fact, their time paths eventually lead back to the initial values. The pattern of change are similar for country 2, though the changes are opposite in direction.

The migration parameters, τ's, not only affect the changes of population in both countries, but also all other variables. As shown in figure 5.2, the larger the τ's, the less is the effect of the shock on the differences in both the demographic and economic variables between countries.

Case (2): Only commodities are mobile internationally

In this case we consider the effects of a temporary increase in the total fertility rate (F) in country 1 without any corresponding change in country 2. There is no population movement between countries, so that the migration elasticity parameters (m*'s and τ's) are set at zero. As in the two foregoing cases, all parameters except the fertility rates are assigned the same values in both countries. Four different sets of experiments have been conducted, including a basic set (standard case) in which alternative values are assigned to ρ, the rate of time preference, and γ, the adjustment parameter in equation (25). The alteratives combinations are: $\rho = 0$, $\gamma = 0$, and $(\rho, \gamma) = (1, .1)$. These values imply particular patterns of individual school attendance behaviour for the ages 15 to 19, according to the changes in expected life time income due to wage-rate changes: $\rho = 0$ implies the least preference for present income; $\gamma = 0$ implies that there is no change in school enrollment rates in response to wage-rate changes; and $(\rho, \gamma) = (1, .1)$ indicates individuals have a strong preference for present income (5 years).

Consider first the effect of the given change in the fertility rate in country 1 on the population. As reported in figure 5.3, the population of country 2 remains constant due to the international immobility of population, whereas country 1 has an increasing population thoughout the entire period. The direction of population increase in country 1 is similar to our previous case (1A) where migration is allowed, but the increases are greater -- 18.1% by year 70 in the standard case compared to a 9.8 % increase in the $\tau = .5$ case. In country 1, there is an initial increase of 6.5% right after the shock, and then a second increase some 20 years later due to an increase in the number of women of child-bearing age. The population then follows a moderately cyclical path leading eventually to a stationary state where the population is 18.7% higher than the initial level.

The changes in the skilled and unskilled labour force occur mainly in country 1 when the population in the youngest cohort reach the working ages (at ages 20 and 15, respectively). This is followed by two other peaks in years 55 and 85 which arise as a result of the occurrence of higher population reproduction around years 30 and 60. The levels of these changes are affected by the different levels of school enrollment rates. With the standard set of parameters, the country 1 labour force increases by 19.9% and 18.9% by year 55, for skilled and unskilled labour, respectively, compared to increases of 20.6% and 18.2% with $\rho = 0$; 20.7% amd 18.4% with $(\rho, \gamma) = (1, .1)$; and 19.3% and 19.4% with $\gamma = 0$. The labour force in country 2 does not change significantly. For example, in year 75, there is only a .8% decrease in the supply of skilled labour and a .7% increase in the supply of unskilled labour with the standard set of parameters. The corresponding changes are 1.9% and 1.6%, respectively, when $\rho = 0$, and 1.5% and 1.0%, respectively, when $(\rho, \gamma) = (1, .1)$.

The school enrollment rates change over time in response to the changes in the wage rates. The wage rates, on the other hand, are also sensitive to the parameters in the school enrollment functions. In country 1, wage rates stay below their initial level, reaching their lowest levels between years 50 and 60 when the supply of effective workers is at the highest level; however, there is a change in the trend in year 70 when the second generation ceases to be part of the labour force. The observed changes in the wage rates in country 2 are particularly interesting. Wage-rates for skilled labour decline more markedly than in country 1. A closer examination of this result reveals that it occurred mainly because of the shape of the production functions. Holding the supply of skilled and unskilled labour constant, as in the case with $\gamma = 0$, the production of consumption goods increases because of its lower cost (=price) advantage in trade and this will depress the return to the factor which is less intensive in the production of consumption goods.[5] The intensiveness of a factor in production can be determined by comparing its relative share in both lines of production. This, in the case of a Cobb-Douglas function, can be inferred from the production elasticities of the corresponding factors.[6] In our case, skilled labour is less intensive in consumption goods, and capital is less intensive in investment goods, whereas unskilled labour is of the same intensity in both industries. This explains why we have lower W^*_s and an almost unchanged W^*_U in country 2. In year 65, W^*_S is 4.2% to 4.3% below its initial value in these cases.

Capital stocks increase in both countries after year 25 as a result of increases in employment, income, and trade. However, the return to capital increases in a manner opposite to the change in W^*_S , as discussed above.

Population increases in country 1 lead to a reduction in the per capita income of that country, but there is only a slight change in country 2. In all cases, per capita income is not very sensitive to the change in educational parameters.

The consequences for international trade are also of interest. The direction of trade is determined by the unequal distribution of factors in both countries and in the two types of production. Assuming identical production technology in both nations, a country exports that good which is relatively more intensive in the factor which is relatively more abundant in that country.[7] With identical production functions, the relative factor intensity of production is the same in both countries. In our case, we cannot determine the intensiveness of unskilled labour in production since its parameters (α_3 and β_3) are the same in both industries, and this explains the absence of trade up to year 20, when country 1 becomes more abundant in unskilled labour. The increase in the supply of skilled labour to country 1 leads to an increase in the export of investment goods, which are skilled-labour intensive, after year 20. Increases in the amount of trade are determined by the increases in the number of skilled workers in country 1, but the effects are reduced by the increasing stock of capital, which is used intensively in the consumption goods industry. In years 60 to 65, country 1 is exporting around 4,000 units of investment goods and importing 6,700 units of consumption goods in the standard case, but exporting around 4,800 units of investment goods and importing 7,700 units of consumption goods in the case with $\rho = 0$; 3,800 units and 5,900 units respectively in the case with $\gamma = 0$; and 4,400 units and 7,200 units in the case with $(\rho, \gamma) = (1, .1)$. After this period, the volume of trade displays an increasingly damped cyclical pattern as country 1's advantage though the relative abundance of skilled labour vanishes.

Case (3): Both goods and population are internationally mobile

The results for the set of experiments in this case are reported in figure 5.4. These experiments combine the foregoing two cases by allowing both population and commodities to move internationally. Initially, both countries are in stationary equilibrium so that there exists no international trade and net immigration is zero. A temporary increase in the total fertility rate (F) in country 1 disturbs this initial state, leading to a sudden increase in population in country 1. As a result of this change, demographic and economic variables in both countries are changed gradually until the next equilibrium state is reached.

As in case (1A), we consider three different values of τ. The results, shown in figure 5.4, indicate that the major variables are sensitive to the changes in the τ, as in case (1A) above. Even though the allowance for trade alters the magnitude of the changes, first through production and then through wage-rate changes (which in turn affect the migration propensities), the effects are not of much significance, leaving essentially the same path of population growth as in case (1A).

The interpretation of the effects on changes in wage rates is similar to that in case (1A) even though the levels of the changes are somewhat different. With commodity trade allowed in this case, the percentage change in W_S^* in country 2 turns out to be larger than that in case (1A) but W_U^* is not significantly different from the case with $\tau = .5$.

Total capital increases at the same rate as in case (1A). However, the return to capital, as compared to that in case (1A), was consistently lower in country 1 and higher in country 2. In year 55, for all three values of τ, the capital return is above its initial value by about 2.5% in country 1 and by about 2.2% in country 2.

The magnitude of commodity trade is much smaller, as compared with case (2), and the direction of trade is somewhat different. The magnitude first reaches a peak at years 25 to 30, then declines gradually up to years 60 to 65. After this, there results a trade reversal. The direction of trade can be predicted from a comparison of endowments at any point in time. Each nation exports the commodity which uses the abundant factor more intensively. The exports of investment goods in country 1 between years 20 and 65 is explained by the abundance of skilled labour, which is intensive in Q_I production. After year 65, skilled labour of the second generation drops out of the labour force, leading to a scarcity of skilled labour, as compared with capital, and resulting in the export of consumption goods instead. When migration is allowed, the magnitude of commodity trade is reduced because the supply of skilled labour in country 1 is lower due to migration. With $\tau = 1$, only 1,280 units of consumption goods and 780 units of investment goods are traded in year 30; with $\tau = .5$, the respective figures are only 1,220 and 740 units; and with $\tau = 0$, only 1,160 and 710 units are traded. This is because, with the higher value of τ, the L_S emigration from country 1 is higher, and at the same time, the capital formation in country 1 is lower, leading to a larger volume of trade through the relative abundance of skilled labour. It indicates that migration has a moderating effect on both demographic and economic disparity between countries; the higher is the migration rate, the sooner is international equalization achieved.

5.4 Production Functions and the Direction of Trade

According to the Heckscher-Ohlin (H-O) theorem, the direction of trade is determined by the inequality of relative factor endowments among countries. In the case of two commodities, the exported commodity is that in which the country's abundant factor is used relatively intensively. The purpose of this section is to test the predictive accuracy of this theory regarding the direction of trade in the case of three factors of production and two commodities. These results will be compared to the familiar 2-input, 2-output model.

As noted in 4.2, the concepts of factor abundance and factor intensity of a commodity are definitionally ambiguous if there are more than two factors of production. Therefore, in the case relevant here where only two goods are involved, the definition of factor abundance of a country, or the factor intensity of a commodity breaks down when a third factor is introduced.[8] For the illustrations of the H-O theorem, an application of the concepts developed by Vanek (1968) and Williams (1970, 1977) regarding the factor abundance of a country and the factor intensity of a commodity can be adopted. According to these concepts, the direction of trade is determined by the ranking of domestic relative to foreign factor endowments:

$$\frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \ldots \geqq \frac{X_j}{x_j} \geqq \ldots \geqq \frac{X_n}{x_n}$$

in which the country will be a net exporter, through commodity trade, of the services of the factors $X_1, X_2, \ldots, X_j$ and will be a net importer of the services of $X_{j+1}, \ldots, X_n$ ($j \neq n$). Alternatively, this concept states that the country is relatively abundant in factors X_1 to X_j and should therefore be a net exporter of commodities which are intensive in these factors. The theorem, as stated, however, requires factor-price equalization as a necessary condition.[9] Without the assumption of perfect international mobility of factors, this condition would not necessarily hold in the case of more factors than goods.[10] However, it will be demonstrated in a simulation experiment that, with additional qualifications, the H-O theorem may hold without factor-price equalization. Therefore, the Vanek theorem is ambiguous unless additional assumptions (discussed below) about the resource-content of commodities are introduced.

Since it is assumed that commodity prices (not factor prices) are equalized in the two nations, we can define the 'intensity' of the jth factor in product Q_1 in a 2-commodity case (Q_1 and Q_2, for example) if the physical amount of jth factor used per unit value of Q_1 exceeds its physical amount used per unit value of Q_2.[11] In other words, the commodity Q_1 is said to be intensive in the use of the jth factor if and only if:

$$(5.1) \qquad a_{j1} > a_{j2}$$

where $a_{ji} = X_{ji}/Q_i.P_i$ is the physical amount of X_j used per dollar value of Q_i. Now we define $e_j^k > 0$ as the net export, through commodities, of the factor j in country k. If $e_j^k < 0$, it is the factor services required to produce imports using the technology of country k. This is equal to the difference between the gross exports (E_j^k), through commodities, and the gross imports (M_j^k), through commodities, of factor j; that is,

$$(5.2) \qquad e_j^k = E_j^k - M_j^k \qquad (j=1,2,3;\ k=\text{country } 1 \ \& \ 2)$$

Without any trade barriers, the values of commodity exports (V_E) and commodity imports (V_M) are the same.

$$(5.3) \qquad V_E = V_M$$

which makes the net export, through commodities, of factor j according to the value of commodity exports equal to:

$$(5.4) \qquad \frac{e_j^k}{V_E^k} = \frac{E_j^k}{V_E^k} - \frac{M_j^k}{V_M^k}$$

Assuming the absence of intermediate production, and since only one commodity is being exported in our 2-commodity case, the contents of factor j in the commodity exports and imports are the same as their contents in production in the corresponding industry; that is:

$$(5.5) \qquad \frac{E_j^k}{V_E^k} = a_{jz}^k \qquad \text{(z=exporting industry)}$$

$$\frac{M_j^k}{V_M^k} = a_{jm}^k \qquad \text{(m=importing industry)}$$

Substituting (5.5) into (5.4), we obtain:

$$(5.6) \qquad \frac{e_j^k}{V_E^k} = a_{jz}^k - a_{jm}^k$$

$$\frac{e_j^k}{V_E^k} \gtreqless 0 \text{ if and only if } a_{jz}^k \gtreqless a_{jm}^k$$

That is to say, there is a net export of factor j from country k if factor j is intensive in the exporting industry. Condition (5.6) is sufficient, but the ranking of the factor endowments between the two countries is not sufficient to tell the direction of factor exports. The linkage of the commodity trade to the relative factor abundance and factor intensities is even more difficult.

The relationship between commodity trade and relative factor abundances has not net been established in the literature for the case of more factors of production than commodities. The difficulty arises because the proof of the H-O theorem has been based on factor-price equalization. And without this assumption, it is difficult to provide a unique linkage of commodity exports to the rankings of relative abundances and relative factor intensities. In order to illustrate the H-O theorem in the 3-factor, 2-commodity case, we specify a set of simple hypothetical assumptions concerning the relationships among commodity trade, factor abundance, and factor intensity.

We hypothesize that each nation will export the commodity most intensive in its most abundant resources. That is to say, if factor X_1 is the most abundant factor in country 1 and is relatively intensive in the production of commodity Q_1, there is an export of Q_1 (EQ_1). That is:

$$(5.7) \qquad \text{if } \frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3}, \text{ and if } a_{11} \geqq a_{12}$$

$$\text{then } EQ_1 \geqq 0 \text{ and } EQ_2 \leqq 0$$

where EQ_i $(i = 1, 2)$ is the export of commodity Q_i and a_{1i} $(i = 1, 2)$ is the physical content of X_1 used per dollar value of Q_i. If the result of (5.7) does hold, and with (5.6), we have:

(5.8) $$\text{if } \frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3} \text{ and } a_{11} \geqq a_{12}, \text{ then}$$

$$EQ_1 \geqq 0,\ EQ_2 \leqq 0, \text{ and therefore } e_1 \geqq 0$$

where e_1 is the net export of factor services X_1. If X_1 is the most abundant factor and it determines the direction of trade, then, under the same condition of (5.6), the signs of e_2 and e_3, the net exports of factor services of X_2 and X_3, respectively, can be determined according to whether $a_{21} \gtreqless a_{22}$ and $a_{31} \gtreqless a_{32}$. But if $a_{11} = a_{12}$, then X_2 becomes the determinent of the direction of trade, if it is abundant, $\frac{X_2}{x_2} \geqq \frac{X_3}{x_3}$, and if it is intensive either in production of Q_1 or Q_2, $a_{21} \gtrless a_{22}$. That is:

(5.9) $$\text{if } \frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3} \text{ and } a_{11} = a_{12}, \text{ then}$$

$$EQ_1 \geqq 0 \text{ and } EQ_2 \leqq 0 \text{ if and only if } a_{21} > a_{22}$$

$$\text{and hence } e_1 = 0,\ e_2 \geqq 0, \text{ and } e_3 \leqq 0$$

The sign of $e_3 \leqq 0$ in (5.9) because, with net exports of resource 1, $e_1 = 0$, and resource 2, $e_2 \geqq 0$, we must have net import of resource 3, $e_3 \leqq 0$. Ruling out the case of an equality, a_{31} must be less than a_{32}, $a_{31} < a_{32}$. Therefore, it follows that a commodity must be least intensive in one resource.

There are three possible senses in the relationship between intensiveness of the two commodities, >, <, or =. The three factors, therefore, provide (3^3) or twenty-seven possible combinations to determine the direction of trade. With the assumption that a commodity must be most intensive in one factor and least intensive in another, we can rule out fifteen possible combinations, i.e., where only one inequality exists, or where one equality and two inequalities with the same sign exist, or all three inequalities with the same sign exist. This leaves twelve possibilities to be investigated. Among ten of the twelve possibilities, (5.8) or (5.9) can be applied directly to determine trade. In the case of other two, the H-O theorem must be modified in order to accommodate them. These two possibilities are (1) $a_{11} > a_{12}$, $a_{21} < a_{22}$, and $a_{31} > a_{32}$, and (2) $a_{11} < a_{12}$, $a_{21} > a_{22}$, and $a_{31} < a_{32}$. In both (1) and (2), the abundant (X_1) and scarce (X_3) factors are intensive in the production of the same commodity. According to the H-O theorem, a country will export the commodity which is intensive in the abundant factor and will import the commodity which is intensive in the scarce factor. Cases (1) and (2) above illustrate a contradiction which is ruled out in the case of the H-O theorem on the assumption that there are more factors than commodities. In these two cases, trade can be explained if we define strong factor abundance as below.

Suppose we have the case which the resource endowments is ranked, $\frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3}$. Strong abundance can be defined by comparing the rank-ordering of the factor-ratios as follows:

$$\text{if} \quad \left|\frac{X_1}{x_1} - \frac{X_2}{x_2}\right| > \left|\frac{X_2}{x_2} - \frac{X_3}{x_3}\right|$$

then X_1 is strongly abundant. If the sign of the inequality is reversed, we refer to X_1 as weakly abundant. Where the abundant factor is strongly so it is assumed to determine trade. If it is weakly so, then the scarce factor is assumed to determine trade. This can be formalized as follows:

(5.10) if $\frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3}$, $a_{11} > a_{12}$, $a_{21} < a_{22}$, and $a_{31} > a_{32}$

and

(a) $\left|\frac{X_1}{x_1} - \frac{X_2}{x_2}\right| > \left|\frac{X_2}{x_2} - \frac{X_3}{x_3}\right|$, then

$EQ_1 \geqq 0$ and $EQ_2 \leqq 0$, and hence $e_1 \geqq 0$, $e_2 \leqq 0$, and $e_3 \geqq 0$

(b) $\left|\frac{X_1}{x_1} - \frac{X_2}{x_2}\right| < \left|\frac{X_2}{x_2} - \frac{X_3}{x_3}\right|$, then

$EQ_1 \leqq 0$ and $EQ_2 \geqq 0$, and hence $e_1 \leqq 0$, $e_2 \geqq 0$ and $e_3 \leqq 0$

(5.10a) assumes that X_1 is a strongly abundant factor in country 1, whereas (5.10b) assumes that X_1 is a weakly abundant factor. The former tells that factor X_1 determines the flow of trade and the latter tells that X_3 determines the direction of trade flows. (5.10) illustrates an outcome ruled out by the assumption of the H-O theorem. It shows that in some cases, where there are more factors than goods, the direction of trade is still be predictable.

The above hypotheses can also be applied to the usual 2-input, 2-output model. Suppose, as above, a_{ji} (j = 1, 2; i = 1, 2) is the physical amount of X_j used per dollar value of Q_i, EQ_i is the export of commodity Q_i, and e_j is the export of factor service X_j. Following the results of (5.6) and (5.7), we hypothesize the direction of trade in a 2-input, 2-output model as below:

(5.11) if $\frac{X_1}{x_1} \geqq \frac{X_2}{x_2}$, $a_{11} > a_{12}$, and $a_{21} < a_{22}$, then

$EQ_1 \geqq 0$ and $EQ_2 \leqq 0$, and hence $e_1 \geqq 0$ and $e_2 \leqq 0$

(5.11) is, therefore, the conventional statement of the H-O theorem and Vanek theorem.

The results are summarized in the table 5.3 where seven possibilities are presented. The other seven possibilities are also covered in the table, since the inequalities of columns 1 to 3 are reversed.

Table 5.3: Factor Abundance, Factor Contents of Production and the Direction of Trade

Cases	Factor Contents of per Dollar Value of Output: X_1 (a_{11} a_{12})	X_2 (a_{21} a_{22})	X_3 (a_{31} a_{32})	Export (+) Imports (-), Commodities: Q_1 (EQ_1)	Q_2 (EQ_2)	Net Factor Services: X_1 (e_1)	X_2 (e_2)	X_3 (e_3)
(I) In a 3-input, 2-output model and with $\frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3}$, the following cases will hold for domestic (country 1):								
(1)	>	>	<	+	-	+	+	-
(2)	>	=	<	+	-	+	0	-
(3)	>	<	<	+	-	+	-	-
(4)	>	<	=	+	-	+	-	0
(5)	=	>	<	+	-	0	+	-
(6a) $\left\lvert\frac{X_1}{x_1} - \frac{X_2}{x_2}\right\rvert > \left\lvert\frac{X_2}{x_2} - \frac{X_3}{x_3}\right\rvert$	>	<	>	+	-	+	-	+
(6b) $\left\lvert\frac{X_1}{x_1} - \frac{X_2}{x_2}\right\rvert < \left\lvert\frac{X_2}{x_2} - \frac{X_3}{x_3}\right\rvert$	>	<	>	-	+	-	+	-
(II) In a 2-input, 2-output model and with $\frac{X_1}{x_1} \geqq \frac{X_2}{x_2}$, we have, for country 1:								
(7)	>	<		+	-	+	-	

In table 5.3, $\frac{X_1}{x_1} \geqq \frac{X_2}{x_2} \geqq \frac{X_3}{x_3}$ indicates that X_1 is the most abundant factor in country 1; $a_{j1} \geqq a_{j2}$ is the relative factor intensity comparison in production; and sign '+' and '-' show that whether it is an export (+) or import (-) of commodities or not factor services. Writing across the first line, we find case (1) subscribes that commodity Q_1 is relatively intensive in the most abundant factor X_1 ($a_{11} > a_{12}$), there is an export of commodity Q_1 ($EQ_1 \geqq 0$) and an import of commodity Q_2 ($EQ_2 \leqq 0$), With equation (5.6) and factor content conditions, there is a net export of factor services of X_1($e_1 \geqq 0$) and of X_2 ($e_2 \geqq 0$), but a net import of factor services of X_3 ($e_3 \leqq 0$).

The empirical results of tests of the above hypothesis are reported in table 5.5. Since the sign of the net export of factor services can be easily derived by equation (5.6), we report here only the amount of trade flows. The results of table 5.5 are based upon the values of parameters of the production function as in table 5.4. All other parameter values remain the same in the simulation.

In table 5.4, cases A, B, C, and D are set to generate the different factor-intensity assumptions and case E and F refer to the 2x2 case. In case E and F, we assume skilled and unskilled labour are aggregated into a single factor, that is, all labour employed in production is unskilled. At the same time, in our model, we assume school enrollment rates are zero, so that a person becomes a worker at the age of 15. In order to prove our hypothesis in a dynamic way, we assume only commodities are mobile internationally and a temporary increase in fertility rates in country 1 breaks the initial

Table 5.4: Assumptions of Production Parameters

Cases		Consumption Goods			Investment Goods		
		α_1	α_2	α_3	β_1	β_2	β_3
(I)	3-input, 2-output cases:						
A	E_U^* equally intensive in two commodities	.6	.2	.2	.4	.4	.2
B	K equally intensive in two commodities	.5	.3	.2	.5	.4	.1
C	E_S^* and E_U^* both intensive in Q_C	.35	.35	.3	.65	.2	.15
D	K intensive in Q_C	.5	.1	.4	.4	.3	.3
(II)	2-input, 2-output cases:						
E	E_U^* intensive in Q_C	.35		.65	.65		.35
F	K intensive in Q_C	.6		.4	.4		.6

stationary state equilibrium in both countries.

In case A, where E_U^* is equally intensive in both commodities, as shown in table 5.5, unequal distribution of factor endowments between the two countries starts at year 15, but international trade exists only after year 20. For instance, at year 20, the supply of unskilled effective workers in country 1 is higher and the ratios of other factors of production for both countries are the same, but no commodity trade exists between countries. This phenomenon is exactly examplified by case (5) of the table 5.3 above. That is to say, international trade may not exist by this definition of factor-abundance if both industries have the same level of intensity of the abundant factor. After year 20, country 1 becomes more abundant in both skilled and unskilled labour; it exports investment goods which are intensive in skilled labour and this result is consistent with our case (2) of the hypothesis. On the other hand, the amount of trade is determined by the level of factor-intensity and factor-abundance. The largest amount of trade exists at years 55 to 65 when the difference between the ratio of skilled labour and the ratio of capital stock between countries is highest, and there is a slowdown after year 65 as the difference between ratios becomes smaller.

Case B, where K is equally intensive in both commodities, of table 5.5 refers to case (4) of the hypothesis regarding the equality of the intensity of the scarce factor in the production of both goods. Unlike case A above, international trade appears right after year 15, when country 1 becomes abundant in unskilled labour. Country 1 exports consumption goods which is intensive in unskilled labour, but the volume of trade is not very large as compared to all other cases because the initial abundance of unskilled labour is being crowded out by the increasing supply of skilled labour. Alternatively, if we look at country 2 which is always capital abundant relative to country 1, there is no net export of capital services because capital does not determine trade-flows, as specified in our hypothesis.

The results of case C, the E^*_S and E^*_U both intensive in Q_C case, in table 5.5, are trivial as mentioned in case (1) of the table 5.3 above, since consumption goods are intensive in both labour-skills. The intensity of both factors in Q_C leads country 1 to export consumption goods whenever the ratio of effective workers in country 1 is higher than that of capital in country 2.

Case D in table 5.5 provides some interesting results concerning case (6) of the hypothesis. In case D, Q_C is relatively intensive in both E_U^* and K and Q_I is relatively intensive in E_S^* only. In year 20, country 1 is strongly abundant in E_U^*, leading it to export Q_C. After year 20, country 1 suffers strong capital scarcity as compared to country 2 even though E_U^* is abundant in country 1; this leads to an export of Q_I. The pattern of trade after year 50 is essentially the same as in case (3) of the hypothesis since skilled labour is again abundant in country 1.

The 2x2 case, as examplified by cases E and F of table 5.5, exactly depict the Vanek approach to the H-O theorem. In both cases, a_{ji}'s have the same values in both countries, leading to the existence of factor-price equalization. In case E, country 1 becomes labour abundant after year 15 and thus exports Q_C which is relatively labour intensive. In case F, the abundance of E_U^* in country 1 leads to an import of Q_C because it is relatively capital-intensive.

In general, table 5.5 shows the Vanek approach to H-O theorem to be correct in most of the cases. However, an assumption of strong or weak abundance of a factor is needed if a commodity is simultaneously intensive in both the abundant and the scarce factors. On the other hand, the volume of trade in cases E and F are approximately double those observed in cases A and C, which indicates that the traditional 2x2 case is somewhat different from our 3x2 case.

5.5 Simulation Results Referring to Various Production Functions

In this section, we present the results of the simulation experiments using the various assumptions about the values of production parameters. Accompanying this presentation is a comparison of the sensitivities of demographic and economic variables to production parameters when we assume that there are only 2 factors of production. Basically we assume the same parameter values for production functions as in section 5.4 above but pay more attention to the intensiveness of capital in each case. Five cases are employed in the test.

Table 5.6: Assumption of Production Parameters

Cases	Consumption Goods			Investment Goods		
	α_1	α_2	α_3	β_1	β_2	β_3
(I) 3-input, 2-output cases:						
A K intensive in Q_C	.6	.2	.2	.4	.4	.2
B K equally intensive in two commodities	.5	.3	.2	.5	.4	.1
C K intensive in Q_I	.35	.35	.3	.65	.2	.15
(II) 2-input, 2-output cases:						
D K intensive in Q_I	.35		.65	.65		.35
E K intensive in Q_C	.6		.4	.4		.6

As reported in table 5.6, case A refers to the case of capital intensity in Q_C, case B assumes equal capital intensity in both Q_C and Q_I, whilst case C assumes capital intensity only in Q_I. In the 2x2 case, we assume no skilled labour exists in either economy therefore the production functions become:

$$Q_C = \alpha_0 K_C^{\alpha_1} E_{UC}^{\alpha_3} \qquad \text{where } \alpha_3 = (1 - \alpha_1)$$

$$Q_I = \beta_o K_I^{\beta_1} E_{UI}^{\beta_3} \qquad \text{where } \beta_3 = (1 -\beta_1)$$

Here we want to compare cases (A) and (E) of table 5.6 on the one hand with cases (C) and (D) on the other, where labour is split into two categories (skilled and unskilled) in former and are considered to be single factor (unskilled labour) in the latter.

Repeating the same situation as in case (2) of section 5.3, we assume no migration exists between the two nations.[13] An exogenous shock of a temporary increase in the total fertility rate (F) in country 1 breaks the initial stationary state equilibruim situation in both economies. In general, the after-shock behaviour of all the relevant variables are the same as in case (2), no labour migration case, of section 5.3, but the levels of the changes vary according to different production functions. The changes of population and per capita incomes are similar to case (2) above, and so, the results will not be shown here. We restrict the exposition to a general description of the outcome.

Consider first the changes of income (Y) and the consumption (C) in both countries after the shock. Since consumption is defined as a fixed proportion to the total income, the percentage change in C is the same as the percentage change in Y. In figure 5.5, Y and C increase after the year 15 as the number of effective workers starts to rise after year 15. Income and consumption reach the peak in years 55 to 65 when the numbers of effective workers are highest, and are reduced in year 70 because of the effect of the retirement of the generation of workers. A further increase in Y and C after year 70 arises because of the increasing influx of younger age groups into the labour force. On the other hand, the changes of Y and C vary according to different production functions. At year 65, with cases C (K intensive in Q_I of 3x2 case) and D (K intensive in Q_I of 2x2 case), they are 15.9% above their initial levels; with case B (K equally intensive in both goods case), they are 14.6% above; and with case A (K intensive in Q_C of 3x2 case) and E (K intensive in Q_C of 2x2 case), they are 10% above. The changes of Y and C in country 2 are not significant due to the fact that population in country 2 is fixed throughout the entire period; their changes are mainly affected by trade. However, changes in cases C (K intensive in Q_I of 3x2 case) and D (K intensive in Q_I of 2x2 case) are slightly noticeable: .2% above their initial levels between years 25 and 40 then .4% below their initial levels afterward; changes in cases A (K intensive in Q_C of 3x2 case) and E (K intensive in Q_C of 2x2 case) are slightly less and in the opposite direction to C (K intensive in Q_I of 3x2 case) and D (K intensive in Q_I of 2x2 case). On the other hand, the changes in Y and C are slightly larger in cases D and E, the 2-input, 2-output case, then those in cases C and A, the 3-input, 2-output case, in both countries, showing that there is greater sensitivity here than in the 2x2 case.

The changes of outputs, Q_C and Q_I, due to the change in total fertility rate (F) in country 1, result from two effects, namely, the price effect and the input effect. Changes in the price ratio lead to changes in the level of production along the transformation curve mainly because of the changes in the international demand conditions, whereas changes in input-supply alter the production levels according to the Rybczynski theorem. The latter situation applies to country 1 alone but the former applies to the changes in both countries. When the supply of effective labour increases in country 1 15 years after the initial shock, the output of Q_C increases while that of Q_I decreased in cases B (unskilled labour intensive in Q_C), C (both labour intensive in Q_C), and D (labour intensive in Q_C of 2x2 case), but the reverse situation results in cases A (K intensive in Q_C) and E (K intensive in Q_C of 2x2 case). These results are essentially in accordance with the Rybczynski theorem which states that an increase in the endowment of a factor will cause a decrease in the production of the commodity which uses that factor less intensively. The changes in the outputs of Q_C and Q_I in country 1 for the rest of the period are the consequence of both the price and input effects. As shown in figure 5.5, E_S and E_U in country 2 do not change much after the shock. The changes in the outputs of Q_C and Q_I in country 2 result mainly from the changes in the price ratio which can be seen in table 5.5. The direction of the change in the outputs of country 2 is opposite to that of country 1. The changes in Q_I are significantly high in cases A and E, where K is intensive in Q_C -- about 40% to 50% change at the peaks in both countries -- whereas the changes in Q_C are lower in cases C and D, where K is intensive in Q_I -- only 15% to 20% change.

Imports and exports of Q_C and Q_I are determined by the levels of production vis-a-vis consumption in the two countries. The direction of trade had been discussed in section 5.4 above. Figure 5.5 shows that the amount of trade is doubled whenever the 2x2 case, case D or E, is employed.

The results show that E_S and E_U are not particularly sensitive to production parameters, although TK is. TK in country 1 increases 25 years after the shock, with a larger change in cases A and E, where K is intensive in Q_C. In country 2, an increased TK appears only in cases A and E, a decreased TK in cases C and D, where K is intensive in Q_I, and an unchanged TK in case B, where K is equally intensive in both goods. The first two cases result mainly from the price effect on trade through the effect of price changes on the demand for Q_I for investment (equation 53 in Ch. 4). The insignificant amount of trade in case B, where the capital is equally intensity in both Q_C and Q_I, lead TK in country 2 to remain unchanged.

Wage rates and the return to capital are determined by both marginal physical products of the factors and commodity prices. Wage rates in country 1 are depressed by the increased supply of effective labour whereas the return to capital increased due to the relatively smaller increase in TK. However, the changes of price ratio as a result of trade lead to changes in the levels of production and this in turn changes the wage rates and the return to capital in country 2. The system found to be sensitive to the choice of production parameters, especially in case B (K equally intensive in both goods case), where W_S^*, W_U^*, and R in country 1 are highly affected -- about 5% to 6% below or above their original levels 55 to 65 years after the shock. Case A, where E_U^* is equally intensive in the two commodities, shows a great response in terms of the change in W^*_S in country 2 but very little change in its W^*_U and R. Case C, where K is intensive in Q_I, concerns the changes in both countries. Note that cases D and E, the 2x2 cases, make the changes in two countries the same -- representing the situation of factor price equalization in the 2x2 case. The changes of W^*_U and R with cases D and E are slightly smaller than with C and A, the 3x2 cases, in country 1 although still higher than that in country 2.

Finally, from the overall simulation results in figure 5.5, it is shown that production functions with various factor-intensities have different effects on all variables when shocks are introduced. The changes in the levels of variables depends on the assumptions of the demographic-economic situations. We find that the 2-factor case produces larger effects, as measured by the size of changes, than does the 3-factor case. This phenomenon shows that there is a significant difference between the 2x2 and 3x2 cases in terms of their economic implications.

5.6 Concluding Remarks

In this chapter, we have investigated the impact of population change on both demographic and economic variables in the international system. The experiments serve to demonstrate the feedback effects of the changes in wage rates on population movements and on school enrollments, and their implications for the distribution of labour types which could be of importance in solving the problems of international inequalities. They also demonstrate that international trade significantly moderates international inequalities, including inequalities in income distribution. The latter case illustrates how gaps in wage differentials between countries are altered and become smaller with trade, and how this will eventually leads to a lower flow of labour between nations.

The results reported in this chapter show that the impact of fertility changes on output and economic variables occurs with a lag of roughly two decades. However, the impact of migration is immediate.

The changes in the level of international trade due to the changes of population are also interesting. The volume of trade is determined by both the differences in the abundance of factors between countries and the differences in the commodity-intensity of factors of production between industries. The results show that the Vanek approach to the H-O theorem is correct only under the proviso of strong abundance of a particular factor. It is possible that trade may not exist if there is no indication of factor intensity of commodities.

Production functions also play an important role in determining the changes of economic variables. A different intensity of factors in production alters not only the direction of trade but also the levels of production and income distribution. In particular, 2-input production functions have a large impact on the changes in these variables.

Overall, the experiments in this chapter suggest that a consideration of the interaction between demographic and economic variables within a particular country, and also among countries, is necessary for proper general equilibrium analysis. This suggestion applies not only to a developed country with specific migration or economic policies, but to a developing country which requires both demographic and economic policies for its economic development. The basic assumptions about educational and migration behaviour in our model are rather simple, applying only to the 2-country case. However, we foresee no major difficulties in extending this model to the general multi-country case.

FOOTNOTES TO CHAPTER 5

1. As we noted in Chapter 4, factor price equalization only exists in the 2-input and 2-output case. The existence of factor-price inequality between 2 nations in the case where there are more than 2 inputs is due mainly to the complications introduced by factor-substitution and differences in factor-endowments between nations.
2. For instance, if the single year mortality rate for ages 10-14 is d_3, the 5 year mortality rate for the same age interval is then equal to $\left(1 - (1 - d_3)^5\right)$.
3. Statistics Canada (1972), Technical Report on Population Projection for Canada and the Provinces, 1972-2001, Cat. #91-516.
4. Statistics Canada (1971), Income and Individual, Cat. #94-760. See Section 4.4 above for the details about the calculation of weights.
5. That is exactly the Stolper-Samuelson Theorem which applies not only in the 2-input case but also in our 3-input case. A similar case can be seen in figure 4.3 in Chapter 4 where the price ratio is lowered from p_1 to p_2 by trade which directs the production of goods from A to B, and at the same time redistributes inputs for production along contract curves. As in (b) of figure 4.2, this change moves the distribution of L_S and L_U from A' to B' such that it makes the relative return to L_S lower, since L_S is less intensive in Q_C production. A more detailed example of this case will be seen in section 5.4 and 5.5 below.

6. See footnote 5 of Ch. 3 and footnote 5 of Ch. 4 above.

7. Although Heckscher-Ohlin Theorem is more concerned with the case of 2-inputs and 2-outputs, it will be noted in section 5.4 that this theorem can also apply to out 3-input and 2-output case with some additional restrictions.

8. This possibility was discussed earlier in section 4.2 of Chapter 4 above.

9. See Vanek (1968) and Williams (1970, 1977) on their assumptions:

10. Since, in our 3-input, 2-output case, we have

$$\begin{bmatrix} P_1^1 \\ P_2^1 \end{bmatrix} = \begin{bmatrix} a_{11}^1 & a_{21}^1 & a_{31}^1 \\ a_{12}^1 & a_{22}^1 & a_{32}^1 \end{bmatrix} \begin{bmatrix} w_1^1 \\ w_2^1 \\ w_3^1 \end{bmatrix} = \begin{bmatrix} a_{11}^2 & a_{21}^2 & a_{31}^2 \\ a_{12}^2 & a_{22}^2 & a_{32}^2 \end{bmatrix} \begin{bmatrix} w_1^2 \\ w_2^2 \\ w_3^2 \end{bmatrix} = \begin{bmatrix} P_1^2 \\ P_2^2 \end{bmatrix}$$

where p_i^k is the price of commodity i (i=1,2) in country k (k=1,2), w_j^k is the wage of input j (j=1,2,3) in country k, and a_{ji}^k is the requirement of input j to produce one unit of commodity i in country k. under the assumptions of full employment and inequality of factor endowments between the two countries, there is no longer any need to have the same input-output ratios or wages between countries. For mathematical illustration, see Batra and Casas (1976).

11. One may define factor intensity in terms of the absolute amount of any resource used in the per unit output of a commodity (Williams, 1970 and 1977; Hillam & Bullard, 1978) or in terms of the distributive share of that factor in the production of commodity (Batra and Casas, 1976). However, a lack of numeraire for comparison in the former and the appearance of unchanged parameter (by Euler's theorem) in the latter makes this difficult to explain within the context of our neoclassical model.

12. See Warne (1973, p. 301 and 305) and Batra and Casas (1976, p. 26) for definitions.

13. Due to the existence of factor price equalization in the 2-input, 2-output case (see section 3.3 of chapter 3 and section 5.4 of this chapter), there is no economic incentive to migrate at any time. Therefore, we can not fully conduct the migration analysis in this section.

Figure 5.1: Case 1(A): Experiments Relating to a Temporary Increase in the Level of Fertility under the Assumption of International Commodity Immobility

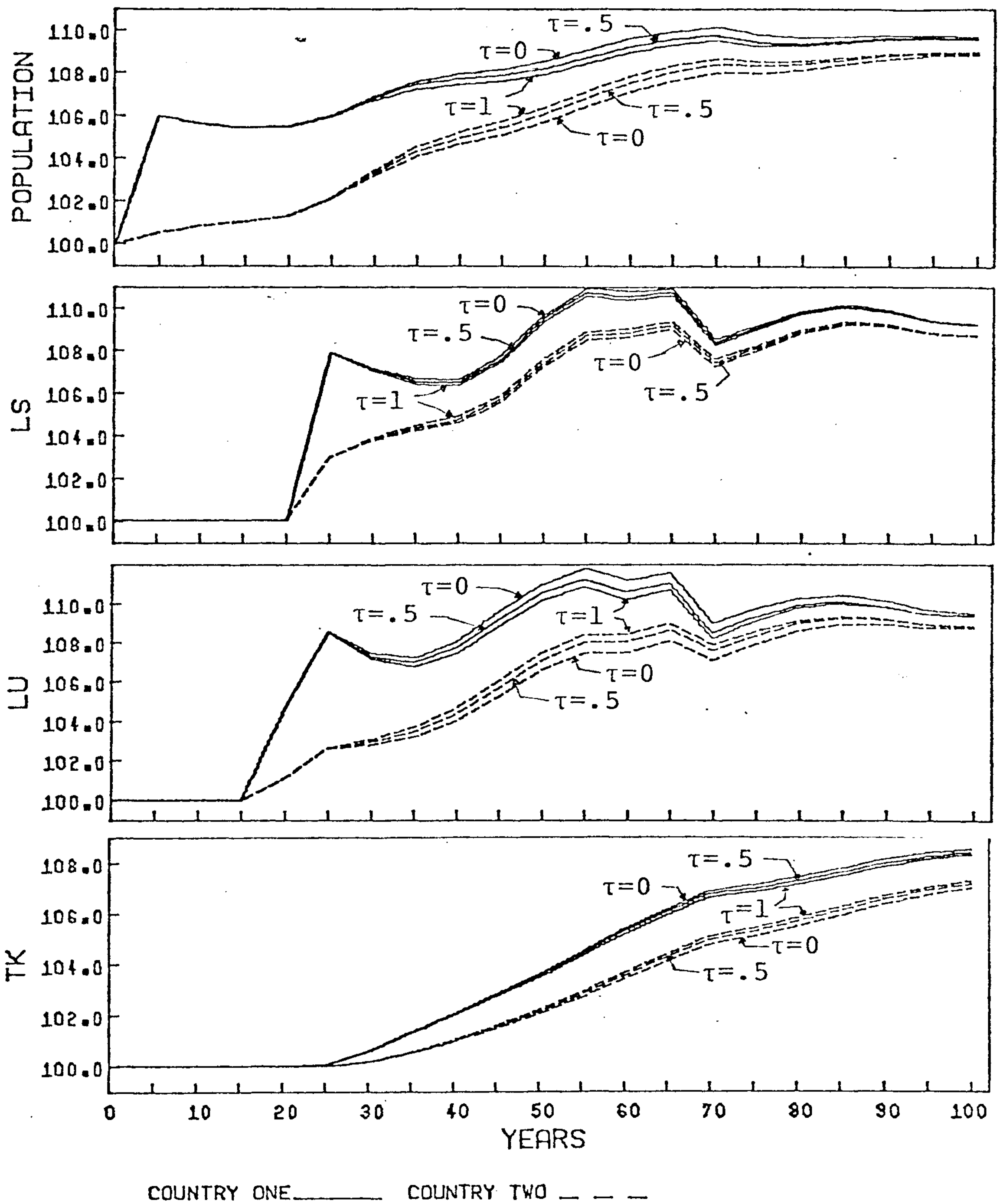


Figure 5.1: (Contd.)

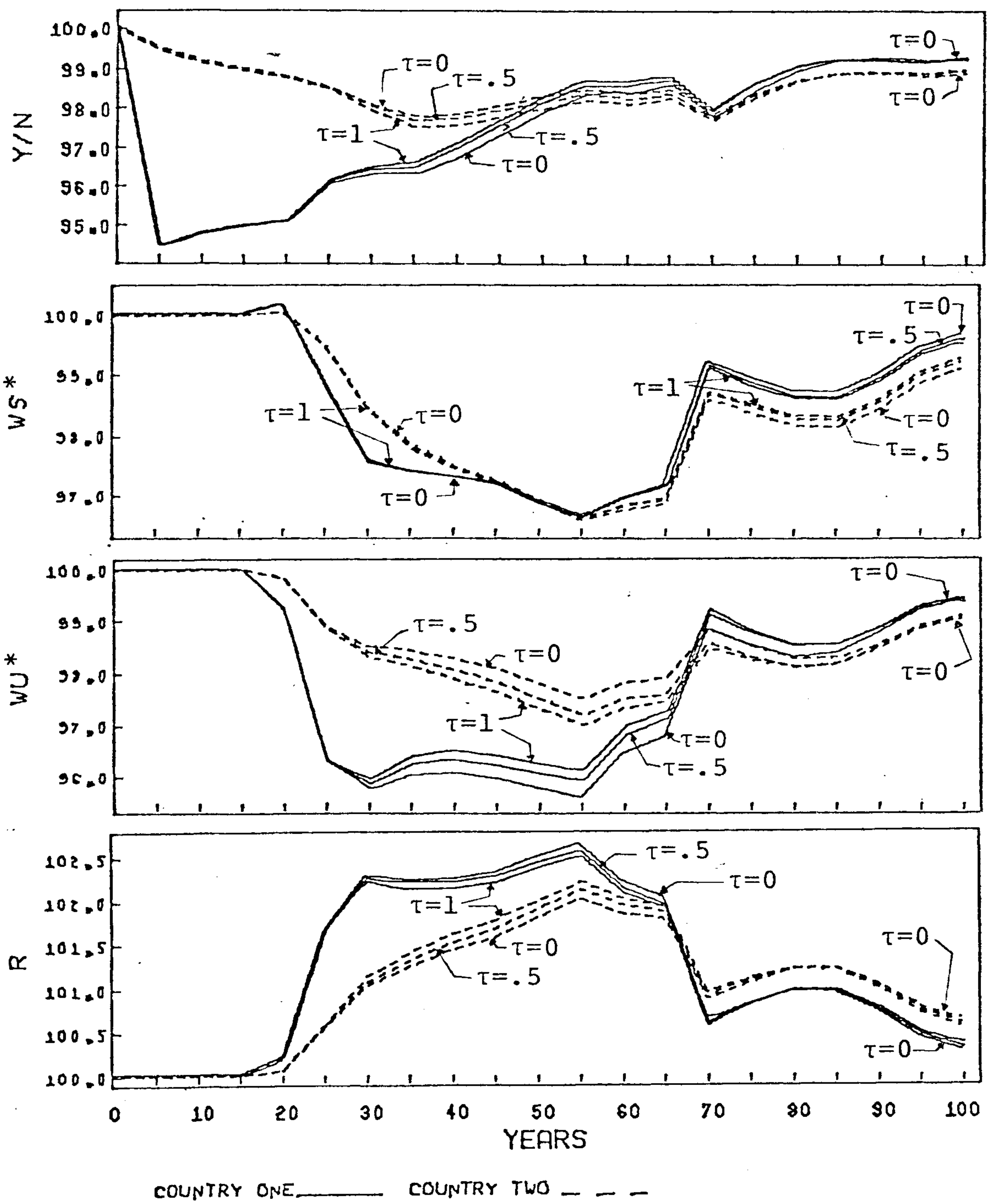
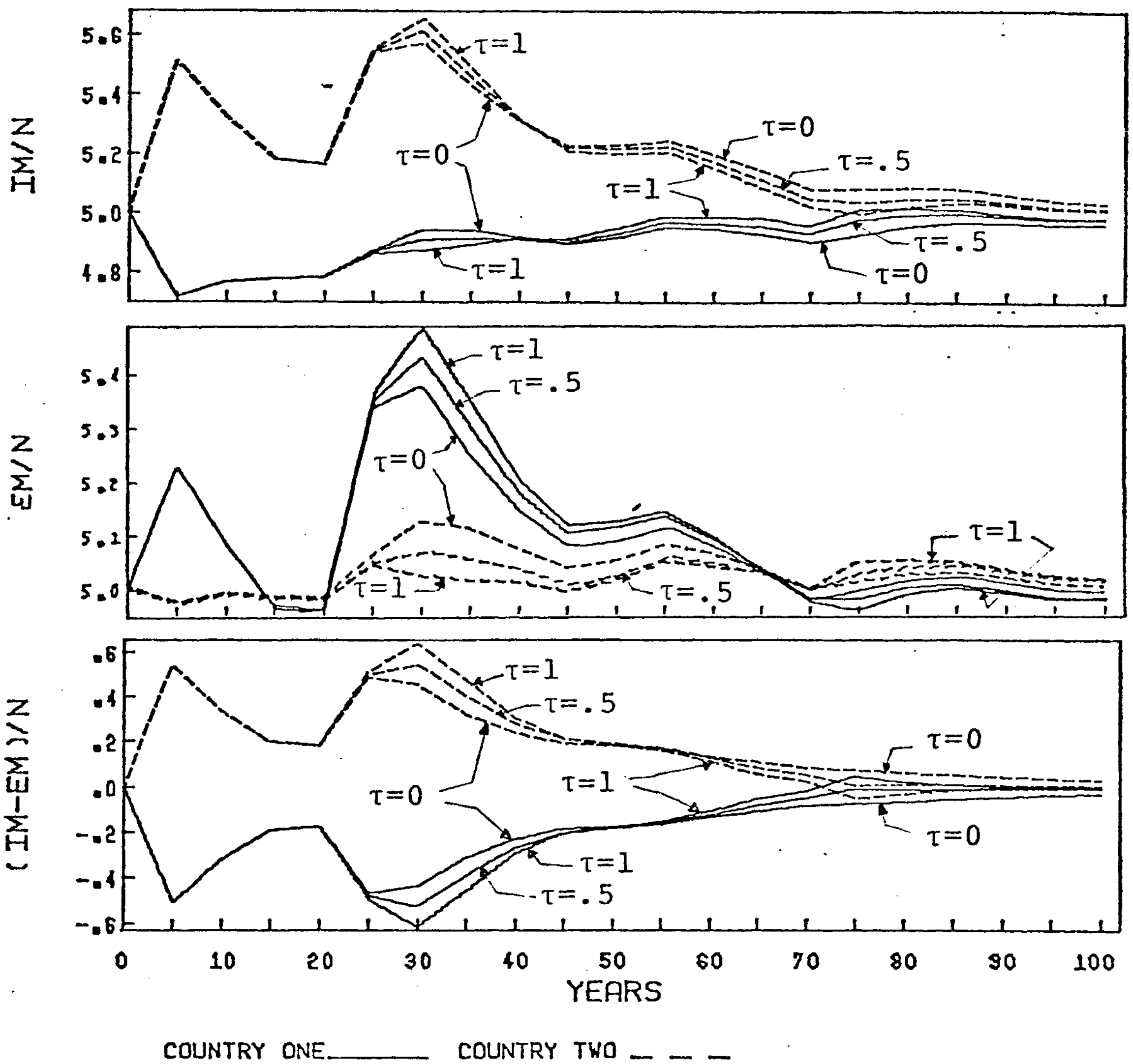


Figure 5.1: (Contd.)



Key to Symbols:

Population,	total population;
LS,	total skilled labour supply;
LU,	total unskilled labour supply;
TK,	total capital stock;
Y/N,	income per capita;
WS*,	effective skilled labour wage rate;
WU*,	effective unskilled labour wage rate;
R,	rate of return to capital;
IM/N,	ratio of total immigrants to total population;
EM/N,	ratio of total emigrants to total population;
(IM-EM)/N,	ratio of net immigrants to total population.

Figure 5.2: Case 1(B): Experiments Relating to a Temporary Increase in the Migration Propensities under the Assumption of International Commodity Immobility

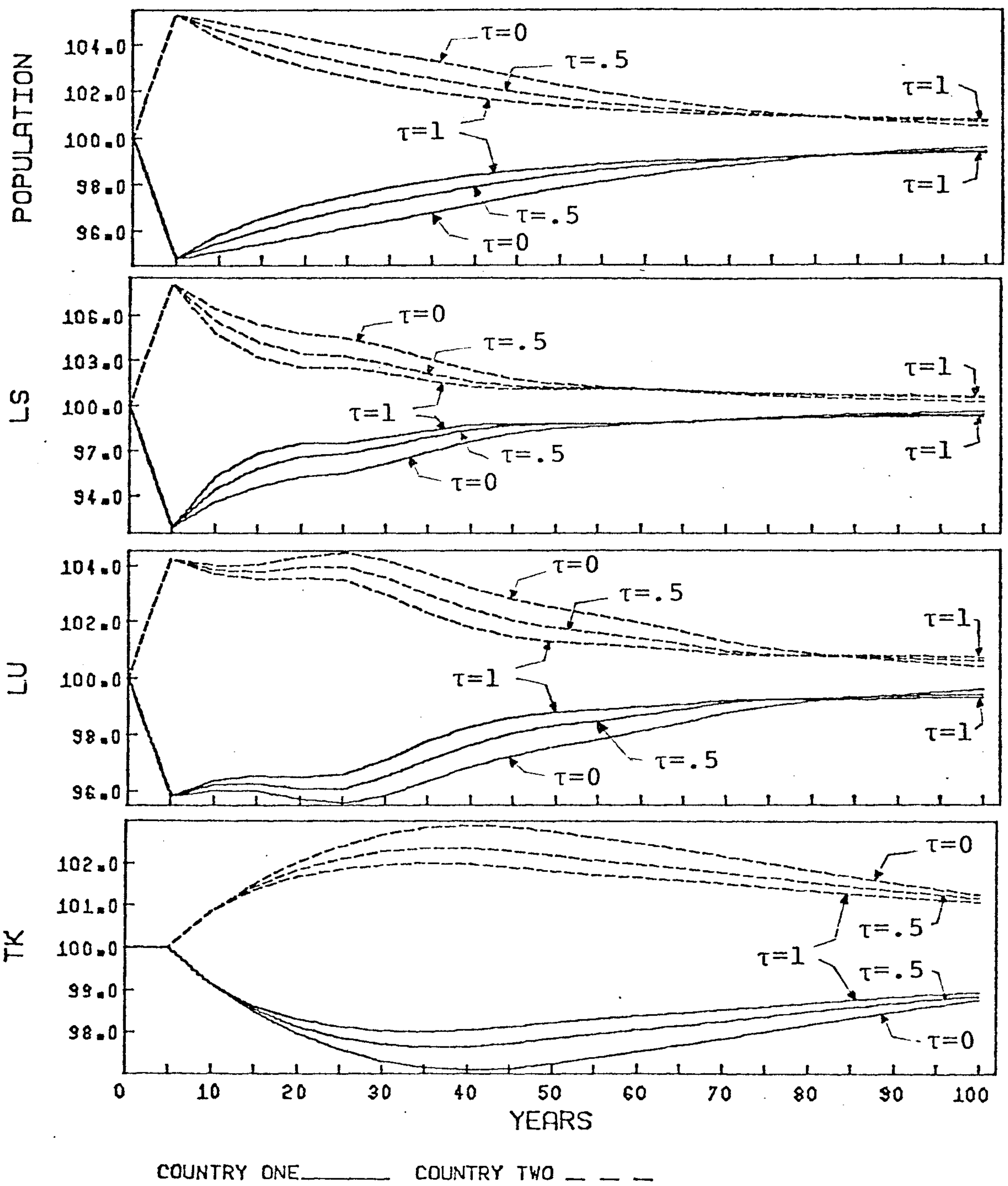


Figure 5.2: (Contd.)

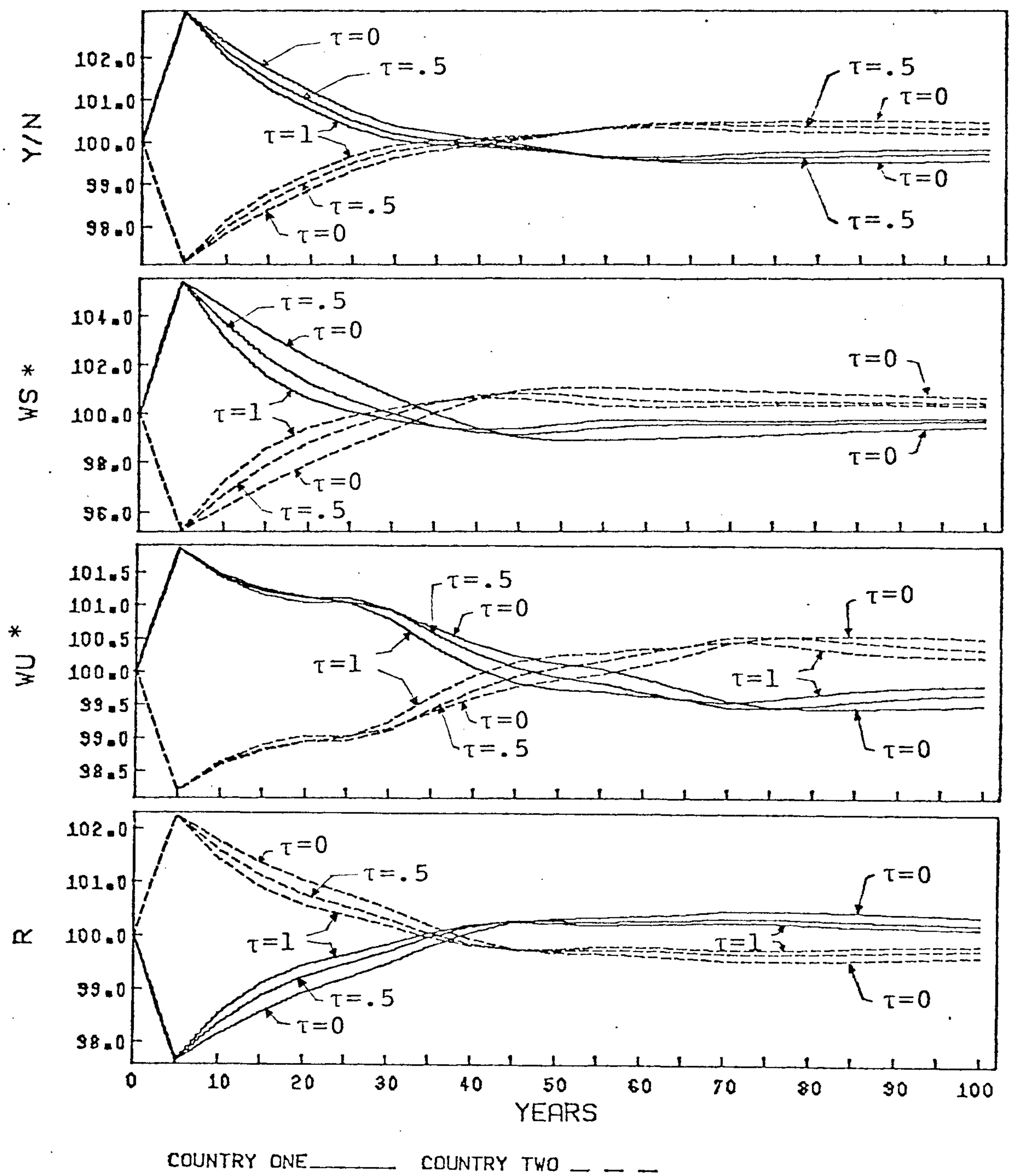
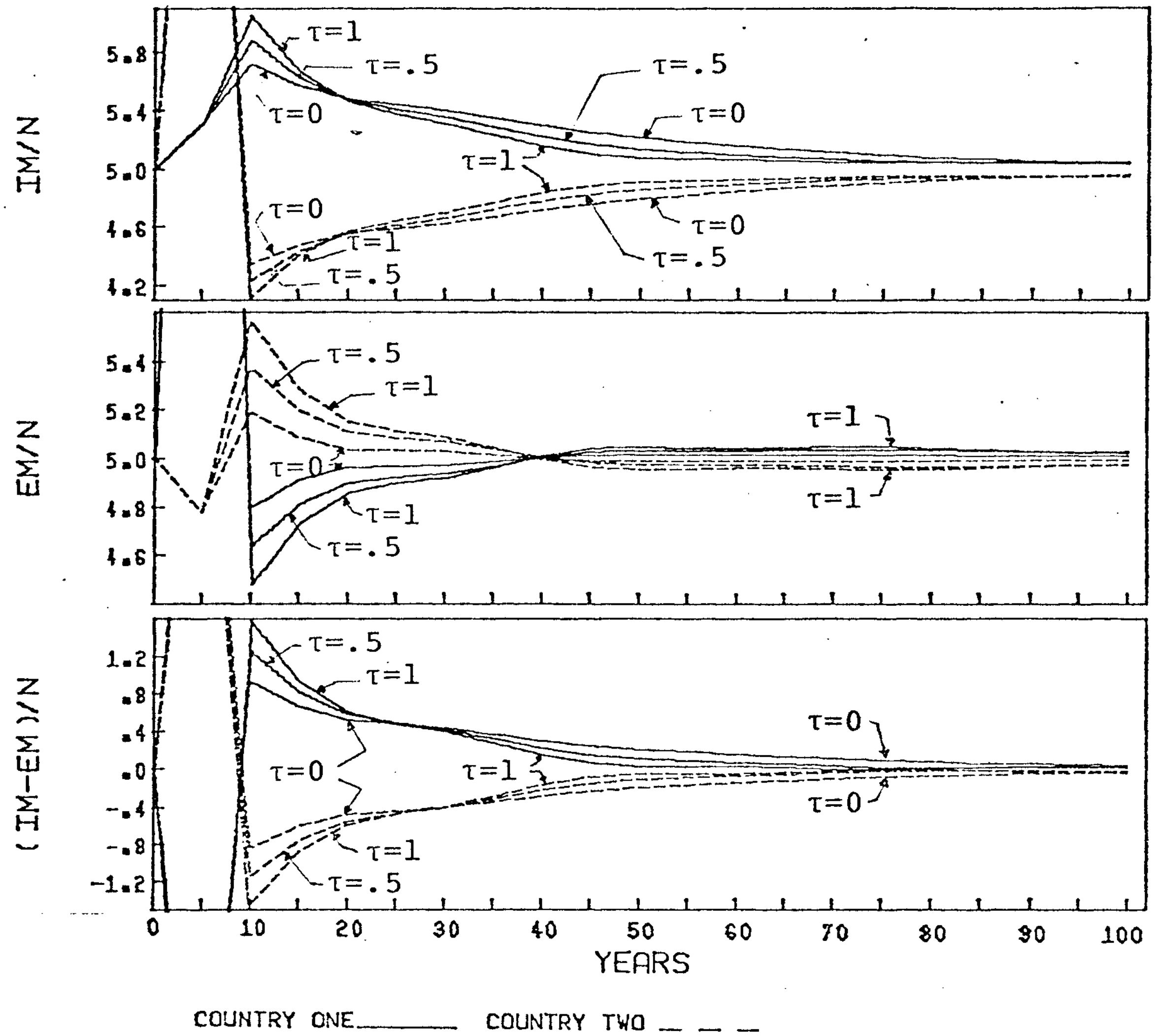


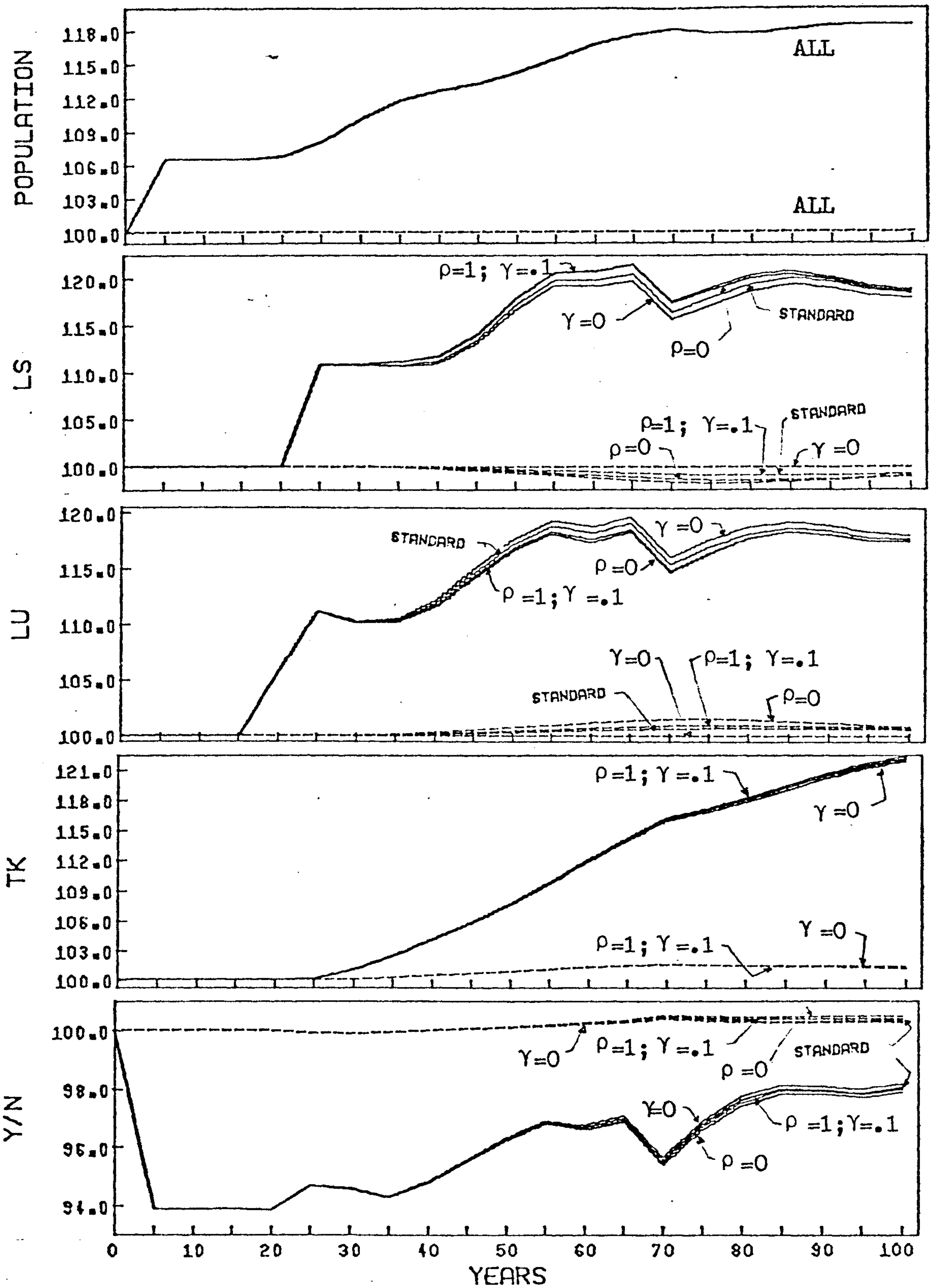
Figure 5.2: (Contd.)



Key to Symbols:

- POPULATION, total population;
- LS, total skilled labour supply;
- LU, total unskilled labour supply;
- TK, total capital stocks;
- Y/N, income per capita;
- WS*, effective skilled labour wage rate;
- WU*, effective unskilled labour wage rate;
- R, rate of return to capital;
- IM/N, ratio of total immigrants to total population;
- EM/N, ratio of total emigrants to total population;
- (IM-EM)/N ratio of net immigrants to total population.

Figure 5.3: Case 2: Experiments Relating to a Temporary Increase in the Level of Fertility under the Assumption of International Population Immobility



COUNTRY ONE______ COUNTRY TWO _ _ _

Figure 5.3: (Contd.)

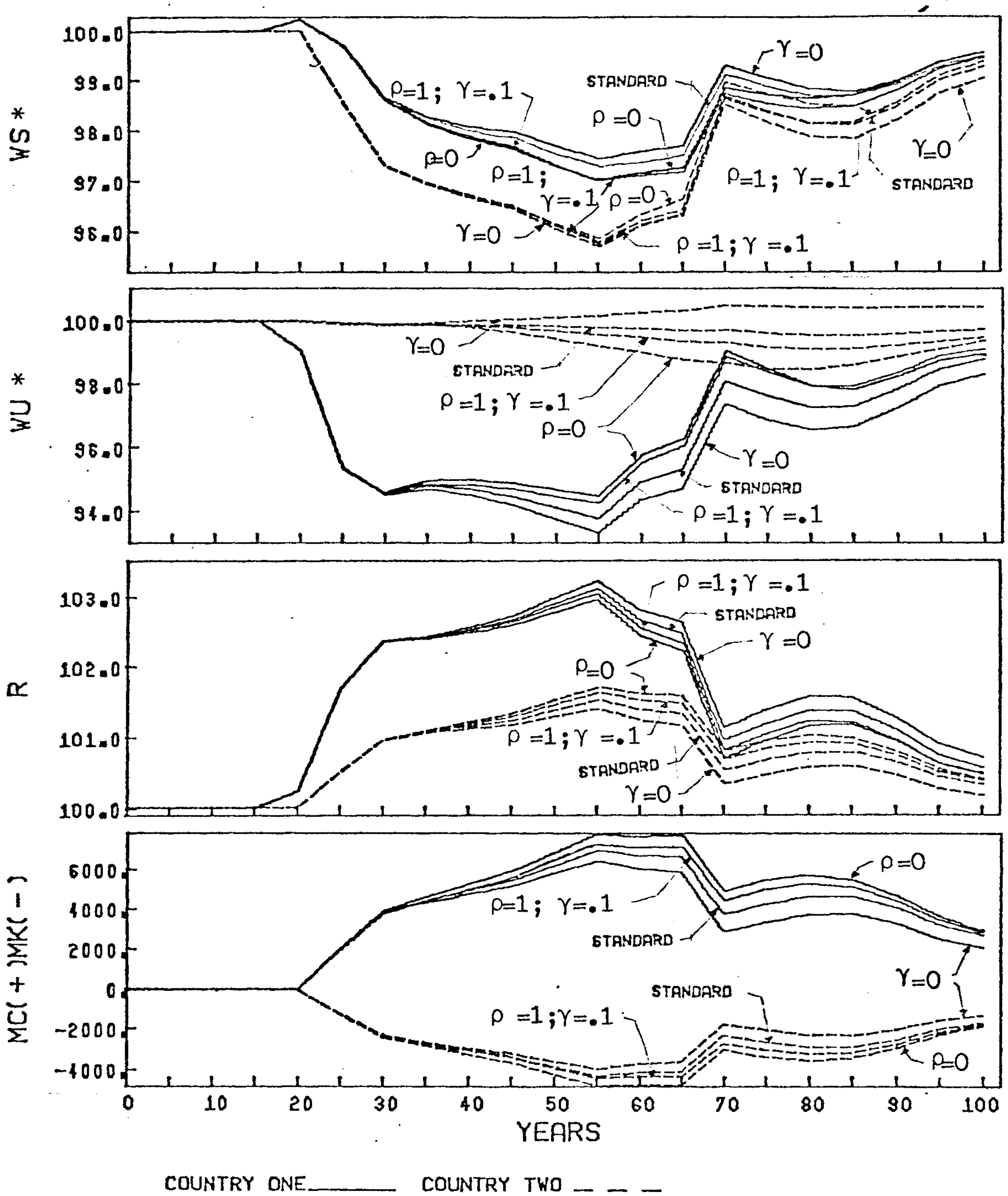


Figure 5.3: (Contd.)

Key to Symbols:

POPULATION,	total population;
LS,	total skilled labour supply;
LU,	total unskilled labour supply;
TK,	total capital stock;
Y/N,	income per capita;
WS*,	effective skilled labour wage rate;
WU*,	effective unskilled labour wage rate;
R,	rate of return to capital;
MC,	net import of consumption goods for country 1;
MK,	net export of investment goods for country 1.

Note: The real units of MC (solid lines) and MK (dash lines) are for country 1 only and their reverse signs apply to country 2.

Figure 5.4: Case 3: Experiments Relating to the Temporary Increase in the Level of Fertility under the Assumption of International Mobility of Population and Commodities

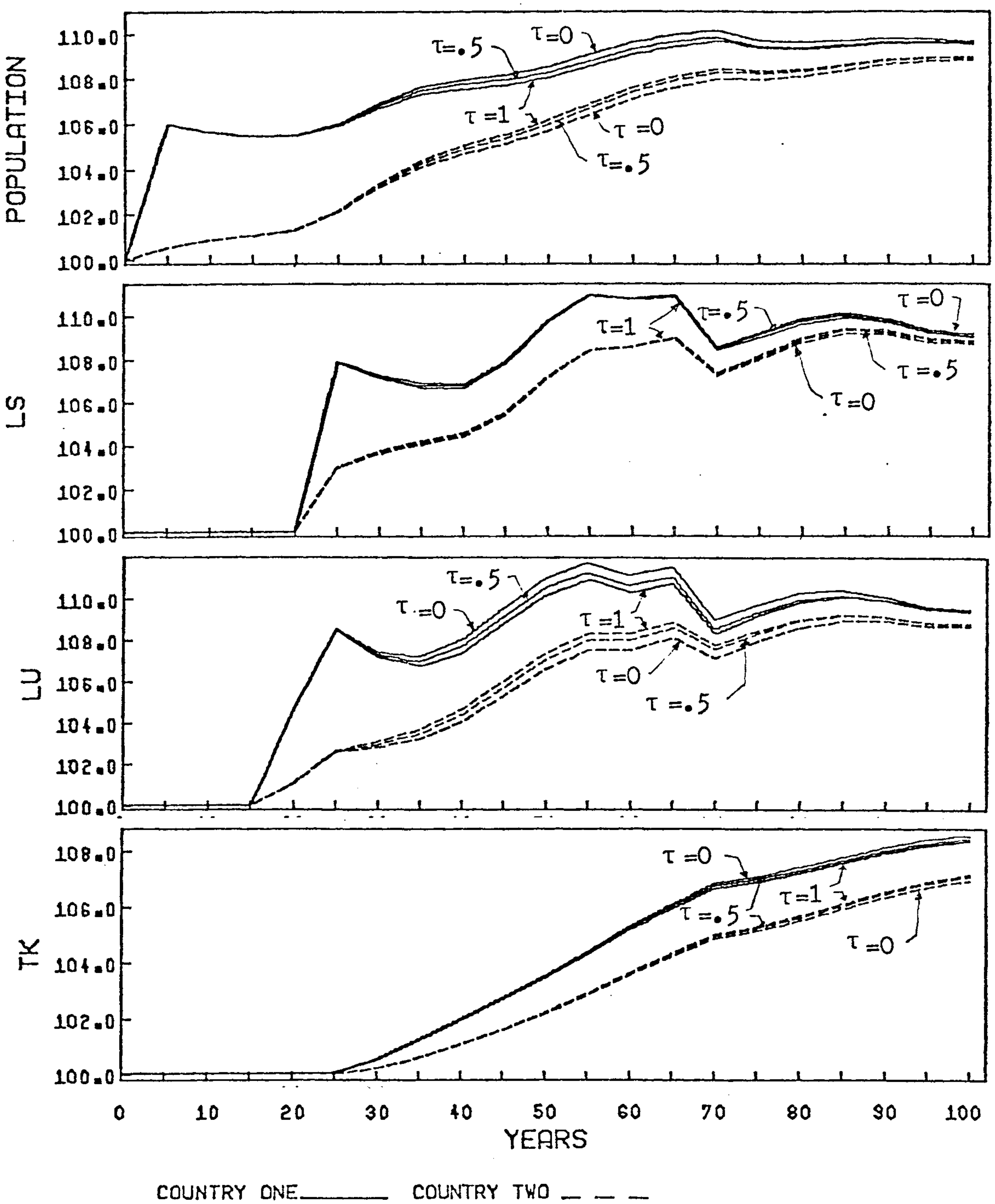


Figure 5.4: (Contd.)

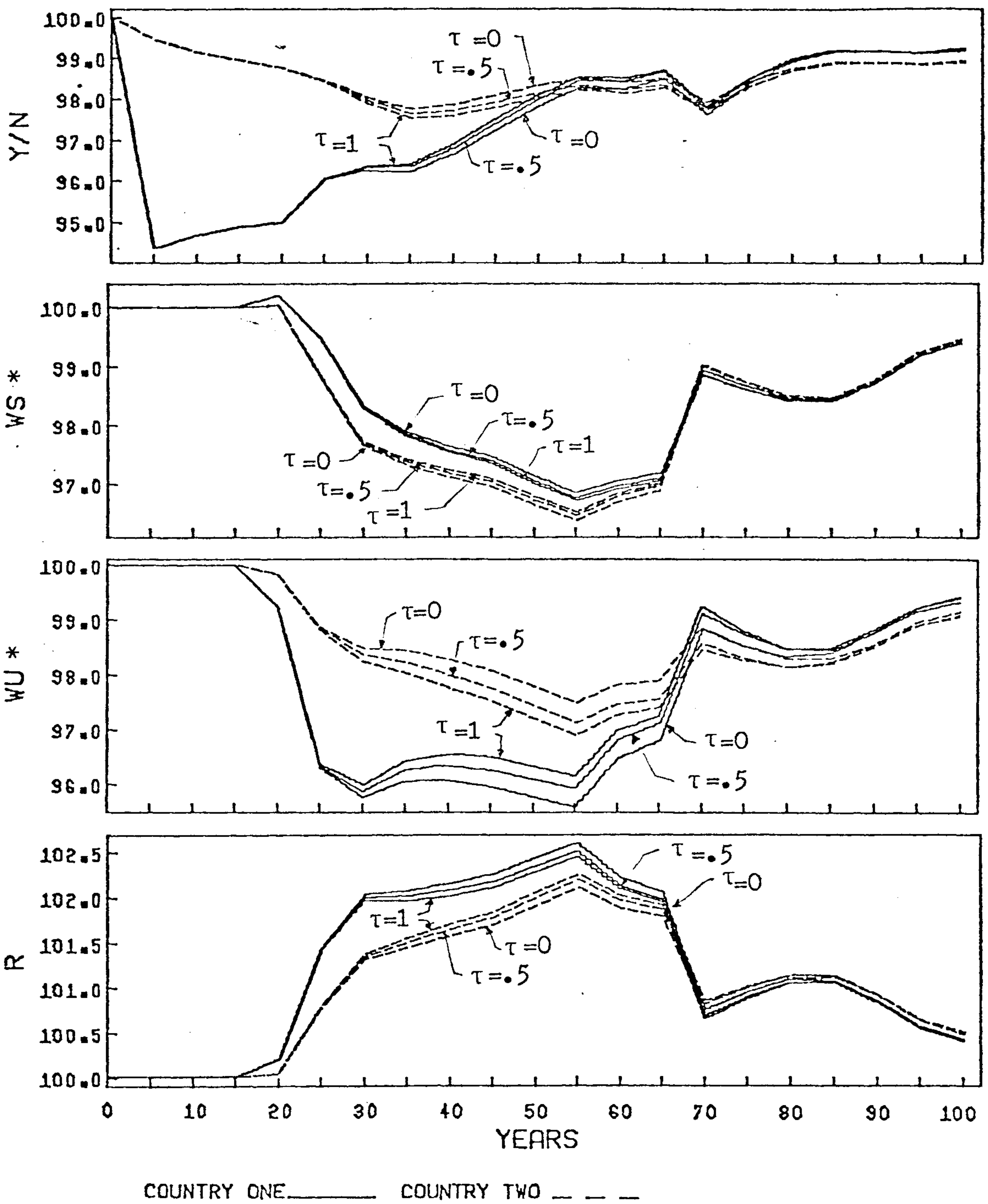


Figure 5.4: (Contd.)

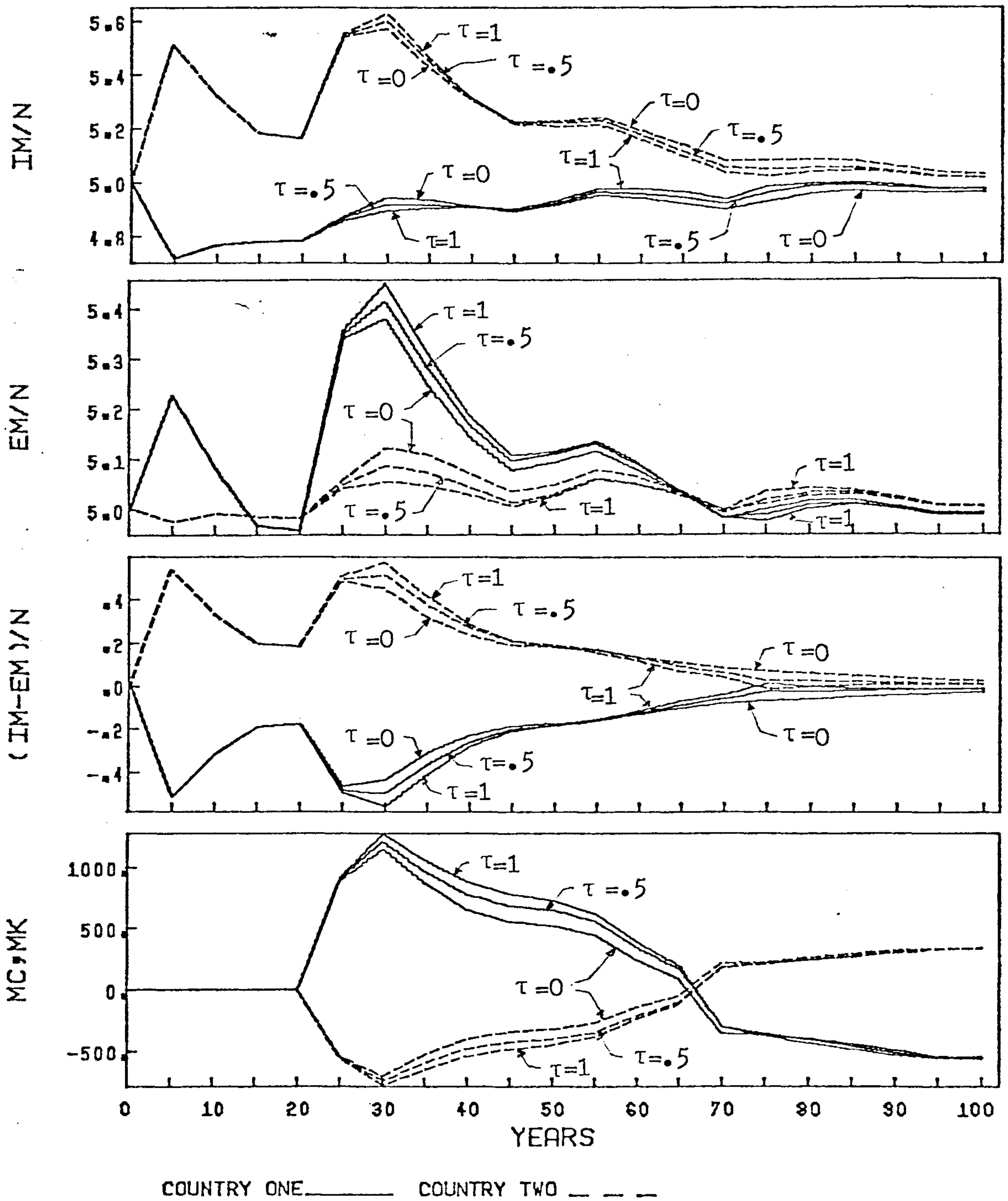


Figure 5.4: (Contd.)

Key to Symbols:

POPULATION,	total population;
LS,	total skilled labour supply;
LU,	total unskilled labour supply;
TK,	total capital stock;
Y/N,	income per capita;
WS*,	effective skilled labour wage rate;
WU*,	effective unskilled labour wage rate;
R,	rate of return to capital;
IM/N,	ratio of total immigrants to total population;
EM/N,	ratio of total emigrants to total population;
(IM-EM)/N,	ratio of net immigrants to total population;
MC,	net import of consumption goods for country 1;
MK,	net import of investment goods for country 1.

Note: The real units of MC (solid lines) and MK (dash lines) are for country 1 only and their reverse signs apply to country 2.

Figure 5.5: Experiments Relating to a Temporary Increase in the Level of Fertility under the Assumption of International Population Immobility

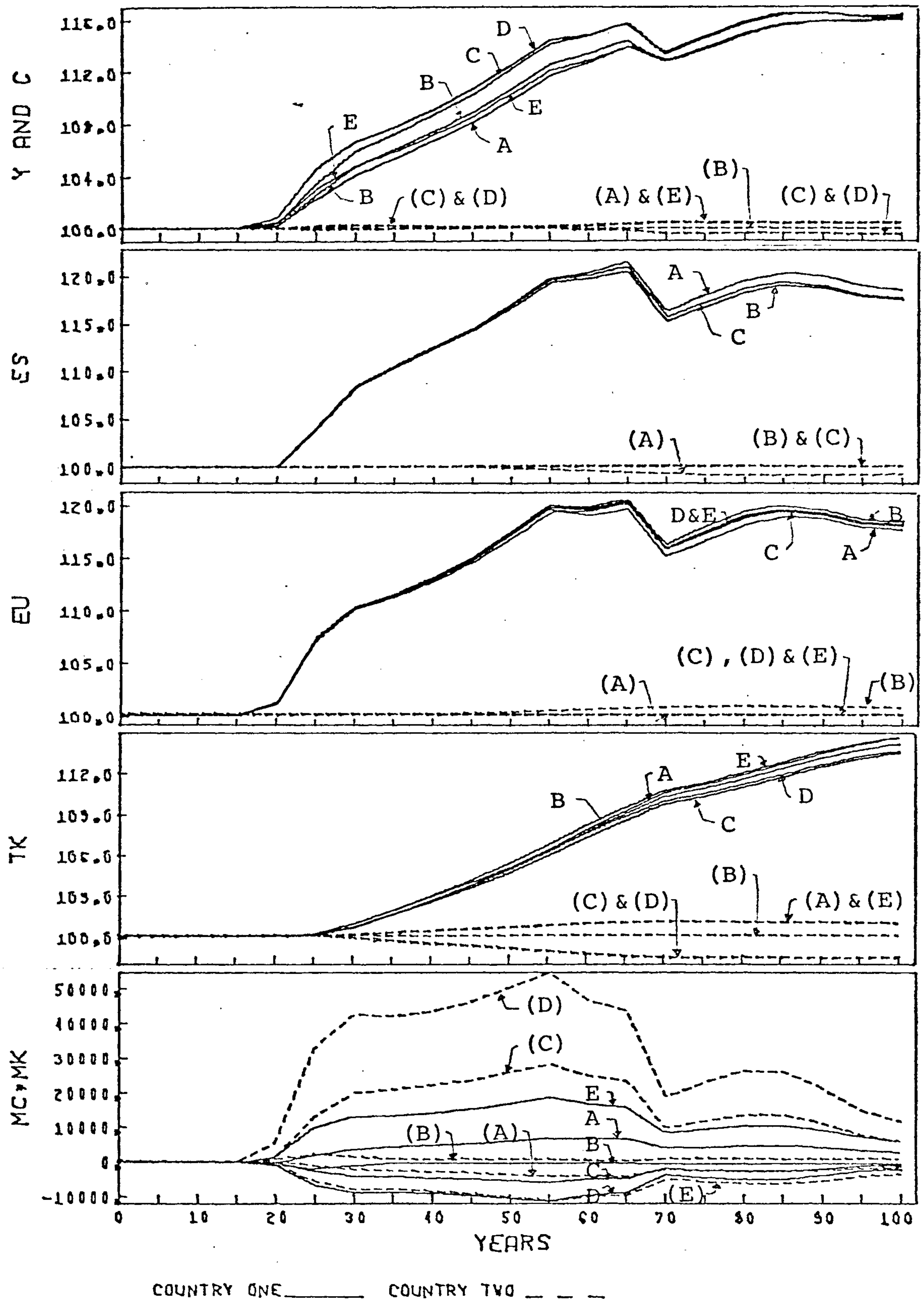


Figure 5.5: (Contd.)

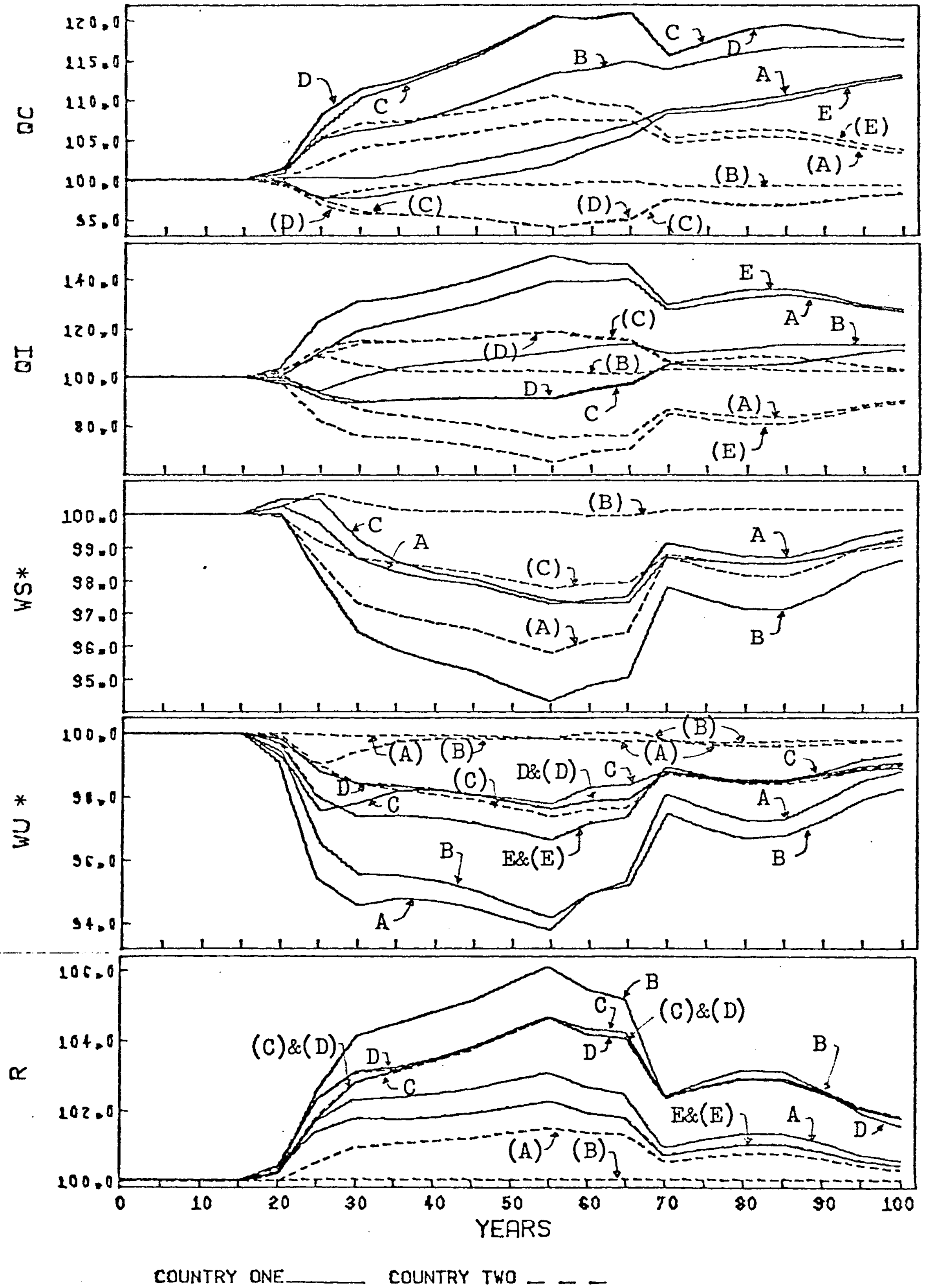


Figure 5.5: (Contd.)

Key to Symbols:

Y,	total income;
C,	total consumption;
ES,	total skilled labour;
EU,	total unskilled labour;
TK,	total capital stock;
MC,	net import of consumption goods for country 1;
MK,	net import of investment goods for country 1;
QC,	total production of consumption goods;
QI,	total production of investment goods;
WS*,	effective skilled labour wage rate;
WU*,	effective unskilled labour wage rate;
R,	rate of return to capital.

Note: Parameters for production functions are shown as:

	Notations	α_1	α_2	α_3	β_1	β_2	β_3
(3x2) cases:	A	.6	.2	.2	.4	.4	.2
	B	.5	.3	.2	.5	.4	.1
	C	.35	.35	.3	.65	.2	.15
(2x2) cases:	D	.35		.65	.65		.35
	E	.6		.4	.4		.6

The real units of MC (solid lines) and MK (dash lines) are for country 1 only and their reverse signs apply to country 2.

Table 5.1: Simulated Effect of a Temporary Doubling of the Fertility Rates in Country 1 on Population, Crude Birth-Rate, and Age Distribution of Population in Both Countries (τ = .5).

Time	Country One									Country Two								
	N	Crude Birth Rate	Percentage Distribution, by Age Group							N	Crude Birth Rate	Percentage Distribution, by Age Group						
			0-4	5-9	10-14	15-19	20-64	65+	N			0-4	5-9	10-14	15-19	20-64	65+	N
Initial State:	100.0	14.2	6.5	6.5	6.5	6.5	55.4	18.6	100.0	100.0	14.2	6.5	6.5	6.5	6.5	55.4	18.6	100.0
Years After Shock:																		
5	106.0	27.5	11.8	6.1	6.1	6.1	52.3	17.5	100.0	100.5	14.1	7.1	6.5	6.5	6.4	55.1	18.5	100.0
10	105.6	13.4	6.2	11.5	6.1	6.1	52.5	17.6	100.0	100.9	14.1	6.5	7.3	6.4	6.4	54.9	18.4	100.0
15	105.4	13.4	6.2	6.2	11.3	6.1	52.6	17.6	100.0	101.1	14.0	6.5	6.4	7.5	6.4	54.8	18.4	100.0
20	105.5	14.0	6.4	6.2	6.2	11.1	52.5	17.6	100.0	101.3	14.1	6.5	6.4	6.4	7.6	54.7	18.3	100.0
25	105.9	15.4	7.1	6.4	6.1	6.1	56.8	17.5	100.0	102.1	14.6	6.8	6.5	6.4	6.3	55.9	18.2	100.0
30	106.8	16.3	7.4	6.9	6.3	6.1	55.9	17.4	100.0	103.3	15.2	7.0	6.7	6.4	6.3	55.6	18.0	100.0
35	107.4	15.4	7.0	7.3	6.8	6.2	55.3	17.3	100.0	104.4	14.9	6.9	7.0	6.7	6.3	55.3	17.8	100.0
40	107.7	14.3	6.6	7.0	7.2	6.8	55.2	17.2	100.0	105.0	14.3	6.6	6.9	7.0	6.6	55.3	17.7	100.0
45	107.8	14.0	6.4	6.5	6.9	7.2	55.7	17.2	100.0	105.5	14.1	6.5	6.6	6.8	6.9	55.6	17.7	100.0
50	108.2	14.3	6.6	6.4	6.5	6.9	56.5	17.2	100.0	106.1	14.3	6.6	6.5	6.5	6.8	56.1	17.5	100.0
55	108.7	14.7	6.7	6.5	6.3	6.4	56.9	17.1	100.0	106.8	14.6	6.7	6.6	6.4	6.5	56.4	17.4	100.0
60	109.2	14.7	6.7	6.7	6.5	6.3	56.9	17.0	100.0	107.5	14.6	6.7	6.7	6.5	6.4	56.4	17.3	100.0
65	109.6	14.2	6.5	6.6	6.6	6.4	56.8	16.9	100.0	108.1	14.3	6.6	6.7	6.6	6.5	56.4	17.2	100.0
70	109.8	14.0	6.4	6.5	6.6	6.6	54.2	19.6	100.0	108.4	14.1	6.5	6.6	6.6	6.6	54.6	19.1	100.0
75	109.4	14.0	6.5	6.4	6.5	6.6	55.0	18.9	100.0	108.3	14.1	6.5	6.5	6.6	6.6	55.2	19.1	100.0
80	109.4	14.2	6.6	6.5	6.4	6.5	55.7	18.4	100.0	108.4	14.3	6.6	6.5	6.5	6.5	55.8	18.2	100.0
85	109.5	14.3	6.6	6.5	6.4	6.4	55.9	18.1	100.0	1.8.6	14.3	6.6	6.5	6.5	6.4	56.0	18.0	100.0
90	109.6	14.2	6.6	6.6	6.5	6.4	55.7	18.3	100.0	108.9	14.3	6.6	6.6	6.5	6.4	55.8	18.1	100.0
95	109.7	14.1	6.5	6.5	6.5	6.5	55.3	18.7	100.0	109.0	14.2	6.5	6.5	6.5	6.5	55.4	18.5	100.0
100	109.6	14.1	6.5	6.5	6.5	6.5	55.1	18.8	100.0	108.9	14.1	6.5	6.5	6.5	6.5	55.2	18.7	100.0
∞	109.3	14.2	6.5	6.5	6.5	6.5	55.4	18.6	100.0	109.3	14.2	6.5	6.5	6.5	6.5	55.4	18.6	100.0

Note: Population is indexed at 100 in initial state. Crude birth-rate is expressed per 1,000.

Table 5.2: Simulated Effect of a Temporary Doubling of the Fertility Rates in Country 1 on Various Migration Rates in Both Countries ($\tau = .5$).

Time	Country One							Country Two						
	$\frac{IM_S}{N_S}$	$\frac{EM_S}{N_S}$	$\frac{IM_U}{N_U}$	$\frac{EM_U}{N_U}$	$\frac{IM}{N}$	$\frac{EM}{N}$	$\frac{(IM-EM)}{N}$	$\frac{IM_S}{N_S}$	$\frac{EM_S}{N_S}$	$\frac{IM_U}{N_U}$	$\frac{EM_U}{N_U}$	$\frac{IM}{N}$	$\frac{EM}{N}$	$\frac{(IM-EM)}{N}$
Initial State:	6.195	6.195	4.395	4.395	5.000	5.000	.000	6.195	6.195	4.395	4.395	5.000	5.000	.000
Years After Shock:														
5	6.195	6.195	4.031	4.780	4.717	5.229	-.512	6.195	6.195	5.170	4.359	5.513	4.973	.540
10	6.195	6.195	4.097	4.564	4.765	5.084	-.318	6.195	6.195	4.887	4.387	5.323	4.990	.333
15	6.195	6.195	4.114	4.392	4.778	4.967	-.189	6.195	6.195	4.675	4.379	5.181	4.983	.197
20	5.814	5.814	4.253	4.516	4.783	4.957	-.174	6.100	6.100	4.683	4.411	5.161	4.980	.181
25	6.074	6.755	4.257	4.637	4.867	5.348	-.481	6.990	6.284	4.816	4.421	5.548	5.049	.499
30	6.232	6.830	4.249	4.742	4.906	5.433	-.528	6.981	6.370	4.927	4.415	5.615	5.069	.545
35	6.251	6.619	4.254	4.655	4.911	5.301	-.390	6.724	6.351	4.824	4.408	5.457	5.055	.402
40	6.192	6.400	4.274	4.576	4.908	5.179	-.271	6.504	6.292	4.714	4.402	5.311	5.033	.278
45	6.117	6.287	4.284	4.508	4.897	5.103	-.206	6.398	6.225	4.619	4.390	5.216	5.006	.210
50	6.147	6.325	4.310	4.500	4.927	5.113	-.186	6.431	6.250	4.594	4.400	5.214	5.024	.190
55	6.219	6.384	4.338	4.504	4.969	5.135	-.166	6.475	6.308	4.589	4.420	5.224	5.056	.169
60	6.211	6.326	4.340	4.471	4.966	5.092	-.125	6.404	6.288	4.547	4.414	5.170	5.043	.127
65	6.166	6.237	4.347	4.434	4.956	5.038	-.082	6.308	6.236	4.501	4.413	5.107	5.025	.083
70	6.109	6,153	4.335	4.390	4.930	4.982	-.051	6.219	6.175	4.449	4.393	5.044	4.992	.052
75	6.150	6.172	4.377	4.378	4.973	4.981	-.007	6.228	6.207	4.425	4.425	5.032	5.025	.007
80	6.186	6.207	4.387	4.392	4.992	5.002	-.011	6.256	6.235	4.433	4.428	5.047	5.036	.011
85	6.200	6.216	4.389	4.397	4.997	5.008	-.010	6.260	6.245	4.433	4.425	5.047	5.037	.011
90	6.186	6.196	4.383	4.390	4.988	4.996	-.008	6.236	6.226	4.423	4.416	5.032	5.024	.008
95	6.166	6.173	4.377	4.381	4.978	4.983	-.005	6.210	6.204	4.411	4.407	5.015	5.011	.005
100	6.165	6.171	4.378	4.380	4.978	4.982	-.003	6.205	6.200	4.406	4.404	5.011	5.008	.003
∞	6.195	6.195	4.395	4.395	5.000	5.000	.000	6.195	6.195	4.395	4.395	5.000	5.000	.000

Note: All ratios are expressed in percentage terms.

Table 5.5: The Direction of Trade

Time	Factor Ratios Between Country (1) and (2): ES(1)/ES(2)	EU(1)/EU(2)	TK(1)/TK(2)	Factor Content of Per Unit Value of Output — Country (1): ESC/QC vs ESI/QI.P	EUC/QC vs EUI/QI.P	KC/QC vs KI/QI.P	Country (2): ESC/QC vs ESI/QI.P	EUC/QC vs EUI/QI.P	KC/QC vs KI/QI.P	Price	Import (+) & Export (-) — Country (1): MC	MK	Country (2): MC	MK
--- Case A: $(\alpha_1,\alpha_2,\alpha_3) = (.6,.2,.2)$; $(\beta_1,\beta_2,\beta_3) = (.4,.4,.2)$ ---														
Initial State:														
	1.000	1.000	1.000	.03 < .06	.04 = .04	.64 > .43	.03 < .06	.04 = .04	.64 > .43	1.65	.0	.0	.0	.0
Years After Shock:														
5	1.000	1.000	1.000	.03 < .06	.04 = .04	.64 > .43	.03 < .06	.04 = .04	.64 > .43	1.65	.0	.0	.0	.0
10	1.000	1.000	1.000	.03 < .06	.04 = .04	.64 > .43	.03 < .06	.04 = .04	.64 > .43	1.65	.0	.0	.0	.0
15	1.000	1.000	1.000	.03 < .06	.04 = .04	.64 > .43	.03 < .06	.04 = .04	.64 > .43	1.65	.0	.0	.0	.0
20	1.000	1.012	1.000	.03 < .06	.04 = .04	.64 > .42	.03 < .06	.04 = .04	.64 > .43	1.65	.0	.0	.0	.0
25	1.040	1.073	1.001	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	1992.7	-1214.2	-1992.7	1214.2
30	1.083	1.102	1.006	.03 < .06	.04 = .04	.62 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	3822.9	-2337.6	-3822.9	2337.6
35	1.104	1.112	1.014	.03 < .06	.04 = .04	.62 > .42	.03 < .06	.04 = .04	.63 > .42	1.63	4448.7	-2722.8	-4448.7	2722.8
40	1.125	1.127	1.024	.03 < .06	.04 = .04	.62 > .41	.03 < .06	.04 = .04	.63 > .42	1.63	4980.5	-3050.4	-4980.5	3050.4
45	1.146	1.144	1.034	.03 < .06	.04 = .04	.62 > .41	.03 < .06	.04 = .04	.63 > .42	1.63	5474.7	-3355.0	-5474.7	3355.0
50	1.174	1.166	1.044	.03 < .06	.04 = .04	.62 > .41	.03 < .06	.04 = .04	.63 > .42	1.63	6250.3	-3834.4	-6250.3	3834.4
55	1.203	1.189	1.057	.03 < .06	.04 = .04	.62 > .41	.03 < .06	.04 = .04	.63 > .42	1.63	6988.6	-4291.4	-6988.6	4291.4
60	1.211	1.183	1.070	.03 < .06	.04 = .04	.62 > .41	.03 < .06	.04 = .04	.63 > .42	1.63	6689.2	-4102.8	-6689.2	4102.8
65	1.224	1.188	1.083	.03 < .06	.04 = .04	.62 > .41	.03 < .06	.04 = .04	.63 > .42	1.63	6654.6	-4079.3	-6654.6	4079.3
70	1.173	1.142	1.095	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	3749.9	-2284.4	-3749.9	2284.4
75	1.192	1.158	1.101	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	4296.9	-2620.1	-4296.9	2620.1
80	1.208	1.172	1.109	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	4679.5	-2855.4	-4679.5	2855.4
85	1.216	1.180	1.117	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	4661.7	-2844.6	-4661.7	2844.6
90	1.212	1.177	1.125	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	4077.6	-2485.6	-4077.6	2485.6
95	1.200	1.170	1.132	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.63 > .42	1.64	3211.6	-1954.8	-3211.6	1954.8
100	1.194	1.169	1.137	.03 < .06	.04 = .04	.63 > .42	.03 < .06	.04 = .04	.64 > .42	1.64	2686.6	-1634.0	-2686.6	1634.0
∞	1.187	1.187	1.187	.03 < .06	.04 = .04	.64 > .43	.03 < .06	.04 = .04	.64 > .42	1.65	.0	.0	.0	.0
--- Case B: $(\alpha_1,\alpha_2,\alpha_3) = (.5,.3,.2)$; $(\beta_1,\beta_2,\beta_3) = (.5,.4,.1)$ ---														
Initial State:														
	1.000	1.000	1.000	.04 < .05	.04 > .02	1.00 = 1.00	.04 < .05	.04 > .02	1.00 = 1.00	.97	.0	.0	.0	.0
Years After Shock:														
5	1.000	1.000	1.000	.04 < .05	.04 > .02	1.00 = 1.00	.04 < .05	.04 > .02	1.00 = 1.00	.97	.0	.0	.0	.0
10	1.000	1.000	1.000	.04 < .05	.04 > .02	1.00 = 1.00	.04 < .05	.04 > .02	1.00 = 1.00	.97	.0	.0	.0	.0
15	1.000	1.000	1.000	.04 < .05	.04 > .02	1.00 = 1.00	.04 < .05	.04 > .02	1.00 = 1.00	.97	.0	.0	.0	.0
20	1.000	1.000	1.000	.04 < .05	.05 > .02	1.00 = 1.00	.04 < .05	.04 > .02	1.00 = 1.00	.97	-815.7	837.6	815.7	-837.6
25	1.040	1.074	1.000	.04 < .05	.05 > .02	.98 = .98	.04 < .05	.05 > .02	1.00 = 1.00	.97	-2210.5	2267.3	2210.5	-2267.3
30	1.082	1.102	1.006	.04 < .05	.05 > .02	.96 = .96	.04 < .05	.05 > .02	1.00 = 1.00	.97	-1269.5	1303.1	1269.5	-1303.1
35	1.103	1.113	1.015	.04 < .05	.05 > .02	.96 = .96	.04 < .05	.04 > .02	1.00 = 1.00	.97	-637.8	655.0	637.8	-655.0
40	1.122	1.130	1.026	.04 < .05	.05 > .02	.95 = .95	.04 < .05	.04 > .02	1.00 = 1.00	.97	-518.1	532.2	518.1	-532.2
45	1.140	1.151	1.037	.04 < .05	.05 > .02	.95 = .95	.04 < .05	.04 > .02	1.00 = 1.00	.97	-632.9	650.0	632.9	-650.0
50	1.165	1.176	1.048	.04 < .05	.05 > .02	.95 = .95	.04 < .05	.04 > .02	1.00 = 1.00	.97	-636.2	653.4	636.2	-653.4
55	1.190	1.202	1.062	.04 < .05	.05 > .02	.94 = .94	.04 < .05	.04 > .02	1.00 = 1.00	.97	-675.5	693.8	675.5	-693.8
60	1.194	1.199	1.076	.04 < .05	.05 > .02	.95 = .95	.04 < .05	.04 > .02	1.00 = 1.00	.97	-276.2	283.8	276.2	-283.8
65	1.203	1.208	1.089	.04 < .05	.05 > .02	.95 = .95	.04 < .05	.04 > .02	1.00 = 1.00	.97	-281.9	289.7	281.9	-289.7
70	1.150	1.163	1.102	.04 < .05	.05 > .02	.98 = .98	.04 < .05	.04 > .02	1.00 = 1.00	.97	-846.2	869.1	846.2	-869.1
75	1.165	1.180	1.108	.04 < .05	.05 > .02	.97 = .97	.04 < .05	.04 > .02	1.00 = 1.00	.97	-914.2	938.8	914.2	-938.8
80	1.181	1.195	1.115	.04 < .05	.05 > .02	.97 = .97	.04 < .05	.04 > .02	1.00 = 1.00	.97	-845.8	868.5	845.8	-868.5
85	1.190	1.201	1.123	.04 < .05	.05 > .02	.97 = .97	.04 < .05	.04 > .02	1.00 = 1.00	.97	-694.0	712.8	694.0	-712.8
90	1.187	1.197	1.131	.04 < .05	.05 > .02	.97 = .97	.04 < .05	.04 > .02	1.00 = 1.00	.97	-623.5	640.3	623.5	-640.3
95	1.178	1.188	1.137	.04 < .05	.05 > .02	.98 = .98	.04 < .05	.04 > .02	1.00 = 1.00	.97	-664.9	682.8	664.9	-682.8
100	1.174	1.185	1.142	.04 < .05	.05 > .02	.98 = .98	.04 < .05	.04 > .02	1.00 = 1.00	.97	-694.8	713.5	694.8	-713.5
∞	1.187	1.187	1.187	.04 < .05	.04 > .02	1.00 = 1.00	.04 < .05	.04 > .02	1.00 = 1.00	.97	.0	.0	.0	.0

Table 5.5: (Contd.)

Time	Factor Ratios Between Country (1) and (2): ES(1)/ES(2)	EU(1)/EU(2)	TK(1)/TK(2)	Factor Content of Per Unit Value of Output, Country (1): ESC/QC, ESI/QI.P	EUC/QC, EUI/QI.P	KC/QC, KI/QI.P	Country (2): ESC/QC, ESI/QI.P	EUC/QC, EUI/QI.P	KC/QC, KI/QI.P	Price	Import (+) & Export (-), Country (1): MC	MK	Country (2): MC	MK
--- Case C: $(\alpha_1,\alpha_2,\alpha_3) = (.35,.35,.3)$; $(\beta_1,\beta_2,\beta_3) = (.65,.2,.15)$ ---														
Initial State:														
	1.000	1.000	1.000	.04 > .02	.04 > .02	3.86 < 7.18	.04 > .02	.04 > .02	3.86 < 7.18	.21	.0	.0	.0	.0
Years After Shock:														
5	1.000	1.000	1.000	.04 > .02	.04 > .02	3.86 < 7.18	.04 > .02	.04 > .02	3.86 < 7.18	.21	.0	.0	.0	.0
10	1.000	1.000	1.000	.04 > .02	.04 > .02	3.86 < 7.18	.04 > .02	.04 > .02	3.86 < 7.18	.21	.0	.0	.0	.0
15	1.000	1.000	1.000	.04 > .02	.04 > .02	3.86 < 7.18	.04 > .02	.04 > .02	3.86 < 7.18	.21	.0	.0	.0	.0
20	1.000	1.012	1.000	.04 > .02	.04 > .02	3.86 < 7.16	.04 > .02	.04 > .02	3.86 < 7.16	.21	-307.4	1449.0	307.4	-1449.0
25	1.040	1.073	1.001	.04 > .02	.05 > .02	3.80 < 7.05	.04 > .02	.04 > .02	3.79 < 7.05	.21	-2840.7	13289.6	2840.7	-13289.6
30	1.083	1.102	1.008	.04 > .02	.05 > .02	3.76 < 6.98	.04 > .02	.05 > .02	3.76 < 6.98	.21	-4266.1	19867.7	4266.1	-19867.7
35	1.104	1.112	1.019	.04 > .02	.05 > .02	3.75 < 6.96	.04 > .02	.05 > .02	3.75 < 6.96	.21	-4494.3	20904.0	4494.3	-20904.0
40	1.124	1.128	1.030	.04 > .02	.05 > .02	3.74 < 6.94	.04 > .02	.05 > .02	3.74 < 6.94	.22	-4781.0	22206.2	4781.0	-22206.2
45	1.144	1.147	1.042	.04 > .02	.05 > .02	3.72 < 6.92	.04 > .02	.05 > .02	3.72 < 6.92	.22	-5087.3	23593.8	5087.3	-23593.8
50	1.169	1.171	1.056	.04 > .02	.05 > .02	3.71 < 6.88	.04 > .02	.05 > .02	3.71 < 6.88	.22	-5613.3	25978.6	5613.3	-25978.6
55	1.196	1.197	1.070	.04 > .02	.05 > .02	3.69 < 6.85	.04 > .02	.05 > .02	3.69 < 6.85	.22	-6098.2	28165.6	6098.2	-28165.6
60	1.200	1.193	1.086	.04 > .02	.05 > .02	3.70 < 6.88	.04 > .02	.05 > .02	3.70 < 6.88	.22	-5331.1	24661.1	5331.1	-24661.1
65	1.209	1.202	1.101	.04 > .02	.05 > .02	3.71 < 6.88	.04 > .02	.05 > .02	3.71 < 6.88	.22	-5029.6	23275.4	5029.6	-23275.4
70	1.156	1.158	1.114	.04 > .02	.04 > .02	3.77 < 7.01	.04 > .02	.04 > .02	3.77 < 7.01	.21	-2053.3	9580.4	2053.3	-9580.4
75	1.171	1.175	1.120	.04 > .02	.04 > .02	3.76 < 6.99	.04 > .02	.04 > .02	3.76 < 6.99	.21	-2557.8	11918.1	2557.8	-11918.1
80	1.186	1.190	1.127	.04 > .02	.05 > .02	3.75 < 6.97	.04 > .02	.05 > .02	3.75 < 6.97	.21	-2921.0	13595.9	2921.0	-13595.9
85	1.194	1.197	1.135	.04 > .02	.05 > .02	3.75 < 6.97	.04 > .02	.05 > .02	3.75 < 6.97	.21	-2894.9	13474.7	2894.9	-13474.7
90	1.191	1.194	1.143	.04 > .02	.04 > .02	3.77 < 6.99	.04 > .02	.04 > .02	3.77 < 6.99	.21	-2349.5	10953.0	2349.5	-10953.0
95	1.181	1.185	1.149	.04 > .02	.04 > .02	3.78 < 7.03	.04 > .02	.04 > .02	3.78 < 7.03	.21	-1602.1	7485.4	1602.1	-7485.4
100	1.177	1.182	1.153	.04 > .02	.04 > .02	3.79 < 7.05	.04 > .02	.04 > .02	3.79 < 7.05	.21	-1233.5	5770.1	1233.5	-5770.1
∞	1.187	1.187	1.187	.04 > .02	.04 > .02	3.86 < 7.18	.04 > .02	.04 > .02	3.86 < 7.18	.21	.0	.0	.0	.0
--- Case D: $(\alpha_1,\alpha_2,\alpha_3) = (.5,.1,.4)$; $(\beta_1,\beta_2,\beta_3) = (.4,.3,.3)$ ---														
Initial State:														
	1.000	1.000	1.000	.02 < .07	.06 > .05	.77 > .61	.02 < .07	.06 > .05	.77 > .61	1.33	.0	.0	.0	.0
Years After Shock:														
5	1.000	1.000	1.000	.02 < .07	.06 > .05	.77 > .61	.02 < .07	.06 > .05	.77 > .61	1.33	.0	.0	.0	.0
10	1.000	1.000	1.000	.02 < .07	.06 > .05	.77 > .61	.02 < .07	.06 > .05	.77 > .61	1.33	.0	.0	.0	.0
15	1.000	1.000	1.000	.02 < .07	.06 > .05	.77 > .61	.02 < .07	.06 > .05	.77 > .61	1.33	.0	.0	.0	.0
20	1.000	1.012	1.000	.02 < .07	.06 > .05	.76 > .61	.02 < .07	.06 > .05	.77 > .61	1.33	-177.5	133.7	177.5	-133.7
25	1.041	1.073	1.001	.02 < .07	.07 > .05	.74 > .60	.02 < .07	.06 > .05	.77 > .61	1.33	131.2	-98.9	-131.2	98.9
30	1.083	1.102	1.008	.03 < .08	.07 > .05	.74 > .59	.03 < .08	.06 > .05	.77 > .61	1.32	832.5	-629.3	-832.5	629.3
35	1.104	1.113	1.019	.03 < .08	.07 > .05	.74 > .59	.03 < .08	.06 > .05	.77 > .61	1.32	1132.6	-857.0	-1132.6	857.0
40	1.124	1.128	1.029	.03 < .08	.07 > .05	.74 > .59	.03 < .08	.06 > .05	.77 > .61	1.32	1327.4	-1004.9	-1327.4	1004.9
45	1.145	1.146	1.041	.03 < .08	.07 > .05	.73 > .59	.03 < .08	.06 > .05	.77 > .61	1.32	1488.7	-1127.5	-1488.7	1127.5
50	1.173	1.169	1.053	.03 < .08	.07 > .05	.73 > .58	.03 < .08	.06 > .05	.77 > .61	1.32	1782.3	-1351.0	-1782.2	1351.0
55	1.202	1.192	1.066	.03 < .08	.07 > .05	.73 > .58	.03 < .08	.06 > .05	.77 > .61	1.32	2052.8	-1557.1	-2052.8	1557.1
60	1.210	1.188	1.081	.03 < .08	.07 > .05	.73 > .59	.03 < .08	.06 > .05	.77 > .61	1.32	2108.0	-1598.9	-2108.0	1598.9
65	1.222	1.194	1.094	.03 < .08	.07 > .05	.74 > .59	.03 < .08	.06 > .05	.77 > .61	1.32	2170.2	-1646.0	-2170.4	1646.0
70	1.172	1.148	1.106	.03 < .08	.06 > .05	.75 > .60	.03 < .08	.06 > .05	.77 > .61	1.32	1257.5	-950.6	-1257.5	950.6
75	1.191	1.163	1.112	.03 < .08	.06 > .05	.75 > .60	.03 < .08	.06 > .05	.77 > .61	1.32	1478.9	-1118.6	-1478.9	1118.6
80	1.207	1.177	1.119	.03 < .08	.06 > .05	.75 > .60	.03 < .08	.06 > .05	.77 > .61	1.32	1636.7	-1238.3	-1636.7	1238.3
85	1.216	1.185	1.127	.03 < .08	.06 > .05	.75 > .60	.03 < .08	.06 > .05	.77 > .61	1.32	1662.9	-1258.2	-1662.9	1258.2
90	1.212	1.181	1.134	.03 < .08	.06 > .05	.75 > .60	.03 < .08	.06 > .05	.77 > .61	1.32	1492.3	-1128.4	-1492.3	1128.4
95	1.201	1.173	1.141	.03 < .08	.06 > .05	.76 > .61	.02 < .07	.06 > .05	.77 > .61	1.32	1205.4	-910.6	-1205.4	910.6
100	1.195	1.172	1.145	.02 < .07	.06 > .05	.76 > .61	.02 < .07	.06 > .05	.77 > .61	1.32	1017.4	-768.1	-1017.4	768.1
∞	1.187	1.187	1.187	.02 < .07	.06 > .05	.77 > .61	.02 < .07	.06 > .05	.77 > .61	1.33	.0	.0	.0	.0

Table 5.5: (Contd.)

Time	Factor Ratios Between Country (1) and (2)			Factor Content of Per Unit Value of Output												Price	Import (+) & Export (-)			
				Country (1)						Country (2)							Country (1)		Country (2)	
	ES(1)/ES(2)	EU(1)/EU(2)	TK(1)/TK(2)	ESC/QC	ESI/QI.P	EUC/QC	EUI/QI.P	KC/QC	KI/QI.P	ESC/QC	ESI/QI.P	EUC/QC	EUI/QI.P	KC/QC	KI/QI.P		MC	MK	MC	MK
--- Case E: $(\alpha_1,\alpha_2,\alpha_3)$ = (.35,0,.65); $(\beta_1,\beta_2,\beta_3)$ = (.65,0,.35) ---																				
Initial State:		1.000	1.000			.04 >	.02	3.87 <	7.19			.04 >	.02	3.87 <	7.19	.21	.0	.0	.0	.0
Years After Shock:																				
5		1.000	1.000			.04 >	.02	3.87 <	7.19			.04 >	.02	3.87 <	7.19	.21	.0	.0	.0	.0
10		1.000	1.000			.04 >	.02	3.87 <	7.19			.04 >	.02	3.87 <	7.19	.21	.0	.0	.0	.0
15		1.000	1.000			.04 >	.02	3.87 <	7.19			.04 >	.02	3.87 <	7.19	.21	.0	.0	.0	.0
20		1.012	1.000			.04 >	.02	3.86 <	7.16			.04 >	.02	3.86 <	7.16	.21	-1179.2	5564.4	1179.2	-5564.4
25		1.072	1.002			.04 >	.02	3.78 <	7.03			.04 >	.02	3.78 <	7.03	.21	-7082.7	33129.4	7082.7	-33129.4
30		1.103	1.011			.04 >	.02	3.76 <	6.97			.04 >	.02	3.76 <	6.97	.21	-9120.1	42509.4	9120.1	-42509.4
35		1.114	1.022			.04 >	.02	3.75 <	6.69			.04 >	.02	3.75 <	6.69	.21	-9002.5	41941.1	9002.5	-41941.1
40		1.130	1.034			.04 >	.02	3.74 <	6.95			.04 >	.02	3.74 <	6.95	.21	-9395.8	43722.5	9395.8	-43722.5
45		1.149	1.047			.04 >	.02	3.73 <	6.93			.04 >	.02	3.73 <	6.93	.22	-9992.7	46433.0	9992.7	-46433.0
50		1.173	1.060			.04 >	.02	3.71 <	6.90			.04 >	.02	3.71 <	6.90	.22	-10919.4	50641.5	10919.4	-50641.5
55		1.198	1.074			.04 >	.02	3.70 <	6.87			.04 >	.02	3.70 <	6.87	.22	-11852.7	54861.9	11852.7	-54861.9
60		1.195	1.090			.04 >	.02	3.72 <	6.90			.04 >	.02	3.72 <	6.90	.22	-9995.2	46361.3	9995.2	-46361.3
65		1.203	1.104			.04 >	.02	3.72 <	6.91			.04 >	.02	3.72 <	6.91	.22	-9377.6	43516.8	9377.6	-43516.8
70		1.158	1.117			.04 >	.02	3.78 <	7.02			.04 >	.02	3.78 <	7.02	.21	-3936.5	18407.9	3936.5	-18407.9
75		1.174	1.122			.04 >	.02	3.77 <	7.00			.04 >	.02	3.77 <	7.00	.21	-4940.4	23070.1	4940.4	-23070.1
80		1.189	1.129			.04 >	.02	3.76 <	6.99			.04 >	.02	3.76 <	6.99	.21	-5622.6	26229.5	5622.6	-26229.5
85		1.195	1.137			.04 >	.02	3.76 <	6.99			.04 >	.02	3.76 <	6.99	.21	-5500.8	25664.5	5500.8	-25664.5
90		1.192	1.144			.04 >	.02	3.78 <	7.01			.04 >	.02	3.78 <	7.01	.21	-4424.6	20675.5	4424.6	-20675.5
95		1.183	1.151			.04 >	.02	3.79 <	7.04			.04 >	.02	3.79 <	7.04	.21	-3036.1	14217.0	3036.1	-14217.0
100		1.180	1.155			.04 >	.02	3.80 <	7.06			.04 >	.02	3.80 <	7.06	.21	-2377.7	11146.6	2377.7	-11146.6
∞		1.187	1.187			.04 >	.02	3.87 <	7.19			.04 >	.02	3.87 <	7.19	.21	.0	.0	.0	.0
--- Case F: $(\alpha_1,\alpha_2,\alpha_3)$ = (.6,0,.4); $(\beta_1,\beta_2,\beta_3)$ = (.4,0,.6) ---																				
Initial State:		1.000	1.000			.04 <	.05	.64 >	.43			.04 <	.05	.64 >	.43	1.65	.0	.0	.0	.0
Years After Shock:																				
5		1.000	1.000			.04 <	.05	.64 >	.43			.04 <	.05	.64 >	.43	1.65	.0	.0	.0	.0
10		1.000	1.000			.04 <	.05	.64 >	.43			.04 <	.05	.64 >	.43	1.65	.0	.0	.0	.0
15		1.000	1.000			.04 <	.05	.64 >	.43			.04 <	.05	.64 >	.43	1.65	.0	.0	.0	.0
20		1.012	1.000			.04 <	.05	.64 >	.42			.04 <	.05	.64 >	.42	1.64	1678.2	-1020.3	-1678.2	1020.3
25		1.072	1.001			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	10062.1	-6152.7	-10062.1	6152.7
30		1.103	1.008			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.63	13229.1	-8105.0	-13229.1	8105.0
35		1.114	1.017			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.63	13444.9	-8235.9	-13444.9	8235.9
40		1.130	1.027			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.63	14334.6	-8784.0	-14334.6	8784.0
45		1.149	1.037			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.63	15495.9	-9500.8	-15495.9	9500.8
50		1.173	1.048			.04 <	.05	.62 >	.42			.04 <	.05	.62 >	.42	1.63	17115.3	-10502.9	-17115.3	10502.9
55		1.198	1.060			.04 <	.05	.62 >	.42			.04 <	.05	.62 >	.42	1.63	18755.8	-11519.7	-18755.8	11519.7
60		1.195	1.074			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.63	16505.3	-10118.8	-16505.3	10118.8
65		1.203	1.086			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.63	15868.5	-9722.4	-15868.5	9722.4
70		1.158	1.097			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	8340.4	-5082.8	-8340.4	5082.8
75		1.174	1.103			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	9680.8	-5905.7	-9680.8	5905.7
80		1.189	1.110			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	10616.3	-6480.8	-10616.3	6480.8
85		1.195	1.118			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	10444.3	-6375.1	-10444.3	6375.1
90		1.192	1.125			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	8909.1	-5432.3	-8909.1	5432.3
95		1.183	1.132			.04 <	.05	.63 >	.42			.04 <	.05	.63 >	.42	1.64	6874.6	-4186.1	-6874.6	4186.1
100		1.180	1.137			.04 <	.05	.64 >	.42			.04 <	.05	.64 >	.42	1.64	5820.5	-3542.0	-5820.5	3542.0
∞		1.187	1.187			.04 <	.05	.64 >	.43			.04 <	.05	.64 >	.43	1.65	.0	.0	.0	.0

CHAPTER 6

SUMMARY AND OUTLOOK FOR FURTHER RESEARCH

6.1 Introduction

This final chapter provides a brief summary and discussion of the simulation results and attempts a review of the possible policy applications of the model. In chapter 5, simulation experiments were conducted under the assumption that the two nations in question were identical at the beginning and we traced the consequences of shocks to the initial stationary state equilibrium introduced by the variation of some basic parameters of the model. It was shown that a temporary change in some basic parameters (for example, changes in the total fertility rate or in migration propensities) in one nation, has a series of economic-demographic consequences for both countries. Our simulation experiments were used to trace the pattern of these consequences over time.

The simulation experiments in this thesis were undertaken with the intention of providing guidelines for policy-making and research in an area where problems of demographic and economic development are still unstructured. Although it is impossible to provide a complete analysis in all dimensions, we hope that this study has highlighted the basic dimensions in which economic-demographic models should be studied.

This concluding chapter starts in section 6.2 with a brief discussion of the various simulation experiments. In section 6.3, we discuss the possible application of the model to the analysis of economic-demographic problems. Section 6.4 concludes the chapter with an overview of the outlook for further research.

6.2 Summary of Simulation Results

This thesis has tried to provide a theoretical exposition of the interrelationships between the population and economy, and between two countries. The results show that changes in the total fertility rate or the migration propensities change not only the composition of population and other demographic variables but also affect major economic variables. At the same time, wage rate changes have feedback effects on the change in population movements and the labour type distribution through education. To facilitate comparison, all the various experiments conducted in this study are listed in table 6.1 with an accompanying specification of the parameter values employed in each case.

In all 18 experiments conducted in this study, two basic shocks have been employed for the tests: a temporary increase in the total fertility rate and a temporary increase in migration propensities. In all cases the shocks occur in country 1. With regard to the changes in the total fertility rate, the changes are introduced in three different situations depending on whether goods and/or labour move internationally; the changes in migration propensities are introduced only when there are migration flows. Apart from the standard set of parameters, alternative sets are specified in order to test the sensitivity of the model to its basic parameters and to examine the results in a variety of possible cases. For instance, the values assigned to the τ's represent various migration elasticities; the ρ's and γ's determine the levels of school enrollment rates; and the α's and β's determine the consequences of the changes in the parameters of the production functions within the framework of four major propositions from international trade theory.

Table 6.1: Listing of the Simulation Experiments

Experiments	Specification of Parameter Values
I. A Temporary Increase in the Total Fertility Rate (F) in Country 1:	
(i) No Trade in Goods:	
(1)	$\tau = .5$
(2)	$\tau = 0$
(3)	$\tau = 1$
(ii) Only Goods Move Internationally:	
(4)	Standard Case
(5)	$\rho = 0$
(6)	$\gamma = 0$
(7)	$\rho = 1;\ \gamma = .1$
(8)	$(\alpha_1, \alpha_2, \alpha_3) = (.5, .3, .2)$; $(\beta_1, \beta_2, \beta_3) = (.5, .4, .1)$
(9)	$(\alpha_1, \alpha_2, \alpha_3) = (.35, .35, .3)$; $(\beta_1, \beta_2, \beta_3) = (.65, .2, .15)$
(10)	$\bar{e}^* = 0$; $(\alpha_1, \alpha_2, \alpha_3) = (.35, 0, .65)$; $(\beta_1, \beta_2, \beta_3) = (.65, 0, .35)$
(11)	$\bar{e}^* = 0$; $(\alpha_1, \alpha_2, \alpha_3) = (.6, 0, .4)$; $(\beta_1, \beta_2, \beta_3) = (.4, 0, .6)$
(12)	$(\alpha_1, \alpha_2, \alpha_3) = (.5, .1, .4)$; $(\beta_1, \beta_2, \beta_3) = (.4, .3, .3)$
(iii) Both Labour and Goods Move Internationally:	
(13)	$\tau = .5$
(14)	$\tau = 0$
(15)	$\tau = 1$
II. A Temporary Increase the Migration Propensities in Country 1: No Trade in Goods:	
(16)	$\tau = .5$
(17)	$\tau = 0$
(18)	$\tau = 1$

In what follows, we summarize the results of the experiments. The major observations are discussed according to the economic and demographic variables affected by the changes. Detailed quantitative results are presented in tables 6.2 to 6.7.

Population Size and Net Immigration Rates (Tables 6.2 and 6.3):

(1) As a result of migration flows, a temporary increase the first country's total fertility rate will increase the population size in both countries. The increase in population is restricted to country 1 if there is no migration allowed.

(2) One effect of international trade is to reduce migration flows, and hence the rate of population growth in country 1, when trade is allowed, is slightly faster whereas it is slower in country 2. That is because trade will alter wage rates and hence migration propensities.[1]

(3) A temporary increase in migration propensities in country 1 will increase country 2's population size for some years, with a subsequent gradual return to the initial sizes through migration reversal. The latter results from the reduction of wage rates in country 2 due to the decline in the marginal productivity of its factors.

(4) In all cases, it is shown that the difference in population growth rates between nations will be smaller if there is a higher migration elasticity. That is to say, a higher migration propensity will tend to lead to international long-run population equilibrium sooner.

<u>Labour Force (Table 6.4)</u>:

(1) Labour force changes generally result from changes in the age-sex-skill composition of population. The increase in the younger age group in country 1 resulting from a temporary increase in the total fertility rate does not change the labour force in both countries in the first 15 years but increases them afterwards.

(2) Since the changes in migration propensities depend on the wage differentials between countries as well as the migration elasticities, the larger the elasticity of migration, the greater the change in the size of the labour force.

(3) The change of age-sex-skill composition of population due to the changes in school enrollment rates affect the total labour force according to the different labour force participation rates in the various categories.

<u>Capital Stocks (Table 6.5)</u>:

(1) A temporary increase in the total fertility rate in country 1 has positive effects on capital, although the effects are rather smooth. However, a larger migration elasticity has the effect of slowing down the growth of capital stock in country 1 as a result of the relatively slow growth of labour force engaged in production. These results apply equally to country 2.

(2) Without migration, the increment to capital stock occurs only in country 1 and the level of the change is affected by the changes in production activity through the changes in

the supply of skilled labour. In particular, when the production of investment goods is capital intensive, the increase in capital stock is much slower.

(3) When migration is not allowed, capital stock in country 2 changes only slightly 20 years after the initial shock resulting from the existence of international trade and from the consequence of changes in the factor intensiveness of commodity production. When the intensity of capital is equal in both commodities, no specific change of capital occurs in country 2.

Per Capita Income (Table 6.6):

(1) Since per capita income increases directly with output and inversely with total population, the increase in the population of the non-working age-group due to fertility increases in country 1, in conjunction with migration to country 2, leads to decreases in per capita income in both countries. This result is followed by a gradual increase in per capita income after some years as a result of the increases in the labour force and capital stock employed in production.

(2) In the no-migration case, an increase in the total fertility rate causes an immediate reduction in per capita income in country 1 but leaves it unchanged in country 2. However, income per capita in country 2 is altered by the levels of production as a result of trade after year 20. These changes are not particularly sensitive to the school enrollment parameters, but are significantly affected by the change in production parameters.

(3) A sudden increase in the emigration propensities in country 1 leads to an increase in per capita income in country 1 but a reduction in per capita income in country 2. However, the occurrence of migration reversal brings the per capita income in both countries back to their initial levels gradually.

Commodity Trade (Table 6.7):

(1) The volume of trade is determined by both the differences in the abundance of factors between countries and the differences in the commodity-intensity of factors of production between industries. Fertility increases in country 1 do not cause any change in trade until the new-born have reached working age.

(2) Experiments show that the Heckscher-Ohlin theorem, which states that a country exports that commodity which uses intensively that factor which is relatively abundant, applies even in our 3-input, 2-output cases, although a strong assumption of factor abundance is needed when both the abundant and scarce factors are equally intensive in the production of the same commodities.

(3) The amount of trade is affected by changes in the amount of each labour type. The amount of trade is highest when more individuals are engaged in occupations requiring skilled labour and is lowest when the school enrollment rates are not responsive to wage-rate changes.[2]

(4) Migration has a large impact on the reduction in the amount of trade since it lowers labour abundance levels. However, experiments indicate that the amount of trade is larger when there is a larger migration elasticity.

Finally, our experiments show that, under the assumption of no technical progress, all variables, except the volume of trade, income per capita, wage rates, and return to capital, grow at the same rate as population in a country in long-run equilibrium. Migration also provides the same growth rate in both countries.

6.3 Application of the Model in Policy Making

In this section we discuss some implications of our simulation results for policy making. Although the model constructed in this thesis is theoretical and does not relate to any existing country, the results of the simulation experiments are of interest in that they shed some light on the basic influences of population changes in specific economic-demographic situations. They also show the patterns of interactions among sectors within the systems, a consideration which is especially important in those cases in which the changing paths may not be seen using comparative statics methods. These outcomes are useful inasmuch as they provide insights into the dynamics of problems to which economic or demographic policies are applied.

We have seen from our results that a sudden increase in the total fertility rate in one country results in an increase in population, not only in that country, but also in the other country, as a result of migration. Consequently, it leads to a larger labour force and capital stock in both countries; the increase starts some 15 to 20 years after the shock and lasts for more than a century. Per capita income falls immediately as a result of the increase in the non-productive population in both countries, through migration. In the absence of migration, the basic variables, except the amount of trade in country 2, are not highly responsive to the changes in the total fertility rate in country 1.

We have also seen that the response to an increase in the migration propensities in country 1 is immediate. The effect is to decrease country 1's population, its labour force, and also its capital stock, for more than a century; however, per capita income is higher in country 1 for only four decades, and lower thereafter. As for country 2, all the variables change in the opposite direction.

Although the simulation experiments do not cover all possibilities, they show the outcomes of different demographic and economic changes, whether these involve the movements of people or goods. The results indicate the need to consider the impact of these patterns of international reaction on both population and commodity movements as well as the time horizon of the expected outcomes after the demographic policies have been initiated. Supposing the time horizon to be very short, migration policies may be most effective since they provide immediate effects on variables. If the planning horizon is long, say more than 50 years, policies affecting fertility would be more appropriate. However, the strength of these policy instruments is greatly affected by the migration propensities: the larger the migration propensities, the more effective would be migration policies.

In fact, the policy employed depends on the particular interest of the policy maker. Generally, a demographic policy has two major types of effects, social and economic. The former include changes in the composition of population, income distribution, education, health care, migration, and so on, whereas the latter relate to the growth of national income, prices, wage rates, investment, and international trade, etc.. In any case, the policy maker may estimate and compare the possible results of each policy or several of them in combination. The selection of the appropriate policy depends on the goals of the society. For example, the policy of increasing fertility rates may depress the per capita income at present but may yield benefits in terms of future economic growth. The policy for increasing immigration, on the other hand, may immediately improve economic welfare but may worsen the situation with regard to the price level and employment. The government may apply both policies simultaneously in pursuing short-term and long-term targets.

Although our simulation experiments are not concerned with social effects, they give guidance about the possible pattern of changes in age-distribution of the population and in skill-distribution of the labour force. Changes in the age-distribution of the population are particularly important to the social planner. The simulated results of these changes provide some indication of the appropriate selection and timing of social policies. For instance, urban development, residential construction, provision of educational facilities and health care expenditures have to be measured and designed according to the time paths of the change in population and its composition as a result of the changes in fertility rates and/or changes in the migration rates. In other words, various stages of social policies should be timed in accordance with the changes in fertility and migration.

Our model does not deal with the feedback effects of changes in income distribution on fertility, although it deals with the effects of wage rate changes on migration and school enrollment. However, it is not particularly difficult to extend the model in this direction. We should note that even if a government has no explicit population policy to alter demographic variables, many social and economic policies and changes in the international system do have important demographic impacts. Our simulation experiments indicate that a change in foreign population affects not only domestic economic variables through trade, but also affects demographic variables directly through migration, indirectly through changes in economic variables. Changes in wage rates influence not only the skill composition of the population (by the change of school enrollment) but also the level of migration (by the change of migration propensities). It will also be possible to extend the analysis to consider the relationships between fertility and education, income distribution, infant mortality and female labour force participation rates.

It is usually stressed that cultural, religious, and sociological variables are the basic determinants of fertility, but economic variables may also be important.[3] Suppose fertility is affected by economic variables. The problem then is to find effective policy instruments for use in influencing fertility. For instance, if the relative cost of children has an important influence on fertility rates, a subsidy for children or a change in the cost of contraception can be considered. However, the effectiveness of such policies would depend on the responsiveness of fertility to changes in cost. Also, while it might be feasible to change the distribution of income through fertility changes, such a policy would have to work through a spectrum of other policies involving economic growth, political stability and social welfare. Furthermore, it is often difficult to measure and alter tastes or preferences; the only possible way may be through education or political influences as in the Chinese cultural revolution or the religious revolution in Iran.

Finally, the government may set some policy guidelines for migration since it has important impacts on demographic growth and economic development. The objectives may be to increase or decrease the levels of immigration or emigration. To decrease the level of migration (in or out), the government may apply restrictive policies either by imposing quotas and limits or by imposing taxes. An attempt to increase the level of migration often requires either economic or political influences. Our model stresses the wage-rate differentials between countries as a major factor causing changes in migration propensities. Wage rates are determined by the economic situation in each country and can be changed only by effective economic policies, including migration subsidies.

6.4 Outlook for Further Research

The foregoing discussion has focussed mainly on our model and the simulation results based on the assumption that two nations are initially identical. However, in the real world, no two nations are identical. Thus it would be desirable to conduct an empirical investigation of the interrelationships among demographic and economic variables in two distinct nations and this would be especially interesting if one is a developed and the other a developing country. These two types of countries would normally have entirely different economic and demographic characteristics. The patterns of production, which are determined by different production processes and different states of technology and skill-composition of the population, will also be different. Different production processes may also imply different relationships between capital and labour in different occupations. In this context, economic factors relating to the country's labour force, unemployment rates, wage rates and per capita income, and so on, are also important. The population size and age-distribution are determined by the fertility, mortality, and migration rates which are all generally higher in developing countries. Other significant differences between these countries may include those relating to consumption and saving patterns, education level and skill patterns.

Since the 2-country, 2-sector simulation model has not been extensively investigated in the literature, we might extend our model to a model for two distinct countries. Supposing that all parameter values of this empirical two country model have been specified, we could generate simulation results for the two countries under various assumptions about the policies being pursued. Such a simulation exercise would have two main purposes. The first would be to examine the prospects of the developed country for economic growth, both absolutely and relative to the developing country, while the other would be to concentrate on the developing country. Obviously, the observed large differential in population growth rates between the developed and developing countries may have important social, economic, and political implications. An understanding of the long-term implications of the demographic phenomena is of importance to policy planners in both countries. For the developed country, policy simulations may concentrate on the effects of immigration restriction, fertility rate increases or decreases, and the effects of trade restriction on the change of demographic and economic variables in both countries. As far as the developing country is concerned, policy simulations may focus on the trade-offs of various strategies to achieve sustained long-term growth of its per capita income. The policy strategies may include accelerated fertility reduction, increased domestic savings, increased investment in education and improved health facilities to induce higher productivity. It is also possible to extend the study to include the impact of the economic assistance from the developed country to the developing country.

The second possible field of research is in the area of trade theory. Our results in section 5.4 indicate some dynamic processes of international trade within the context of the Heckscher-Ohlin theorem. We have demonstrated that the Vanek approach to the Heckscher-Ohlin theorem is correct under certain circumstances. We may first apply the model to study the dynamic effects of other trade theorems, extending the study to the areas of commercial policy. The basic framework of the analysis may then be extended to more-than-2-country, 3-input, 2-output cases. The latter extension should be particularly interesting since no dynamic proof for it exists.

Finally, our simulation experiments have been restricted to the consequences of fertility and migration propensity changes for some selected variables. We may investigate the effects of demographic changes on other variables, especially the relationships among the changes in the level of education, consumption, the quality of health care, and so on, and the effects of these on demographic and economic variables. Furthermore, our model can also be employed as the basis for an extension to a framework of econometric-demographic modelling with particular reference to 2-country models. The application of the model to the study of two regions or nations would be a major concern in future research with this model.

The above brief discussion, we hope, will suffice to suggest to the reader a range of possibilities for extension of this thesis and will provide the necessary stimulation for further research and policy analysis of an economic-demographic variety.

FOOTNOTES TO CHAPTER 6

1. It is not necessarily true that trade will always lower the level of migration, but in fact, in addition to the Stolper-Samuelson theorem, it also depends on the shape of production functions which determines whether the level of wage differentials between countries will converge or diverge.
2. According to experiments (4) to (7), unskilled labour is not a dominant factor in the determination of trade since it is equally intensive in the production of both goods. However, when the production functions are changed, unskilled labour could become relevant in determining trade as school enrollment rates and the intensity of this factor in commodity production become altered.
3. Among the notable authors on this topic, we should mention Backer (1960), Easterlin (1969), Cochrane (1975), and Enke (1970) to name just a few. Since this topic is not within the scope of this thesis, it would not be discussed any further here.

Table 6.2: Index of Population Size in Experiments Involving Various Assumptions On Trade, Migration, and Parameters

Time	Exp.1	Exp.2	Exp.3	Exp. 4–12	Exp.13	Exp.14	Exp.15	Exp.16	Exp.17	Exp.18
Country (1):										
Initial State:										
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:										
5	106.0	106.0	106.0	106.5	106.0	106.0	106.0	94.7	94.7	94.7
10	105.6	105.6	105.6	106.5	105.6	105.6	105.6	95.4	95.1	95.8
15	105.4	105.4	105.4	106.5	105.4	105.4	105.4	96.0	95.4	96.5
20	105.5	105.5	105.5	106.8	105.5	105.5	105.5	96.4	95.8	97.0
25	105.9	106.0	105.9	108.1	105.9	106.0	105.9	96.8	96.1	97.4
30	106.8	106.9	106.7	110.1	106.8	106.9	106.7	97.2	96.4	97.8
35	107.4	107.7	107.2	111.8	107.5	107.7	107.4	97.5	96.7	98.1
40	107.7	108.0	107.4	112.6	107.7	108.0	107.6	97.8	97.1	98.3
45	107.8	108.2	107.6	113.3	107.9	108.2	107.7	98.1	97.5	98.5
50	108.2	108.5	107.9	114.3	108.3	108.5	108.1	98.3	97.8	98.7
55	108.7	109.1	108.4	115.5	108.8	109.1	108.6	98.6	98.1	98.8
60	109.2	109.6	108.9	116.8	109.3	109.6	109.1	98.7	98.4	98.9
65	109.6	110.0	109.3	117.7	109.7	108.0	109.5	98.9	98.6	99.0
70	109.8	110.1	109.5	118.1	109.8	110.1	109.7	99.0	98.8	99.1
75	109.4	109.8	109.3	117.7	109.5	109.7	109.4	99.1	99.0	99.1
80	109.4	109.6	109.3	117.8	109.4	109.6	109.3	99.2	99.1	99.1
85	109.5	109.7	109.4	118.1	109.5	109.7	109.5	99.2	99.3	99.2
90	109.6	109.8	109.6	118.5	109.6	109.8	109.6	99.3	99.4	99.2
95	109.7	109.8	109.6	118.6	109.7	109.8	109.6	99.3	99.5	99.3
100	109.6	109.7	109.6	118.5	109.6	109.7	109.5	99.4	99.6	99.3
∞	109.3	109.3	109.3	118.7	109.3	109.3	109.3	100.0	100.0	100.0
Country (2):										
Initial State:										
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:										
5	100.5	100.5	100.5	100.0	100.5	100.5	100.5	105.3	105.3	105.3
10	100.9	100.9	100.9	100.0	100.9	100.9	100.9	104.6	104.9	104.2
15	101.1	101.1	101.1	100.0	101.1	101.1	101.1	104.0	104.6	103.5
20	101.3	101.3	101.3	100.0	101.3	101.3	101.3	103.6	104.2	103.0
25	102.1	102.1	102.1	100.0	102.1	102.1	102.1	103.2	103.9	102.6
30	103.3	103.2	103.5	100.0	103.3	103.2	103.4	102.8	103.6	102.2
35	104.4	104.1	104.6	100.0	104.3	104.1	104.4	102.5	103.3	101.9
40	105.0	104.7	105.2	100.0	104.9	104.7	105.1	102.2	102.9	101.7
45	105.5	105.1	105.8	100.0	105.4	105.1	105.6	101.9	102.5	101.5
50	106.1	105.7	106.4	100.0	106.0	105.7	106.2	101.7	102.2	101.3
55	106.8	106.4	107.1	100.0	106.7	106.4	106.9	101.4	101.9	101.2
60	107.5	107.1	107.8	100.0	107.4	107.1	107.6	101.3	101.6	101.1
65	108.1	107.6	108.3	100.0	108.0	107.7	108.1	101.1	101.4	101.0
70	108.4	108.0	108.6	100.0	108.3	108.0	108.5	101.0	101.2	100.9
75	108.3	108.0	108.5	100.0	108.2	108.0	108.4	100.9	101.0	100.9
80	108.4	108.1	108.5	100.0	108.4	108.1	108.5	100.8	100.9	100.9
85	108.6	108.4	108.7	100.0	108.6	108.4	108.7	100.8	100.7	100.8
90	108.9	108.7	108.9	100.0	108.8	108.7	108.9	100.7	100.6	100.8
95	109.0	108.8	109.0	100.0	109.0	108.8	109.0	100.7	100.5	100.7
100	108.9	108.9	109.0	100.0	109.0	108.9	109.0	100.6	100.4	100.7
∞	109.3	109.3	109.3	100.0	109.3	109.3	109.3	100.0	100.0	100.0

Table 6.3: Percentage Ratio of Net Immigration to Population in Experiments Involving Various Assumptions on Trade, Migration, and Parameters

Time	Exp.1	Exp.2	exp.3	Exp. 4-12	Exp.13	Exp.14	Exp.15	Exp.16	Exp.17	Exp.18
Country (1):										
Initial State:										
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Years After Shock:										
5	-.51	-.51	-.51	.00	-.51	-.51	-.51	-5.19	-5.19	-5.19
10	-.32	-.32	-.32	.00	-.32	-.32	-.32	1.25	.93	1.58
15	-.19	-.19	-.19	.00	-.19	-.19	-.19	.82	.66	.94
20	-.17	-.17	-.17	.00	-.17	-.17	-.17	.59	.51	.61
25	-.48	-.47	-.50	.00	-.48	-.47	-.50	.50	.47	.48
30	-.53	-.44	-.62	.00	-.50	-.44	-.56	.42	.43	.40
35	-.39	-.31	-.46	.00	-.36	-.31	-.41	.33	.36	.28
40	-.27	-.23	-.30	.00	-.26	-.23	-.28	.22	.29	.15
45	-.21	-.18	-.21	.00	-.20	-.19	-.21	.15	.24	.07
50	-.19	-.18	-.18	.00	-.19	-.18	-.18	.11	.20	.03
55	-.17	-.17	-.16	.00	-.17	-.16	-.15	.09	.17	.03
60	-.13	-.13	-.11	.00	-.13	-.13	-.11	.08	.14	.03
65	-.08	-.11	-.05	.00	-.09	-.11	-.07	.06	.12	.02
70	-.05	-.08	-.02	.00	-.06	-.08	-.04	.04	.10	.00
75	-.01	-.07	.05	.00	-.03	-.07	.01	.02	.08	-.01
80	-.01	-.06	.03	.00	-.02	-.06	.00	.02	.07	-.01
85	-.01	-.05	.01	.00	-.02	-.05	-.01	.02	.06	.01
90	-.01	-.04	.01	.00	-.02	-.04	-.01	.02	.05	.02
95	-.00	-.03	.01	.00	-.01	-.03	-.01	.02	.04	.02
100	-.00	-.03	.00	.00	-.01	-.03	-.01	.02	.03	.02
∞	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Country (2):										
Initial State:										
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Years After Shock:										
5	.54	.54	.54	.00	.54	.54	.54	4.68	4.67	4.67
10	.33	.33	.33	.00	.33	.33	.33	-1.15	-.84	-1.45
15	.20	.20	.20	.00	.20	.20	.20	-.76	-.60	-.88
20	.18	.18	.18	.00	.18	.18	.18	-.55	-.47	-.58
25	.50	.49	.51	.00	.50	.49	.51	-.46	-.44	-.46
30	.55	.45	.64	.00	.52	.45	.58	-.40	-.40	-.38
35	.40	.32	.47	.00	.37	.32	.42	-.31	-.34	-.27
40	.29	.24	.30	.00	.27	.24	.29	-.22	-.28	-.18
45	.21	.19	.21	.00	.21	.19	.21	-.14	-.22	-.07
50	.19	.18	.18	.00	.19	.18	.18	-.11	-.19	-.03
55	.17	.17	.16	.00	.17	.17	.16	-.09	-.16	-.03
60	.13	.13	.11	.00	.13	.13	.12	-.07	-.14	-.03
65	.08	.11	.05	.00	.09	.11	.07	-.05	-.12	-.02
70	.05	.08	.02	.00	.06	.08	.04	-.04	-.09	-.00
75	.01	.07	-.05	.00	.03	.07	-.01	-.02	-.08	.01
80	.01	.06	-.03	.00	.02	.06	-.00	-.02	-.07	.01
85	.01	.05	-.01	.00	.02	.05	.01	-.02	-.05	-.01
90	.01	.04	-.01	.00	.02	.04	.01	-.02	-.05	-.01
95	.01	.03	-.06	.00	.01	.03	.01	-.02	-.04	-.02
100	.00	.03	-.00	.00	.01	.03	.01	-.02	-.03	-.02
∞	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Table 6.4: Index of Labour Force in Experiments Involving Various Assumptions on Trade, Migration, and Parameters

Time	Exp.1	Exp.2	Exp.3	Exp.4	Exp.5	Exp.6	Exp.7	Exp.8	Exp.9	Exp.10	Exp.11	Exp.12	Exp.13	Exp.14	Exp.15	Exp.16	Exp.17	Exp.18
Country (1):																		
Initial State:																		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:																		
5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	94.0	94.0	94.0
10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.4	94.9	95.8
15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.1	95.4	96.7
20	102.5	102.5	102.5	103.1	103.0	103.2	103.3	102.9	103.1	105.7	105.7	103.6	102.5	102.5	102.5	96.3	95.5	96.9
25	108.2	108.3	108.2	111.1	111.0	111.1	111.1	111.1	111.1	111.1	111.1	111.1	108.2	108.3	108.2	96.4	95.5	97.0
30	107.2	107.3	107.1	110.6	110.5	110.6	110.5	110.6	110.6	110.4	110.4	110.5	107.3	107.3	107.2	96.8	96.0	97.4
35	106.8	107.0	106.6	110.7	110.6	110.7	110.6	110.7	110.7	110.6	110.6	110.6	106.9	107.0	106.8	97.5	96.6	98.0
40	107.1	107.4	106.9	111.7	111.6	111.7	111.7	111.7	111.7	112.2	112.2	111.7	107.2	107.4	107.1	98.0	97.2	98.5
45	108.4	108.7	108.2	114.1	114.1	114.2	114.2	114.1	114.2	115.0	115.0	114.3	108.6	108.7	108.4	98.3	97.7	98.7
50	110.1	110.4	109.8	117.3	117.3	117.3	117.3	117.3	117.3	117.7	117.7	117.3	110.2	110.4	110.0	98.5	98.0	98.8
55	111.0	111.4	110.7	119.4	119.4	119.4	119.4	119.4	119.4	119.4	119.4	119.4	111.8	111.4	111.0	98.6	98.2	98.8
60	110.6	111.0	110.3	119.0	119.1	119.0	119.0	119.0	119.0	118.8	118.8	119.0	110.7	111.0	110.5	98.7	98.5	98.9
65	110.9	111.3	110.6	119.8	119.9	119.8	119.9	119.8	119.8	119.8	119.8	119.8	111.0	111.3	110.8	99.0	98.7	99.0
70	108.4	108.8	108.2	116.0	116.0	115.9	116.0	115.9	116.0	116.1	116.1	116.0	108.5	108.8	108.4	99.1	99.0	99.2
75	109.2	109.5	109.0	117.5	117.6	117.5	117.6	117.4	117.5	117.7	117.7	117.6	109.2	109.5	109.1	99.2	99.2	99.2
80	109.9	110.1	109.7	118.9	118.9	118.8	118.9	118.8	118.8	118.9	118.9	118.9	109.8	110.1	109.8	99.3	99.3	99.2
85	110.1	110.3	110.0	119.4	119.5	119.4	119.5	119.4	119.4	119.3	119.3	119.4	110.1	110.3	110.9	99.3	99.4	99.2
90	109.9	110.0	109.8	119.1	119.1	119.0	119.1	119.0	119.0	119.0	119.0	119.1	109.9	110.0	109.8	99.3	99.5	99.3
95	109.4	109.5	109.4	118.3	118.3	118.3	118.4	118.3	118.3	118.3	118.3	118.3	109.4	109.5	109.4	99.4	99.6	99.3
100	109.3	109.4	109.3	118.1	118.1	118.1	118.1	118.0	118.1	118.1	118.1	118.1	109.3	109.4	109.2	99.4	99.7	99.3
∞	109.3	109.3	109.3	118.7	118.7	118.7	118.7	118.7	118.7	118.7	118.7	118.7	109.3	109.3	109.3	100.0	100.0	100.0
Country (2):																		
Initial State:																		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:																		
5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	106.0	106.0	106.0
10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	104.6	105.1	104.2
15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	103.9	104.6	103.3
20	100.6	100.6	100.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.6	100.6	100.6	103.7	104.5	103.1
25	102.8	102.8	102.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	102.8	102.8	102.8	103.6	104.5	103.0
30	103.4	103.3	103.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	103.3	103.3	103.4	103.2	104.0	102.6
35	103.9	103.7	104.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	103.8	103.7	103.9	102.5	103.4	102.0
40	104.6	104.3	104.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	104.4	104.3	104.6	102.0	102.8	101.5
45	105.7	105.4	106.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	105.6	105.4	105.7	101.7	102.3	101.3
50	107.2	106.9	107.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	107.1	106.9	107.3	101.5	102.0	101.2
55	108.4	108.0	108.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	108.2	108.0	108.4	101.4	101.8	101.2
60	108.4	108.0	108.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	108.3	108.0	108.5	101.3	101.5	101.1
65	108.9	108.5	109.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	108.8	108.5	109.0	101.1	101.3	101.0
70	107.5	107.2	107.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	107.4	107.2	107.6	100.9	101.0	100.8
75	108.3	108.0	108.4	100.0	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.0	108.2	108.0	108.4	100.8	100.8	100.8
80	109.0	108.7	109.1	100.0	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.0	108.9	108.7	109.0	100.7	100.7	100.8
85	109.3	109.1	109.4	100.0	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.0	109.3	109.1	109.4	100.7	100.6	100.8
90	109.2	109.0	109.2	100.0	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.0	109.2	109.0	109.2	100.7	100.5	100.7
95	108.8	108.7	108.9	100.0	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.0	108.9	108.7	108.9	100.6	100.4	100.7
100	108.8	108.7	108.8	100.0	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.0	108.8	108.7	108.8	100.6	100.3	100.7
∞	109.3	109.3	109.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	109.3	109.3	109.3	100.0	100.0	100.0

Table 6.5: Index of Total Capital in Experiments Involving Various Assumptions on Trade, Migration, and Parameters

Time	Exp.1	Exp.2	Exp.3	Exp.4	Exp.5	Exp.6	Exp.7	Exp.8	Exp.9	Exp.10	Exp.11	Exp.12	Exp.13	Exp.14	Exp.15	Exp.16	Exp.17	Exp.18
Country (1):																		
Initial State:																		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:																		
5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	99.1	99.1
15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.5	98.5	98.6
20	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.1	97.9	98.3
25	100.0	100.0	100.0	100.1	100.1	100.1	100.1	100.0	100.1	100.1	100.1	101.1	100.0	100.0	100.0	97.9	97.6	98.1
30	100.6	100.6	100.6	100.7	100.7	100.7	100.7	100.6	100.6	100.9	101.0	100.8	100.5	100.5	100.5	97.7	97.3	98.0
35	101.3	101.3	101.3	101.6	101.6	101.6	101.6	101.5	101.5	101.8	102.0	101.9	101.2	101.2	101.2	97.6	97.1	98.0
40	102.0	102.0	102.0	102.7	102.7	102.7	102.7	102.5	102.4	102.8	103.1	103.0	101.9	102.0	101.9	97.6	97.1	98.0
45	102.8	102.8	102.7	103.8	103.8	103.8	103.8	103.6	103.5	103.8	104.3	104.2	102.7	102.7	102.7	97.7	97.1	98.1
50	103.5	103.6	103.4	105.1	105.1	105.1	105.1	104.8	104.6	104.9	105.5	105.5	103.5	103.5	104.4	97.8	97.2	98.2
55	104.4	104.5	104.3	106.4	106.5	106.4	106.5	106.1	105.8	106.2	106.9	107.0	104.3	104.4	104.3	97.9	97.4	98.3
60	105.3	105.4	105.1	108.0	108.0	107.9	108.0	107.6	107.2	107.5	108.4	108.5	105.2	105.3	105.2	98.0	97.5	98.4
65	106.0	106.2	105.9	109.3	109.4	109.3	109.4	108.9	108.4	108.7	109.7	109.9	106.0	106.1	106.0	98.1	97.7	98.4
70	106.7	106.9	106.6	110.6	110.7	110.6	110.8	110.2	109.6	109.8	110.9	111.2	106.7	106.8	106.9	98.2	97.8	98.5
75	106.9	107.1	106.8	111.2	111.3	111.2	111.4	110.8	110.2	110.4	111.5	111.8	107.0	107.1	106.9	98.3	98.0	98.6
80	107.2	107.4	107.1	111.9	112.0	111.9	112.1	111.5	110.9	111.1	112.1	112.9	107.3	107.4	107.2	98.5	98.2	98.7
85	107.6	107.8	107.4	112.7	112.8	112.7	112.9	112.3	111.6	111.8	112.9	113.3	107.6	107.8	107.6	98.6	98.3	98.7
90	107.9	108.1	107.8	113.5	113.6	113.5	113.8	113.1	112.4	112.6	113.7	114.1	108.0	108.1	107.9	98.7	98.5	98.8
95	108.2	108.4	108.1	114.2	114.3	113.1	114.4	113.7	113.0	113.2	114.3	114.7	108.3	108.4	108.2	98.8	98.6	98.9
100	108.4	108.5	108.3	114.7	114.7	114.6	114.9	114.2	113.5	113.7	114.8	115.2	108.4	108.6	108.4	98.8	98.8	98.9
∞	109.3	109.3	109.3	118.7	118.7	118.7	118.7	118.7	118.7	118.7	118.7	118.7	109.3	109.3	109.3	100.0	100.0	100.0
Country (2):																		
Initial State:																		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:																		
5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.8	100.8	100.8
15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	101.4	101.5	101.4
20	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	101.8	102.0	101.7
25	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	102.1	102.4	101.9
30	100.2	100.2	100.2	100.1	100.1	100.1	100.1	100.0	99.8	99.8	100.1	100.0	100.2	100.2	100.2	102.3	102.7	102.0
35	100.5	100.5	100.6	100.2	100.2	100.2	100.2	100.0	99.6	99.6	100.3	100.0	100.6	100.6	100.6	102.4	102.9	102.0
40	101.0	101.0	101.0	100.3	100.3	100.3	100.3	99.9	99.4	99.4	100.4	100.1	100.1	101.1	101.1	102.4	102.9	102.0
45	101.5	101.5	101.6	100.5	100.5	100.5	100.5	100.0	99.3	99.2	100.6	100.2	101.6	101.6	101.6	102.3	102.9	101.9
50	102.1	102.1	102.2	100.6	100.6	100.6	100.6	100.0	99.0	99.0	100.7	100.2	102.2	102.2	102.2	102.2	102.7	101.8
55	102.8	102.7	102.9	100.7	100.7	100.7	100.7	100.0	98.9	98.8	100.8	100.3	102.9	102.8	102.9	102.1	102.6	101.7
60	103.6	103.4	103.7	100.9	100.9	100.9	100.9	100.0	98.7	98.6	100.9	100.4	103.6	103.6	103.7	102.0	102.5	101.6
65	104.3	104.1	104.4	101.0	101.0	101.0	101.0	100.0	98.5	98.5	101.0	100.5	104.3	104.2	104.3	101.9	102.3	101.6
70	105.0	104.8	105.1	101.0	101.1	101.1	101.0	100.0	98.4	98.4	101.1	100.5	105.0	104.9	105.0	101.8	102.2	101.5
75	105.3	105.1	105.4	101.0	101.0	101.0	101.0	100.0	98.4	98.4	101.0	100.5	105.3	105.2	105.3	101.7	102.0	101.4
80	105.7	105.5	105.8	101.0	101.0	101.0	100.9	100.0	98.4	98.4	101.0	100.5	105.6	105.5	105.7	101.5	101.8	101.3
85	106.1	105.9	106.3	101.0	100.9	101.0	100.9	100.0	98.4	98.4	101.0	100.5	106.1	105.9	106.1	101.4	101.7	101.2
90	106.5	106.4	106.7	100.9	100.9	101.0	100.9	100.0	98.4	98.4	101.0	100.5	106.5	106.4	106.6	101.3	101.5	101.2
95	106.9	106.7	107.0	100.9	100.8	101.0	100.8	100.0	98.4	98.4	101.0	100.5	106.9	106.7	106.9	101.2	101.4	101.1
100	107.2	107.0	107.3	100.9	100.8	100.9	100.8	100.0	98.4	98.4	100.9	100.5	107.1	107.0	107.2	101.2	101.2	101.1
∞	109.3	109.3	109.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	109.3	109.3	109.3	100.0	100.0	100.0

Table 6.6: Index of Income Per Capita in Experiments Involving Various Assumptions on Trade, Migration, and Parameters

Time	Exp.1	Exp.2	Exp.3	Exp.4	Exp.5	Exp.6	Exp.7	Exp.8	Exp.9	Exp.10	Exp.11	Exp.12	Exp.13	Exp.14	Exp.15	Exp.16	Exp.17	Exp.18
Country (1):																		
Initial State:																		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:																		
5	94.3	94.3	94.3	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	94.3	94.3	94.3	103.1	103.1	103.1
10	94.7	94.7	94.7	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	94.7	96.7	94.7	102.1	102.3	102.0
15	94.9	94.9	94.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	94.9	94.9	94.0	101.5	101.7	101.3
20	95.0	95.0	95.0	93.9	93.9	93.9	93.9	93.8	94.0	94.3	94.1	94.1	95.0	95.0	95.0	101.0	101.2	100.1
25	96.0	96.0	96.0	94.7	94.7	94.7	94.7	94.9	95.7	96.7	95.4	95.6	96.0	96.0	96.1	100.5	100.7	100.3
30	96.3	96.2	96.4	94.6	94.6	94.6	94.6	95.1	96.1	96.8	95.2	95.6	96.3	96.2	96.4	100.2	100.4	100.1
35	96.3	96.2	96.5	94.3	94.3	94.3	94.3	94.8	95.9	96.3	94.7	95.3	96.3	96.2	96.4	100.1	100.2	99.9
40	96.8	96.7	97.0	94.8	94.8	94.8	94.8	95.3	96.5	96.8	95.2	95.8	96.8	96.7	96.9	100.0	100.1	99.9
45	97.4	97.3	97.6	95.5	95.5	95.5	95.6	96.1	97.3	97.6	95.9	96.6	97.4	97.2	97.5	99.9	99.9	99.8
50	98.0	97.9	98.2	96.3	96.3	96.2	96.3	96.9	98.2	98.5	96.6	97.4	98.0	97.8	98.1	99.8	99.8	99.7
55	98.5	98.3	98.6	96.8	96.8	96.8	96.9	97.5	98.9	99.1	97.1	98.0	98.5	98.3	98.6	99.6	99.6	99.7
60	98.5	98.3	98.6	96.6	96.7	96.6	96.8	97.2	98.4	98.4	96.8	97.6	98.4	98.2	98.5	99.6	99.5	99.6
65	98.7	98.5	98.8	96.9	97.0	96.9	97.1	97.4	98.5	98.5	97.0	97.8	98.6	98.5	98.7	99.6	99.5	99.6
70	97.8	97.7	97.9	95.5	95.6	95.4	95.7	95.5	96.0	96.1	95.6	96.0	97.8	97.6	97.8	99.6	99.5	99.7
75	98.5	98.4	98.5	96.7	96.8	96.6	96.9	96.8	97.3	97.5	96.8	97.2	98.5	98.4	98.5	99.6	99.5	99.7
80	99.0	98.9	99.0	97.5	97.6	97.4	97.7	97.6	98.3	98.4	97.6	98.1	99.0	98.9	99.0	99.6	99.5	99.7
85	99.2	99.2	99.2	97.9	98.0	97.8	98.1	98.0	98.7	98.7	97.9	98.5	99.2	99.2	99.2	99.6	99.5	99.8
90	99.2	99.2	99.1	97.9	98.0	97.8	98.1	97.9	98.4	98.5	97.9	98.4	99.2	99.2	99.2	99.7	99.5	99.8
95	99.1	99.1	99.1	97.8	97.8	97.7	98.0	97.7	98.1	98.1	97.8	98.2	99.1	99.1	99.1	99.7	99.5	99.8
100	99.2	99.2	99.2	98.0	98.0	97.9	98.1	97.9	98.1	98.2	98.0	98.3	99.2	99.2	99.2	99.7	99.5	99.8
∞	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Country (2):																		
Initial State:																		
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Years After Shock:																		
5	99.5	99.5	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.5	99.5	97.1	97.1	97.1
10	99.1	99.1	99.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	99.1	99.1	98.0	97.8	98.1
15	98.8	98.9	98.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	98.9	98.9	98.6	98.4	98.8
20	98.8	98.8	98.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.8	98.8	98.8	99.1	98.9	99.3
25	98.5	98.5	98.5	99.9	99.9	99.9	99.9	100.0	100.2	100.2	99.9	100.0	98.4	98.4	98.4	99.5	98.3	99.7
30	98.0	98.1	97.9	99.9	99.9	99.9	99.9	100.0	100.2	100.2	99.9	99.9	98.0	98.0	97.9	99.8	98.6	99.9
35	97.6	97.8	97.5	99.9	99.9	99.9	99.9	100.0	100.2	100.2	100.0	99.9	97.6	97.8	97.5	99.9	98.8	100.0
40	97.7	97.8	97.5	100.0	100.0	100.0	100.0	100.0	100.1	100.1	100.1	100.0	97.7	97.9	97.6	100.0	99.9	100.0
45	97.9	98.1	97.8	100.1	100.1	100.1	100.1	100.0	100.1	100.1	100.1	100.0	97.9	98.1	97.8	100.1	100.1	100.2
50	97.1	98.3	98.0	100.1	100.1	100.1	100.1	100.0	100.1	100.0	100.2	100.0	98.2	98.3	98.0	100.2	100.2	100.2
55	98.3	98.5	98.2	100.2	100.2	100.2	100.1	100.0	100.0	100.0	100.2	100.0	98.3	98.5	98.2	100.4	100.4	100.3
60	98.2	98.4	98.1	100.3	100.3	100.3	100.2	100.0	99.9	99.9	100.3	100.1	98.2	98.4	98.1	100.4	100.4	100.4
65	98.3	98.5	98.2	100.3	100.3	100.3	100.3	100.0	99.8	99.8	100.3	100.1	98.3	98.5	98.3	100.4	100.5	100.3
70	97.7	97.9	97.7	100.5	100.4	100.5	100.4	100.0	99.6	99.6	100.4	100.2	97.8	97.9	97.7	100.4	100.5	100.3
75	98.3	98.4	98.3	100.4	100.4	100.5	100.3	100.0	99.6	99.6	100.5	100.2	98.3	98.4	98.3	100.4	100.5	100.3
80	98.7	98.7	98.7	100.4	100.3	100.4	100.2	100.0	99.6	99.6	100.5	100.2	98.7	98.8	98.7	100.4	100.5	100.2
85	98.9	98.9	98.9	100.3	100.3	100.4	100.2	100.0	99.6	99.6	100.5	100.2	98.9	98.9	98.9	100.4	100.5	100.2
90	98.9	98.9	98.9	100.4	100.3	100.5	100.2	100.0	99.6	99.6	100.0	100.2	98.9	98.9	98.9	100.3	100.5	100.2
95	98.8	98.8	98.9	100.4	100.3	100.5	100.3	100.0	99.5	99.5	100.5	100.3	98.8	98.8	98.9	100.3	100.5	100.2
100	98.9	98.9	99.0	100.4	100.3	100.5	100.3	100.0	99.5	99.5	100.5	100.3	98.9	98.9	98.9	100.3	100.4	100.2
∞	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6.7: The Volume of Trade in Experiments Involving Various Assumptions on Trade, Migration, and Parameters

Time	Exp.4	Exp.5	Exp.6	Exp.7	Exp.8	Exp.9	Exp.10	Exp.11	Exp.12	Exp.13	Exp.14	Exp.15
Country (1): MC												
Initial State:												
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Years After Shock:												
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	-815.7	-307.4	-1179.2	1678.2	-177.5	0.0	0.0	0.0
25	1992.7	2015.5	1972.9	1957.4	-2210.5	-2840.7	-7082.7	10062.1	131.2	909.4	898.1	920.8
30	3822.9	3883.6	3776.8	3737.6	-1269.5	-4266.1	-9120.1	13229.1	832.5	1217.1	1155.6	1276.9
35	4448.7	4578.0	4359.4	4376.3	-637.8	-4494.3	-9002.5	13444.9	1132.6	968.0	862.5	1062.3
40	4980.5	5233.1	4812.8	4966.7	-518.1	-4781.0	-9395.8	14334.6	1327.4	778.0	648.5	882.3
45	5474.7	5882.3	5205.6	5552.1	-632.9	-5087.3	-9992.7	15495.9	1488.7	690.5	553.6	788.0
50	6250.3	6833.7	5859.9	6433.0	-636.2	-5613.3	-10919.4	17115.3	1782.3	652.6	520.2	733.8
55	6988.6	7753.3	6466.3	7277.5	-675.5	-6098.2	-11852.7	18755.8	5052.8	563.8	441.3	626.9
60	6689.2	7618.1	6038.8	7107.0	-276.2	-5331.1	-9995.2	16505.3	2108.0	343.2	232.7	390.1
65	6654.6	7730.5	5877.1	7181.8	-281.9	-5029.6	-9377.6	15868.5	2170.2	169.9	79.5	196.0
70	3749.9	4899.3	2882.6	4446.0	-846.2	-5053.3	-3736.5	8340.4	1257.5	-298.9	-360.2	-295.8
75	4296.9	5469.5	3358.2	5006.4	-914.2	-2557.8	-4940.4	9680.8	1478.9	-351.3	-274.7	-377.1
80	4679.5	5740.4	3746.8	5314.6	-845.8	-2921.0	-5622.6	10616.3	1636.7	-401.3	-399.8	-438.5
85	4661.7	5533.4	3781.3	5181.8	-694.0	-2894.9	-5500.8	10444.3	1662.9	-454.6	-442.2	-488.4
90	4077.6	4739.7	3269.2	4484.5	-623.5	-2349.5	-4424.6	8909.1	1492.3	-513.5	-500.4	-535.2
95	3211.6	3663.4	2491.2	3507.2	-664.9	-1602.1	-3036.1	6874.6	1205.4	-553.0	-546.5	-558.5
100	2686.6	2950.5	2060.8	2866.5	-694.8	-1233.5	-2377.7	5820.5	1017.4	-559.0	-563.1	-550.3
∞	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Country (2): MK												
Initial State:												
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Years After Shock:												
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	-837.6	-1449.0	-5564.4	1020.3	-133.7	0.0	0.0	0.0
25	1214.2	1236.8	1196.8	1179.8	-2276.3	-13289.6	-33129.4	6152.7	98.9	554.1	547.2	561.1
30	2337.6	2391.6	2298.8	2260.7	-1303.1	-19867.7	-42509.4	8105.0	629.3	744.2	706.5	780.7
35	2722.8	2822.1	2655.8	2649.6	-655.0	-20904.0	-41941.1	8235.9	857.0	592.4	527.8	650.1
40	3050.4	3228.5	2933.9	3009.4	-532.2	-22206.2	-43722.5	8784.0	1004.9	476.5	397.1	540.3
45	3355.0	3631.2	3175.0	3366.3	-650.0	-23593.8	-46433.0	9500.8	1127.5	423.1	339.2	482.9
50	3834.4	4223.1	3577.9	3905.0	-653.4	-25978.6	-50641.5	10502.9	1351.0	400.3	319.1	450.1
55	4291.4	4795.9	3951.9	4422.2	-693.8	-28165.6	-54861.9	11519.7	1557.1	346.2	270.9	384.9
60	4102.8	4706.6	3686.4	4313.7	-283.8	-24661.1	-46361.3	10118.8	1598.9	210.5	142.7	239.2
65	4079.3	4772.9	3585.8	4356.7	-289.7	-23275.4	-43516.8	9722.4	1646.0	104.1	48.7	120.1
70	2284.4	3005.8	1747.9	2680.2	-869.1	-9580.4	-18407.9	5082.8	950.6	-182.1	-219.4	-180.2
75	2620.1	3358.2	2038.3	3020.7	-938.8	-11918.1	-23070.1	5905.7	1118.6	-214.2	-228.5	-229.9
80	2855.4	3526.3	2276.1	3208.5	-868.5	-13595.9	-26229.5	6480.8	1238.3	-244.9	-244.0	-267.5
85	2844.6	3399.3	2297.2	3128.0	-712.8	-13474.7	-25664.5	6375.1	1258.2	-277.4	-269.8	-298.0
90	2485.6	2908.7	1984.0	2704.0	-640.3	-10953.0	-20675.5	5432.3	1128.4	-313.0	-305.0	-326.3
95	1954.8	2244.9	1509.6	2111.4	-682.8	-7485.4	-14217.0	4186.1	910.6	-336.6	-332.6	-339.9
100	1634.0	1806.9	1247.8	1724.3	-713.5	-5770.1	-11146.0	3542.0	768.1	-340.5	-342.5	-334.7
∞	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: We report MC for country 1 and MK for country 2 here since their reverse signs are for other country.

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