WorldScan

the Core version

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Preface

WorldScan is a flexible model CPB has developed to analyse long-term issues in the world economy such as globalization, ageing, the depletion of energy sources and the emission of greenhouse gasses. WorldScan is also used to perform policy analysis — on trade and environmental policies, for example.

Economic models are especially valuable if they are used as a sort of discussion partner. A model is an organising device, combining theoretical insights with empirical evidence. It is the combination of several elements that makes a model so instructive for users, who appreciate the richness of the interactions within the model. At the same time, the model should not be a rigid system, but open to the ideas and the needs of the users. New policy problems may require an emphasis on new mechanisms. Thus, in order to be able to act as a good discussion partner, the model should be flexible, just like the mind of an economist should be open. This is especially true if issues at hand are surrounded by huge uncertainties, and sensitivity analyses are required to separate the sensible from the nonsensical.

WorldScan has a history of about a decade. The first version of the model was built by Ben Geurts and Hans Timmer, and was used for the scenario study "Scanning the Future" (CPB, 1992). After the first version, Arjen Gielen, Paul Tang, Arjan Lejour, and Richard Nahuis joined the WorldScan team. Since then many new versions of the model have appeared, and many applications have been analysed — often in collaboration with international institutes such as the OECD, EU and IPCC. The team of researchers developed the model further, either by enlarging it or by simplifying it. From the beginning, Hans Timmer guided the development of the model, his skills and enthusiasm inspiring the research team.

To structure the many versions of WorldScan, CPB decided to develop a core version: a starting point for all other versions. This publication is the result of this effort. The WorldScan team currently consists of Nico van Leeuwen, Arjan Lejour, Ton Manders, Guido van Steen, Hans Timmer, and Gerard Verweij. Johannes Bollen of RIVM also makes important contributions to the model and uses it intensively. The whole team contributed to this publication. Arjan Lejour has written a large part of the text.

Henk Don
Director of CPB Netherlands Bureau for Economic Policy Analysis

Summary

This publication presents the core version of WorldScan, a dynamic model for the world economy. WorldScan is an applied general equilibrium model that has been developed at CPB to construct long-term scenarios for the world economy, to analyse certain events or trends, and to perform policy analysis. We present an overview of the model, the data, and applications. We begin by discussing the main mechanisms of WorldScan and its theoretical foundations and properties. Characteristic elements of the model are an Armington trade specification, combined with Heckscher-Ohlin mechanisms in the long run, converging consumption patterns, a low-productivity sector in developing regions, from which the high-productivity economy may draw labour, and a division between low- and high-skilled labour. We further present our calibration procedure and our data needed for calibration. Then, we show the projections of exogenous trends that are necessary for the construction of scenarios. The mechanisms of the model are illustrated by presenting simulation results of a globalization scenario. The applications demonstrate that WorldScan can be used to construct scenarios for all kinds of studies, to analyse events like ageing and globalization, and to analyse trade policies and climate policies.

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1 Scanning future worlds

Should countries stimulate investment in infrastructure or schooling and encourage domestic savings? What are the consequences if a country opens its borders to attract foreign capital, technology or labour, or if it seeks to benefit from foreign competition? How can countries coordinate their actions to prevent climate change? The answers to these kinds of questions require insights into long-term interactions in the world economy and assessments of future demographic and technological trends. *WorldScan*, a *World* model for *Sc*enario *an*alysis, has been developed to generate these insights and to structure these assessments. The model was originally built for CPB's long-run scenario study "Scanning the Future" (CPB, 1992). It was used later on in other scenario studies, such as "The world in 2020" (OECD, 1997a).

This chapter briefly examines the characteristics of long-run scenarios and then summarises the main features of WorldScan, especially the sources of growth and the modelling of international trade. The chapter ends with a reader's guide for the rest of the book.

1.1 Long-run scenarios

Long-run scenarios, indispensable ingredients in the preparation of structural policies, serve two purposes. First, they may be used as an organising device to discuss the potential impact of future developments such as ageing, the rise of emerging countries, depletion of energy sources or emission of greenhouse gasses. The simulation of such developments may uncover unexpected impacts on the world economy. Policymakers, confronted with new policy problems or policy options by such simulations, must then anticipate developments in future decades.

Second, long-run scenarios can be used as baselines for policy analysis. Such baselines may be crucially important in assessing the impact of policy measures. For example, income effects of trade policies may be positive or negative, depending on whether a region is a net exporter or net importer of certain products. Another evident

example of the relevance of the baseline is burden-sharing in agreements to stabilise emissions of greenhouse gasses. That burden hinges on expected growth of production in different regions of the world. Thus, not only the current specialization and growth patterns, but also plausible future specialization and growth patterns are crucial for policy analysis.

Unfortunately, the construction of long-term scenarios is by no means a straightforward exercise. It is an understatement to say that future developments are uncertain. Fundamental uncertainty and unpredictability more aptly describe the future. In scenario analysis there are two options to deal with this uncertainty. First, several alternative scenarios may be developed to sketch the range of possibilities. Such an approach can still be seen as a form of forecasting. Instead of the standard point estimate, an interval estimate of future developments is given. Because uncertainty is so large and so many dimensions are involved, this is often not a realistic option. The actual future may easily take place outside the ranges explored by the scenarios.

If uncertainty is extremely large, the second option is a useful one. In that approach there is no attempt to systematically explore possible future trends. Scenarios are then more or less thought-experiments. They describe worlds that will perhaps never be realised, but are nevertheless realistic and consistent. Such worlds provide a valuable framework with which we can organise discussions about future developments and think through possible actions. It can be used as a kind of contingency exercise. One simulates a calamity with realistic detail to test a contingency plan. Even if one admits that the future may significantly differ from the scenario, the exercise can still be an effective way to anticipate future events, and future changes.

WorldScan has been developed to support both approaches to scenario analysis. To perform that task, WorldScan includes demographic and technological trends to sketch possible upper and lower limits of developments. At the same time, it has been constructed as a flexible model. It should be able to reproduce scenario assumptions, even if these significantly deviate from historical trends. For the same reason, several versions of WorldScan exist, each suited for specific analysis. The environmental version, for example, includes a lot of detail on the energy side of the economy, and the version that will be used to analyse ageing contains adequate demographic detail. All these versions of the model are derived from the so-called CORE version, which contains the basic general mechanisms. It is this CORE version that is presented in this publication.

1.2 General characteristics

WorldScan fits into the tradition of applied general equilibrium (AGE) models: it builds upon neoclassical theory, has strong micro-foundations and explicitly determines

simultaneous equilibrium on a large number of markets. The model is calibrated on data in a base year (both levels and growth rates). WorldScan is a dynamic model, but does not pretend to describe realistic short-run dynamics. The focus is long-run, but the way in which the model focusses on the long run differs from the approach used in many other AGE models.

AGE models traditionally use comparative statics or comparative dynamics to analyse the long-run impact of current policy shocks (see, *e.g.*, Francois, McDonald and Nordström, 1997). In contrast, WorldScan is not designed merely to study steady-state growth paths. Its objective is to analyse structural change over several decades. Key issues include the following: the rise and decline of regions; demographic dynamics; shifts in patterns of consumption, production, trade and capital flows; and the changing distribution of income. The model must be able to describe unbalanced growth, where growth rates differ among regions and sectors and are not necessarily constant.

WorldScan divides the world into twelve regions (see Box 1.1). It is our experience that this classification facilitates the analysis of a broad range of structural shifts in the coming decades, while it still includes options for some unexpected developments. To carry out more specific analyses, one would need more country detail, and for more general analyses a North-South distinction would be sufficient, but we see the twelve regions as an effective compromise. As the occasion arises, we use other versions of WorldScan with a different level of regional detail.

The need to consider future specialization patterns imposes limits on the degree of sectoral detail in the model. Many AGE models contain a detailed description of economic activities based on current specialization patterns. Given the amount of uncertainty, it would be inadvisable to design future developments for each detailed activity. Furthermore, very detailed statistical classifications may lose their meaning in the longer run. Products and technology in specific sectors may change dramatically in the course of decades. Statistical classifications, which may prove convenient in describing the current situation, then become ineffective in characterising future economic structures. WorldScan therefore distinguishes only broadly defined sectors that retain a meaningful interpretation in the longer run, such as Consumer Goods or Capital Goods.

Sectors in WorldScan have different factor requirements. For a given sector these factor requirements are more or less similar across regions. This means that if a sector is relatively capital intensive in one region, then it is also relatively capital intensive in other regions. Agriculture (including food processing) and Consumer Goods employ relatively few high-skilled workers, whereas Capital Goods, Trade and Transport and Services (including the government) absorb many high-skilled workers. Sectoral restructuring can easily be linked to changes in relative endowments and changes in

(region-specific) demand patterns. This also holds because in WorldScan substitution elasticities between domestic and foreign goods are believed to be high in the long run — at least much higher than in the short run. In principle, all goods are tradable, although trade in services is much lower than in manufacturing and raw materials. The sectors Intermediate Goods and Raw Materials are relatively energy intensive.

Box 1.1 The characteristics of WorldScan

At the heart of WorldScan are the neoclassical theories of economic growth and international trade. The characteristics are:

- an Armington trade specification, allowing market power to determine trade patterns in the medium run, while allowing Heckscher-Ohlin mechanisms in the long run, and explaining two-way trade;
- imperfect financial capital mobility;
- consumption patterns depending upon per capita income, and developing towards a universal pattern;
- a Lewis-type low-productivity sector in developing regions, from which the high-productivity economy may draw labour, enabling high growth for a long period;
- two types of labour: low skilled and high killed.

The model distinguishes the following regions, sectors and productive factors:

Regions
United States
Western Europe
Japan
Pacific OECD
Eastern Europe
Former Soviet Union
Sub-Saharan Africa
Middle East & N. Africa
Latin America
China
South-East Asia
South Asia + Rest

Sectors
Agriculture
Raw Materials
Intermediate Goods
Consumer Goods
Capital Goods
Trade and Transport Services

Productive factors
Primary inputs
Low-skilled labour
High-skilled labour
Capital
Fixed factor

Intermediary inputs
all sectors

1.3 Sources of economic growth

The neoclassical theory of growth distinguishes three factors to explain changes in production: physical capital, labour, and technology. WorldScan augments the simple growth model in three ways. First, WorldScan allows overall technology to differ across countries. Potentially, countries can catch up: backward countries can learn relatively easily the state-of-the-art technology employed in leading countries. Second, the model distinguishes two types of labour: high-skilled and low-skilled labour. Sectors differ according to the intensity with which they use both types of labour. Countries can raise per capita growth by schooling and training the labour force. Moreover, the distinction between high and low-skilled labour broadens the scope for explaining trade patterns on the basis of comparative advantage. Regions with abundant supply of high-skilled labour tend to export skill-intensive products and to import skill-extensive products. Third, part of the labour force in developing countries works in a low-productivity, informal sector, within which workers have no access to capital and technology. Reallocation of labour from the low-productivity sector to the high-productivity sectors enables countries to raise per capita growth as well. In principle, these three factors affect the performance of a region only temporarily. Catching-up, training of low-skilled workers and reallocating labour to the high-productivity sector do not raise the growth rate indefinitely. Instead, they have a permanent effect on the level of (national) income. Nevertheless they are important in our scenarios. Adjustments in the economies of developing regions take a great deal of time and will surely show up in the growth rates of these regions until 2050.

1.4 International trade

To account for transition dynamics, WorldScan models international trade in a special manner. Most AGE models apply the so-called Armington approach. Armington (1969) assumes that internationally traded products differ between country of origin, using finite cross-price elasticities in demand equations to explain intra-industry trade and to avoid abrupt changes in specialization patterns. However, this approach has some undesirable effects. It implies that relatively fast-growing countries can only penetrate world markets at the cost of substantial terms-of-trade losses, while in reality these losses seem to be only temporary. The Armington approach also suggests that a country can gain from applying export taxes. The flaw in this approach is that it assumes that countries have a fixed product mix. However, the composition of goods changes gradually over time. Relatively fast-growing countries may broaden their product mix while conquering world markets without being forced to lower the relative price of their products.

Modern trade theories of monopolistic competition consider the product mix to be endogenous, with explicit entry and exit conditions. A similar approach is followed in WorldScan, albeit in an implicit way. In WorldScan, the static Armington utility function is changed into a dynamic one, describing temporary brand loyalty. It is assumed that preferences with respect to the current product mix depend on realised market shares in previous periods. Countries can gain market share by temporarily offering their products at lower prices than competitors. Once the market shares are conquered, brand loyalty for the new products is established gradually, and prices can return to the level of competitors' prices. In the opposite case, if countries can no longer compete in a certain sector because their costs exceed competitors' costs, they will gradually disappear from the market. This gives the model Heckscher-Ohlin-like long-term properties.[1]

1.5 A readers' guide

The next chapters describe the mechanisms in the model, as well as its characteristics and properties. We describe the data and exogenous trends in the model and explain our calibration procedure. Finally, we present a baseline scenario and show the results of some simulations and sensitivity analyses.

Chapter 2 presents and motivates the basic behavioural equations in the model and provides some intuition of how the model works. First, we discuss consumer and producer behaviour, including a description of product markets. Then, we present the core characteristics and the equilibrium mechanisms in the labour and capital markets, respectively. Moreover, we discuss the structure of expectations and long-run properties of the model.

Chapter 3 presents the data. The first section concentrates on the projections of labour supply and the division between high- and low-skilled workers. The other sections concentrate on the macroeconomic and sectoral data for the calibration year. This includes data on consumption, production and trade, and tariff and other non-tariff barriers.

Our calibration procedure is explained in Chapter 4, which explains how parameters are derived from the base-year data and how they may depend on scenario assumptions.

Chapter 5 describes a globalization scenario that includes rapid growth in emerging economies and intensifying trade relations — mainly because of abolishment of trade barriers. This scenario is very well suited to illustrate the processes related to growth and trade in WorldScan.

[1] Van de Klundert and Nahuis (1998) analysis international trade in WorldScan and compare it with the Heckscher-Ohlin theory

To further illustrate the mechanisms in WorldScan, we present some of the elements in the globalization scenario as a simulation exercise in Chapter 6. These simulations show the separate impact of more schooling, an increased propensity for saving, more rapid technological progress, trade liberalization and shifts in demand patterns. Chapter 6 also includes a sensitivity analysis that shows how the impact of trade liberalization depends on the substitution elasticities.

Chapter 7 concludes with a brief discussion of the applications and other versions of WorldScan.

2 The model

This chapter presents the basic structure of WorldScan. Section 2.1 provides a non-technical overview of the model. The main behavioural equations, which are based on microeconomic principles, are clustered into four groups. Section 2.2 focusses on consumer behaviour. The behaviour of firms is derived in section 2.3. Section 2.4 presents the labour markets in WorldScan, and section 2.5 discusses the capital markets. After this discussion of the building blocks of the model, we will focus on some properties of the integrated system. Sections 2.6 and 2.7 will present the expectations structure, as well as the long-term properties.

2.1 A bird's eye view

WorldScan is an applied general equilibrium model that focuses on long-term growth and trade in the world economy. The model is based on neoclassical theories of growth and trade. Given this basic structure, the model contains four characteristic elements to describe long-term developments in a more realistic way. These characteristic elements cause the model to deviate significantly from other applied general equilibrium models.[1]

First, we allow for an Armington specification explaining two-way trade, with a tendency to the law of one price in the long term. Second, we model a low-productivity sector in developing countries. During the process of economic development, labour will be reallocated from the traditional low-productivity sectors to the modern high-productivity sectors. Third, consumption patterns are not constant over time. The consumption patterns in developing regions converge to those in the OECD regions. If per capita income rises, consumers will spend relatively more on services and less on food. Fourth, we distinguish low- and high-skilled labour. This distinction allows for a better description of specialization patterns. OECD countries endowed with much

[1] Examples of AGE models developed for the world economy are the GTAP model (Hertel, 1997) and the G-Cubed model (McKibbin and Wilcoxen, 1999). The theory and structure of AGE models, as well as developments in these models, have recently been discussed in Starr (1997), Ginsburgh and Keijzer (1997), Shoven and Whalley (1992) and Francois and Reinert (1997).

high-skilled labour specialise in skill-intensive goods, while non-OECD countries endowed with much low-skilled labour specialise in skill-extensive goods.

Section 2.2 describes consumers' behaviour. Consumers maximise their lifetime utility, which depends on their consumption in current and future periods. Their budget consists of accumulated financial wealth and human wealth, which is defined as the discounted value of future income flows. In addition to labour income, these flows include government transfers and surplus profits. The latter originate from monopoly power. Given total consumption, consumers allocate their expenditures on various goods: Agriculture and Food, Raw Materials, Services, Consumer Goods, Intermediate Goods, Capital Goods and Trade and Transport. Allocation depends on their preferences. We assume that if consumption per capita grows, consumer preferences will converge towards those in the United States. Total demand for a good within a country is the aggregate of consumer demand, intermediary demand and investment demand. These goods can be bought in every region. The demand for a specific variety of a good in a certain region depends on the preferences for that variety, its price compared to the average price of the other varieties, and total demand for that good.

Section 2.3 concentrates on the behaviour of firms. Firms minimise the costs of the required inputs. These inputs are capital, which they have to buy in the current period, and other inputs, which they purchase in the next period. These other inputs are low-skilled and high-skilled labour, and all intermediary inputs. Capital is a mixture of Capital Goods and Services, because the latter includes construction activities. Production processes in the sectors Agriculture and Raw Materials also need land and natural resources as a fixed factor for production. Producers derive investment demand as the difference between the volume of the required capital stock minus the depreciated volume of the capital stock from the previous period.

Because each region produces its own unique variety of a good, these varieties are imperfect substitutes. The market structure is one of imperfect competition. Producers derive their prices on the basis of profit maximisation. The producer price is thus equal to the unit cost price plus a proportional mark-up. The size of the mark-up depends on the degree of substitutability on each market. Consumer prices are equal to the producer prices for the country in which the variety of the good is produced. In the other regions, import and export taxes, together with the transport services, are added to the producer prices in order to derive the consumer price.

Section 2.4 discusses labour markets. Labour supply of high- and low-skilled workers is exogenous. For OECD regions, we assume an exogenous natural rate of unemployment for both skill levels. Given these exogenous unemployment rates, the labour markets clear for both skill levels. For non-OECD regions, we assume also an exogenous rate of unemployment for high-skilled workers. The unemployment rates for low-skilled workers in non-OECD regions are endogenous and much higher than

in OECD regions. In the non-OECD regions, many low-skilled workers have no access to the formal labour market. They survive by working in the low-productivity sector. The allocation of low-skilled workers between low-productivity and formal, high-productivity activities depends on the ratio of low-skilled wages in the formal sector and per capita income in the low-productivity sectors.

The modelling of the informal or low-productivity sector in developing countries is based on Lewis (1954). The low-productivity sector is a traditional subsistence sector in which the marginal productivity of workers is (close to) zero. These workers have no access to capital and modern technologies. The other (high-productivity) sectors grow through the accumulation of capital and technical progress, and demand labour from the low-productivity sector. As regions develop, labour will move from the low- to the high-productivity sectors.

Section 2.5 focusses on capital markets. Capital owners invest their wealth in the various regions. The allocation of their wealth over these regions is based on a portfolio model in which the allocation is determined by the regional returns on investment and the preferences to invest in certain regions. The supply of capital in a region is the aggregate of all capital allocated to that region. In every region, the supply of capital has to match the firms' demand for required capital. The interest rates clear these capital markets. Equilibrium between global investments and global savings implies that global outlays equal global income. The relative output prices make sure that also every single product market is in equilibrium.

Section 2.6 explains the way in which expectations are modelled in WorldScan. The main dynamics in the model result from the accumulation of capital and wealth. Because investment and saving decisions are endogenous in the model, the model contains endogenous expectations. We will explain why we have not opted for fully model-consistent expectations, while at the same time the model contains an elaborate sub-model for sectoral demand and supply in the next period.

Section 2.7 discusses the relationship between the data in our model, regional convergence and a steady state. Because a steady state requires equal growth rates in all regions and sectors, we argue that a steady state is not a realistic aim for a global model such as WorldScan.

2.2 Consumer behaviour

This section describes consumer behaviour. Consumers make decisions about current and future consumption, and allocate their expenditures over various categories (sectors) and varieties. For simplicity, we assume that labour supply is given. Consumers, thus, have to make decisions only about consumption expenditures. These

consumption decisions are complex due to allocation over time, categories and varieties. However, the decisions underlying these three allocations are separable.[2] Section 2.2.1 derives consumption over time based upon optimisation of an inter-temporal utility function. Once the consumption budgets for each period are determined, section 2.2.2 derives the allocation of these budgets over the various categories. This allocation is based on a Cobb-Douglas type of instantaneous utility function. In the final step, consumer spending on the various categories is allocated over the varieties. Every region produces one unique variety of each category of goods. Based upon an Armington utility function, section 2.2.3 derives the demand for the varieties of a good.

2.2.1 Allocation of consumption over time[3]

Following Yaari (1965) and Blanchard (1985), we consider an economy in which agents have a finite planning horizon — that is, there is a positive probability of death. The probability of death is related to an individual's life expectancy. We assume that the probability of death, d, is constant over time for all agents. Each agent's life expectancy and planning horizon is thus given by 1/d. Moreover, in every period a new generation is born. So, the rate of population growth, n, equals the birth rate minus the probability of death. Agents are assumed to maximise expected utility. In period t' the utility function reads[4]

$$U_{t'} = \sum_{t=t'}^{\infty} \left(\frac{1-d}{1+\rho}\right)^{t-t'} v(c_t) \qquad \textbf{(2.1)}$$

$1+\rho$ represents the discount factor, and 1-d is the probability that the consumer will be alive the next period. The combination of both represents the time preference of the consumer. A higher probability of death lowers the time preference of an agent, as does a higher discount factor. Agents with a lower time preference will consume relatively more now than in the future. c_t represents the consumption volume of the representative agent in period t, and its utility is given by $v(c_t)$. Utility is thus not affected by leisure. For convenience, labour supply is assumed to be exogenous.

Consumption expenditures are paid out of income and wealth. The consumer receives nominal income, $p_y y$ consisting of labour income, profits, transfers from the

[2] Hereby we assume that the consumption shares over the categories of goods are constant.

[3] This section describes the Blanchard-Yaari model. This model is discussed more extensively in Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996).

[4] Most of the variables are region specific. As long as it is not confusing we ignore the relevant subscript in the equations. If variables of various regions are introduced in one equation we will introduce this subscript.

government and other income. Moreover, he receives nominal returns on his wealth at the end of the previous period, $R_{t-1}\, b_{t-1}$. Total income is used for nominal consumption, $p_{ct}\, c_t$, and nominal savings, $b_t - b_{t-1}$. The one-period budget constraint reads as follows:

$$p_{ct}c_t = p_{yt}\, y_t + (1 + R_{t-1})\, b_{t-1} - b_t \qquad \textbf{(2.2)}$$

Before solving the maximisation problem, we find it convenient to rewrite the budget restriction as an inter-temporal budget restriction. We thereby use the following transversality condition:

$$\lim_{T\to\infty} (1 + R)^{-T}\, b_{t'+T} = 0 \qquad \textbf{(2.3)}$$

The transversality condition implies that the discounted value of wealth at the end of the planning horizon converges to zero. Using this condition, the inter-temporal budget restriction in period t' reads

$$\Sigma_t\, (1 + R_t)^{t'-t}\, (p_{ct}c_t - p_{yt}\, y_t) = (1 + R_{t'-1})\, b_{t'-1} \qquad \textbf{(2.4)}$$

The present value of all future 'deficits' thus equals the current return on assets. The optimal consumption path from period t' onwards can be derived by maximising the utility function given the inter-temporal budget restriction. The agents assume that prices and real income per capita grow with a constant rate, π^e and g, respectively, and that the real interest rate, r, is constant. The nominal interest rate, R_t, is defined as

$$R_t = (1 + r_t)\, (1 + \pi_t^e) - 1 \qquad \pi_t^e \equiv p_t^e / p_t - 1 \qquad \textbf{(2.5)}$$

p^e is the (expected) price. The nominal interest rate thus depends on the expected inflation rate. We assume that the instantaneous utility functions v(c) are logarithmic. Using these assumptions, we maximise the utility function (equation (2.1)), given the inter-temporal budget restriction (equation (2.4)), which leads to the following consumption function in period t':

$$p_{ct'}c_{t'} = \frac{\rho + d}{1 + \rho} \left((1 + R_{t'-1})\, b_{t'-1} + \sum_{t=t'}^{\infty} (1+R)^{t'-t}\, p_{yt'}\, (1+\pi)^{t-t'}\, y_{t'}(1+g)^{t-t'}\right) \qquad \textbf{(2.6)}$$

As is clear from equation (2.6), a higher probability of death or a higher discount factor shortens the time horizon and therefore increases consumption in period t′. Aggregate consumption can be derived by adding consumption of all individuals born in different periods. We assume that newly born individuals do not possess financial wealth. The aggregate consumption function in period t′ reads

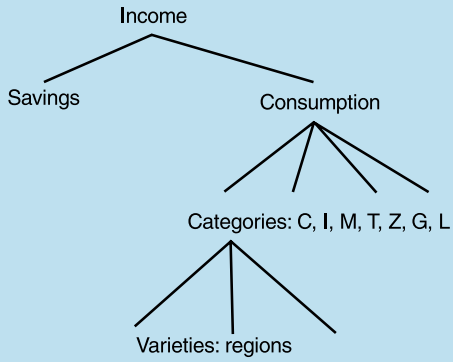
$$p_{ct'}C_{t'} = \frac{\rho + d}{1 + \rho}\left((1 + R_{t'-1})\,B_{t'-1} + \zeta p_{yt'}Y_{t'}\right) \quad \zeta \equiv \frac{1 + r}{r - g} > 0 \qquad \textbf{(2.7)}$$

C represents the volume of aggregate consumption. Because consumers assume that, first, future income per capita grows at a constant rate and, second, the real interest is constant, future income can be written as $\zeta\, p_y\, Y$. Present consumption is thus based on wealth, B, and its return in the previous period t′-1, plus all future income from now on. This formulation is quite familiar (see Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996)). Consumption is often expressed as a function of financial and human wealth. Because future income consists most often of labour income, the net present value of future income is often interpreted as human wealth.

We considered financial wealth as one entity in the derivation of the consumption function. Financial wealth yields a nominal return of R_t. One of the characteristics of WorldScan is an imperfectly integrated capital market. Agents are able to invest their wealth in the regional capital markets. This issue is discussed more extensively in Section 2.5. These markets are not perfectly integrated, so every market yields a different rate of return. Then, R_t has to be interpreted as the average rate of nominal returns weighted by shares of wealth invested in the various regions.

Box 2.1 The consumption decision

The consumption decision is split up into three stages. Each of these stages refers to a specific dimension. The three dimensions are time, categories of goods (corresponding to production sectors) and varieties of a particular good (with different regions of origin). In the first stage, consumers determine their expenditures over time. The allocation of consumption over time depends, among other things, on the discount factor, the mortality rate, initial wealth and expectations concerning future income, and interest rates. In the second stage, consumers divide their consumption expenditures within a period over the various categories. There are seven consumption categories. These consumption shares are related to the stage of economic development of a region, and thus vary over time. Consumers in low-income countries spend a relatively large part of their budget on food services, while consumers in developed countries spend much more on services. As low-income countries develop, consumers in those countries will shift their expenditure patterns from food to services. Consumption shares therefore depend on consumption per capita in a region. In the third stage, consumers allocate their budget for a specific consumption category over the varieties. Each region produces a unique variety of a particular good. The number of varieties thus equals the number of regions. This allocation pattern depends on relative consumer prices of these varieties and the preferences for certain varieties.



2.2.2 Allocation of consumption over categories

We distinguish several categories (sectors) of consumption goods in the model. These categories are necessary for analysing specialization patterns between regions in the model. Consumers allocate their expenditures to these categories. Nominal consumption is allocated to sectors in accordance with the Cobb-Douglas specification of the instantaneous utility function. Maximisation of utility (by a representative consumer) is constrained by total nominal consumption expenditure. As a result, we get

$$p_s C_s = \gamma_s p_c C \quad , \quad s = C, T, I, G, M, L, Z \qquad \textbf{(2.8)}$$

where C_s is the consumption volume of good s, and, γ_s is the consumption share parameter. We assume that these shares are constant for the United States, but not for the other regions. Their consumption patterns will, over time, evolve towards those in the United States.

In developing economies, the production structure changes drastically in terms of value added and employment. In general, less developed economies are characterised by a relatively large agricultural sector. Developing economies expand their manufacturing sector, while in developed economies the services sector is the most important for the economy. Figure 2.1 illustrates this development for some selected countries and regions, depicting the value-added shares on agriculture and services for 1980 and 1995.

In WorldScan, the changes in value-added shares are explained by changes in the demand structure. We assume that the consumer share parameters in all regions converge towards those in the United States in the base year 1995. The speed of convergence depends on per capita consumption. If consumption possibilities are limited, people spend a relatively high amount of their income on Agriculture. As incomes and consumption possibilities rise, people buy more Consumer Goods and spend more on Services.

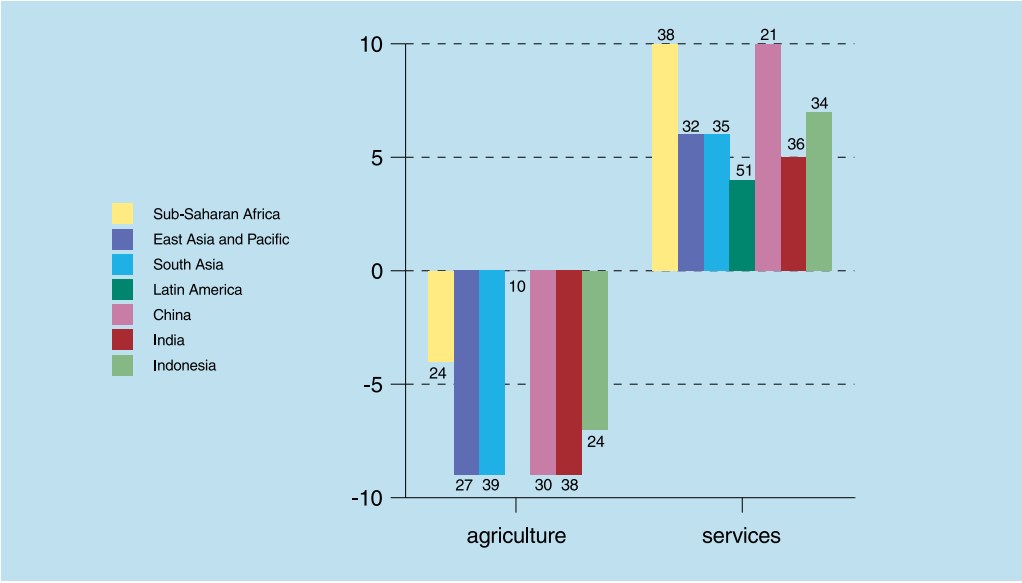
Based on this reasoning we endogenise the parameter γ_s. It now reads

$$\gamma_{st} = \gamma_s^* + (\gamma_{s0} - \gamma_s^*) \left(\frac{c_{t-1}}{c_0} \right)^{-\mu} \quad , \quad \mu > 0 \qquad \textbf{(2.9)}$$

The expenditure share of a good in a region equals a target value, γ^* (say, the consumption share in the United States for that good), minus the difference between the share in the base period and the target value, multiplied by consumption growth per capita from the base period. The parameter, μ, determines the speed of convergence.[5]

[5] The specification of the development of consumption shares in time is rather ad hoc. However, it is a direct way to incorporate convergence of consumption shares. Alternatively, we could underpin the development of consumption shares by a CES function with minimal subsistence requirements, (see De Groot (1998)). A low subsistence level for a sector would lead to an income elasticity higher than one, while a high subsistence level would lead to low income elasticities.

Figure 2.1 *Change in value added shares of agriculture and services numbers below and above columns reflect value added shares (in %) in 1980. Number on left axis indicate absolute percentage changes in 1995.*



2.2.3 *Allocation of consumption over varieties*

Firms in each region produce a unique variety of a particular good. The number of varieties of a particular category of goods equals the number of regions. Regional varieties are imperfect substitutes. Therefore, firms have some monopoly power over their own variety and can choose their price, given demand (see, among others, Dixit and Stiglitz (1977)). Consumers derive utility from the consumption of all goods (see Armington (1969)). The volume of total demand for a certain category of goods within a region is considered to be a CES composite of all varieties. Total demand consists not only of consumer demand, but also of investment demand and intermediary demand. Given the CES composite for the total volume of demand for a sector and the relevant budget restriction, the demand for a variety from region h in region b in a certain sector equals[6]

$$X_{hb} = s_{hb}\, X_b \left(\frac{p_{cb}}{p_{chb}} \right)^{\epsilon} \qquad \textbf{(2.10)}$$

[6] Text books, like Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996) among others, discuss this model and the derivation of the demand equations extensively.

The variable s_{hb} represents the agents's preference in region b for the variety produced in region h. In general, the preference for goods produced in the home country is relatively high. The variable ϵ represents the short-term price elasticity, and p_{chb} the consumer price in region b of the good produced in region h. p_{cb} represents the consumer price index in region b for a specific category of goods. It is constructed as

$$p_{cb} = \left[\sum_{h} s_{hb} \left(p_{chb}\right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \tag{2.11}$$

Given the demand functions in equation (2.10), the market share of a particular good from region h in region b, ms_{hb}, reads

$$ms_{hb} = s_{hb} \left(\frac{p_{cb}}{p_{chb}} \right)^{\epsilon-1} \tag{2.12}$$

So far, the preference variables s_{hb} have been constant. This implies that the preference for varieties does not depend on historical consumption patterns. However, it seems easier for producers to maintain their market share then to increase it. In the latter case they have to lower their prices. After consumers get accustomed to varieties, the preferences for these varieties increase. Then, demand and production grow even when prices are not lowered. We therefore endogenise the preference variable, which is assumed to be a function of the lagged market share and a preference variable calibrated in the base year, β_{hb}. It reads

$$s_{hb} = \frac{\left(ms_{hb,-1}\right)^{1-\theta} \left(\beta_{hb}\right)^{\theta}}{\sum_{h} \left(ms_{hb,-1}\right)^{1-\theta} \left(\beta_{hb}\right)^{\theta}} \tag{2.13}$$

$ms_{hb,-1}$ denotes region h' s market share in the previous period. The parameter indicates the importance of the lagged market share. If $\theta = 1$, the preference variable is exogenous. The denominator scales the preference variables such that $\Sigma_h\, s_{hb} = 1$. By substituting equation (2.13) into (2.12), we derive the long-term market share assuming that the market shares are constant in the long term. It reads

$$\overline{ms}_{hb} = \frac{\beta_{hb}}{\left(\sum_{h} \left(ms_{hb,t-1}\right)^{1-\theta} \left(\beta_{hb}\right)^{\theta} \right)^{\frac{1}{\theta}}} \left(\frac{p_{chb}}{p_{cb}} \right)^{\frac{1-\epsilon}{\theta}} \tag{2.14}$$

Note that the long-term (asymptotic) price elasticity, $((\epsilon-1)/\theta)+1$ exceeds the short-term price elasticity, ϵ. As a result, market shares are more sensitive to price differences in the long term than in the short term. This can be seen by comparing equation (2.14) with (2.12).The lower the parameter θ, the more sensitive the market shares are to price differences, and the less important the initial preferences for varieties are. If θ approaches zero, the long-term price elasticity becomes infinite. This replicates a market structure of nearly perfect competition. So, a lower parameter θ increases the tendency to the law of one price.

2.3 Behaviour of the firm

Each sector within a region produces a unique variety of a good. Because of imperfect substitution between the varieties within a sector, firms have market power to raise producer prices above marginal costs at given input prices. They base their decisions on expected output and input prices. Expected factor demand is derived from cost minimisation, given the level of technology. Expected output equals expected demand, which, in turn, is determined by producer prices. Production and factor demand in the current period equal expected production and factor demand in the past period. With output given, producer prices in the current period are set at a market-clearing level that also maximises profits.

2.3.1 The production function

The production technology can be represented by a production function. This function relates output and factor inputs. In addition to intermediary inputs, we distinguish four production factors: two types of labour (low- and high-skilled), capital and a fixed factor (land). We assume constant returns to scale in production. Technological progress is exogenous and factor neutral (Hicks-neutral disembodied technological progress).

The production function is modelled as a nested structure of constant elasticity of substitution (CES) functions and Cobb-Douglas (CD) functions. We assume a similar structure for each sector and region. Figure 2.2 depicts the nested production structure.

At the top level, value added, v, is combined with intermediary input, x, by a CES function to generate output q. At the second level, value added is generated by a CD function combining high- and low-skilled labour, A and B, respectively, capital K and the fixed factor F. Intermediary input x is a CES aggregate of all seven sector inputs:

G, L, C, I, M, T and Z. More formally, the production function can be expressed by equations (2.15), (2.16) and (2.17).[7]

$$q = (\alpha_v^{1-\rho} q_v^{\rho} + \alpha_x^{1-\rho} q_x^{\rho})^{1/\rho} \quad \textbf{(2.15)}$$

$$q_v = A\prod_i q_i^{\alpha_i},\ i = A, B, K, F \quad \textbf{(2.16)}$$

$$q_x = [\sum_j \alpha_j^{1-\rho_x} q_j^{\rho_x}]^{1/\rho_x},\ j = G, L, C, I, M, T, Z \quad \textbf{(2.17)}$$

Cost-share parameters are denoted by α. Since not all prices equal one in the base year, the parameters α_j are not equal to the cost shares in the relevant nests. However, within a nest, cost-share parameters add up to one. Substitution parameters are given by ρ and ρ_x, respectively.

[7] For the ease of notation indices for sectors and regions are omitted.

Box 2.2 The CES structure in production

A nesting structure reflects views on substitution possibilities. Choosing a specific structure restricts substitution possibilities between production factors. Distinguishing more than two production factors creates the possibility for complementarity between factors. Two factors are complements if demand for one factor decreases in response to a price rise in the other. The cross-price elasticity has a negative sign. A nested structure creates the possibility for complementarity between certain factors, but excludes complementarity between others.

Parameter values may further restrict substitution possibilities. A substitution parameter equal to zero would imply a Leontief structure between value added and intermediaries (no substitution). The Cobb-Douglas function for value added (substitution parameter equals one), guarantees constant ("cost") shares for labour, capital and the fixed factor into value added. Thus, the value-added shares do not vanish in the long run. In our opinion, this characteristic outweighs the exclusion of skill-capital complementarity. Such a complementarity, which is often considered a stylized fact, is only possible in a structure with skilled labour and capital in a different nest, sufficient low substitution within this nest, and sufficient high substitution between the skill-capital nest and other nests (*e.g.* unskilled labour).

Choosing a structure is often the outcome of a trade-off between different — often competing — properties. A production function should be flexible, easy to compute, parsimonious in the number of parameters, and based on sound theoretical properties. The latter means that the cost function (the dual of the production function) should be concave, non-decreasing and positive. A nested CES structure is restrictive, but its properties are well understood — and it yields convenient analytical expressions. More importantly, in applied general equilibrium modelling, a (nested) CES satisfies the desired theoretical requirements.

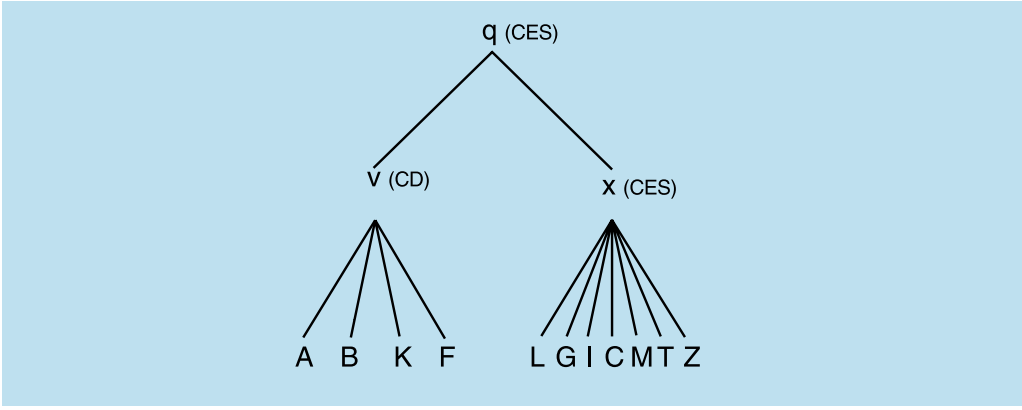
Total factor productivity is given by A. Technology enters the production function through the value-added nest. Technology is described by an efficiency index χ. Total factor productivity is equal to this efficiency index times a constant scaling factor, *i.e.* $A = A_0 \chi$.

The costs for the individual firm are defined as

$$C = \sum_j p_j q_j \ , \ j = A, B, K, F, L, G, I, C, M, T, Z \qquad \textbf{(2.18)}$$

where p_j denotes the price of factor j.

Figure 2.2 Production structure



2.3.2 Cost prices and factor demand

Optimisation leads to expressions for aggregate unit cost prices and factor demand. Prices are determined bottom-up, factor demands are determined top-down.

$$p_v = \frac{1}{A} \prod_i \left(\frac{p_i}{\alpha_i}\right)^{\alpha_i} \ , \ i = A, B, K, F \qquad \textbf{(2.19)}$$

$$p_x = \left[\sum_i (\beta_j p_j^{\,1-\sigma_x})\right]^{1/1-\sigma_x} \ , \ j = G, L, C, I, M, T, Z \ , \ \sigma_x = 1/(1-\rho_x) \qquad \textbf{(2.20)}$$

$$p_q = (\alpha_v p_v^{\,1-\sigma} + \alpha_x p_x^{\,1-\sigma})^{1/1-\sigma} \ , \ \sigma = 1/(1-\rho) \qquad \textbf{(2.21)}$$

The price of the composite intermediary goods, p_x, is the weighted average of the marginal costs of the underlying production factors. The price of value added, p_v, is the Cobb-Douglas aggregate of the prices of labour, capital and the fixed factor.

At the top level, the unit cost p_q is the CES aggregate of the prices of value-added goods and the composite intermediary goods.

The input prices of the production factors are defined below. The input price of labour equals the wages for high- and low-skilled labour. Because we assume that the existing capital stock could be sold after one period – correcting for depreciation – capital costs are equal to the real return on capital, r, compensation for entrepreneurial risk, o, and depreciation times the investment price, p_I.[8] The input price for intermediary inputs is equal to the consumer prices for these goods, which are defined later on.

$$\begin{aligned} p_1 &= W_1 && 1 = A, B \\ p_K &= (r + o + \delta)p_I \\ p_j &= p_{cj} && j = L, G, I, C, M, T, Z \end{aligned} \qquad \textbf{(2.22)}$$

Factor demand is determined by the cost-share parameter, the output at the higher nest level, the price ratio and the substitution parameters (equal to one in the Cobb-Douglas value-added nest).

$$q_v = \alpha_v q \left(\frac{p_q}{p_v}\right)^{\sigma}, \quad q_x = \alpha_x q \left(\frac{p_q}{p_x}\right)^{\sigma} \qquad \textbf{(2.23)}$$

$$q_i = \alpha_i q_v p_v / p_i \quad , \quad i = A, B, K, F \qquad \textbf{(2.24)}$$

$$q_j = \alpha_j q_x \left(\frac{p_x}{p_j}\right)^{\sigma_x}, \quad j = L, G, I, C, M, T, Z \qquad \textbf{(2.25)}$$

[8] The price of capital services is derived as follows. The capital stock corrected for depreciation, δ, can be sold after each period at the expected investment price, p_I^e. Capital which is to be used in the succeeding period has to be bought in the current period at price, p_I . Firms have to pay capital owners for the use of their wealth and producers receive some income as a reward for entrepreneurship. This reward is a proportion of the return on capital and is denoted by o. It is consumed in the own country. Therefore, it is treated in the same way as labour income in the consumer maximisation problem. Given all other inputs the capital price follows from minimising $(1+R)\ (1+o)\ p_I\ K-(1-\delta)\ p_I^e K$, given the production volume $q = f(\bar{q})$.

Box 2.3 Factor demand and substitution elasticities

Demand elasticities reveal something about the magnitude of substitution possibilities. The elasticity of demand η_{ij} gives the relative change in demand for factor *i* in response to a relative change in the price of factor j *at a given output level, e.g.* $\eta_{ij} = \partial \ln(q_i)/\partial \ln(p_j)$. Elasticities are determined by the substitution possibilities within a nest, as well as substitution possibilities between nests (*intra* and *inter* substitution). For example, the own-labour demand elasticity η_{aa} is given by

$$\eta_{aa} = \alpha_a(1-\sigma\beta_x) - 1$$

where β_x denotes the cost share of intermediaries. The larger the substitution parameter or the cost share β_x is, the larger the substitution between value added and intermediaries (inter-substitution), and the smaller (more negative) the demand elasticity for labour.

The value of the elasticity of demand is an empirical matter. Hamermesh (1993) summarises empirical research on this issue. The constant-output elasticity of demand for homogeneous labour for the aggregate economy in the long run is probably bracketed by [-0.75, -0.15], with -0.30 a good "best guess." Labour and energy are found to be substitutes (positive elasticity of demand). In WorldScan, the constant-output demand elasticity for labour is at the lower end of the given range.

2.3.3 Tangible investment

The value of investment, I, equals the differences in volume of the expected capital stock and the current depreciated capital stock times the investment price.

$$I = (K - (1 - \delta)\, K_{-1})p_1 \qquad K \equiv \Sigma_s\, q_{Ks} \qquad s = L, G, I, C, M, T, Z \qquad \textbf{(2.26)}$$

The investment goods are a Cobb-Douglas aggregate of products from the sectors Capital Goods (machinery) and Services (buildings).

Worldwide expected investment equals worldwide expected savings. The regional shares are based on current regional shares of worldwide investment. These expectations do not necessarily materialise, but in practice the deviations are very small. Here, expected regional investment equals

$$I_r^e = \frac{I_r K_r^e / K_r}{\sum_r I_r K_r^e / K_r} (Y_T^e - C_T^e) \qquad \textbf{(2.27)}$$

As has already been stated, each firm produces a unique variety of a good and therefore has market power. Producer prices are determined by profit maximisation. Total demand is the aggregate of consumer demand, investment demand and intermediary demand. The volume of intermediary demand follows from the production decisions in the previous period, and is thus given in the current period. Regional demand for the intermediary good j, V_j, is the aggregate of the demands for these goods of each sector s. Moreover, also included in this definition are investment goods, which are by assumption a mix of Capital Goods and Services.

$$V_M = \kappa I + \sum_s q_{Ms}$$

$$V_Z = (1 - \kappa)\, I + \sum_s q_{Zs} \qquad s = L, G, I, C, M, T, Z \qquad \textbf{(2.28)}$$

$$V_j = \sum_s q_{js} \qquad j = L, G, I, C, T$$

2.3.4 Prices

It follows from profit optimisation that the expected producer price equals the expected unit cost (equation (2.18)) plus a proportional mark-up. The mark-up depends on the short-term price elasticity of demand of the home country. The expected producer price equals

$$p_p^e = \mu C, \quad \mu \geq 1 \tag{2.29}$$

μ represents one plus the mark-up. Production capacity in the current period is already given by the decisions in the previous period. Firms adjust their prices to sell all produced goods. So

$$p_p = D^{-1}(q) \tag{2.30}$$

Consumer prices equal producer prices in the home country. In the case of imports, the consumer price includes also export and import taxes, t_{hb}^x, and t_{hb}^m, and transport costs. The transport costs are a combination of the trade margin, b, times the global price for international transport, p_D. Expected prices have the same structure as current prices.

$$p_{chb} = p_{ph}\,(1 + t_{hb}^m + t_{hb}^x) + bp_D \tag{2.31}$$

The global price for international transport is a weighted average of the producer prices in the Trade and Transport sector of all regions, p_{pTh}. It is defined as

$$p_D = \left[\sum_h s_{Dh}\,(p_{pTh})^{1-\epsilon_D}\right]^{\frac{1}{1-\epsilon_D}} \tag{2.32}$$

s_{Dh} represents the preference to obtain transport services from region h.

2.4 Labour markets

Labour supply for both high- and low-skilled workers is exogenous. As will be discussed in Chapter 4, labour supply trends are based on projections on population size, participation rates and educational attainment. Projections on educational attainment are used to classify labour supply into the categories of high-skilled and low-skilled. High-skilled labour is relatively abundant in the OECD regions, and low-skilled labour is relatively abundant in developing regions. The distinction between high- and low-skilled workers thus facilitates the description of specialization patterns between OECD and non-OECD regions.

For high-skilled labour, B, and low-skilled labour, A, we assume that an exogenous share of labour is unemployed. We interpret this as the natural rate of unemployment. Subtracting this rate of unemployment from labour supply, we derive effective labour supply, which equals the demand for labour. For both types of workers, employment, L, thus equals labour supply, L^s, minus unemployment, U. Only for low-skilled workers in non-OECD regions do we interpret the share of unemployment not as natural unemployment, but rather as the size of the informal sector, which is discussed below.

$$L_1 = L_1^s - U_1 \qquad 1 = A, B \qquad \textbf{(2.33)}$$

Wages, W_1^e, for both skill levels are determined by equilibrium on the labour market:

$$\sum_s q_{1s}(W_1^e) = L_1$$

$$1 = A, B \qquad s = L, G, C, I, M, Z, T \qquad \textbf{(2.34)}$$

$$W_1 = W_{1,-1}^e$$

q_s represents the labour input in a sector. The latter equation (in (2.34)) shows that the expectations on wages are always met.

One of the characteristic elements of WorldScan is the modelling of the informal or low-productivity sector in developing countries. This idea goes back to Lewis (1954) and the formal analysis of Harris and Todaro (1970). Lewis distinguishes two sectors. The first one is a subsistence sector. The marginal productivity of workers in this sector is (close to) zero. They cultivate the land or provide simple services in cities. These workers do not have access to capital and modern technology, or lack the skill to work with those. The second sector is a high-productivity sector in which technology, capital and labour are combined efficiently. This sector grows through the accumulation of capital and technological progress, and demands increasing inputs of labour from the first sector. We make a similar distinction. Workers in developing countries are engaged either in formal high-productivity activities or in informal low-productivity activities.

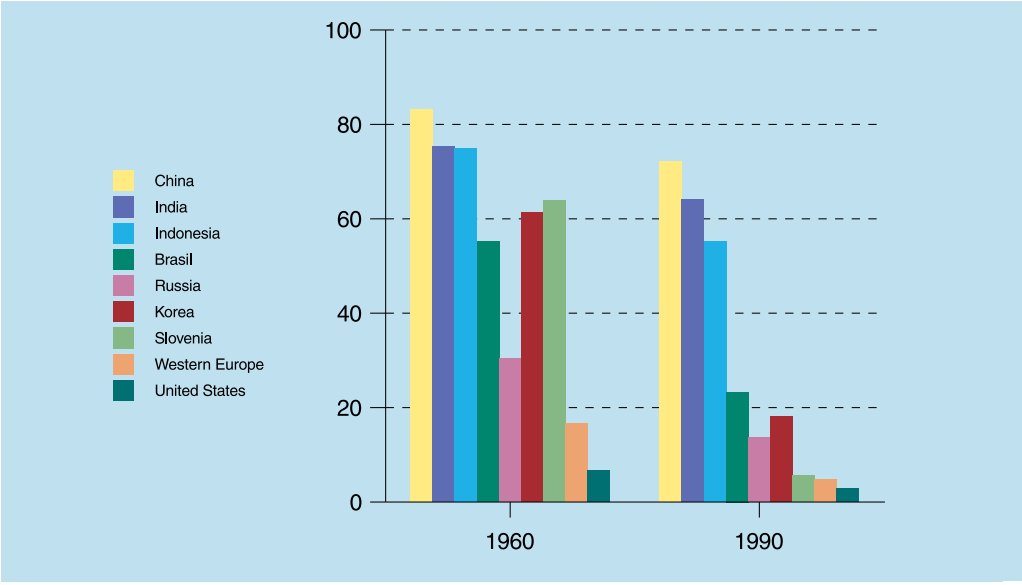
Lewis makes a drastic assumption. He assumes a completely elastic labour supply coming from the traditional sector. However, it seems reasonable that labour allocation between the low-productivity sector and the high-productivity sector depends on the wage difference between these two sectors. WorldScan therefore assumes that the wage elasticity of low-skilled labour supply in the formal sector is finite for the non-OECD regions. More precisely, the model postulates a labour-supply function that links the wage difference between low-productivity and high-productivity

sectors to low-skilled employment in these sectors. Recent research from Peng, Zucker and Darby (1997) supports this view. For China, they find that employment in high-productive rural industries is lower the higher the land-labour ratio is. A high land-labour ratio indicates high returns in agriculture.

Box 2.4 Labour reallocation in the past

By definition, it is hard to quantify the size of labour reallocation. We have to rely on other data, such as employment in agriculture, to characterise the flow from low- to high-productivity sectors. As is discussed in Hof *et al.* (1999), the share of labour supply employed in agriculture is heavily correlated with the share of non-wage earners in a country. The latter share is used as indicator for the size of the informal sector in persons (see Worldbank (1995)). The ILO (1996) provides historical data on the share of labour employed in agriculture. Figure 2.3 shows that some countries experienced a considerable fall in agricultural employment between 1960 and 1990. Typically, the countries that went through a process of rapid structural change also started to catch-up with the group of rich countries. However, also in Brazil, where growth has been much less spectacular than in Korea or Japan, changes in the sectoral structure have been pronounced. Figure 2.3 also shows that in some countries changes have only just begun. In the Asian countries — China, India and Indonesia — the share of agricultural employment is 50% or more, and even in Brazil and Russia the share of agriculture is still large compared to the average share in the OECD.

Figure 2.3 Employment in agriculture (% of total employment)



Source: ILO (1996)

Our labour-supply function reads

$$0 \leq U_A = 1 - \left(\frac{W_A}{\upsilon \underline{W}} \right)^{\omega} \qquad \upsilon, \omega > 0 \tag{2.35}$$

where $\underline{W}$ is the wage in the low-productivity sector, and U_A is the share of low-productivity workers in the labour supply. Once all low-skilled workers have been reallocated to the formal sector, the relation between the wage differential and labour reallocation will no longer be valid. The labour market will clear such that total labour supply equals total demand in the high-productivity sectors. Employment in low-productivity sectors can be as high as 60% (see Table 2.1), and guess estimates of the ratio of wages in the high-productivity sectors to the low-productivity sectors by the ILO range from 4 to 7. Equation (2.35) ignores the micro-economics of reallocation, migration and wage formation. It assumes that productivity differences exist and will continue to exist. Productivity in low- and high-productivity sectors develops at a different rate, which increases the wage difference and induces labour reallocation between these sectors. The extent to which wage differences induce a flow from low- to high-productivity sectors depends crucially on the wage elasticity of labour supply, ω.

WorldScan assumes that the sectors Agriculture and Services can be split up in a formal and an informal part. Goods produced in both parts are perfect substitutes. In the model, the price of low-productivity output is a weighted sum of the price of Agriculture and Services, because low-productivity workers are employed in Agriculture and Services. The weights are region-specific, based on ILO (1996) data. Moreover, these weights do not change over time, since we do not want to focus on reallocation between low-productivity activities or migration from backward rural areas to city slums. The wage for low-productivity workers equals

$$\underline{W} = \left(\sum_i \iota_i p_i \right) \underline{A}, \qquad \sum_i \iota_i = 1 , \qquad i = L, Z \tag{2.36}$$

where ι_i is the number of low-productivity workers in sector i as a share of the total number, p_i denotes the producer price in sector i, and $\underline{A}$ is an index for technology.

If the production methods in formal Agriculture become more efficient, prices of agricultural products will fall, increasing the wage difference between high- and low-productivity sectors and pushing labour towards the high-productivity industrial sectors. This mechanism refines Lewis' analysis. He emphasises that productivity growth in the high-productivity sectors will 'pull' labour from the low-productivity sectors. However, China serves as an illustration that booming rural industries are not necessarily the driving force behind labour reallocation. Instead, the Chinese industrial revolution started in agriculture (see, eg., Sachs and Woo (1997)). Reforms and productivity growth in Agriculture 'push' labour towards the high-productivity industrial sectors.

The Worldbank (1995, Table A.3.1) reports for numerous countries the share of non-wage (=low-productivity) workers in the total working population in the following sectors: agriculture, manufacturing and services. The share of non-wage workers in developing countries exceeds by far the share in developed countries. At the beginning of the nineties, the share was 84% in China and 75% in India, whereas the share was less than 10% in the United States. The number of non-wage workers provides an indication for employment in the informal sectors; from the Worldbank data we derive employment of low-productivity workers in agriculture and services (and thus L and Z in equation (2.36)). The raw data have been adjusted for a natural share of non-wage workers and a natural unemployment rate. The 'natural' share and the 'natural' rate are set equal to the average values for the OECD. Table 2.1 gives the resulting characteristics of the low-productivity sectors.

Table 2.1 *Low-productivity sectors in developing countries value added, employment and GDP per capita in 1995*

	Latin America	Middle East	Sub-Saharan Africa	China	South-East Asia	South-Asia & Rest
informal sector % of total value added	1.9	1.5	8.2	19.0	4.3	14.1
informal employment % of low-skilled workers	25.2	23.8	60.0	63.4	37.7	61.9
informal agrarian employment % of informal employment	39.4	50.6	68.8	85.6	55.1	80.1
ratio of high and low wages	5.8	5.9	4.2	4.0	5.3	4.1
GDP per capita ($1000)	3.4	2.4	0.5	0.7	2.9	0.5

Source: own calculations, based on McDougall *et al.* (1998), Worldbank (1995) and ILO (1998)

2.5 Capital markets

Capital demand by producers has to be matched by capital supply. In a closed economy, regional savings equal regional investment. We assume that regions are linked not only by trade in goods and services, but also by international capital mobility. This implies that regional savings and investment can diverge. Therefore, only at a global level do savings have to be equal to investment in WorldScan. In spite of the integration of regional capital markets, we do not model one international capital market. Box 2.5 argues that international capital mobility is still far from being perfect. The elimination of capital controls and other barriers have stimulated capital mobility, but this is not sufficient to equalise returns on investment internationally. On the other hand, the increasing importance of foreign direct investment suggests that regional capital markets have to be linked. We therefore model regional capital markets in which capital supply comes from various regions.

The amount of capital supplied within a region follows from a portfolio model. The global supply of capital equals global wealth. We use a portfolio model to allocate regional wealth over the various regions in which capital owners invest. They have preferences to invest their wealth, B_h, in the various countries that depend on the return on investment, R_r, and preferences for certain regions, λ_{hr}. These preferences are not

Box 2.5 Imperfect capital mobility

Savings and investment can diverge in integrated capital markets. In the sixties and seventies, capital markets were not heavily integrated — in spite of the elimination of capital controls and other barriers. In a classic paper, Feldstein and Horioka (1980) show that even among industrial countries capital mobility is limited: changes in the national savings rate ultimately change investment rates by the same amount. For the period 1960-1974, they showed that savings and investment were heavily correlated. However, capital was not as mobile in that period as it is now. Regression analysis by Obstfeld and Rogoff (1996) over the decade 1982-1991 for nearly all OECD countries shows that that correlation is still high, although it is weakening. The correlation between savings and investment does exists not only in industrial countries, but also in developing countries. However, massive foreign investment flows in countries like China, Indonesia and Brazil have increased the importance of international capital mobility. For the developing world as a whole, the importance of foreign direct investment (FDI) increased during the last two decades (as can been seen in Table 2.2). This increase indicates rising capital mobility, in particular for private capital. Another indicator is the share of inward FDI stocks to GDP. Worldwide, these shares rose from 4.6% in 1980 to 9.4% in 1994 (see UN, 1996). These numbers reflect the growing importance of international capital mobility.

Table 2.2 Savings and Investment in developing countries.

	1973-1980	1981-1990	1990-1994
Domestic Savings	25.7	23.1	25.6
Investment	25.7	24.6	27.2
Foreign Savings (net)	0	-1.5	-1.6

Source OECD (1997). All numbers are percentages of GDP.

discussed here extensively. However, the strong bias to invest in the home country could be explained by information asymmetries (see, among others, Gordon and Bovenberg (1996)). In general, foreign capital owners do not have the same information as local capital owners on the rate of return of certain investment projects.

Using a portfolio model, we find that the amount of capital from region h invested in region r, F_{hr}, equals

$$F_{hr} = \frac{\lambda_{hr}\exp^{\phi R_r}}{\sum_r \lambda_{hr}\exp^{\phi R_r}} B_h \qquad \textbf{(2.37)}$$

Equation (2.37) shows that the allocation of wealth depends on exogenous preferences to invest in certain regions and differences in the nominal return on investment. The parameter ϕ indicates the degree to which capital markets are integrated. If it is low, then differences in nominal returns are not so important for the allocation of wealth. In the limiting case of $\phi = 0$, only preferences matter. If the parameter is high, then small differences in the rates of return steer the allocation of wealth.

Equation (2.37) has a drawback. If some regions grow faster than others, the faster growing regions need more capital. According to the standard model, capital owners can be persuaded to invest in these regions only if the rate of return increases. This would imply that higher growth rates can occur only in tandem with rising nominal rates of return relative to other regions. In the short term, the correspondence of high growth rates and high rates of return is plausible. From a longer term perspective, however, it does not seem realistic that regions that become relatively more important in the world economy can only attract more capital by rising nominal returns. The mere fact that emerging economies become more mature may lower the risks for capital owners to invest in these economies.

For this reason, WorldScan adjusts equation (2.37) by endogenising λ_{hr} such that growing regions do not need to increase their nominal return on investment in the long run. λ_{hr} depends on the value in the previous period and the GDP share of region r in the world economy. It reads

$$\lambda_{hr} = \eta\lambda_{hr,-1} + (1 - \eta)\, Y_r / \Sigma_h Y_h \qquad 0 \leq \eta \leq 1 \qquad \textbf{(2.38)}$$

Y_r denotes GDP for region r. Notice that $\Sigma_r \lambda_{hr} = 1$. As regions grow faster, their share in the world economy increases, such that the preference of capital investors to allocate their wealth to that region increases.

The wealth in a region, B, is equal to the wealth in the previous period plus the nominal return on wealth and savings — expressed as the difference between income and consumption — minus the real return on capital and depreciation costs. It reads

$$B_r = B_{r,-1} + \Sigma_h R_{h,-1} F_{rh,-1} + p_{yr} Y_r - p_{cr} C_r - (r_r + \delta)\, p^e_{Kr,-1} K_{r,-1} \qquad \textbf{(2.39)}$$

The value of the real return on capital is subtracted from wealth to guarantee that the value of wealth is affected only by the inflation component of the nominal returns and savings. We also correct for depreciation by subtracting the value of the depreciation to guarantee that total wealth is equal to the total value of capital at a global level.
Capital supply, K^s, within region r is the aggregate of all wealth allocated in region r by capital owners from all regions. It reads

$$K^s_r = \sum_h F_{hr} \qquad \textbf{(2.40)}$$

The demand for capital within a region equals the required capital needed for production. From the equilibrium conditions on the regional capital markets, we derive the real interest rates, r. The equilibrium conditions are

$$K_r^s = p_I K_r \qquad r = \text{all regions minus region x} \qquad \textbf{(2.41)}$$

$$q_{Mx} = d_{Mx} \qquad \text{region x}$$

We impose an equilibrium condition on the capital markets in all regions minus one. This determines all minus-one real interest rates. The other interest rate is used to guarantee that global savings are equal to global investment — that is to say that all product markets clear. The price of Capital Goods in one region is the numeraire. The real interest rate condition guarantees an equilibrium on the Capital Goods market. Because we imposed equilibria for all product markets and labour markets, global investment has to equal global savings. Because equation (2.41) imposes equilibria on all regional capital markets minus one, the latter capital market must also be in equilibrium.

Some accounting identities

Net foreign capital income, YF_r, within region r is the difference between received capital income minus capital income paid to foreigners. It equals

$$YF_r = \Sigma_h F_{rh,-1} R_{h,-1} - \Sigma_r F_{rh,-1} R_{r,-1} \qquad \textbf{(2.42)}$$

The following equations describe some regional identities. These identities have a similar structure for the current and expected period, taking into account that expectations of lags are equal to realizations in the current period. The general price level is the weighted aggregate of all sectoral consumption prices within a region. The weights are the consumption shares.

$$p = \prod_s \left(\frac{p_s}{\gamma_s}\right)^{\gamma_s} \qquad s = C, I, M, L, G, T, Z \qquad \textbf{(2.43)}$$

Gross Domestic Product, Y, is defined as value added at producer prices plus tax revenues, T. Value added is defined as the value of production minus the value of intermediary inputs aggregated for all sectors.

$$Y = \sum_s \left(Q_s p_{ps} - \sum_f V_{fs} p_{Ifs}\right) + T \qquad s,f = C, I, M, L, G, T, Z \qquad \textbf{(2.44)}$$

Tax revenues consist of the value of export taxes and import taxes, aggregated over all sectors.

$$T_r = \sum_s \left(\sum_h \left([t^x p_p X]_{srh} + [t^m p_p X]_{shr} \right) \right) \qquad h \neq r \qquad \textbf{(2.45)}$$

2.6 Expectations in WorldScan

Expectations can be framed as forward-looking or backward-looking variables. Most models incorporate a mix of these two extremes. Those who stress short-term forecasting accuracy favour backward-looking regressions for framing expectations, because model-consistent expectations do not perform as well. Those who favour forward-looking model-consistent elements argue that these expectations are less vulnerable for the Lucas critique (see, *e.g.,* IMF (1998)). Furthermore, model consistency is also advocated because it is the natural starting point for welfare analysis. The assumption that agents use all available information while optimising their utility enables a rather straightforward definition of the welfare impact of policies.

In spite of the attractiveness of model-consistent expectations, and despite the fact that the purpose of WorldScan is not short-term forecasting accuracy, we have chosen not to impose complete model consistency. The reason is that such an approach would have had two major disadvantages. The first one is that we would have to chose so-called end-point conditions (*i.e.* values of variables that are assumed to remain constant after a certain period). The formulation of a steady state in a global model is problematic because it would imply that all regions and sectors grow at the same pace. The second drawback is that the calculation of a rational-expectation path is time consuming. Both disadvantages will be examined below.

In theory, model-consistent, rational expectations require the formulations of expectations over an infinite horizon, which is of course infeasible in practise. In practical applications, therefore, one assumes that from a distant future period onwards, the economy is in a steady state. That assumption implies that growth rates, interest rates and market shares, for example, are constant over time after that period. It also implies that expectations about these variables can be easily calculated for this steady-state period once the steady state is assumed. However, an essential characteristic of the global economy is that growth rates differ between countries and sectors. Countries are in different demographic phases, implying different growth rates of population and employment. Countries or sectors that operate at the technological frontier will experience different rates of technological growth rates than will countries or sectors that are catching up. It is difficult to imagine what it would be like if countries converge to the same growth rates, let alone how difficult it would be to approximate market shares in such a steady state.

Instead of perfect, model-consistent, foresight, we assume adaptive expectation for some central variables, like interest rates, macro growth rates and market shares. These adaptive expectations are modelled in such a way that they would be model consistent in a steady state.

For the allocation of investments over sectors we follow a different approach. In a static model, this allocation is the heart of the general equilibrium mechanism. The optimal allocation of endowments is determined by substitution elasticities in production functions and price elasticities in demand functions. In a dynamic model in which investments become operational in a future period (one period ahead in WorldScan), current investments or allocations of capital are combined with future variable inputs. We assume that with the allocation of capital also the input intensities for the next period are fixed. As a result, the sectoral allocation of capital also determines the demand for other inputs in the next period. To avoid serious mismatches between input demand and factor supply in the next period, and between sectoral capacity and demand for sectoral output, we use in the sectoral allocation of investment all available information about next-period factor supply and product supply.

WorldScan assumes that the only uncertainty in the next period is investment demand. Factor demand and intermediary demand have already been determined in the current period. It is assumed that the macro savings rate is also known one period in advance. That means that also global savings and global investments are known one period in advance. That leaves the regional investment decisions in the next period as the primary source of uncertainty. Once regional investments are correctly foreseen, all other expectations will also be met. This emphasises the relatively large uncertainty surrounding investments.

With this treatment of the next period, the static equilibrium mechanism is split into two parts. One part allows the supply of capacity, determined in the current period, to be confronted with demand in the next period. In this confrontation both demand and supply are flexible, reacting to relative prices. In the second part, WorldScan's current period, given capacity, given factor supply and given intermediary and consumption demand are all combined with flexible investment demand. If investment demand deviates from the demand that was expected in the previous period, then prices will deviate somewhat from expected prices. In practise, these deviations appear to be very small. Table 2.3 shows that the expectations about investment in 2019 deviate about 1% from the realizations in 2020, the time horizon of many scenario studies. These deviations are only about 0.1% GDP.

Table 2.3 Realizations of expectations in 2019 relative deviations of expected values in 2019 to realized values in 2020 (%)

Country	Investment	GDP
Western Europe	-0.5	0.0
United States	-0.4	0.0
Japan	-1.5	-0.2
Pacific OECD	-1.4	-0.1
Eastern Europe	-1.2	-0.1
Former Soviet Union	-0.9	-0.1
Middle East & N. Africa	1.6	0.2
Sub-Saharan Africa	0.0	0.0
Latin America	1.5	0.1
China	1.3	0.3
South-East Asia	0.9	0.1
South Asia & Rest	1.0	0.1

Summarising, the combination of backward-looking macro expectations and an accurate equilibrium mechanism at the sectoral level has several advantages.

- Computational problems are relatively small because we do not need rational expectations over very long time horizons.
- Significant forecasting errors and disequilibrium situations are avoided.
- Uncertainty is concentrated around the investment decisions, which seems plausible.
- In the steady state, expectations are fully model consistent.

2.7 Long term properties

WorldScan aims to describe the relationship between developed and developing regions. It is suited, among other things, for the analysis of globalization processes, trade liberalization and the catching-up manoeuvring of developing regions. By focussing on these structural developments, the model must be able to describe unbalanced growth among various regions and sectors, or even scenarios that are characterised by divergence between regions. For these reasons, WorldScan is neither modelled to deliver steady-state growth paths, nor calibrated to reach these growth paths a few hundred years ahead.

Although the model does not contain a steady state, the long-term properties of the model are important — in particular for scenarios with a time span of about hundred years. We do not want to model exploding growth paths, or unlimited debt-to-GDP ratios. Moreover, the model must be able to describe convergence scenarios in which developed

and developing regions converge to some extent. This section, therefore, describes the long-term properties of the model. First, we focus on the long-run properties of the model, which include some convergence tendencies. Second, we discuss those properties that do not contain convergence tendencies.

2.7.1 Convergence tendencies

Many characteristic elements of the model contain a tendency to convergence. First of all, if non-OECD regions develop, labour will reallocate from the low-productivity to the high-productivity sectors. In the long run, everybody will be employed in the high-productivity sectors.

On the imperfectly integrated capital markets, investors prefer to invest in specific regions. If these preferences would remain unaltered, some regions, in particular the OECD, would receive much more capital than other regions. However, by introducing a relationship between the relative size of an economy and the portfolio preferences (see equation (2.38)), these preferences would depend in the long run only on the relative size of the economy. Thus, if economies converge, these preferences will also converge. Moreover, convergence of real interest rates on the capital market can be stimulated by increasing the interest rate elasticity, ϕ, in equation (2.37). The value of ϕ could be interpreted as a measure for transparency on international capital markets.

Besides characteristic elements such as the informal sector and the portfolio model, the endogeneity of sectoral consumption shares leads also to convergence. Because the consumption shares converge to those in the United States, every region will have the same consumption pattern in the long run if income per capita converges. The adjusted Armington specification with large long-run price elasticities contributes to the convergence of producer prices.

Another longer-term property of the model is the constant labour-income share. By specifying the value-added nest in the CES production function as a Cobb-Douglas, we set the labour- income and capital- income share as a constant proportion of value-added in a sector.[9] If the shares of the sectors in regional value-added remains constant, the labour- and capital-income shares in regional GDP are constant.

Besides model mechanisms, convergence depends also on exogenous trends. High- and low-skilled labour supply varies by region because of varying participation rates and skill levels. The projected skill composition includes convergence properties: in the end, developing regions will have the same skill levels as developed regions. The projected participation rates do not converge at the moment. First, participation rates differ per age cohort and sex. Second, the age structure of the population differs. Only if the projected rates per age cohort converge, and the

[9] We ignore the fixed factor in the sectors Agriculture and Raw Materials. Income from the fixed factor is also a constant share of value-added.

demographic projections include convergence of the age structure, will participation rates converge.[10]

2.7.2 Non-convergence tendencies

We calibrate our model for the base year 1995 mainly on the GTAP database. We want to represent the data in the model as well as possible, apart from our regional and sectoral classification, which differs from the original GTAP data. This implies that factor intensities in production, savings rates, trade and trade taxes vary by region and by sector. We do not take account of convergence in the calibration procedure with respect to the elements mentioned above. Convergence can only take place if the model incorporates mechanisms that reduce these differences. Differences in import and export taxes can be resolved by introducing trade liberalization in the model. However, other regional differences based on the GTAP data have a long-term impact.

First of all, different savings rates in the base year imply different discount factors in the regions. Even if real interest rates, future income growth, and nominal returns on wealth are equal in all regions, discount factors will vary because of differences in savings rates. Only an update rule for the discount factor could lead to equal discount factors in the far future and thereby to equal saving rates. Such an update rule could include a relation between the discount factors and income levels.

Second, consumer preferences to buy varieties of a category of goods produced in a certain region depend on the values of imports and exports in the base year. As a consequence, varieties from some regions are far more popular than those from others — even if consumer prices are equal. In principle, this will not lead to stable development of regions, because some regions export much more than others do. If convergence of the preferences for varieties originating from various regions is important, then these preferences have to depend on the share of global production of that sector. In the long run, preferences would be equal to these production shares. In that case, the export-to-value-added ratios would be equal for all regions in a sector. Such an update rule for the preferences is comparable to the modelling of the preferences on the international capital markets.

Third, the factor intensities in a sector differ by region. This is the implication of calibrating the input intensities with the GTAP data. Regions thus have different input intensities for all inputs: intermediary goods, labour and capital per sector. As a consequence, the convergence of total factor productivity levels does not lead to equal productivity of labour, capital and the other inputs. Sectors in various regions develop at different paces, even if all other relevant variables are similar in the regions. If convergence is important, production structures have to converge. Such convergence rules are fairly

[10] Recent research of Bloom and Williamson (1997) has shown that the age structure of the population affects GDP growth per capita significantly.

complicated. Otherwise, we have to impose the restriction in the calibration procedure that the input intensities of a sector for all regions have to be equal. This conflicts with our aim to mimic the GTAP data as accurately as possible. Note that convergence of total factor productivity levels is not guaranteed in the model. The rate of technological progress is exogenous without an endogenous catching-up mechanism.

Summarising, WorldScan has been developed to study structural changes within and between regions. Growth rates per sector and region can be unbalanced for a long time. This is not consistent with the modelling of steady states. These steady states are also not realistic for time spans of about 25 to 50 years. Therefore, the scenarios deviate from steady states. Long-term properties are of course important, not only for the model, but also for the scenarios that we want to describe with WorldScan. Although a steady state is not an aim, we want to avoid exploding growth paths and/or exploding debt levels. Moreover, we want to run scenarios that incorporate some convergence tendencies. Some characteristics of the model, such as the informal sector, the portfolio model for investment, and the changes in consumption shares incorporate convergence tendencies. Other elements of the model, such as consumer preferences for varieties, the discount factor and especially the production structures do not lead to convergence. If convergence is an aim, the calibration procedure has to be modified. This conflicts, however, with our intention to mimic the GTAP data as accurately as possible.

3 Data

This chapter provides an overview of the data and exogenous projections used in the model. We rely heavily on the GTAP database, version 4 (McDougall *et al.*,1998). This database contains sectoral information on production, consumption, trade and trade taxes for 1995. Moreover, we present data and projections on labour supply trends as well as our monetary data.

We start with the projections on labour supply and the decomposition into low- and high-skilled labour. Section 3.2 discusses the current consumption patterns and the patterns of trade and production, showing that current relative endowments matter. Trade and existing import tariffs and export taxes — other determinants of trade patterns — are discussed in Section 3.3. Section 3.4 presents macroeconomic data such as GDP, GDP per capita, employment, savings and investment. Section 3.5 focusses on the monetary data.

The data in this chapter apply to three aggregate regions: the OECD, Asia and the Rest of the World. Appendix A3 contains similar tables and figures for twelve regions.

3.1 Labour supply

3.1.1 Total labour supply

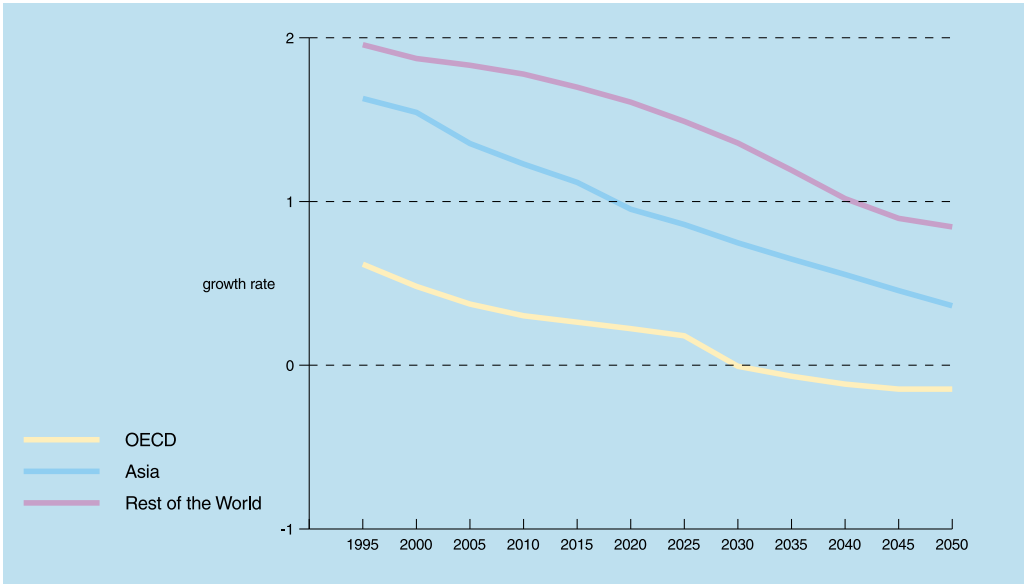
Total labour supply is derived from population data and participation rates. The projections on total population size are taken from United Nations (1995), and those on participation rates are from ILO (1996).

Figure 3.1 presents population growth in the aggregated three regions in the model until 2050.[1] It shows a declining growth rate for all three regions. The growth rates in the OECD are lower than in other regions. After 2030, the growth rate becomes slightly

[1] Here, we present demographic projections until 2050. The reason is that for some studies we run scenarios until 2050. However, Chapters 5 and 6 present simulations until 2020.

negative. Population growth rates in the other regions are much higher. Nevertheless, the decrease is substantial. Declining birth rates are an important explanation for this decrease. The demographics of the different regions within the Rest of the World are, however, quite diverse. Some regions, like Eastern Europe and Russia, follow the demographic profile of the OECD, while the African regions will become increasingly populous.

Figure 3.1 Growth of total population from 1995 to 2050



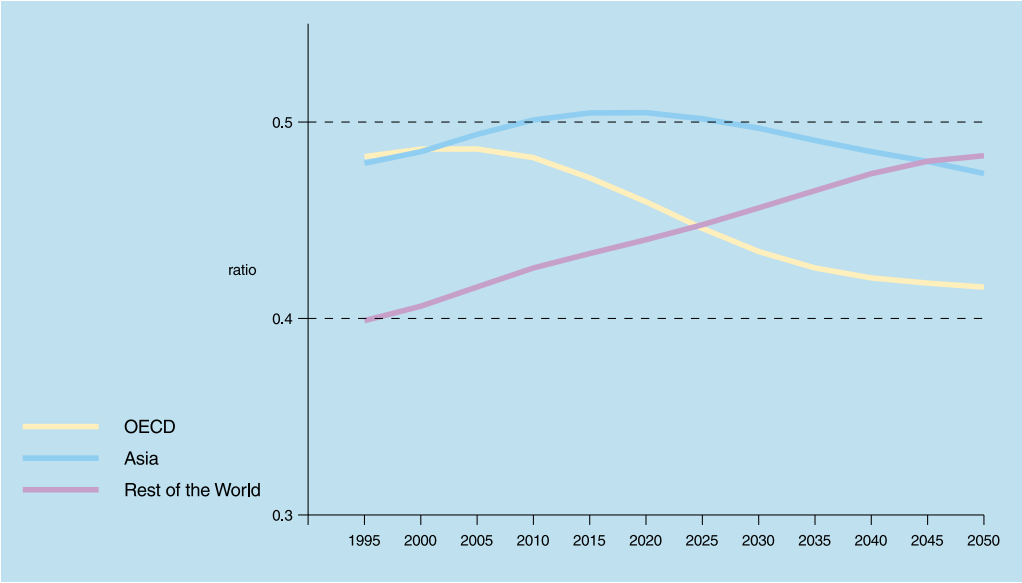
Source: UN (1995)

The demographic developments and participation rates together determine labour supply. ILO (1996) provides projections on participation rates for about 160 countries, 14 five-year age-cohorts and both sexes until 2010. Moreover, they present historical data from 1950 onwards. We aggregate the country data for the twelve WorldScan regions, using the population projections of United Nations (1995) for each age cohort and sex. We pool the time series between 1950 and 2010 of all twelve regions for each cohort and sex. Using a multilogistic function, we regress the data points on two lags. The estimated coefficients are used to extrapolate the participation rates per cohort and sex after 2010.[2] From the participation rates and the demographic projections of United Nations (1995), we derive the macro participation rates. These rates are expressed as a share of the total population. Figure 3.2 presents the macro participation rates for the three regions.

[2] Van Leeuwen and Lejour (1999) discuss this method extensively.

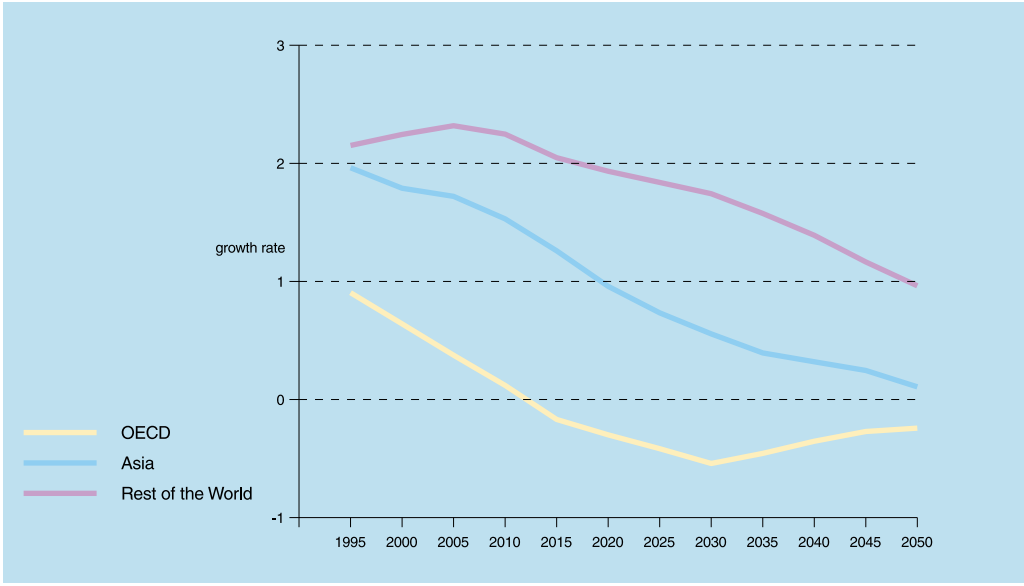
The patterns are quite diverse. The participation rates in the OECD decline due to ageing. The participation rates of the elder age cohorts are much lower than those of the younger age cohorts. As an effect, the macro participation rate declines. The participation rate of the Rest of the World follows the opposite pattern. In 1995 this rate is fairly low due to the low participation rates of women in Africa and the Middle East, and the high proportion of young children in these regions. Increasing participation rates of women and of elderly men are the underlying causes of the increase until 2050. In Asia, the change in participation rates is fairly modest. After an increase until 2020, the rate will decline slightly (see also Appendix A3.1).

Figure 3.2 Participation rates from 1995 to 2050 (share of total population)



Source: Own calculations based on ILO (1996), and UN (1995).

Figure 3.3 Growth of total labour supply from 1995 to 2050



Source: Own calculations based on UN (1995) and ILO (1996).

Using the projections on population growth and the participation rates, we derive the projections on labour supply. Figure 3.3 shows that labour supply will shrink after 2010 in the OECD. The reasons have been discussed above. Because the decrease in population and participation rates in the OECD will slow down after 2030, labour supply will shrink only marginally from that period onwards.

Labour supply growth in Asia and the Rest of the World is much higher in 1995 at about 2%. From then onwards, labour supply growth will slow down substantially. Declining population growth is the main cause. Rising participation rates in the Rest of the World partially offset this decline.

3.1.2 Skill composition

Our model distinguishes low-skilled and high-skilled labour. This is relevant, not only for the analysis of the labour market, but also for the analysis of economic growth. Moreover, it improves the description of specialization patterns. OECD regions endowed with a relatively high amount of high-skilled labour specialise in the production of high-skilled labour-intensive goods, and regions endowed with relatively much low-skilled labour specialise in low-skilled labour-intensive goods.

Labour can be divided into high- and low skilled according to two methods. The first uses a criterion based on the professional status of employees. Professional workers are classified as high-skilled, and production workers as low-skilled.[3] The second method uses a criterion based on schooling levels. High-skilled workers are classified as those who completed secondary education. We have incorporated the latter method for two reasons. First, education levels provide a better indication of endowments in regions. Second, pronounced differences between the regional quality of employment are better described by average education levels than by occupational classification.

The classification of high- and low-skilled workers in a region is based on current and projected stocks of human capital for the different levels of education in a region. Barro and Lee (1993, 1996) have constructed a stock of human capital for every schooling level for about hundred countries using a perpetual inventory method. The four relevant levels are none, primary, secondary, and higher education. For the latter three levels they also distinguish attainment and completion levels. Changes in the number of people who have attained or completed a certain level depend on the mortality rate of that group and the inflow. The inflow is determined by the size of the new age cohort times the enrollment rate for the specific schooling level. The method thus needs data on enrollment rates, age cohorts, and age-specific death rates (see UNESCO (1989)). In this way Barro and Lee (1996) have constructed stocks of human capital for the age category 15-64 between 1960 and 1990.

Ahuja and Filmer (1995) have constructed projected stocks of educational attainment of the population aged 6 and over until 2020. They have used projections on enrollment rates, age cohorts and age-specific death rates, as well as the stocks of human capital from Barro and Lee (1993). However, their projections do not include the OECD countries. Furthermore, they only construct projections for attained levels, because projections on drop out rates and by consequence completed levels are not available.

The resulting stocks of human capital raise several questions, given our purpose to classify high- and low-skilled labour. First, the differences between the United States and most other OECD countries are quite large. The proportion of the population that attained only primary education is much higher in Europe, where the attainment in higher education, however, is much lower. Moreover, for most large European economies convergence tendencies to the United States do not show up. Within Europe the differences (in secondary education) are also striking. Attainment in secondary education rose from 1960 to 1990 in Austria by about 40% of the population, while the rise is only 10% in Germany and France.[4]

In our opinion, the implied differences in projected skill levels in these countries are not plausible if they are related to actual differences in skill-intensive production

[3] This method is followed by GTAP4; see McDougall *et al.* (1998).

[4] These problems go back to the raw data of UNESCO (1989). Van Leeuwen and Lejour (1998) discuss some of the causes, such as different classifications of education levels and institutional differences.

technologies in the OECD. OECD (1997b) supports this reasoning. In comparing literacy rates for the different age groups (p. 225), they report that there are few differences between the United States and Europe. One has to notice that literacy rates do not imply merely the capacity to read and write, but also skills to keep pace in modern society. The charts on the results of international maths and science tests also show no higher skill level for students in the United States. On the contrary, in maths American students perform significantly worse than do students in other OECD countries (p. 200).

It thus seems reasonable to assume that educational levels are similar within OECD regions. Moreover, WorldScan emphasises differences between OECD and non-OECD regions, and not differences within the OECD. So, we are particularly interested in distinguishing different skill levels between the OECD and non-OECD. According to the data of Barro and Lee (1996), educational levels in Eastern Europe and the Former Soviet Union are comparable to the OECD. We therefore assume for our projections that the stocks of human capital are similar in the OECD, Eastern Europe and the Former Soviet Union.

Besides the problem mentioned above, the projections of Ahuja and Filmer (1995) on human capital include only developing countries, and are not available beyond 2020. For the developed regions and beyond 2020, we have to construct our own projections. Moreover, Ahuja and Filmer (1995) provide projections only for attained levels of education. However, we classify high-skilled workers as those who have completed secondary education or more. The reason is that other classification criteria lead to a very large share of high-skilled workers in the OECD (*e.g.* if attained secondary education is a criterion) or a negligible share of high-skilled workers in the non-OECD (e.g if attained tertiary education is a criterion).

We use the following method to derive projections until 2050 for the population share that completed secondary education.[5]

1. We calculate the drop-out ratios at the secondary level for the relevant WorldScan regions using Ahuja and Filmer data for the years 1985, 1990 and 1995. For these years they have data on secondary education attained and completed. The drop-out rates are fairly high: about 55% in most non-OECD regions; for Sub-Saharan Africa the rate is even 75%. Subsequently, we analyse the drop-out ratios in Barro and Lee (1996) for the period 1960 to 1990. The drop-out rates for most regions (including the OECD) are fairly constant over time, except for Sub-Saharan Africa. Moreover, the drop-out ratios for OECD and non-OECD regions do not differ significantly. From this analysis we assume that the 'projected' drop-out rates from 2000 to 2020 are 55%. The only exceptions are Sub-Saharan Africa, for which we assume a gradual decrease in the drop-out ratio from 75% to 55% in 2020, and Latin America, for which we assume a drop-out ratio of 50%. We use these drop-out rates and the projections on secondary attainment by

[5] Van Leeuwen and Lejour (1998) extensively discuss the method used.

Ahuja and Filmer to derive the projections on the completion of secondary education until 2020.

2. We derive the average growth rate of the population share that completed secondary education in the non-OECD between 1990 and 2020. We use this growth rate to project these shares between 2020 and 2050, upon the share levels in 2020 in the non-OECD regions. As a result, steps 1 and 2 deliver the growth rates of the population share that completed secondary education for the developing regions between 1990 and 2050.

3. We use the Barro and Lee data (1996) to compute the high-skilled ratios, defined as the number of high-skilled workers divided by the total labour force, for the OECD and non-OECD (excluding China[6]) for the period 1960 and 1990. We define the relative high-skilled ratio as the high-skilled ratio of the non-OECD compared to the one of the OECD. We calculate the increase in the relative high-skilled ratio during the period 1960 to 1990, and extrapolate this increase until 2050.

4. We normalise the high-skilled ratio in the OECD and the transition countries at 50%. The reason is that increases in the supply of skilled labour are often accompanied by increases in demand in the longer term.[7] One of the causes is the shift in production technologies in favour of high-skilled labour. However, apart from increases in total factor productivity, production processes do not change in WorldScan. Moreover, the classification criterion for the skill split changes in time. Fifty years ago, people who attained some years of secondary education were classified as high-skilled in the OECD. In the future one might have to complete the tertiary level to obtain this classification. Diploma inflation thus occurs. For both reasons we assume the share of high-skilled labour is constant in time for the OECD regions. As a result, the skill premium is more or less constant in time.

5. From 1 to 4 we derive the high-skilled ratio for the non-OECD regions, relative to those in the OECD and the transition countries. The high-skilled ratio in non-OECD regions is 50% (4) times the increase in the relative high-skilled ratio in the non-OECD (3) times the growth in the high-skilled ratio of the particular region (1 and 2) compared to the average growth in the non-OECD regions.[8]

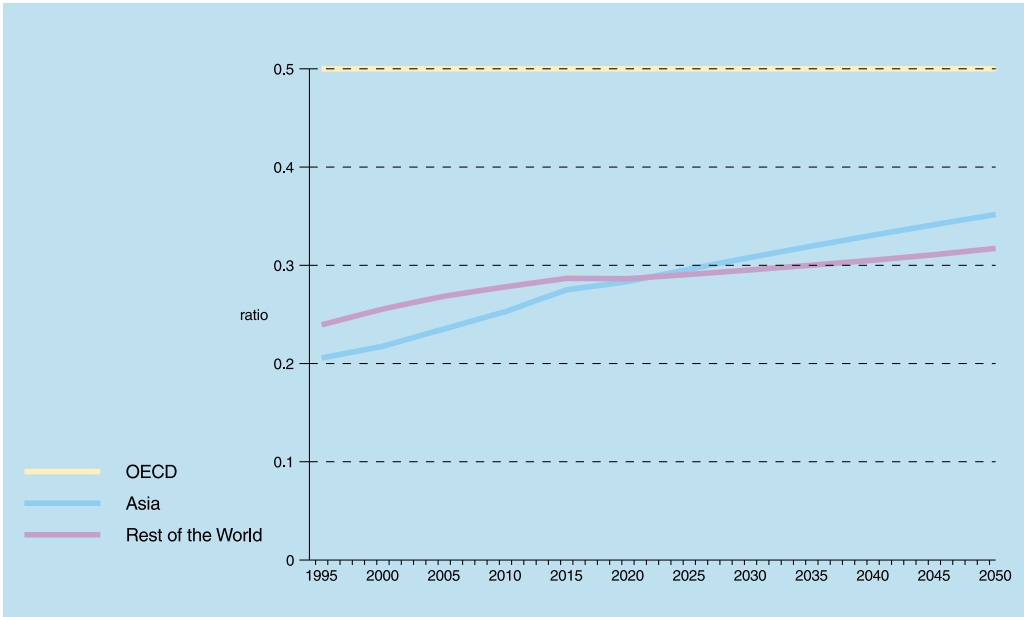
[6] Data for China are only available from 1975. This implies that our extrapolation would only be based on a period of 15 years. The exclusion of China doubles the length of this period.

[7] Much research has been done for the United States; see *e.g.* Baldwin and Caine (1997) and Johnson (1997). Here we also touch upon the trade wage-inequality debate, but do not discuss it. Whether or not increased trade has affected the skill premium, other demand factors such as skill-biased technological change are important as well. We do not want to focus on this issue here.

[8] The last multiplication is relevant only for the period 1990 to 2020, because the growth in high-skilled labour for the non-OECD regions differs per region. After 2020, the growth rates for the non-OECD regions are assumed to be equal (see 2).

Figure 3.4 shows that the relative supply of high-skilled labour in the non-OECD regions will increase based upon this method. It will, however, take a long time before OECD standards are reached, because many developing countries are a long way from even providing basic education at this moment as the Worldbank (1995) points out. Nevertheless, slowly but surely they are getting closer (except for Sub-Saharan Africa).[9] Appendix A3.2 presents the results for all regions.

Figure 3.4 Share of high-skilled labour in total labour supply from 1995 to 2050



Source: Own calculations based on Ahuja and Filmer (1995), and Barro and Lee (1996)

[9] Due to the large population increases and the relatively low stocks of human capital in Africa, the average amount of schooling per capita will not increase in the Rest of the World.

3.2 GTAP sectoral data on production and consumption

This section describes the consumption patterns, as well as production and trade patterns, in 1995, based on the GTAP data base; see McDougall *et al.* (1998).

Box 3.1 The GTAP consortium

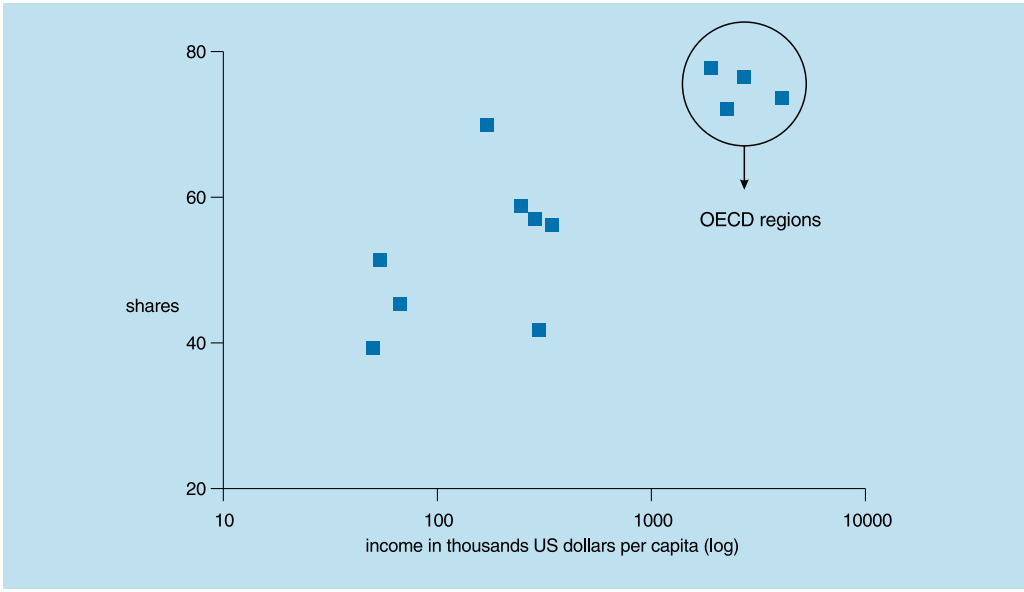
Our most important data source is GTAP. The Global Trade Analysis Project (GTAP) provides data, models, and software for multi-regional, applied general equilibrium analysis of global economic issues. It also organises training and conferences. GTAP, with headquarters at Purdue University, has organised a consortium of national and international agencies (including CPB) which provide guidance and base-level support for the Project. More information can be found on the website http://www.agecon.purdue.edu/gtap/index.htm.

The most recent database is version 4 (see McDougall *et al.* (1998)). This version of the database contains detailed bilateral trade, transport and protection data characterising economic linkages among regions, linked together with individual country input-output data bases, which account for inter sectoral linkages among the 50 sectors within each of 45 regions. The concordance to our seven-sector, 12-region model can be found in Table A3.11. All monetary values of the data are in $US billions, and the base year is 1995.

3.2.1 Consumption

Consumer preferences vary by region. Figure 3.5 plots the consumption shares of Services against the log of per capita income in 1995 for each region, based on GTAP data. Consumers in the rich OECD regions spend a much larger part of their budget on services than do the poorer developing regions.

Figure 3.5 *Consumption shares of services vs per capita income in 1995*



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

The developing regions spend a larger part of their budget on Agriculture and Food than do the OECD regions. This can also be seen from the data in Table 3.1, which presents the consumption shares of all sectors in the three aggregated regions for 1995. Consumers in the OECD spend relatively more money on Trade and Transport and Capital Goods, while consumers in the other regions spend relatively more on Consumer Goods and Raw Materials. In general, demand for high-skilled, labour-intensive goods is high in the OECD, while demand for low-skilled, labour-intensive goods is relatively high in the non-OECD regions.

Table 3.1 *Consumption shares in 1995*

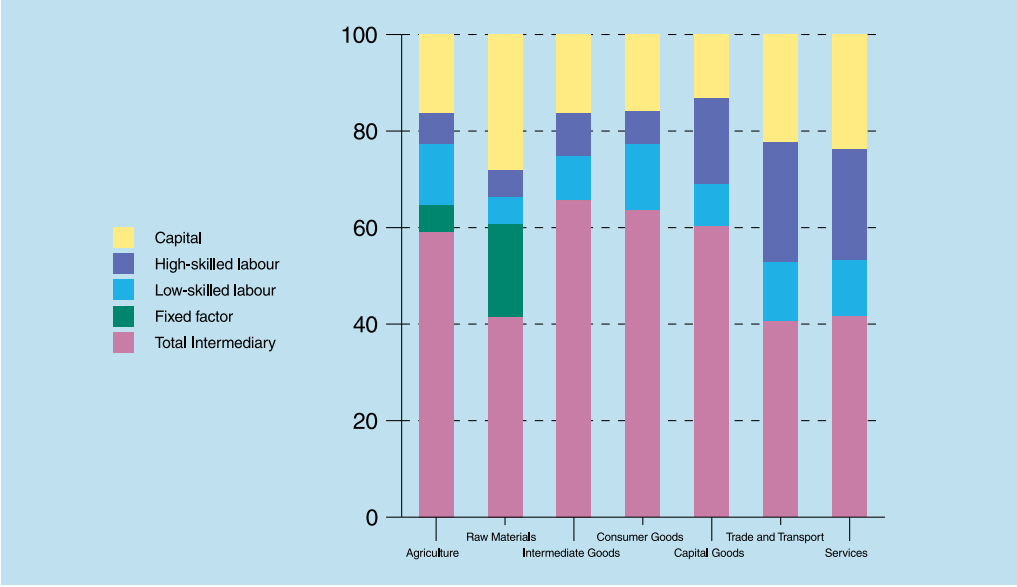
	Agriculture	Raw Materials	Intermediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
OECD	9.6	0.1	2.3	6.8	6.9	23.9	50.3
Asia	31.0	0.5	2.8	11.5	5.4	19.1	29.8
Rest of the World	22.5	0.4	3.9	11.3	4.8	21.3	35.7

Source: GTAP data (McDougall, *et al.* 1998) and own calculations

3.2.2 Production

Production functions relate output to the inputs of labour, capital, fixed factor and intermediary goods. The sectoral input intensities are comparable in different regions, and are derived from the GTAP data base. The split of the input value of labour into high- and low-skilled labour is based on our own classification. The sectors in WorldScan differ considerably with regard to their production technology. Agriculture and Manufacturing Goods use a lot of intermediary goods, about 60% of the total input value, whereas this is much lower for other sectors. In the sectors Services and Trade and Transport this is only 40%. In these sectors labour, in particular high-skilled labour, is an important input factor; see Figure 3.6.

Figure 3.6 Global factor intensities per sector in 1995 intermediary goods are aggregated



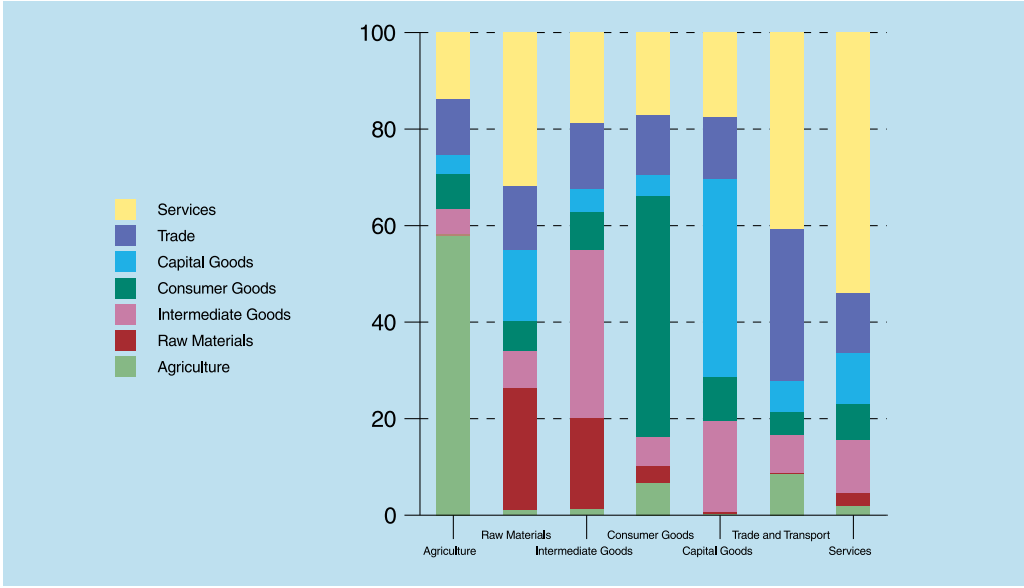
Source: GTAP data (McDougall *et al.* (1998)) and own calculations

The sector Raw Materials needs a lot of capital and natural resources for production (fixed factor). In the Manufacturing Sectors (Intermediate Goods, Consumer Goods, and Capital Goods), intermediary deliveries account for about 60% of the input value. The main difference between these sectors is their high-skilled labour intensiveness. Consumer Goods produces primarily mass-made products, which are low-skilled intensive. Capital

Goods produces more specialised products, which are high-skilled intensive. Intermediate Goods is neither high-skilled nor low-skilled labour intensive. Figure 3.7 presents the global composition of intermediary goods per sector. Because the differences between regions are limited, we present only the world-wide average.

Figure 3.7 shows that the 'own' good is one of the most important inputs in production. This share is biased upwards by the broad sectoral aggregation in WorldScan. Agriculture is only important as an input in its own production. Raw Materials is important in the production of Raw Materials and Intermediate Goods, which are energy intensive. Services and Capital Goods are the most important input factors in intermediary demand.

Figure 3.7 Global composition of intermediary goods for all sectors in 1995



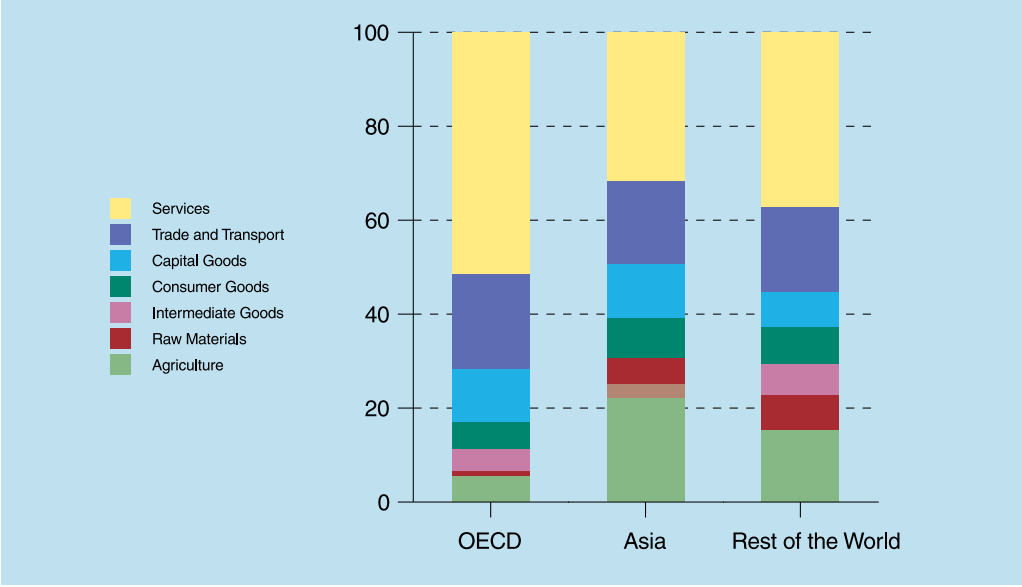
Source: GTAP data (McDougall *et al.* (1998)) and own calculations

3.2.3 Specialization

The regional specialization patterns in 1995 reflect both domestic consumption patterns and relative endowments. Figure 3.8 depicts value-added shares of all sectors for the OECD, Asia and the Rest of the World. The patterns are reasonably clear: less developed regions specialise in Agriculture and Consumer Goods, while the developed

regions specialise in Capital Goods and Services. Partly, this is a result of domestic consumption patterns: in developing regions demand is biased towards Agriculture and Consumer Goods; see Table 3.1. The value-added share of services is higher in the Rest of the World than in Asia, due to the inclusion of the transition countries in the former region. Table A3.4 presents the value-added shares for all twelve regions.

Figure 3.8 Value-added shares in 1995



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Specialization is a result of relative endowments. The production of Capital Goods is intensive in high-skilled labour. This factor is relatively abundant in the OECD regions. Low-skilled labour, an important input for the production of Consumer Goods, is relatively abundant in non-OECD regions — Asia, in particular. Figure 3.9 shows that the OECD indeed exports skill-intensive goods and imports skill-extensive goods. The net export of skill-neutral goods in the Rest of the World reflects the vast natural resources in the Former Soviet Union, Middle East and Africa.[10]

[10] High-skilled labour-intensive sectors include Capital Goods, Services, and Trade and Transport. Low-skilled labour-intensive sectors include Consumer Goods and Agriculture and Food. The other sector consists of Raw Materials and Intermediate Goods.

Figure 3.9 *Trade surpluses of sectors according to skill intensity in 1995 ratio of net regional trade to worldwide production (per sector)*

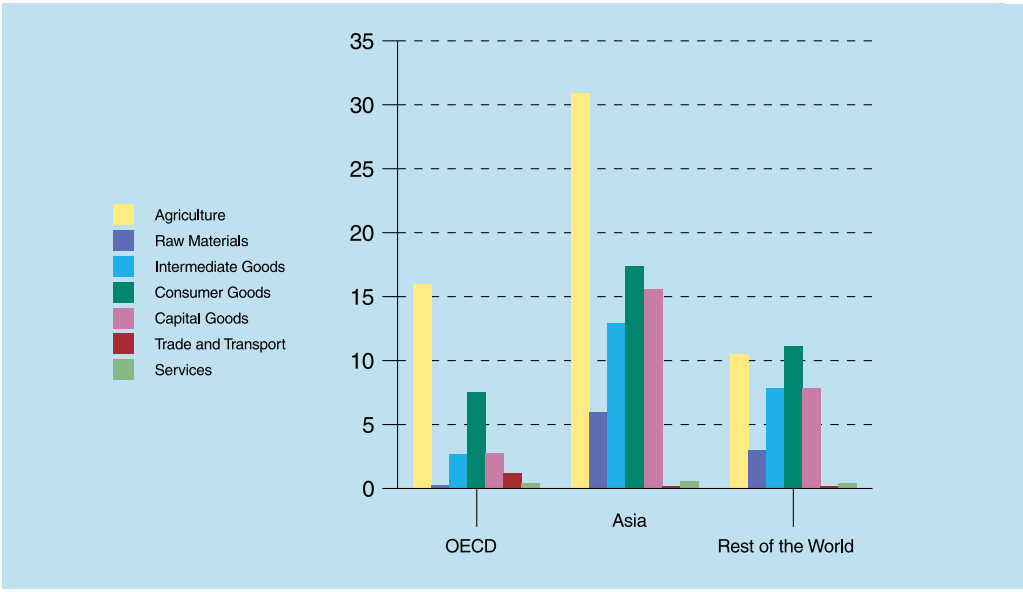
Source: GTAP data (McDougall *et al.* (1998)) and own calculations

3.3 Trade distortions

This section describes trade distortions due to import tariffs, export subsidies and export taxes at the beginning of the simulation period, 1995. Figures 3.10 and 3.11 show that barriers to trade are sometimes significant, and differ across sectors and regions. In general, Asia is more heavily protected than the Rest of the World. The average import tariffs are the lowest in the OECD.

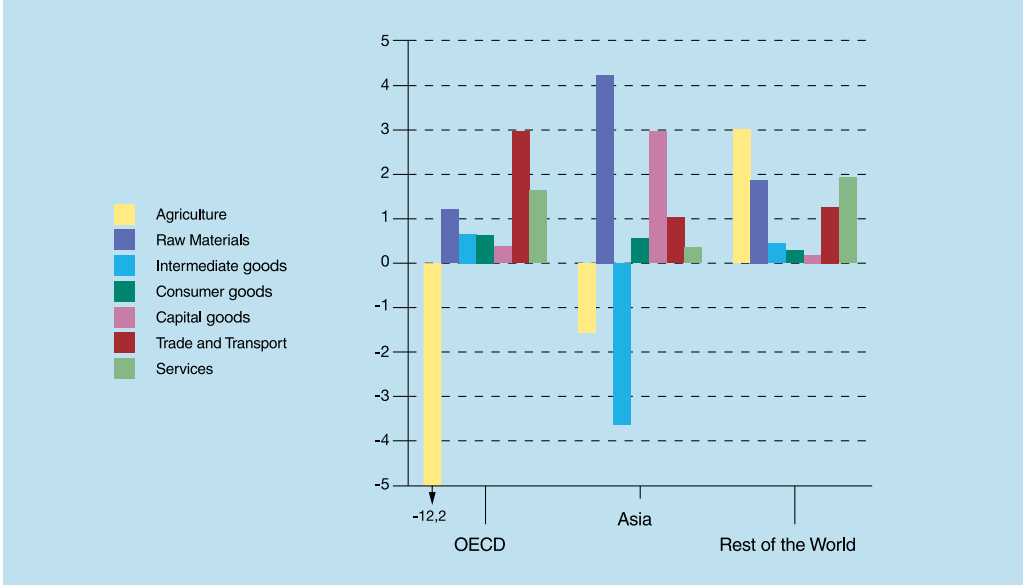
First of all, the agricultural sector is heavily protected in all regions. Both import tariffs and export subsidies (OECD) protect this sector. Import tariffs in the sectors Services and Trade and Transport are negligible, but there are some export taxes. The OECD raises significant tariffs only in the Consumer Goods sector. Asia and the Rest of the World levy average tariffs between the 5% and 10%. Because trade in the manufacturing sectors is much larger than in Services, the average import tariffs are still significant. Only Asia imposes some taxes in the sector Raw Materials. They also levy export taxes. To stimulate production, moreover, they subsidise the import of Intermediate Goods.

Figure 3.10 Import tariffs levied by the regions in 1995 (% value of trade)



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Figure 3.11 Export taxes levied by the regions in 1995 (% value of trade)

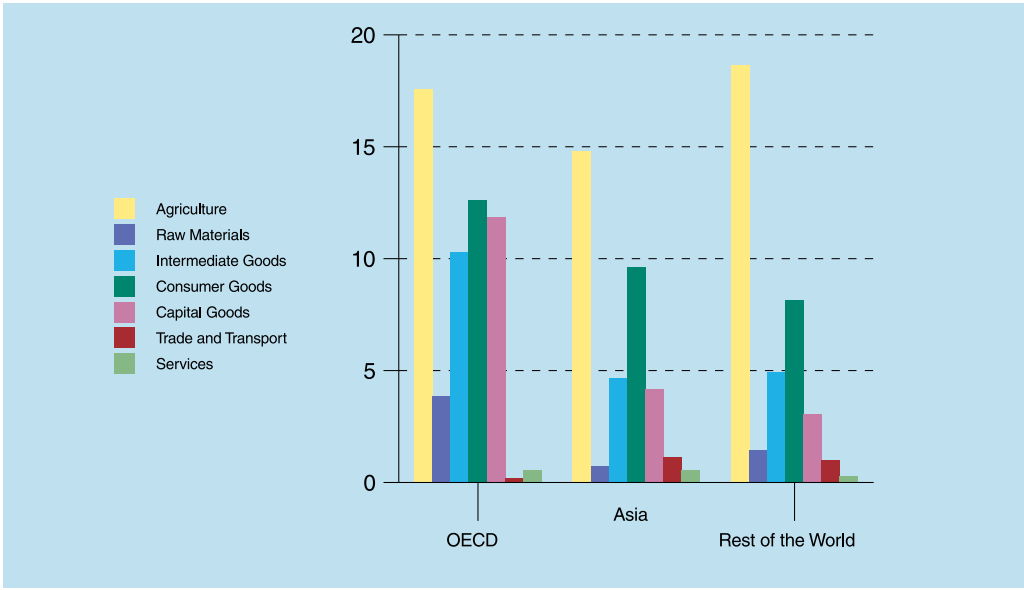


Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Note, that import and export taxes are a weighted average of subsidies and taxes. The sectors are strongly aggregated. The drawback of aggregation is that high tariffs for specific types of goods are averaged out by aggregation, due to subsidies for other types of goods or low tariffs. Furthermore, in markets distorted by high tariffs, trade is limited. It is high in sectors that are not hampered by trade restrictions. The latter sectors have much more weight in the average tariffs rate. For such reasons, the levels of import taxes presented in Figure 3.10 and 3.11 underestimate the distortionary nature of trade barriers.

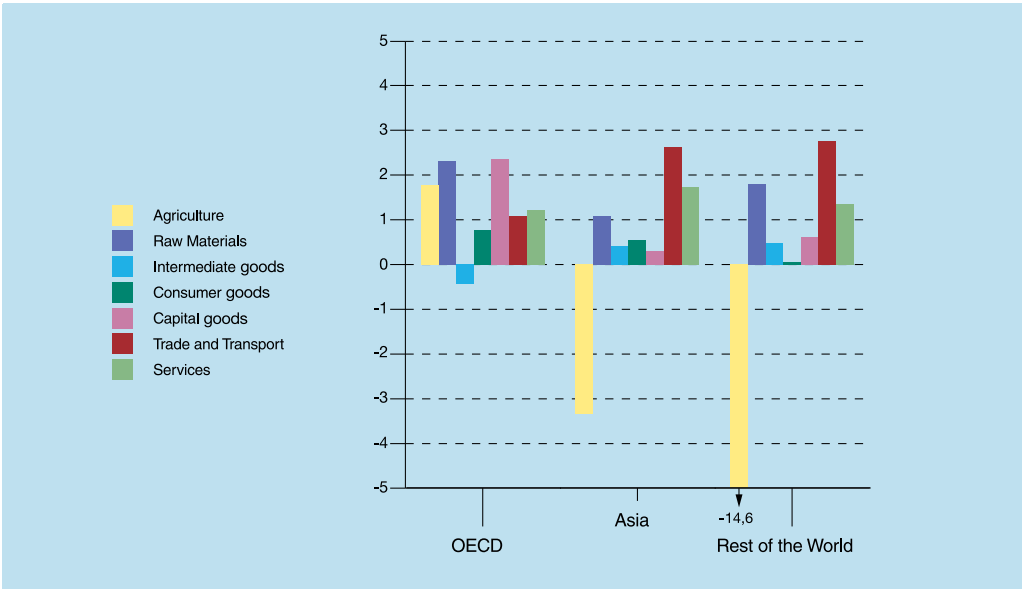
Not all regions are affected to the same extent by these import taxes. Regions that specialise in different sectors face different tariffs. The OECD faces relatively high import tariffs on Intermediate and Capital Goods. They also face tariffs on Raw Materials levied in Asia. All regions face tariffs on Agriculture and Consumer Goods. The Rest of the World benefits from the export subsidies on Agriculture, the Middle East and Africa, in particular. As export taxes are on average fairly low, the effects on the importing regions are also modest. Most levels are lower than 2%. This is shown in Figures 3.12 and 3.13.

Figure 3.12 Import tariffs faced by the regions in 1995 (% value of trade)



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Figure 3.13 Export taxes faced by the regions in 1995 (% value of trade)



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

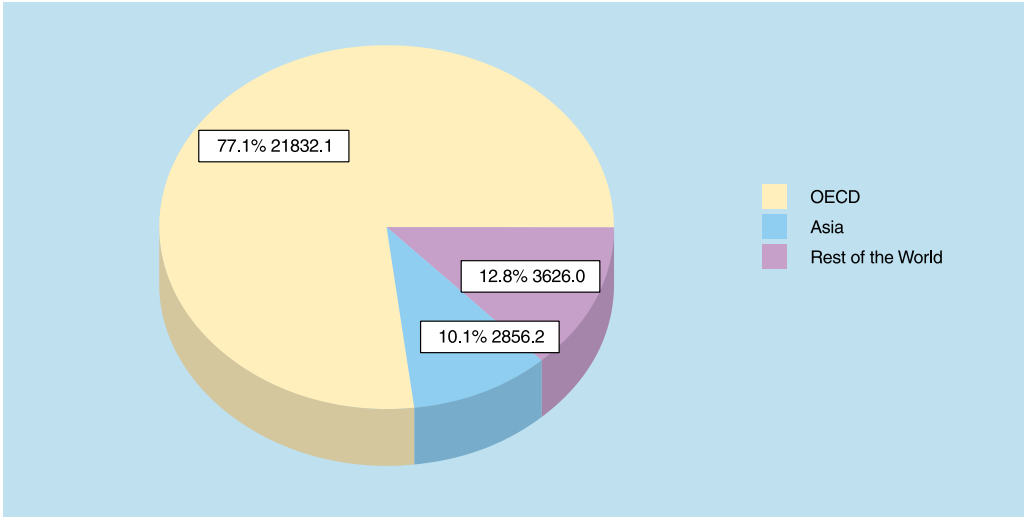
3.4 Macroeconomic data

This section presents macroeconomic data. Data on gross domestic product (GDP), savings and investment are derived from the GTAP database. Data on employment follow from labour demand and labour supply, discussed in Sections 2.4 and 3.1.

3.4.1 Gross domestic product

Figure 3.14 shows the huge differences in gross domestic product for the three regions. The OECD produces about 75% of worldwide GDP, while its population share is only about 10%. In 1995, the value of GDP was 21.8 trillion US dollars, while it was only 2.9, and 3.6 trillion US dollars, respectively, in Asia and the Rest of the World. At a regional level the differences are larger. The value of GDP for Sub-Saharan Africa and Eastern Europe is about 0.3 trillion US dollars, while it is 8.6 trillion US dollars for Western Europe.

Figure 3.14 Gross domestic product in 1995 (billion US dollars)

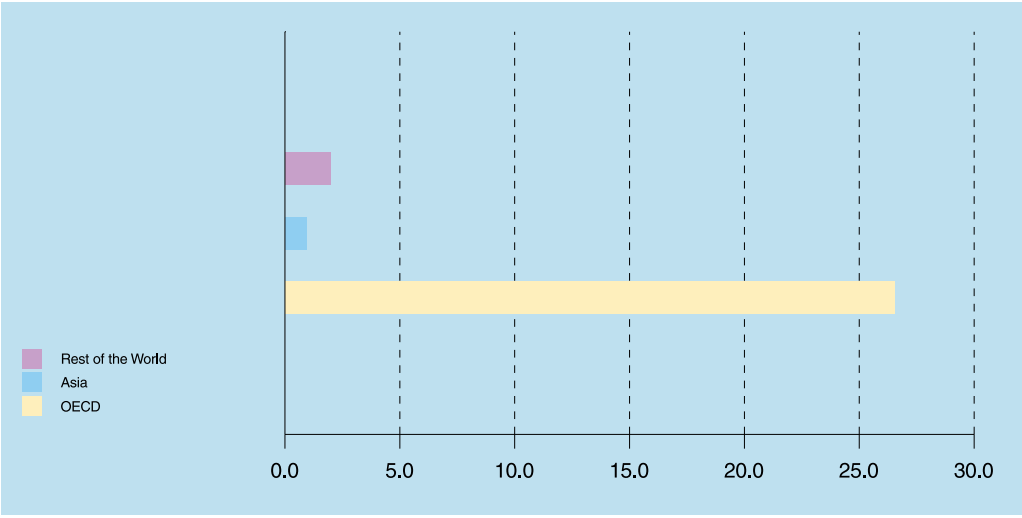


Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Of course, absolute differences in GDP do not accurately indicate the stage of economic development of the various regions. Therefore, we present Figure 3.15, which depicts GDP per capita for 1995. This figure shows that the differences in GDP

per capita are immense. GDP per capita is about 30 times larger in the OECD than it is in Asia. It is twice as large in the Rest of the World than in it is Asia. The latter result is due to the economic development in Eastern Europe and the Former Soviet Union, which are included in the Rest of the World.

Figure 3.15 Gross domestic product per capita in 1995 (thousand US dollars)

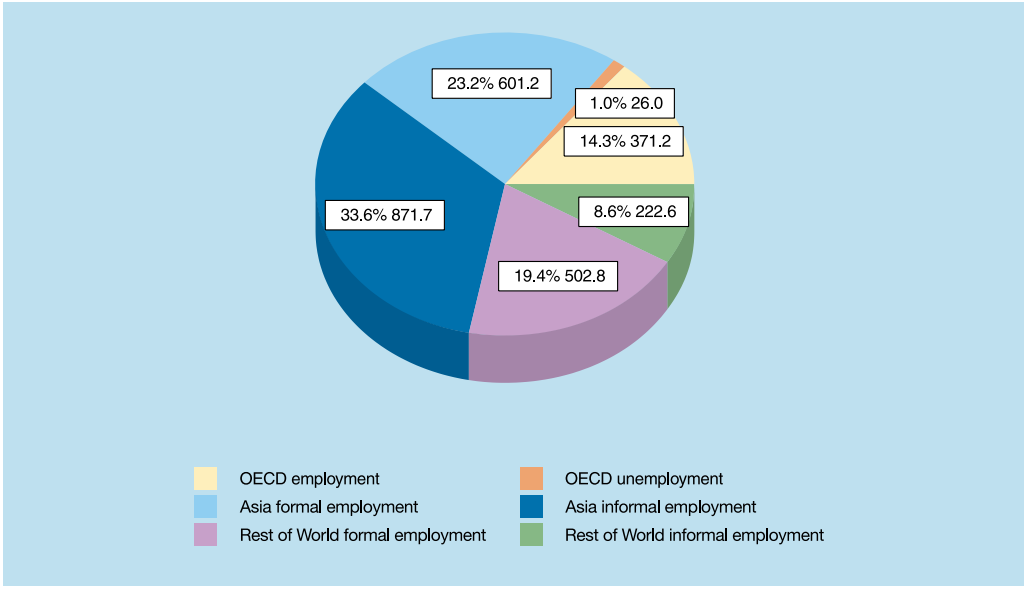


Source: GTAP data (McDougall *et al.* (1998)) and own calculations

3.4.2 Employment levels

Employment levels, ignoring differences in participation rates, provide a reasonable approximation for the differences in population size. The size of the labour force is 397 million persons in the OECD, of which 6% is unemployed.

Figure 3.16 *Employment and unemployment levels in 1995 (millions) and as ratio of the global labour force*



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

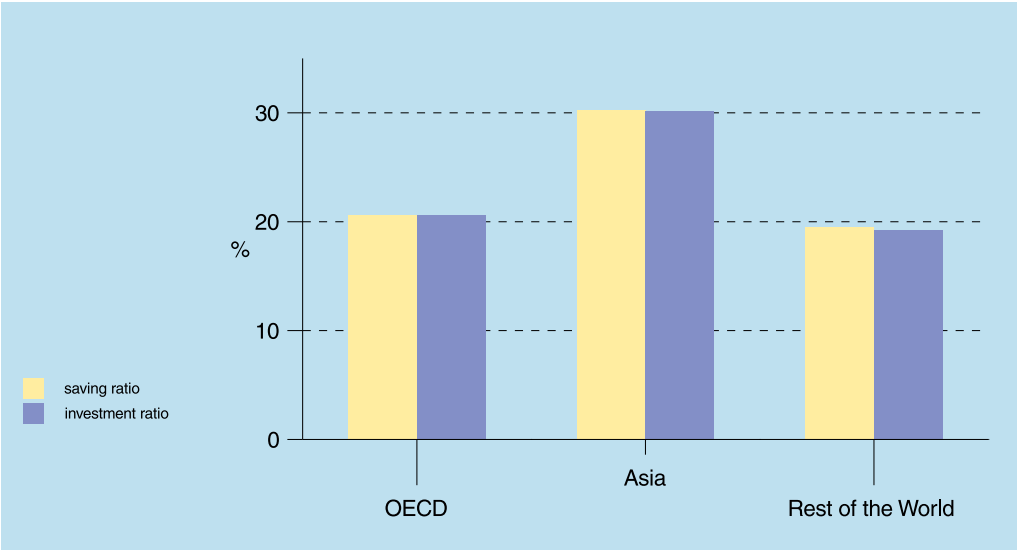
The labour force in Asia and the Rest of the World is 1473 and 725 million persons, respectively. The larger part of the labour force works in the low-productivity sectors in Asia. In the Rest of the World this share is much lower (about 30%). As Table A3.9 in the Appendix illustrates, the economic structure of the transition countries and Latin America implies a smaller low-productivity sector in the Rest of the World compared to Asia. The size of the informal sector is closely related to the stage of economic development.

3.4.3 Savings and investment

In principle, savings and investment may differ in every region. Because the value of exports does not necessarily equal the value of imports (on basis of the GTAP data), savings and investment differ. However, these differences are not substantial, as is shown in Figure 3.17. The savings and investment shares are nearly identical, which implies balanced current accounts. The reason is that market transactions take place mainly within the OECD, and also within the other aggregated regions. The variation between investment and savings is higher for the twelve regions separately; see Table A3.9 in the Appendix.

Figure 3.17 shows that savings are very high in Asia. The population saves about 30% of national income. These savings are the most important source for capital accumulation and stimulate economic growth. Savings in the other two regions are lower.

Figure 3.17 *Savings and investment shares in 1995 ratios of national income*



Source: GTAP data (McDougall *et al.* (1998)) and own calculations

3.5 Monetary data

We assume that the value of wealth equals the value of the capital stock used for production. The capital stock is not fully possessed by the capital owners in the home region. For each region, we model a capital market that is partially integrated with the other capital markets. A share of the regional capital stock is possessed by foreign capital owners. These shares are derived by using the data of De Jong *et al.* (1993). They calculated world accounting frameworks for the years 1989 and 1990, from which the wealth positions of all our regions can be compiled. According to these data, the OECD owes 264 billion US dollars in Asia and more than 700 billion dollars in the Rest of the World; see Table 3.2. The large claims of the Rest of the World in the OECD are surprising. Table A3.10 in the Appendix shows that these claims originate mainly from the Middle East and Latin America. The Middle East invests heavily in Western Europe, and Latin America invests in the United States and Western Europe.

Table 3.2 *Wealth invested in foreign regions in 1990 (billions of US dollars)*

	OECD	Asia	Rest of world
OECD	0.0	263.7	716.8
Asia	172.1	0.0	4.6
Rest of world	628.7	5.6	0.0

Source: De Jong *et al.* (1993).

Appendix A3

Table A3.1 Population, participation and labour supply

	Population			Participation rate			Labour supply		
	level 1995	growth 1996-2020	growth 2021-2050	ratio 1995	growth 1996-2020	growth 2021-2050	level 1995	growth 1996-2020	growth 2021-2050
United States	263	0.79	0.28	0.49	-0.20	-0.20	130	0.63	0.06
Japan	125	-0.04	-0.40	0.50	-0.33	-0.45	63	-0.37	-0.85
Western Europe	384	0.01	-0.31	0.47	-0.19	-0.44	179	-0.18	-0.74
Pacific OECD	51	0.95	0.29	0.51	-0.28	-0.30	26	0.67	-0.01
Eastern Europe	98	0.04	0.00	0.48	-0.13	-0.34	47	-0.09	-0.34
Former Soviet Union	292	0.27	0.14	0.49	0.04	-0.36	142	0.31	-0.22
M. East and N. Africa	351	1.98	1.09	0.33	0.96	0.29	117	2.97	1.38
Sub-Saharan Africa	596	2.67	1.66	0.39	0.39	0.67	230	3.06	2.35
Latin America	482	1.36	0.72	0.39	0.57	-0.07	190	1.94	0.65
China	1228	0.79	0.25	0.58	-0.17	-0.50	707	0.62	-0.27
South-East Asia	466	1.23	0.66	0.45	0.52	-0.26	211	1.75	0.40
South Asia & Rest	1380	1.61	0.82	0.40	0.61	0.05	555	2.22	0.87

Population and labour supply levels are in millions. Growth rates are average growth rates in that period and are expressed in %.
Source: United Nations (1995), ILO (1996) and own calculations.

Table A3.2 Share of high-skilled workers in total labour supply

	level 1995	growth 1996-2020	level 2020	growth 2021-2050	level 2050
OECD + transition regions	0.36	0.52	0.41	0.45	0.47
Middle East and N. Africa	0.14	2.84	0.27	1.05	0.37
Sub-Saharan Africa	0.04	3.84	0.09	2.53	0.19
Latin America	0.18	2.47	0.32	0.91	0.42
China	0.16	1.47	0.23	1.23	0.33
South-East Asia	0.20	2.54	0.37	0.80	0.47
South Asia & Rest	0.12	1.95	0.19	1.42	0.29

Source: Own calculations based on Ahuja and Filmer (1995), Barro and Lee (1996)

Table A3.3 Consumption shares of total consumption in 1995

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	6.6	0.0	2.4	6.1	8.4	24.3	52.1
Japan	14.0	0.0	1.3	7.4	3.7	28.7	44.9
Western Europe	10.2	0.2	2.6	7.3	7.6	20.4	51.7
Pacific OECD	8.8	0.3	3.1	6.2	3.9	28.6	49.2
Eastern Europe	29.3	2.1	2.3	16.4	8.1	17.9	23.9
Former Soviet Union	12.1	1.1	6.1	6.8	3.9	18.9	51.0
Middle East & N.A	23.3	0.3	5.8	9.3	2.4	23.2	35.6
Sub Saharan Africa	29.9	0.2	2.8	9.3	6.3	18.3	33.1
Latin America	22.3	0.1	2.9	13.1	5.5	22.2	34.1
China	35.2	0.7	2.5	13.7	2.6	19.6	25.7
South-East Asia	25.8	0.6	2.3	7.9	6.4	21.3	35.8
South Asia & Rest	35.3	0.2	3.7	15.2	6.3	15.2	24.1

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.4 Sectoral structure: value-added shares in 1995

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	4.3	1.4	3.7	5.3	10.7	21.5	53.0
Japan	6.9	0.2	5.3	6.6	12.0	21.7	47.2
Western Europe	5.8	0.9	4.8	6.1	11.5	18.3	52.7
Pacific OECD	6.6	3.5	5.7	5.0	7.1	23.4	48.7
Eastern Europe	16.2	3.3	7.4	11.3	10.4	20.1	31.3
Former Soviet Union	6.7	9.0	10.2	4.1	7.2	15.1	47.7
Middle East and N.A	13.5	14.9	6.3	6.5	4.1	21.5	33.2
Sub Saharan Africa	23.7	9.5	5.5	5.9	6.6	16.0	32.7
Latin America	17.4	3.6	5.3	9.6	8.9	17.3	37.9
China	25.1	3.4	6.4	8.5	11.6	19.1	25.9
South-East Asia.	16.8	2.5	5.6	8.0	13.4	18.5	35.3
South Asia & Rest	29.7	3.0	4.4	10.0	7.2	14.5	31.2

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.5 Import taxes levied by the 12 regions in 1995 (% value of trade)

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	7.8	0.2	2.1	6.3	1.9	0.0	0.0
Japan	56.8	0.4	1.3	4.3	0.8	3.3	2.5
Western Europe	20.4	0.1	2.9	6.5	4.5	0.0	0.0
Pacific OECD	4.1	3.7	2.8	6.6	3.4	0.1	0.0
Eastern Europe	14.4	1.3	6.7	8.8	8.7	0.0	0.0
Former Soviet Union	3.5	0.0	0.0	0.0	0.0	1.6	1.7
M. East and N. Africa	5.9	-2.2	7.3	7.8	2.2	0.0	0.1
Sub-Saharan Africa	-0.9	-2.8	1.1	9.5	6.4	0.0	0.0
Latin America	3.1	13.0	7.7	9.8	10.7	0.0	0.0
China	6.8	2.3	10.6	25.7	17.6	0.0	0.9
South-East Asia	40.6	5.6	8.8	10.0	11.5	0.3	0.5
South Asia & Rest	55.4	11.9	48.9	65.0	45.8	0.1	0.3

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.6 Export taxes levied by the 12 regions in 1995 (% value of trade)

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	0.1	5.4	1.3	1.2	0.7	10.0	4.9
Japan	-9.7	0.0	0.0	0.0	0.0	0.0	0.0
Western Europe	-19.5	0.5	0.5	0.5	0.4	0.6	0.7
Pacific OECD	-2.3	0.2	0.3	0.1	0.1	0.2	0.3
Eastern Europe	-6.0	0.0	0.0	0.0	0.0	0.0	0.0
Former Soviet Union	2.4	1.9	0.7	0.4	0.3	0.1	1.1
M. East and N. Africa	1.0	0.5	0.5	-0.3	0.1	2.9	5.8
Sub-Saharan Africa	7.0	7.9	-1.2	0.2	-0.5	1.1	0.6
Latin America	4.0	1.3	0.9	0.8	0.3	0.7	0.9
China	2.2	14.0	-9.8	-3.0	5.0	0.0	0.0
South-East Asia	-4.5	2.3	0.7	1.9	1.8	1.7	0.5
South Asia & Rest	1.7	0.1	1.9	4.0	0.6	1.2	0.6

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.7 Import taxes faced by the 12 regions in 1995 (% value of trade)

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	44.2	1.4	3.7	6.1	4.9	0.7	0.4
Japan	14.3	3.5	10.8	13.8	9.2	0.1	0.5
Western Europe	14.2	2.7	9.0	10.0	8.7	0.5	0.3
Pacific OECD	30.9	0.9	2.0	2.3	1.4	1.4	0.6
Eastern Europe	22.5	0.6	6.6	6.3	6.1	1.1	0.2
Former Soviet Union	16.5	0.5	4.2	7.7	10.5	1.1	0.4
M. East and N. Africa	12.6	2.2	9.6	12.3	6.2	0.8	0.2
Sub-Saharan Africa	21.6	1.0	5.7	7.6	7.4	1.1	0.3
Latin America	14.1	0.5	3.8	5.4	1.0	0.8	0.3
China	23.7	4.6	7.7	11.4	6.9	0.6	0.5
South-East Asia	16.1	1.3	11.1	18.5	6.0	1.3	0.6
South Asia & Rest	11.9	0.7	1.6	8.0	1.0	1.1	0.3

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.8 Export taxes faced by the 12 regions in 1995 (% value of trade)

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	-1.5	2.8	-0.1	1.5	1.0	0.6	0.7
Japan	-0.7	1.7	-0.4	-0.7	1.4	2.5	3.0
Western Europe	1.8	1.7	0.3	0.7	1.3	3.7	3.7
Pacific OECD	-1.8	1.2	0.0	0.3	0.5	1.0	0.9
Eastern Europe	-6.3	1.4	0.6	0.2	0.5	2.7	1.5
Former Soviet Union	-8.3	0.1	0.0	-0.2	0.4	2.7	1.6
M. East and N. Africa	-15.4	1.3	0.3	0.1	0.7	2.5	1.0
Sub-Saharan Africa	-14.8	0.6	0.3	-0.3	0.4	2.6	1.2
Latin America	-9.6	2.2	0.7	0.3	0.7	2.9	1.7
China	-4.4	1.3	0.4	0.5	0.5	1.9	1.4
South-East Asia	-3.9	1.3	-0.2	-0.5	0.3	2.4	1.7
South Asia & Rest	-6.1	1.6	0.1	-0.6	0.4	2.3	1.0

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.9 Macroeconomic data for all regions in 1995

	GDP (mld US dollars)	GDP per capita (thz. US dollar)	share of world GDP (%)	savings ratio (% GDP)	invest-ment ratio (% GDP)	employ-ment (mln persons)	employ-ment informal sector
United States	7126.8	2707.2	25.2	16.9	15.0	123.3	6.5
Japan	5086.0	4065.8	18.0	28.6	29.7	59.5	3.1
Western Europe	8637.6	2250.7	30.5	19.2	19.9	164.3	14.3
Pacific OECD	981.7	1915.3	3.5	19.4	20.6	24.1	2.1
Eastern Europe	293.3	300.2	1.0	18.3	15.0	44.8	2.4
Former Soviet Union	498.2	170.5	1.8	20.5	23.8	135.0	7.1
Middle East & N.A	850.4	242.4	3.0	22.0	22.3	88.9	27.6
Sub-Saharan Africa	325.3	54.6	1.1	16.7	17.5	92.2	137.8
Latin America	1658.8	344.4	5.9	18.2	17.9	141.8	47.7
China	821.4	66.9	2.9	35.1	37.2	258.7	448.5
South-East Asia	1342.3	287.7	4.7	32.9	33.4	131.7	79.6
South Asia & Rest	692.5	50.2	2.4	18.9	16.0	210.9	343.6

Source: GTAP data (McDougall *et al.* (1998)) and own calculations

Table A3.10 Wealth invested in foreign regions

	U	J	W	P	E	F	M	S	L	C	N	O
United States	0.0	224.0	615.8	129.4	4.7	0.0	21.7	9.3	246.6	0.8	34.4	8.8
Japan	264.0	0.0	517.7	78.8	6.4	1.6	18.3	10.3	36.7	24.4	104.4	21.1
Western Europe	848.2	767.8	0.0	208.5	59.5	43.5	60.6	76.1	102.9	12.3	30.2	21.0
Pacific OECD	95.8	22.1	86.2	0.0	2.4	0.0	3.5	1.4	11.3	0.5	4.0	1.8
Eastern Europe	7.8	2.2	14.2	0.6	0.0	0.0	4.8	1.3	1.4	0.2	0.2	0.5
Former Soviet Union	0.4	1.6	13.7	0.5	1.4	0.0	13.6	8.4	4.3	0.0	1.1	1.1
Middle East & N.A.	45.8	40.9	226.8	9.5	0.1	0.2	0.0	8.6	1.5	0.5	0.5	1.3
Other Africa	4.1	5.0	30.6	1.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Latin America	113.1	22.9	82.0	5.9	1.3	0.0	0.6	0.7	0.0	0.1	0.1	0.0
China	7.0	2.8	15.0	0.6	0.2	0.0	0.7	1.6	0.4	0.0	0.2	0.5
South-East Asia	38.4	9.9	75.4	2.8	0.1	0.0	0.3	0.5	0.3	0.0	0.0	0.8
South Asia & Rest	4.8	2.2	12.7	0.5	0.0	0.0	0.1	0.4	0.0	0.0	0.1	0.0

U=United States, W=Western Europe, J=Japan, P=Pacific OECD, E=Eastern Europe, F=former Soviet Union, M=Middle East & North Africa, S=Sub-Saharan Africa, L=Latin America, C=China, N=South-East Asia, and O=South Asia & Rest.

Source: de Jong *et al.* (1993).

Table A3.11 Regional and sectoral concordances for WorldScan from GTAP

1	United States
2	Japan
3	Western Europe United Kingdom, Germany, Denmark, Sweden, Finland, Rest of European Union, EFTA
4	Pacific OECD Canada, Australia, New Zealand
5	Eastern Europe
6	Former Soviet Union
7	Middle East and North Africa Turkey, Rest of Middle East, Morocco, Rest of North Africa
8	Sub-Saharan Africa South African Customs Union, Rest of Southern Africa, Rest of Sub-Saharan Africa
9	Latin America Central America and Carribean, Mexico, Argentina, Brazil, Chile, Uruguay, Venezuela, Colombia, Rest of South America
10	China China, Hong Kong
11	South East Asia Republic of Korea, Indonesia, Malaysia, Philippines, Singapore, Thailand, Taiwan, Vietnam
12	South Asia & Rest India, Sri Lanka, Rest of South Asia, Rest of the World

1	Agriculture and food production Paddy rice, Wheat, Grains, Cereal Grains, Non grain crops, Vegetables, Oil seeds, Sugar cane Plant-based fibres, Crops, Bovine cattle, Animal products, Raw milk, Wool, Forestry, Fisheries, Processed rice, Meat products, Vegetable Oils, Dairy products, Sugar, Other food products, Beverages and tobacco
2	Consumer Goods Textiles, clothing, Leather etc, Wood products, Chemical, rubbers and plastics
3	Intermediate Goods Pulp paper, Petroleum and coal, Non metallic minerals, Ferrous metals, Nonferrous metals
4	Capital Goods Fabricated metal products, Transport industries, Machinery and equipment, Electronic equipment, Motor vehicles and parts, Rest of manufacturing
5	Services Gas manufacture and distribution, Water, Construction, Financial, business and recreational services, Public administration, education and health, Dwellings, Electricity
6	Trade and Transport
7	Raw Materials Oil, Natural Gas, Coal, Minerals

4 Calibration

4.1 Data, calibration and scenario assumptions

To run a scenario, one needs, apart from the model itself, three other ingredients: parameter values, values of lagged endogenous variables and values of exogenous variables. Traditionally, these three ingredients are prepared in three different processes. Parameter values are determined through estimation or calibration procedures, lagged endogenous variables are read from a database, and exogenous variables depend on scenario assumptions (such as projections on labour supply and education levels).

For two reasons we want to describe these three processes as a combined and integrated strategy for introducing empirical and numerical elements in the model. The first reason is that the distinction between parameters and variables is often arbitrary. Parameters can be turned into exogenous variables if their value is time dependent, and exogenous variables can be called parameters if they are assumed to be constant over time. Furthermore, lagged endogenous variables can be unobserved (like the capital stock) and should therefore be estimated, which again blurs the distinction between parameters and variables.

The second reason for combining these processes is that in our exercises the contrast between historical evidence and assumptions about future developments is sometimes faint. Similar to many AGE models, WorldScan assumes that at the start of a scenario parts of the economy are in equilibrium or even in a steady state. Observed relations in the data (like investment and consumption ratios) are assumed to be steady-state values. Parameters and unobserved variables are chosen in such a way that the model reproduces these values in a steady state. Therefore, the values of parameters and unobserved variables may depend on growth rates that characterise the steady state. Because these growth rates are part of the scenario assumptions, the calibration of parameters may depend on these assumptions.

In this integrated procedure, the GTAP 4 database[1] is the main data source. GTAP provides a consistent set of input-output tables and bilateral trade data in current prices for 1995. It also contains an extensive set of tax payments. The GTAP data are indicated below by time index 0. Not all parameters and variables are derived from these data sources. Some of them (*e.g.*, elasticities of substitution) are fixed at levels that are often found in the literature or that are consistent with the character of a scenario. The model also contains some parameters that do not have an economic meaning, but are merely a unit of measurement. The value of these parameters depends on the initial price levels that are chosen in the model. We will discuss the determination of parameters and variables successively for four model blocks: the behaviour of consumers, the behaviour of firms, technological progress, and interregional capital markets.

4.2 Consumer behaviour

4.2.1 Allocation of consumption over time

Equation (2.7), which determines the savings rate, contains a time-preference parameter ρ, the death rate d, the structural interest rate r, the structural growth rate of per capita income g, the lagged nominal interest rate R_{-1}, the lagged assets B_{-1} and current income Y.

$$p_c C = \frac{\rho + d}{1 + \rho} \langle (1 + R_{-1}) B_{-1} + \zeta p_y Y \rangle \qquad \zeta \equiv \frac{1 + r}{r - g} > 0 \qquad \textbf{(4.1)}$$

The death rate is determined as the reciprocal of life expectancy. The structural growth rate is set equal to the average growth rate in the scenario, and therefore depends on the scenario characteristics. The structural real interest rate is, like R_0, set equal to the real interest rate in the data. The assets are derived from the matrix F_{hr} of assets and liabilities described above.

$$B_{-1} = \sum_r F_{hr} \qquad \textbf{(4.2)}$$

Finally, the time-preference parameter is determined by inverting equation (2.7), which indicates the nominal interest rate in the data by R_0 and the expected real interest rate by r.

[1] See McDougall *et al.* (1998)

$$\rho = \frac{(1 - d)\, Z}{Z - p_{c0}C_0} - 1 \qquad , \qquad Z = (1+R_{-1})B_{-1} + \frac{(1 - r)p_{y0}Y_0}{r - g} \tag{4.3}$$

$p_{c0}C_0$ denotes the value of consumption in the base year.

4.2.2 Allocation of consumption over categories

The sectoral pattern of consumption expenditure is steered by parameters γ_s in equation (2.8). Since this sectoral pattern is available in the GTAP database, these share parameters can be directly computed for the base year. The rules that determine the convergence of consumption patterns are described in the model itself, outside the calibration process.

4.2.3 Allocation of consumption over varieties

The allocation of sectoral consumption demand over varieties from different regions is based on so-called Armington preferences. According to equations (2.12) and (2.13), the market shares of domestic and foreign producers depend on the lagged endogenous variables $ms_{hb,-1}$ and parameters β_{hb}, θ and ϵ.

$$ms_{hb} = \frac{(ms_{hb,-1})^{1-\theta}\ (\beta_{hb})^{\theta}}{\left(\sum_{h}\ (ms_{hb,-1})^{1-\theta}\ (\beta_{hb})^{\theta}\right)} \left(\frac{p_{chb}}{p_{cb}}\right)^{1-\epsilon} \tag{4.4}$$

The lagged endogenous variables $ms_{hb,-1}$ and parameters β_{hb} are determined in the calibration model on the basis of the GTAP data set. The parameters θ and ϵ, determining the short-run and long-run price elasticities, are fixed at levels that are often found in the literature or that are consistent with the character of the scenario. The initial price levels in equation (4.4) are fixed at an arbitrary level (often 1), implying a unit of measurement for the goods under consideration (see also Box 4.1).

We assume that market shares in the GTAP database ($ms_{hb,0}$) are long-run equilibrium market shares at current relative prices. That means that we assume in the calibration that

$$ms_{hb} = ms_{hb,-1} = ms_{hb,0} \tag{4.5}$$

The parameters β_{hb} are then calculated by inverting equation (4.4) and using condition (4.5).

$$\beta_{hb} = \frac{ms_{hb,0}\,(p_{chb})^{(\epsilon-1)/\theta}}{\sum_{h}\left(ms_{hb,0}\,(p_{chb})^{(\epsilon-1)/\theta}\right)} \qquad \textbf{(4.6)}$$

Because the preference variables are scaled such that they sum up to one, it follows by assumption that.

$$\sum_{h} \beta_{hb} = 1 \qquad \textbf{(4.7)}$$

The prices in these demand equations are consumer prices. They differ from producer prices as a result of taxes and transportation costs. Because the data on domestic taxes in GTAP contain several gaps, we include only import and export tariffs. They are fixed as a percentage of producer prices according to the ratios in the GTAP database. The so-called CIF-FOB margin in GTAP, *i.e.* the difference between the value at the importer's border and the value at the exporter's border, is used to fix transportation costs as a percentage of producer prices. This relation is interpreted as a fixed relation in volume terms. That implies that the trade margin declines during a scenario if prices of the transportation sectors decline relative to prices of other sectors.

4.3 Behaviour of the firm

4.3.1 Production functions

Production possibilities are described in a two-level CES function (see Figure 2.2 and equations (2.15) - (2.17)). The production function contains three sets of parameters: substitution elasticities, share parameters and technology levels. Considerations underlying the choice of the elasticities were discussed in Box 2.3. Factor-specific technology levels are all set to one in the base year, and the overall technology index (tfp-index) in the value-added nest is a unit of measurement that is implied by the choice of price levels in the base year. The share parameters are calculated by inverting the factor-demand equations (2.23) to (2.25). Those equations determine nominal factor shares in output, which are provided by the GTAP database.

First, the share parameters in the two lower nests are determined by inverting the factor-demand equations (2.24) and (2.25), under the restriction that they add up to unity. For example, for the nest of intermediary goods:

Box 4.1 Irrelevance of initial price levels

Initial prices can be set at an arbitrary level. They just imply a unit of measurement and have no further economic meaning. The calibration of the parameters β_{hb} ensures that market shares do not depend on the initial price level. Suppose that we multiply the price of one good, indicated by index 1, by ξ. That means we choose a new unit of measurement so that the new price p^* is ξ times the old one — not only in the initial period, but throughout the scenario.

$$p^*_{1b} = \xi\, p_{1b}$$

Equation (4.6) shows that in the calibration process the new price leads to new β's. If we again use an asterix to indicate the new β's, the following equation will hold.

$$\left(\frac{\beta^*_{hb}}{\beta^*_{1b}}\right)^{\theta} = \left(\frac{\beta_{hb}}{\beta_{1b}}\right)^{\theta} \xi^{(\epsilon-1)} \qquad h \neq 1$$

These two equations can be combined into an equality independent from ξ.

$$\left(\frac{\beta^*_{hb}}{\beta^*_{1b}}\right)^{\theta} \left(\frac{p_{chb}}{p^*_{c1b}}\right)^{1-\epsilon} = \left(\frac{\beta_{hb}}{\beta_{1b}}\right)^{\theta} \left(\frac{p_{chb}}{p_{c1b}}\right)^{1-\epsilon}$$

This equality implies that in the model the market shares do not depend on ξ, and thus also not on the initial price levels. This becomes clear if we look at the relation that determines the relative market shares; see also equation (4.4).

$$\alpha_j = \left(\frac{p_j q_j}{p_x q_x}\right)_0 \left(\frac{p_x}{p_j}\right)^{1-\sigma_x} , \qquad j = L, G, I, C, M, T, Z \qquad \textbf{(4.8)}$$

The subscript 0 indicates that the first term on the right-hand side, the relevant input share, is derived from the GTAP database. This equation is combined with the definition of the price level of the composite good q_x

$$p_x = [\sum_j (\beta_j p_j^{1-\sigma_x})]^{1/1-\sigma_x}, \qquad j = L, G, I, C, M, T, Z \qquad \textbf{(4.9)}$$

and the condition

$$\sum_j = \alpha_j = 1, \quad j = L, G, I, C, M, T, Z \qquad \textbf{(4.10)}$$

Since normally the input prices at factor costs are set to 1, the market prices of the inputs in the lower nests are close to 1. That means that the share parameters in these nests are close to the factor shares in the GTAP database. This is always true for the value-added nest, because of its Cobb-Douglas structure:

$$\alpha_j = \left(\frac{p_j q_j}{p_v q_v}\right)_0 , \qquad j = A, B, K, F \qquad \textbf{(4.11)}$$

In the second step, the unit costs of output (p_q) are set equal to 1, implying a unit of measurement for output. Then the unit cost of production is computed by subtracting the normal surplus from the output price. Given the price of the composite intermediary goods (equation (2.20)) and the unit cost of production, the share parameters in the upper nest (see equation (2.23)) can be calculated in the same way as the share parameters in the lower nest of intermediary goods. Here again the condition is used that the two share parameters in the upper nest add up to 1.

$$\alpha_x = \left(\frac{p_x q_x}{p_q q}\right)_0 \left(\frac{p_q}{p_x}\right)^{1-\sigma} ; \qquad \alpha_v = 1 - \alpha_x \qquad \textbf{(4.12)}$$

In the third step, the value-added price(pv) is determined by inverting price equation (2.21).

$$p_v = [(p_q^{1-\sigma} - \alpha_x p_x^{1-\sigma})/\alpha_v]^{1/1-\sigma} \qquad \textbf{(4.13)}$$

Finally, the tfp-index in the value-added nest is computed by inverting equation (2.19)

$$A = \frac{1}{p_v} \prod_i \left(\frac{p_i}{\alpha_i}\right)^{\alpha_i} \quad , \quad i = A, B, K, F \qquad \textbf{(4.14)}$$

4.3.2 Capital stock and the rate of return

The GTAP database contains data on the investment rate (nominal investments as a percentage of nominal GDP) for every region. In the calibration model we determine the desired rate of return and the sectoral capital stocks in such a way that the model reproduces on a regional level the nominal investments in GTAP. In calibrating the capital stocks and the desired rate of return, we assume that the sectors are in a steady state - *i.e.* that the sectors are willing to expand their capacity at a given growth rate and a constant desired rate of return.

To illustrate this part of the calibration model, we start with an economy producing a single good. According to the accumulation equation, the capital stock K depends on its lagged value, depreciation δ rate and the volume of investments I.

$$K = (1 - \delta)\, K_{-1} + I \qquad \textbf{(4.15)}$$

If value added is produced with a Cobb-Douglas technology, optimal capital input is

$$(r^* + \delta)\, p_{ik}\, K = \alpha_k\, p_v q_v \qquad \textbf{(4.16)}$$

This equation implies that total capital income is a constant fraction α_k of value added. Capital income equals capital costs times the capital stock, where the former depends on the desired rate of return r^*, depreciation rate δ and price of investment goods p_{ik}. Value added is written as the volume index q_v times the value-added deflator p_v .

If we assume that equation (4.16) holds both for the current and the previous period, and if r is constant over time, equations (4.15) and (4.16) imply

$$r^* = [(1 + g)(1 + \pi) - (1 - \delta)] \frac{\alpha_k}{IR_0} - \delta \qquad \textbf{(4.17)}$$

In this equation, we use g for the growth rate of real value added, π for the relative change of the price ratio p_v / p_i and IR_0 for the investment ratio, *i.e.* nominal investment divided by nominal GDP in the GTAP database.

Consequently, if we assume a steady state, an observed investment ratio implies the desired rate of return that is used in the production process. If we know the rate of return, the price levels and the depreciation rate, equation (4.15) determines the capital stock.

In case of more sectors, as is the case in WorldScan, the calibration process is essentially the same. The depreciation rate is assumed to be 5% in all sectors. The rate of return, equal for all sectors, is determined under the condition that the model reproduces the macro investment rate; for each sector the capital stock is subsequently computed. The difference between the desired rate of return and the market real interest rate is called the risk premium.

4.4 Technological progress

The growth rate of real value added is exogenous for every sector in every region. Under the assumption that all sectors are in a steady state, technological progress can be derived from these exogenous growth rates. Note that technological progress is not input specific, since value added is produced with Cobb-Douglas technology (see equation (2.16)).

The value-added function, linearised in growth rates that are indicated by dots, reads

$$\dot{y} = \alpha_k \dot{K} + \alpha_h \dot{H} + \alpha_l \dot{L} + \dot{A} \qquad \textbf{(4.18)}$$

The growth rate of the value added, y, is a weighted sum of growth rates of the capital stock, K, high-skilled employment, H, low-skilled employment, L, and the technology index, A. The fixed factor does not enter this equation because we assume that its volume is fixed. In a steady state, the following relation holds

$$\dot{K} = \dot{y} + \dot{p}_y - \dot{p}_k \qquad \textbf{(4.19)}$$

Combining both equations yields

$$\dot{y} = \frac{1}{1-\alpha_k} (\alpha_k (\dot{p}_y - \dot{p}_k) + \alpha_h \dot{H} + \alpha_l \dot{L} + \dot{A}) \qquad \textbf{(4.20)}$$

We approximate the change in relative prices of value added and the capital stock by sectoral differences in the rate of technological progress, indicating the technology index in the capital goods sector by A_k.[2]

$$\dot{p}_y - \dot{p}_k = \dot{A}_k - \dot{A} \qquad \textbf{(4.21)}$$

In the capital goods sector, equation (4.20) reduces then to

$$\dot{y} = \frac{1}{1-\alpha_k} (\alpha_h \dot{H} + \alpha_l \dot{L} + \dot{A}) \qquad \textbf{(4.22)}$$

and technological progress in that sector can be determined by inverting this equation.

$$\dot{A} = (1 - \alpha_k) \dot{y} - \alpha_h \dot{H} - \alpha_l \dot{L} \qquad \textbf{(4.23)}$$

For other sectors, the combination of (4.20) and (4.21) leads to

$$\dot{A} = \dot{y} - \frac{\alpha_k}{1-\alpha_k} \dot{A}_k - \frac{1}{1-\alpha_k} (\alpha_h \dot{H} + \alpha_l \dot{L}) \qquad \textbf{(4.24)}$$

[2] This is used only for illustrative purposes. In fact, capital comes from two sectors : Capital Goods and Services. So, the technology index is a mix of technological progress in these two sectors. This would complicate equations (4.21) to (4.24).

4.5 Capital markets

The allocation of wealth over regional capital markets is described in a non-linear portfolio model (see equation (2.37)). That model contains the parameter , indicating the interest rate sensitivity, and the parameters λ_{hr}, describing the preferred allocation if all expected rate of returns are equal. The latter parameters are updated in the model on the basis of equation (2.38), which implies that in the calibration process the lagged value of that parameter has to be determined.

The parameter ϕ is not based on data analysis, but is chosen in accordance with the character of the scenarios. A scenario with integrated capital markets is characterised by a large ϕ . In case of significant impediments to international capital flows, a small value is chosen.

The lagged values of λ_{hr} are determined on the basis of data on the regional distribution of assets and liabilities. A matrix of the stock of financial investments in other regions is derived from De Jong *et al.* (1993). That source does not contain domestic investments. In other words, the mean diagonal elements are zero. We compute these elements by assuming that the gross debt of a country, owned by both foreign and domestic investors, equals the value of the regional capital stock as derived in the calibration programme. This gives us a full matrix F_{hr} of assets and liabilities. Once these data are available, the current values of λ_{hr} can be determined by inverting equation (2.37) under the restriction that $\Sigma_r \lambda_{hr} = 1$.

$$\lambda_{hr} = \frac{F_{hr} \exp(-\phi R_r)}{\sum_r F_{hr} \exp(-\phi R_r)} \qquad \textbf{(4.25)}$$

Given this value of λ_{hr}, its lagged value is derived by inverting equation (2.38) and using GDP figures in the GTAP database.

$$\lambda_{hr,-1} = \frac{\lambda_{hr}}{\eta} - \frac{(1-\eta)}{\eta} \frac{Y_r}{\sum_h Y_h} \qquad \textbf{(4.26)}$$

5 Globalization scenario

5.1 Qualitative characteristics

This chapter presents a basic scenario that plays an important role as benchmark scenario in further analyses. It is an optimistic scenario on economic progress in both developed and developing regions, emphasising globalization tendencies and market-oriented policies in the world economy. Therefore, this scenario is akin to the High Growth scenario that CPB and the OECD constructed for their collaborative study on globalization and the consequences for OECD countries (OECD, 1997a). The idea of this scenario is that when developing countries grow fast or start to grow rapidly, the linkages between OECD and non-OECD countries intensify. Fast development outside the OECD area and liberalization of capital, goods and service markets produce closer economic integration of rich and poor countries. More generally, the scenario extrapolates and probably exaggerates the current globalization tendencies.

We introduce this scenario as a basic scenario because it stresses the linkages between regions, especially those between developed and developing regions. The ties between the regions are fairly close. As a consequence, spillovers between the regions are large. We do not suggest that this scenario is the most plausible scenario. We use this scenario only to illustrate the mechanisms of the model. Because of the intensified linkages between regions in this scenario, it fits that purpose fairly well.

To attain and sustain the high growth rates assumed in the scenario, developing countries should pursue sound domestic policies. Countries that do not create favourable conditions for market-based development are likely to fail. Governments must also promote, or at least not discourage (private) savings, invest in public infrastructure and human capital and at the same time try to control or even curb fiscal deficits and public debt. Not all the elements mentioned above are variables in WorldScan. We assume, however, that favourable market-oriented policies, investment in infrastructure and the like stimulate productivity, which is expressed by high technological progress in the model.

Fast economic growth in the developing regions leads also to a convergence of consumer preferences towards the United States. Moreover, rising per capita incomes

in OECD countries lead to a higher demand for Services and a relatively lower demand for Agriculture and Food.

Table 5.1 Characteristics globalization scenario

Economy	*high economic growth rates*
Politics	*increasing market-oriented policies* *trade liberalization*
Technology	*strong technological development* *convergence of the non-OECD*
Labour	*more education* *reallocation from low-productivity sectors in the non-OECD*
Consumer preferences	*convergence of consumer patterns*

5.2 Growth

Economic growth is one of the most important characteristics of this scenario. This section presents the determinants of GDP growth by means of a growth-accounting exercise. Capital accumulation, labour supply of low-skilled and high-skilled workers, labour reallocation from low-productivity sectors and technical progress are the determinants of GDP growth. Not all of these determinants are endogenous in the model. Growth-accounting thus shows the relevance of the endogenous variables and exogenous trends for GDP growth.

In our basic scenario many poor countries converge, though not completely, with rich countries. Due to education, population growth, and labour reallocation from low-productivity to high-productivity sectors, labour is one of the engines for growth (see Figure 5.1). Labour contributes to about 2% of GDP growth in Asia and the Rest of the World. The greater part of this contribution is due to education, the development of which is already depicted in Figure 3.4. Additionally, labour reallocation contributes to growth in Asia, while labour supply of low-skilled workers induced by population growth is relatively more important in the Rest of the World.

Capital accumulation is important in all regions. On average, it contributes to about 40% of economic growth. The high savings rates in Asia contribute substantially to the supply of capital in the non-OECD regions. Because of the lack of population growth and stable schooling levels in the OECD, (exogenous) technology is the main contributor to economic growth. Technology is also important for the transition countries in order to reform the inefficient production processes inherited from the communist past.

Figure 5.1 *Growth accounting*
annual contributions of the productive factors, 1996-2020

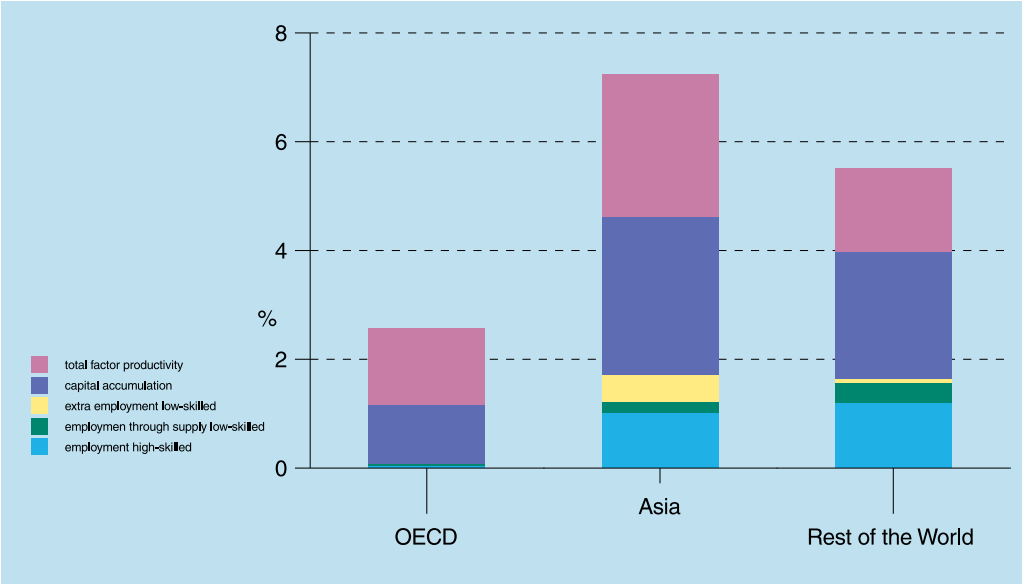
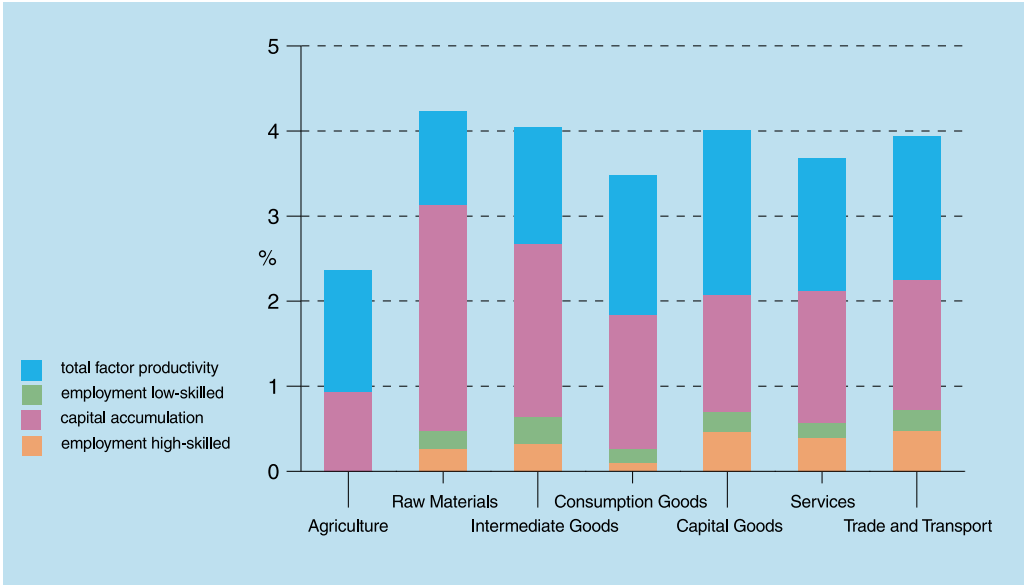


Table A5.1 in the appendix presents the results of the growth accounting for the twelve regions. Within the OECD there is some variation, because labour supply grows in the United States and Pacific OECD, while this is not the case in Western Europe and Japan. In Asia, labour supply grows less sharply in China, due to its population policy, but much labour reallocation and technological progress raises GDP growth above the average. The differences within the Rest of the World are large. On the one hand, there are the transition countries with stable population and education levels. Technological progress is the engine for growth in these regions. On the other hand, labour supply growth, in particular of high-skilled labour, is very important in the Middle East, Sub-Saharan Africa and Latin America. We assume that technological progress is relatively less important in these regions.

The determinants of growth can also be studied from a sectoral perspective. Figure 5.2 presents the growth-accounting results for all sectors at a global level. Growth in the sector Agriculture is the lowest. This is not surprising, because the demand for Agriculture and Food decreases as regions develop. Technological progress and capital accumulation are the sole engines of growth in this sector. Technological progress is important in the sectors Capital Goods and Trade and Transport. The importance of high-skilled labour compared to low-skilled labour in Capital Goods, Services, and Trade and Transport reflects the intensity of high-skilled labour in the

production of these goods. The sectors Raw Materials and Intermediate Goods are the most capital-intensive sectors, as can be seen by the weight of Capital Goods in economic growth.

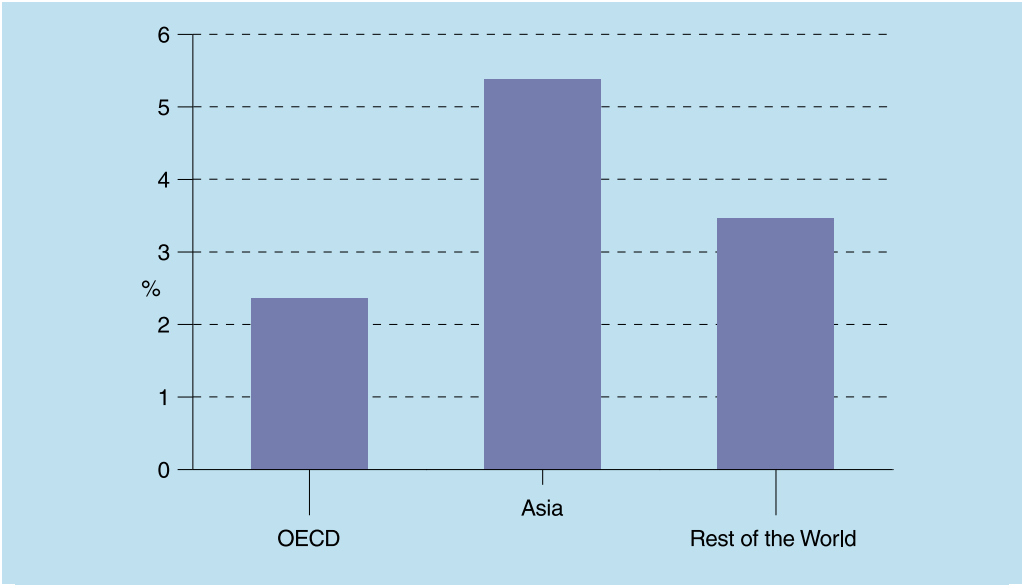
Figure 5.2 *Sectoral growth accounting*
annual contributions of the productive factors 1996-2020



As Figure 5.1 already showed, the growth rates between the three regions vary from 2.5% to 7.2%. Per capita differences are a bit smaller, due to high population growth in Asia and, in particular, the Rest of the World (see Figure 3.1). Figure 5.3 presents GDP growth per capita during the scenario period.

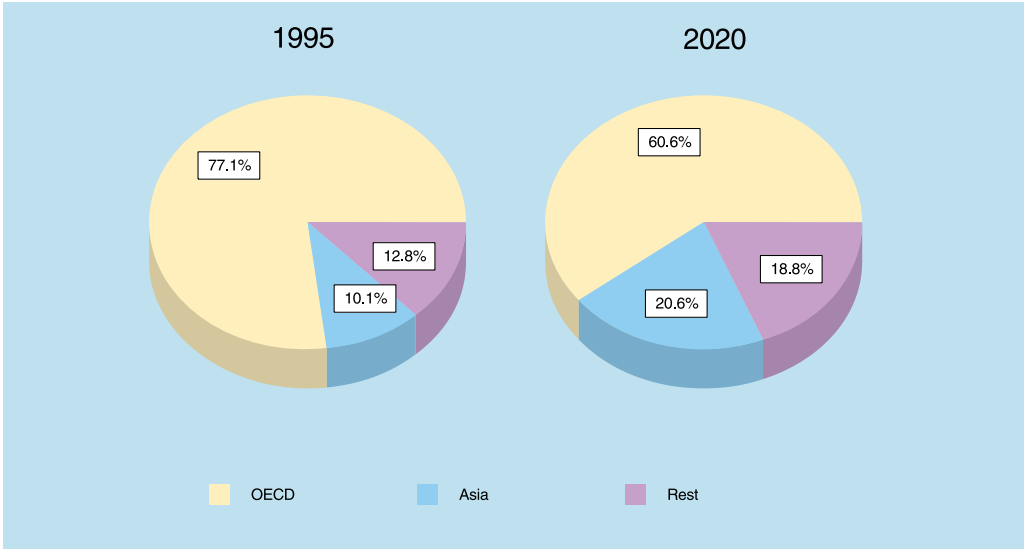
The average GDP per capita growth rates range from 2.4% in the OECD to 5.4% in Asia. In an historical context, this is an optimistic scenario, because only a few countries have been able to maintain growth rates of about 4% per capita for two decades or longer. Large population growth in the Rest of the World lowers the GDP per capita to 3.5%. Sub-Saharan Africa is lagging behind (see Table A5.2). Although the macro growth rates are impressive given the developments during the last two decades, the large population increase will keep per capita growth rates at European levels. In all regions, GDP growth per capita decreases slightly over time. This is caused by the drop in participation rates.

Figure 5.3 Average GDP growth per capita between 1995 and 2020



High economic growth rates in the developing regions shift, to some extent, the centre of production from the OECD to Asia. Between 1995 and 2020, the OECD share of production drops from 77.1 to 60.6% (see Figure 5.4). Asia benefits most from the shift. In 2020 it produces 20% of the world output. It doubles its share compared to 1995. China and South-East Asia increase their market shares on the world market by about 5% points, while the United States and Japan lose about 5% points (see Table A5.2). Western Europe's market share shrinks from 30 to 23%.

Figure 5.4 World shares of GDP in 1995 and 2020

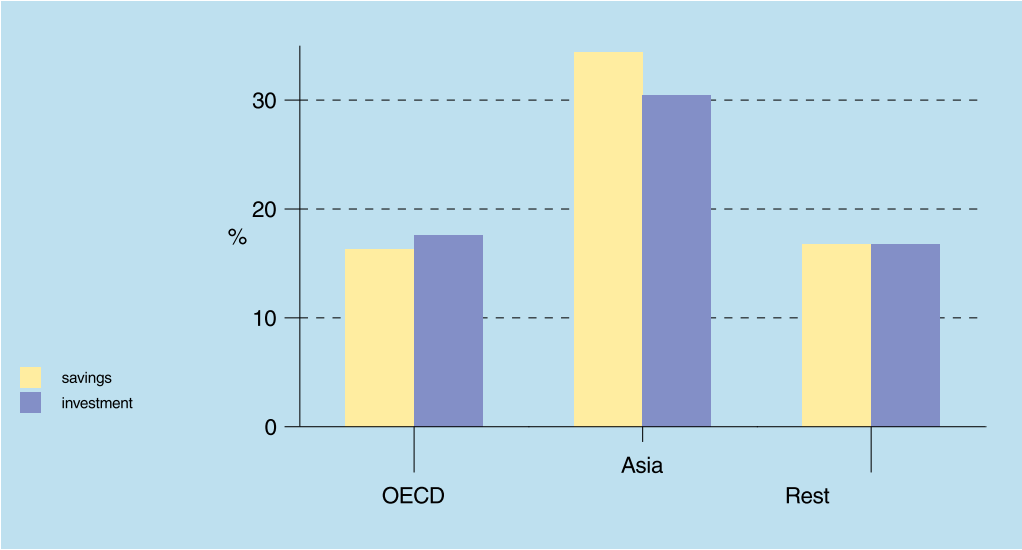


5.3 Savings and investment

High growth is accompanied by high investment and savings rates. Savings in the OECD are reduced in response to ageing. As a consequence, Asia partly finances the investment in the OECD. While the current accounts seem to be in balance in 1995 for the three regions, in 2020 there is a substantial surplus for Asia (see Figure 5.5).

All Asian regions have a surplus of about 2% in 2020, while Western Europe, Pacific OECD and the Former Soviet Union have a deficit of the same order of magnitude (see the differences between savings ratio and investment ratio in Table A5.2).

Figure 5.5 *Savings and investment ratios in 2020*
ratios of national income



The globalization process induces capital owners also to invest more capital abroad. While in 1995 all regions invest more than 80% of their wealth in the home region, this is reduced by 6 to 18% points in 2020. Table 5.2 presents the differences in the shares of wealth invested in the specific regions between 1995 and 2020.

Table 5.2 *Shares of own wealth invested in the various regions*
differences between 1995 and 2020

destination: origin of wealth	OECD	Asia	Rest of the World
OECD	-6.4	3.2	3.2
Asia	14.7	-18.2	3.5
Rest of the World	13.3	3.3	-16.6

The relative reduction of investment in the OECD by capital owners from the OECD is used for investment in both Asia and the Rest of the World. Although the capial flow from the OECD toward the non-OECD regions does not increase drastically, capital mobility within the OECD increases considerably. This can be seen in Table A5.3 in the Appendix. The capital owners in Asia and the Rest of the World increase substantially their investment in the OECD. This corresponds to Figure 5.5, which shows a trade deficit for the OECD and a surplus for the other two regions.

High economic growth per capita shifts consumption from Agriculture and Food towards Services. In particular, in the non-OECD regions, these shifts are substantial. As Figure 5.6 shows, the consumption share in Agriculture and Food decreases from about 30% to 10%. This is also reflected by the increase in the share of Services by the same amount. The drop in the consumption share for Agriculture by consumers in the Rest of the World is also substantial, but a bit lower. The reasons are that, first, the initial share is already lower than it is in Asia, and second, the increase in GDP per capita is lower.

Figure 5.6 *Shifts in consumption shares in Agriculture and Services*
Difference in shares between 1995 and 2020.
Numbers below columns are consumption shares in 1995

Consumers in Western Europe, Japan and Pacific OECD change their consumption patterns towards those in the United States. In the latter country, the consumption share in Services is higher than in other regions, and is lower in Agriculture. At the regional level, Table A5.4 shows a remarkable change in consumption from Agriculture to Services in Eastern Europe. It is of the same order of magnitude as that in Asia.

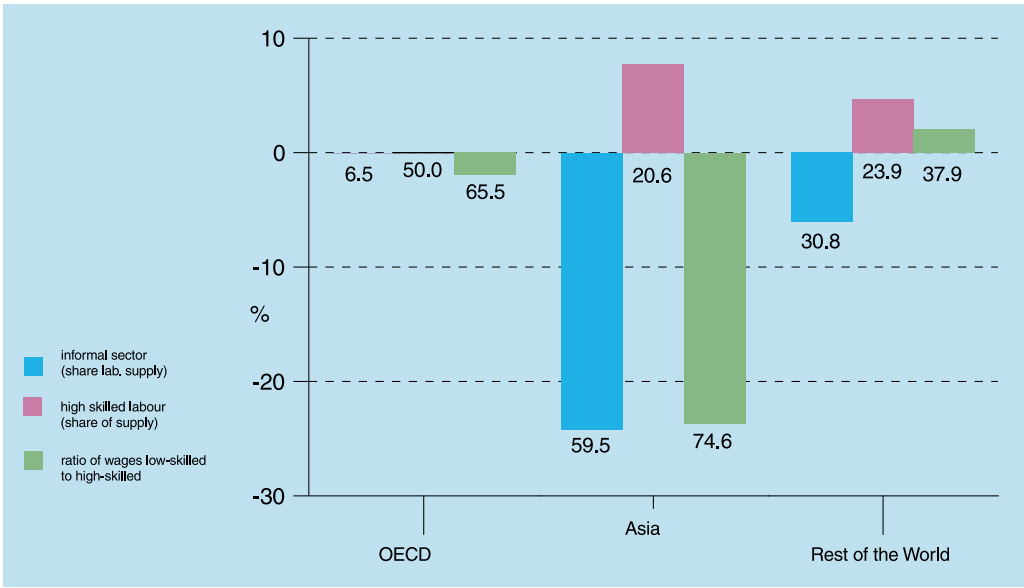
5.4 Labour markets

Several trends affect demand and supply of high- and low-skilled labour. First, demand shifts from low-skilled labour-intensive goods such as Agriculture, to high-skilled labour-intensive goods, such as Services. As a consequence, the demand for low-skilled labour decreases, while the demand for high-skilled workers increases. This does not necessarily lower the relative wages of low-skilled workers compared to high-skilled workers because the relative supplies for both labour types are not constant in time in the non-OECD regions. In particular, the growth in high-skilled labour supply in the non-OECD regions rises, as shown by Figure 3.4. This trend exerts upward pressure on the relative wages of low-skilled workers.

In addition to these two trends in demand and supply of labour, labour reallocation takes place from low- to high-productivity sectors in developing regions. Because productivity in the latter sectors grows faster than in the former sectors, workers reallocate to high-productivity sectors. This raises effective labour supply in the latter sectors. Labour reallocation thus exerts downward pressure on the relative wages of low-skilled workers compared to high-skilled workers.

Figure 5.7 shows that more than 20% of the total labour supply in Asia is reallocated to high-productivity sectors. This is induced by the increasing gap in productivity in both types of sectors. The changes in the Rest of the World are smaller. There are two reasons for this result. First, GDP growth per capita is smaller, so that the productivity gap does not change as fast as in Asia. Second, the informal sector is, on average, much smaller.

Figure 5.7 *Employment and wages in 2020*
differences in unemployment ratio, ratio of high-skilled workers to labour supply, and relative wages of low-skilled towards high-skilled compared to 1995. Numbers below columns refer to levels in 1995

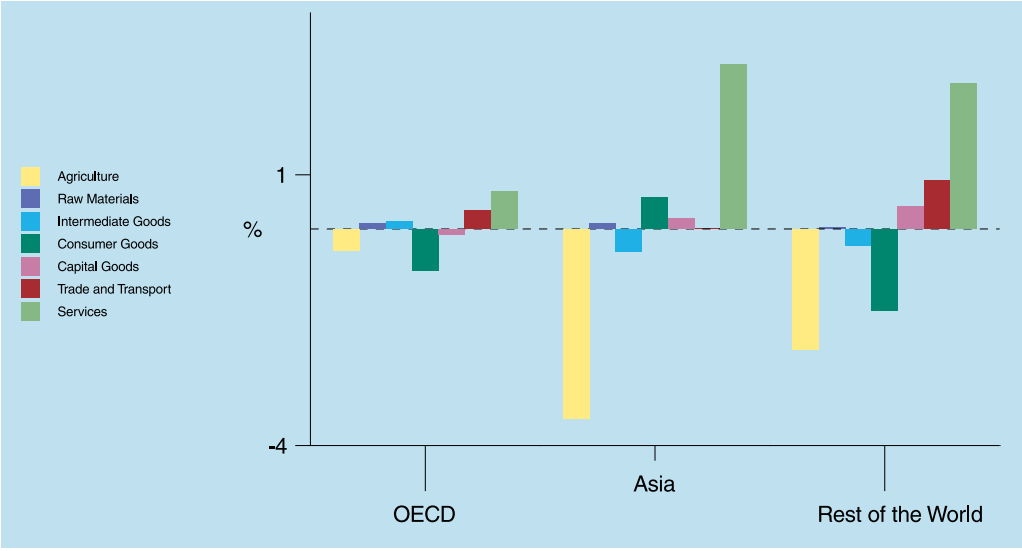


The increase in the labour supply of low-skilled workers in the formal sectors, as well as the decrease in demand for low-skilled labour-intensive goods, exerts a serious downward pressure on the relative wages of low-skilled workers in Asia. In spite of the increase in supply of high-skilled labour due to increased education, the relative wages drop by more than 20% in 25 years' time. As can be seen in Table A5.2, this is particularly the case for China. The increase in high-skilled labour is relatively small compared to the outflow from the informal sector. As a consequence, the downward pressures on the relative wages dominate. In the Rest of the World, labour reallocation is much smaller than in Asia. Moreover, the production shifts from low-skilled to high-skilled labour-intensive goods are much smaller. As a result, relative wages rise in the Rest of the World. This is not the case in the OECD. Shrinking demand for low-skilled workers exerts a downward pressure on relative wages.

At a sectoral level, employment shifts from Agriculture to Trade and Transport and Services in all regions. This shift is more pronounced in Asia and the Rest of the World than it is in the OECD (see Figure 5.8). The demand shift from Agriculture and Food towards Services is responsible for this effect. Except for this demand shift, the shifts

in sectoral employment represent also changes in the specialization pattern, as will be discussed extensively in Section 5.5. The OECD specialises in Services and Intermediate Goods, while Asia specialises in Consumer Goods. More details are presented in the Appendix, Table A5.4.

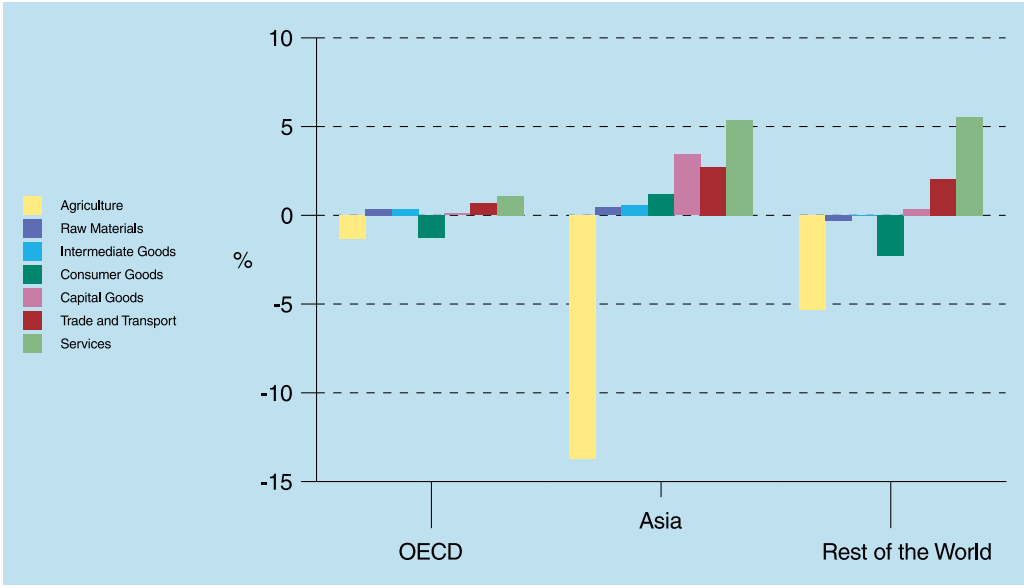
Figure 5.8 Absolute changes in sectoral employment shares from 1995 to 2020



5.5 Trade and specialization

The global shifts from demand for Agriculture and Food towards Services have a large impact on the value-added shares in the various regions. In particular, in Asia and the Rest of the World value-added shares of Agriculture and Food decrease by 6 to 13%, while those in the sector Services increase by about 6%. Besides Services, the developing regions also produce relatively more in the sectors Capital Goods and Trade and Transport in 2020 (see Figure 5.9). In the OECD, the shifts are smaller because the demand shift is very modest, and trade in Services is limited. The spillover effects of demand shifts in other regions are thus modest.

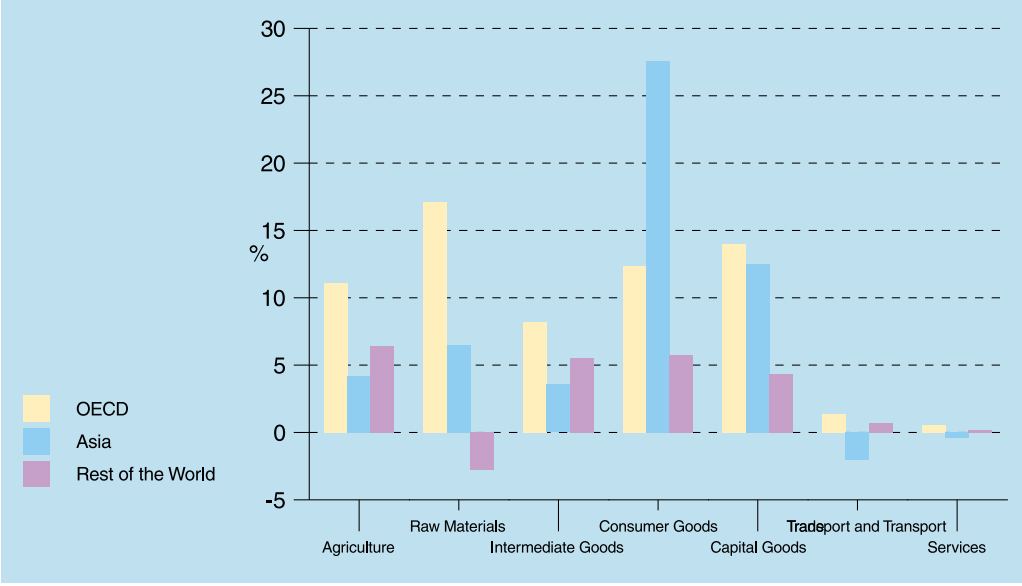
Figure 5.9 Absolute changes in sectoral value added shares from 1995 to 2020



The changes within the OECD are a bit more pronounced. Due to the convergence of consumer preferences in Western Europe, Japan and the Rest of the OECD, the value-added shares in Agriculture and Food decrease, while they rise for Services. Within the non-OECD regions, the size of the shifts varies substantially (see Table A5.4). The increases in value-added shares of Services are the largest in Eastern Europe, South Asia and the Rest of the World, while the decreases in the value-added shares of Agriculture are most pronounced in China, South Asia and the Rest of the World. With the exception of more Services, China also produces relatively more Capital Goods, Intermediate Goods and Trade and Transport. For the other regions, the shifts to the latter three sectors are smaller.

Trade liberalization makes a large impact on the trade flows between regions. While the changes in value-added shares reflect mainly the shift in consumption patterns, Figure 5.10 reflects the increase in trade. It depicts for all sectors the difference in the ratio of exports to production between 1995 and 2020. The size of the changes is caused mainly by reducing the trade distortions. The increase in trade in Services and Trade and Transport is very limited. Trade liberalization hardly affects trade in these sectors because the initial tariff barriers in 1995 are negligible. Figures 3.10 to 3.13 depict the size of these distortions. The substantial increase in the value-added share of services in most regions is thus mainly sold in the home region.

Figure 5.10 Differences in ratio of export to production between 1995 and 2020



Particularly remarkable is the increase in the export of Consumer Goods by Asia. The elimination of trade barriers induces specialization of these low-skilled labour-intensive goods. The breakdown of the substantial trade barriers in Capital Goods and Intermediate Goods stimulates trade significantly. The increase in trade of Agriculture seems to be modest, given the large initial distortions in this area. However, taxes and subsidies are reduced by only 50%. The increase in trade of Raw Materials is induced by lower distortions and the increase in production, which needs Raw Materials as intermediary input.

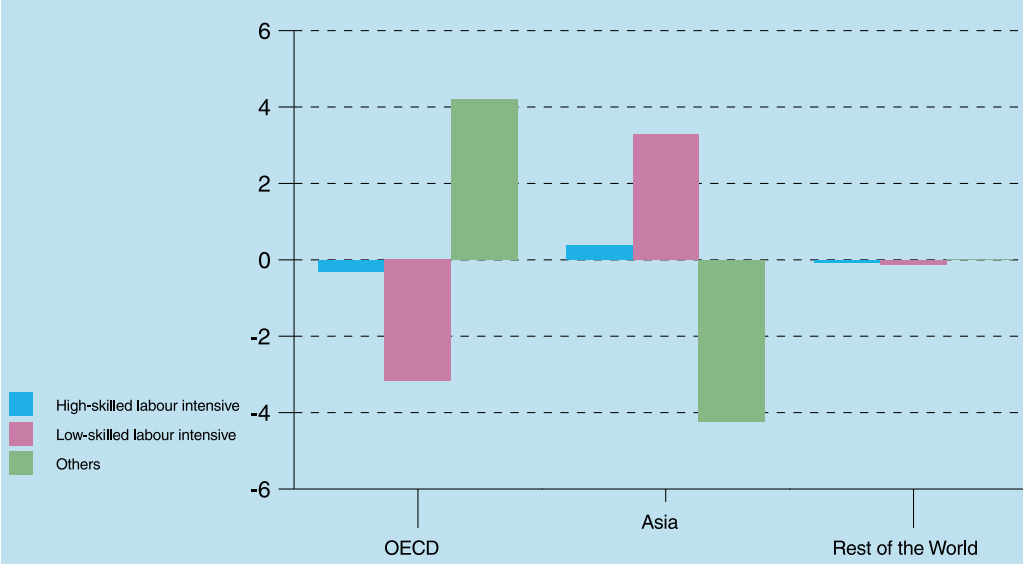
Figure 5.10 reflects mainly the increase in intra-industry trade. Specialization can better be analysed using ratios of net trade to production. Net trade is defined as the difference between the value of exports and imports. Figure 5.11 depicts these ratios. It shows that Asia specialises in Consumer Goods and Capital Goods. The variation within Asia is large. South Asia and the Rest of the World specialise in Consumer Goods, while China specialises in Capital Goods (see Table A5.7 in the Appendix). China has, relative to South Asia and the Rest of the World, a relative abundance of high-skilled labour (see Table A4.2). The Rest of the World specialises in Agriculture. Table A5.7 shows also that Sub-Saharan Africa and Latin America are the main exporters in this sector. The OECD specialises in Raw Materials. The OECD faces the highest import tariffs for exporting Raw Materials, which is no longer the case after trade liberalization. Moreover, the production of Raw Materials is relatively capital intensive.

Figure 5.11 Differences in ratio of net export to production between 1995 and 2020

The trend towards specialization between 1995 and 2020 can also be presented by shifts in trade surpluses for high-skilled and low-skilled labour-intensive goods and others, as is done in Figure 5.12.[1] The group 'others' in the figure are the Intermediate Goods and Raw Materials sectors. These sectors are relatively capital intensive. In particular, the Pacific OECD produces more Raw Materials at the expense of the Middle East (see Table A5.4). The large deficit for Asia in this sector is due to the huge rise in energy demand induced by economic growth. This can not be compensated by regional supply. Asia specialises in the production of low-skilled labour-intensive Consumer Goods at the expense of the OECD.

[1] High-skilled labour-intensive sectors are Capital Goods, Services, and Trade and Transport. Low-skilled labour-intensive sectors are Consumer Goods and Agriculture and Food. The other sectors consist of Raw Materials and Intermediate Goods.

Figure 5.12 Differences in trade surpluses according to skill intensity in 2020



Appendix A5

Table A5.1 Sources of economic growth from 1995 to 2020

country	Western Europe	United States	Japan	Pacific OECD	Eastern Europe	Former Soviet Union
employment high-skilled	0.0	0.3	-0.1	0.3	0.0	0.1
employment low-skilled	0.0	0.1	-0.1	0.1	0.0	0.1
labour reallocation	0.0	0.0	0.0	0.0	0.0	0.0
capital accumulation	1.1	1.2	1.0	1.1	2.0	2.3
total factor productivity	1.6	1.2	1.5	0.9	3.0	3.0
gross domestic product	2.6	2.8	2.4	2.4	4.9	5.6

country	Middle East and N.A.	Sub-Saharan Africa	Latin Amer.	China	South-East Asia	South Asia & Rest
employment high skilled	1.7	1.9	1.3	0.5	1.3	1.1
employment sup. low skilled	0.5	0.7	0.2	0.1	0.1	0.4
labour reallocation	0.2	0.2	0.2	0.8	0.3	0.6
capital accumulation	2.5	2.2	2.3	3.2	2.8	2.7
total factor productivity	1.0	0.3	1.4	3.5	2.3	2.0
gross domestic product	5.9	5.4	5.4	8.0	7.0	6.8

Table A5.2 Differences of macroeconomic variables in 2020 compared to 1995 all variables are ratios, except GDP per capita (= average growth from 1995 to 2020)

	invest-ment ratio	savings ratio	share of world GDP	cons. share services	informal sector	relative wage ratio	GDP capita
United States	-1.7	-1.8	-4.8	0.0	0.0	-0.3	2.0
Japan	-5.5	-6.0	-4.2	2.6	0.0	-3.8	2.5
Western Europe	-2.7	-5.3	-6.7	4.0	0.0	-2.2	2.6
Pacific OECD	-2.1	-5.0	-0.8	-1.1	0.0	-0.5	1.4
Eastern Europe	-0.9	2.1	0.3	27.4	0.0	-10.6	4.9
Former Soviet Union	-0.9	-3.5	1.0	5.5	0.0	-3.0	5.4
Middle East and N.A	-2.7	-1.0	1.8	13.0	-15.0	14.2	4.0
Sub- Saharan Africa	-2.4	-4.5	0.5	15.8	-10.1	8.4	2.7
Latin America	-3.6	-4.2	2.3	15.2	-15.3	16.7	4.1
China	1.0	4.3	4.1	27.8	-28.2	-60.1	7.5
South-East Asia	-2.2	1.5	4.7	16.4	-22.3	19.4	5.9
South Asia & Rest	1.4	5.0	1.7	29.8	-20.5	-14.3	5.5

Table A5.3 Differences in share of wealth invested in various regions (compared to 1995)

	U	J	W	P	E	F	M	S	L	C	N	O
United States	-15.2	3.2	5.1	0.5	0.3	0.5	0.8	0.3	1.2	1.0	1.5	0.7
Japan	4.8	-17.5	5.5	0.6	0.3	0.5	0.8	0.3	1.6	1.0	1.4	0.7
Western Eur.	4.2	2.7	-13.8	0.5	0.2	0.5	0.8	0.2	1.5	1.0	1.5	0.7
Pacific OECD	4.1	3.3	5.2	-19.2	0.2	0.5	0.8	0.3	1.5	1.0	1.5	0.7
Eastern Europe	4.7	3.4	5.4	0.7	-20.4	0.5	0.7	0.3	1.5	1.0	1.5	0.7
Former Sov. U.	5.1	3.5	5.8	0.7	0.2	-20.9	0.6	0.1	1.5	1.0	1.5	0.7
M. E. & N.A.	4.5	3.1	3.4	0.6	0.3	0.5	-17.4	0.2	1.6	1.0	1.5	0.7
Sub-Sah. Af.	4.9	3.3	4.4	0.6	0.3	0.5	0.9	-19.7	1.6	1.0	1.6	0.7
Latin America	4.0	3.3	5.3	0.6	0.3	0.5	0.9	0.3	-18.5	1.0	1.5	0.7
China	5.0	3.5	5.9	0.7	0.3	0.5	0.9	0.3	1.6	-20.8	1.5	0.7
South-East As.	4.8	3.5	5.6	0.7	0.3	0.5	0.9	0.3	1.6	1.0	-19.8	0.7
S. Asia & Rest	4.9	3.5	5.8	0.7	0.3	0.5	0.9	0.3	1.6	1.0	1.5	-21.0

U=United States, W=Western Europe, J=Japan, P=Pacific OECD, E=Eastern Europe, F=former Soviet Union, M=Middle East & North Africa, S=Sub-Saharan Africa, L=Latin America, C=China, N=South-East Asia, and O=South Asia & Rest.

Table A5.4 Absolute changes in value added shares in 2020 (compared to 1995)

	Agri-culture	Raw Materials	Interm. Goods	Cons Goods	Capital Goods	Trade & Transport	Services
United States	1.3	0.3	0.0	-1.6	-0.9	0.8	0.1
Japan	-5.1	0.3	1.3	-0.8	2.3	-1.8	3.7
Western Europe	-1.6	0.2	0.3	-1.2	-0.1	2.1	0.3
Pacific OECD	1.3	1.7	-0.4	-2.0	-1.4	-0.8	1.6
Eastern Europe	-7.7	0.5	0.5	-3.5	-0.5	1.7	9.0
Former Soviet Union	-1.8	-0.7	-0.2	-1.1	1.3	2.0	0.5
Middle East and NA.	-4.9	-2.5	-0.7	-0.7	1.5	2.4	4.8
Sub-Saharan Africa	-7.1	0.3	0.4	-2.7	1.4	2.9	4.9
Latin America	-5.6	0.2	0.2	-3.0	-0.4	1.6	7.1
China	-14.6	0.3	1.4	-0.1	5.5	2.7	4.9
South-East Asia	-11.4	-0.1	0.8	2.0	3.5	1.2	3.9
South Asia & Rest	-17.3	1.8	-1.7	1.9	-0.9	5.2	11.1

Table A5.5 *Absolute changes in sectoral employment shares in 2020 (compared to 1995)*

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	0.7	0.1	0.0	-0.9	-0.5	0.3	0.3
Japan	-2.6	0.1	0.7	-0.4	1.3	-0.6	1.5
Western Europe	-0.7	0.1	0.2	-0.6	0.0	0.7	0.5
Pacific OECD	0.7	0.4	-0.2	-1.2	-0.8	-0.1	1.2
Eastern Europe	-3.6	0.1	0.3	-1.9	-0.4	0.5	5.0
Former Soviet Union	-0.9	-0.1	-0.1	-0.7	0.8	0.6	0.3
Middle East and NA.	-3.6	-0.7	-0.6	-1.0	1.1	1.0	3.8
Sub-Saharan Africa	-4.3	0.1	0.2	-2.6	1.2	1.1	4.3
Latin America	-3.5	0.0	0.0	-2.4	0.0	0.7	5.3
China	-0.3	0.0	0.2	-0.2	1.2	-1.0	0.2
South-East Asia	-5.8	-0.1	0.2	0.6	2.1	0.3	2.7
South Asia & Rest	-6.1	0.3	-1.2	1.1	-1.2	1.1	5.8

Table A5.6 *Absolute changes in ratio of export to production in 2020 (compared to 1995)*

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	15.6	15.5	5.1	13.6	13.3	3.1	1.1
Japan	1.1	20.6	9.5	8.3	13.7	0.4	0.1
Western Europe	2.1	15.5	9.5	15.0	15.1	0.3	0.4
Pacific OECD	17.6	21.2	9.6	15.0	8.9	0.4	0.2
Eastern Europe	8.8	4.6	10.3	11.8	11.2	-1.3	-1.0
Former Soviet Union	2.3	-7.5	6.3	-4.5	2.0	-1.8	-0.3
Middle East and NA.	1.8	-5.2	4.9	11.0	2.5	2.5	0.9
Sub-Saharan Africa	10.0	-1.7	2.8	9.0	20.4	-0.4	-0.3
Latin America	7.7	4.2	4.9	1.7	3.4	0.7	0.2
China	1.7	-1.7	-1.2	21.6	16.1	-2.9	-0.9
South-East Asia	3.9	6.0	5.7	17.7	7.5	-2.3	-0.7
South Asia & Rest	10.9	21.7	23.1	61.7	33.3	2.5	1.0

Table A5.7 Absolute changes in ratio of net export to production in 2020 (compared to 1995)

	Agri-culture	Raw Materials	Inter-mediate Goods	Consumer Goods	Capital Goods	Trade & Transport	Services
United States	13.2	16.8	1.7	-29.9	-3.9	1.6	0.8
Japan	-71.6	154.9	7.6	-7.7	6.8	-6.6	-0.6
Western Europe	-5.0	19.0	6.4	-9.5	0.2	-2.9	-0.4
Pacific OECD	15.8	19.6	2.3	-49.9	-38.4	-2.7	-0.5
Eastern Europe	6.7	7.3	6.4	2.3	-7.0	-0.9	-0.9
Former Soviet Union	-1.6	-8.9	6.8	-21.8	3.5	-2.5	-0.5
Middle East and NA.	4.6	-10.1	-5.7	-1.2	27.7	6.5	2.1
Sub-Saharan Africa	10.6	-8.7	1.1	-59.4	20.1	1.3	-0.1
Latin America	8.4	-5.5	2.7	-9.2	-9.3	1.9	0.6
China	-0.1	-56.4	-1.6	5.6	10.2	-2.0	0.5
South-East Asia	-35.4	-38.0	-2.1	10.3	7.9	-0.8	1.2
South Asia & Rest	0.9	27.2	-69.2	30.6	-48.6	8.2	1.8

6 WorldScan at work

6.1 Model simulations

WorldScan is used for three different purposes. First, it is a tool for constructing scenarios, such as the one described in the previous chapter. Second, it helps to analyse the impact of certain events or trends, like a technology shock or ageing. Third, it is used to perform policy analysis, on global environmental policies or trade policies, for example. For all three of these exercises the model provides information about the interactions between different parts of the global economy. That information is extracted from the model by means of simulation analysis: what happens if one changes an assumption in the model? This chapter will describe some of those simulations.

These simulations are not restricted to policy-oriented issues. The role of WorldScan, as opposed to many other econometric models, is not merely to analyse changes in policy instruments, given a reliable empirical description of the economy. Since WorldScan wants to address long-term future developments, it does not attempt such an empirical description of the economy. The long-term scenarios, which are needed for the analysis of strategic policies, are based more on assumptions and theoretical knowledge of interactions than on empirical evidence. Although the future is fundamentally uncertain, educated guesses are possible. Those guesses are based on possible trends in certain parts of the economy and their potential impacts on other parts of the economy. What impact, for example, might rapid ageing have in developed economies? How would technological catching-up in Asia affect the income distribution between and within regions? What would be the consequence of changing consumption patterns on production and trade patterns?

Constructing scenarios plays an important role in answering those and other questions. Once scenarios are constructed, actual policy analysis can begin. How can global CO_2-emission targets be reached? What are the consequences of lower barriers to international trade and capital markets? What will be the impact of investment in schooling? But once again, the analysis is then not restricted to pure policy simulations. Because of the great uncertainties involved, these simulations are always supplemented

by uncertainty simulations. How does the outcome of a policy simulation depend on the scenario assumptions?

In a number of simulations we will analyse some ingredients of the scenario described in the previous chapter. That scenario assumes rapid growth, especially in the emerging Asian economies, and intensifying trade relations. Important growth-determining factors in the model are technological progress, physical capital accumulation and schooling. We will analyse the impact of these three factors separately. Trade intensity depends, among other things, on tariffs, price elasticities and consumption patterns. Therefore, in a second set of three simulations we will discuss the impact of lower tariffs, lower price elasticities and no convergence in consumption patterns. In that discussion we will focus mainly on the resulting trade pattern. Next, we present some uncertainty analysis. We will show how the impact of tariff reductions depends on price elasticities in trade relations.

6.2 Growth-determining factors

Factor supply and technological progress are the driving forces behind economic growth. More specifically, this section examines the role of three important growth factors. We investigate the impact of skill upgrading, more rapid technological progress, and an increased propensity to save.

6.2.1 Skill upgrading

One of the salient features of WorldScan is the division of labour by skill. Compared to OECD regions, non-OECD regions feature a low average skill level. In the scenario described in Chapter 5, we assume exogenous skill upgrading in non-OECD regions, so that the difference in skills with OECD regions narrows over time. To understand the effects of skill upgrading in WorldScan, we run a simulation without skill upgrading and compare the results with the baseline scenario. Skill upgrading in non-OECD regions leads to more high-skilled workers and, on average, higher productivity. As a consequence, GDP in those regions will grow. Productivity (and GDP) is boosted further by the reallocation of workers from the informal sector to the formal sector. This reallocation is induced by the decline in the number of low-skilled workers. The relative scarcity in the formal sector will exert upward pressure on low-skilled wages, which will stimulate the flow of low-skilled workers into this sector.

Table 6.1 Impact of skill upgrading on wage ratio and informal sector

	OECD	Asia	ROW
		absolute changes[1]	
high-skilled labour (share of total)	0.0	9.0	8.1
wage ratio (low / high)	0.1	11.4	6.0
informal labour (share of total)	0.0	-10.6	-17.2

[1] cumulated differences in 2020 with reference scenario

Table 6.1 shows the effects of skill upgrading on the labour market in three aggregate regions. The supply of high-skilled workers increases in Asia and the Rest of the World. The increasing supply exerts serious downward pressure on high-skilled wages. The wage ratio, defined as low-skilled wages as a percentage of high-skilled wages, increases. Reallocation leads to a decline of the informal sector: the (absolute) change in the share of informal labour is larger than the increase in the share of high-skilled labour.

Table 6.2 Impact of skill upgrading on average annual output growth

	OECD	Asia	ROW
		percentages	
high-skilled labour	0.0	0.5	0.6
low-skilled labour	0.0	-0.1	-0.2
reallocation	0.0	0.1	0.3
capital accumulation	0.0	0.3	0.4
total	0.0	0.8	1.1

Some condensed results on growth are given in Table 6.2. This table presents the contribution of skill upgrading to growth. Results are presented for the three aggregated regions. Figures relate to average annual output growth in percentages. In OECD regions, no further skill upgrading is assumed in the baseline scenario. Hence, the entries in the first column of Table 6.2 are zero. In other regions the total contribution of skill upgrading is substantial. Upgrading adds 0.8% to the average annual growth rate of 7.2% in Asia. The effect of upgrading can be split up further. Skill upgrading leads to more high-skilled labour and less low-skilled labour. The net contribution to growth of this shift is positive, because high-skilled labour is more productive than low-skilled labour. The reallocation of labour from the informal to the formal sector causes an extra impulse to growth. The more intensive use of high-skilled labour leads to a fall in unit costs. Output prices in all sectors fall. Capital, which is obtained from Capital Goods and Services, becomes less expensive. The decline in capital costs leads to higher investments. Capital accumulation boosts growth further.

6.2.2 *Technology*

Technological change determines factor productivity and thereby economic growth. In WorldScan technological progress is exogenous. There is a constant augmenting factor (Hicks neutral technological progress). This factor varies by sector and region. Values range from close to zero to 4% annually. In general, technological progress is highest in Asian regions. Annual rates of total factor productivity in the sectors Agriculture and Raw Materials are at the low end of the range, Capital Goods is at the high end. To understand the impact of technology on growth, we run a simulation with a higher rate of technological progress. The shock we apply to WorldScan is an instant 1%-point increase in the technology-augmenting factor in all regions and all sectors.[1] The outcomes are presented in Table 6.3.

Total factor productivity rises by 1%, but total growth increases by more than 1%. This 'multiplier' effect is caused by the increase in the amount of capital. A technology shock reduces the costs of production. Just as in the case of skill upgrading, considered above, this leads to higher investment and capital accumulation. In Asia and the ROW there is a small effect of reallocation on economic growth. The higher (real) wages attract more low-skilled labour from the informal sector.

Table 6.3 Impact of a TFP shock of 1% on growth

	OECD	Asia	ROW
		percentages	
reallocation	0.0	0.1	0.1
capital accumulation	0.6	0.7	0.7
total factor productivity	1	1	1
total	1.7	1.8	1.8

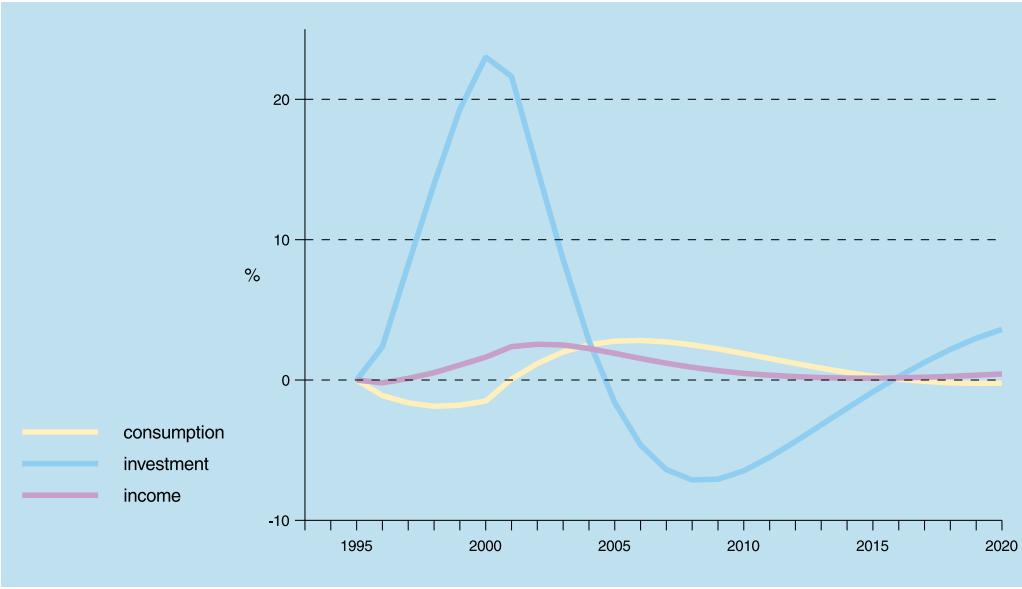
6.2.3 *Capital accumulation*

Output grows with capital accumulation. Capital accumulation is the result of higher levels of investments. Investments are closely related to savings. In WorldScan, consumers are assumed to maximize lifetime utility. Consumption and savings are determined by the time preference (or discount rate) of consumers. A higher time preference puts more weight on immediate consumption and less on savings. To analyse the linkages between time preference, capital accumulation and growth, we run an experiment with a lower time preference. We apply a gradual decrease in the time preference by 5% in all regions. In the baseline, the annual discount rates, depending on region, range from 2.1% to 2.8%.

[1] Probably, a region- or sector-specific shock would be more realistic. However, such a shock leads to changes in specialization and trade patterns and somehow distracts from the focus on growth in this section.

In the long run, average annual growth is hardly affected by reducing the time preference. However, there are considerable fluctuations over time. Figure 6.1 shows the development of global consumption, investment and output for the world as a whole in the period 1995-2020 as cumulated percentage differences to the baseline values.[2] Although there are fierce swings, consumption, investments and output growth return more or less to the baseline value in the long run. In the short run, lower consumption rates, or a higher savings rate, lead to a rise in investments and capital accumulation. After a while, this will boost output. With higher output, consumption rises again. More importantly, interest rates fall. The increase in savings leads to a decrease in the (real) interest rates. This leads to a higher future income and an increase in consumption (see equation (2.7)). Changing the time preference does not affect the propensity to consume in the long run, as can be expected from a neoclassical growth engine.

Figure 6.1 Impact of a lower time preference[1]



[1] measured as a cumulated percentage difference from the baseline

[2] In this experiment the time preference is decreased gradually over five years - hence, the gradual change in consumption, investment and output in the first five years.

A decrease in the time preference in one region only might have more permanent effects, since in this case structural interest rates abroad do not fall accordingly. The initial decrease in consumption leads to an increase in foreign investments. This is reflected in a temporary improvement of the trade balance and, consequently, an improvement of the current account. This increases the stock of net wealth invested abroad. As a result, net interest income from abroad rises. Once the capital stock is adjusted, investments return to the level needed for structural expansion and replacement of depreciated capital. Also the current account will return to its baseline level, but its composition will be remain different. The temporary increase in net savings leads to a permanent increase in net wealth invested abroad and to a permanent increase in net interest income from abroad. The trade balance ultimately converges to a level below the baseline, financed by increased interest income.

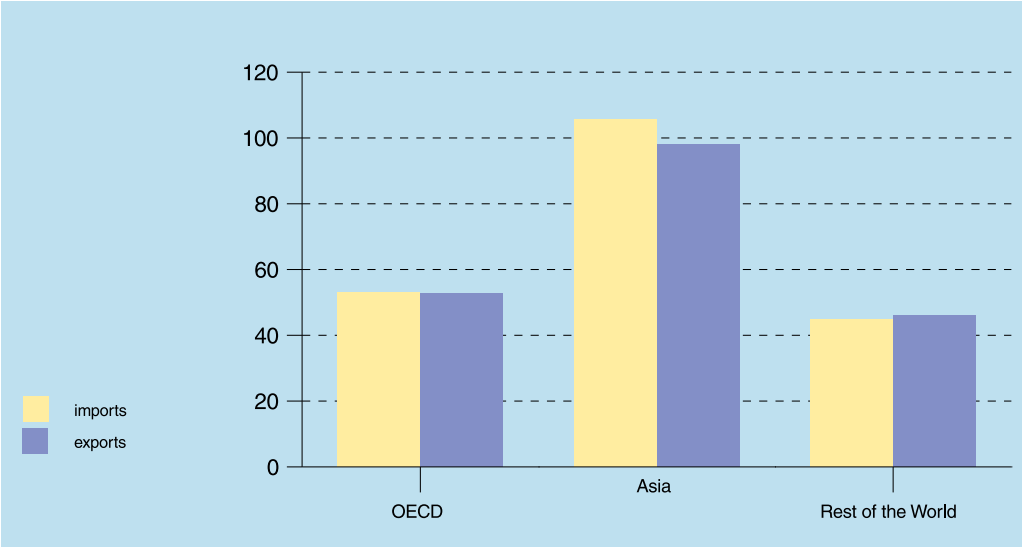
6.3 Specialization and intra-industry trade

The scenario described in the previous chapter assumes intensifying trade relations during the next two decades. As a result of more openness and catching up of emerging countries, trade grows more rapidly than production. Specialization increases and intra-industry trade expands. This section will analyse two factors that determine trade. The first one, the gradual abolishment of tariffs, is the most important cause of increasing trade in the scenario. The second factor, convergence of consumption patterns, curbs the growth in trade because it mainly implies a shift in developing economies towards services, which are traded less than agriculture and manufacturing goods.

6.3.1 Trade liberalization

What is the impact of the gradual elimination of export and import tariffs, or in other words what are the effects of trade liberalization? The direct impact is an increase in trade flows. Foreign goods become less expensive, which stimulates demand for these products. Figure 6.2 shows the cumulated increase in the volume of exports and imports for three aggregated regions in 2020 as a result of trade liberalization. For Asia, the volume doubles and the other two regions see their trade flows grow by about 50%. This reflects the relatively huge import barriers in Asia at the moment, as was described in Chapter 3. The abolishment of these barriers implies a relatively large incentive for imports in Asia.

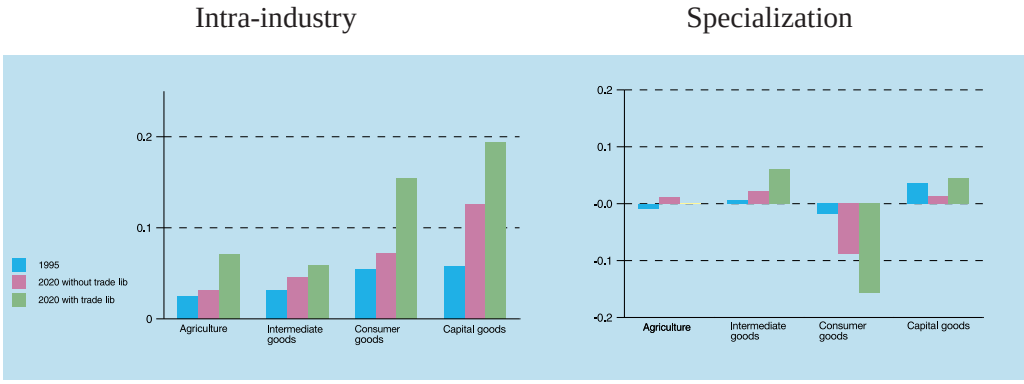
Figure 6.2 The effects on imports and exports of trade liberalization cumulated % change in 2020



For each region, the increase in exports closely matches the increase in imports. This is only partly the result of the abolishment of export and import tariffs abroad. The main reason that imports and exports move closely together in a region is the general equilibrium character of the model. This provokes strong feedback mechanisms. Domestic consumption and investment rates are not significantly affected by the tariffs. Therefore, the current account is relatively independent of tariffs. That means that exports have to increase in order to finance the higher imports, or that income from additional exports is spent on imports. In Asia, where the decline in import prices is relatively large, prices of domestic production decline. This improves competitiveness abroad and stimulates exports. This process continues until domestic resources are again fully utilised. These extra exports as a result of trade liberalization come from all sectors, albeit with a different intensity.

The global decline in prices of foreign products, in combination with the equilibrium mechanism that keeps imports and exports close together, implies that the main impact of trade liberalization is a boost in intra-industry trade. In all sectors both imports and exports will increase. At the same time, trade liberalization has an impact on the specialization pattern, which should be more consistent with the comparative advantages after trade liberalization. Moreover, the specialization pattern may change because import and export tariffs are not uniformly imposed over sectors.

Figure 6.3 *Intra-industry trade and specialization between OECD and non OECD as percentages of the OECD economies in 1995 and in 2020, with and without trade liberalization*



To illustrate the impact of trade liberalization on intra-industry trade and specialization, we analyse the trade relations between the OECD economies and the non-OECD economies, ignoring trade within both economies. Intra-industry trade can be defined for every sector as the minimum of the value of exports and imports. Trade as a result of specialization is indicated, again for every sector, by net exports, *i.e.* the value of exports minus the value of imports. Figure 6.3 shows these two components of trade between the OECD and the non-OECD as shares of the OECD economies.[3]

The left-hand panel in Figure 6.3 shows that trade liberalization is the most important source of increased intra-industry trade between the OECD and the non-OECD. The increase is especially large in the sectors Agriculture and Consumer Goods, reflecting the relatively high initial trade barriers in those sectors. However, not only intra-industry trade, but also specialization patterns become more pronounced as a result of trade liberalization. Without export and import tariffs, net trade flows between OECD and non-OECD areas will represent the comparative advantages between both regions more clearly, especially in manufactured products. The OECD will be a significant net exporter of capital-intensive Intermediate Goods and knowledge-intensive Capital Goods, while net exports from non-OECD regions of low-skilled-intensive Consumer Goods are more pronounced.

[3] The magnitude of these economies is defined as the unweighted average of the value of production and the value of absorption.

Figure 6.4 *Intra-industry trade and specialization between OECD and non OECD as percentages of the non-OECD economies in 1995 and in 2020, with and without trade liberalization*

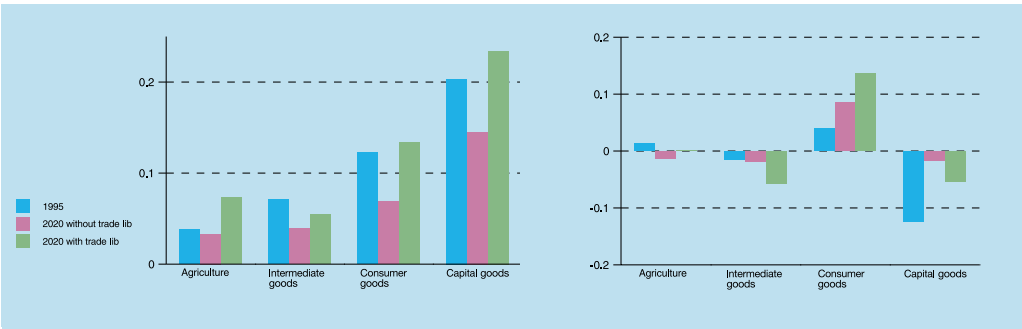


Figure 6.4 shows again intra-industry trade and specialization, but now as shares of the non-OECD economies. This figure is almost the mirror image of the previous one. Exports by the OECD are of course at the same time imports by the non-OECD regions, and vice versa. Only the denominators differ. In 1995 the OECD is about twice as large as the non-OECD area in almost all sectors, while in 2020 this ratio is on average two-thirds. In some sectors, the non-OECD regions even surpass the OECD. As a result of the different denominators, the non-OECD area has larger trade ratios in 1995 than the OECD. During the scenario period, intra-industry trade of the OECD increases significantly as a percentage of their economy. In addition to trade liberalization, the fast growth of the non OECD explains the increased trade intensity of the OECD. For the non OECD, the increase in trade ratios is much less impressive. Without trade liberalization, intra-industry trade with the OECD would even decline as a percentage of the non-OECD's economy during the next decades.

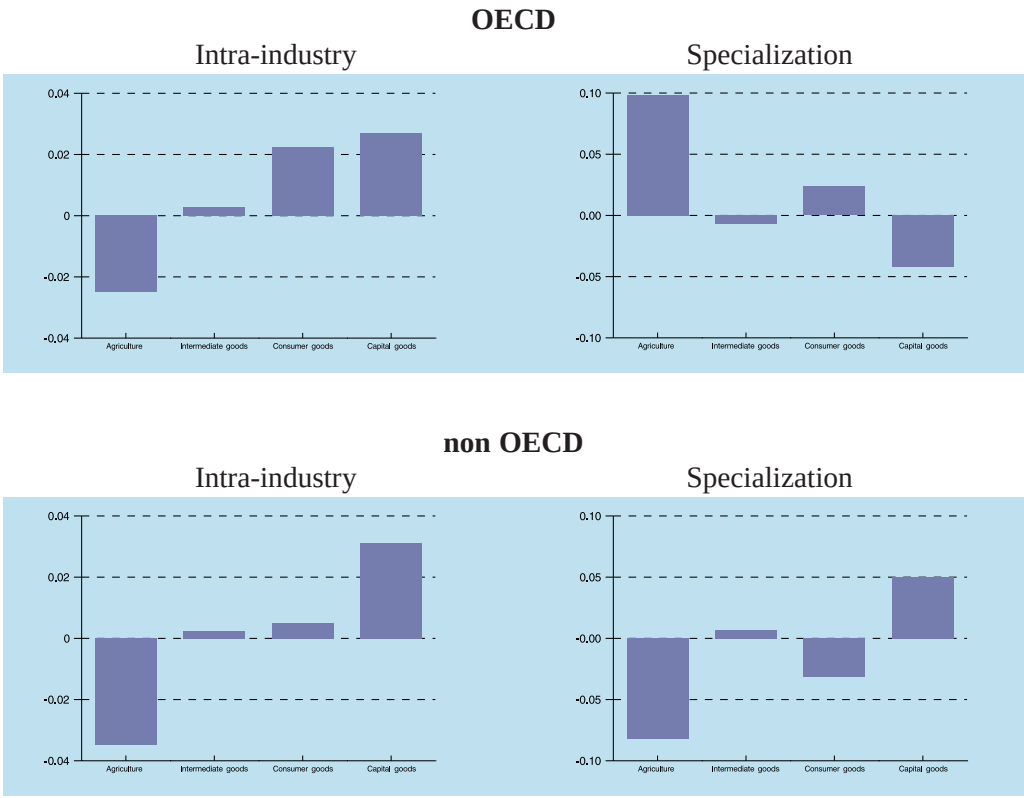
6.3.2 Convergence of consumption patterns

In the baseline scenario, which was described in the previous chapter, less developed economies experience high growth rates, which leads to a rapid increase in per capita incomes. As a result, consumption patterns in those regions converge towards the patterns we observe in more developed regions. Gradually, a larger proportion of income is spent on services and a smaller part on agricultural products, while demand for manufactured products also shows some fluctuation, albeit less pronounced. What

are the consequences of these demand shifts for trade flows? Or, to put that question in a different way: what would trade flows look like in a scenario with constant consumption patterns, but the other ingredients the same as in the baseline scenario? To answer that question, we have run a simulation in which consumption patterns remain fixed over time. We compare the outcome with the scenario described in the previous chapter.

Just as in the simulation of trade liberalization above, we first show the impact on intra-industry trade and specialization between the OECD and non-OECD regions. Figure 6.5 is based on the same concepts as Figure 6.3, but now the intra-industry trade ratio and the net export ratio are given only for 2020 and as deviations from the baseline. It shows the impact of constant consumption patterns.

Figure 6.5 *The impact on trade of fixing consumption patterns cumulated impact in 2020 on trade ratios in deviation from the baseline scenario (%-points)*



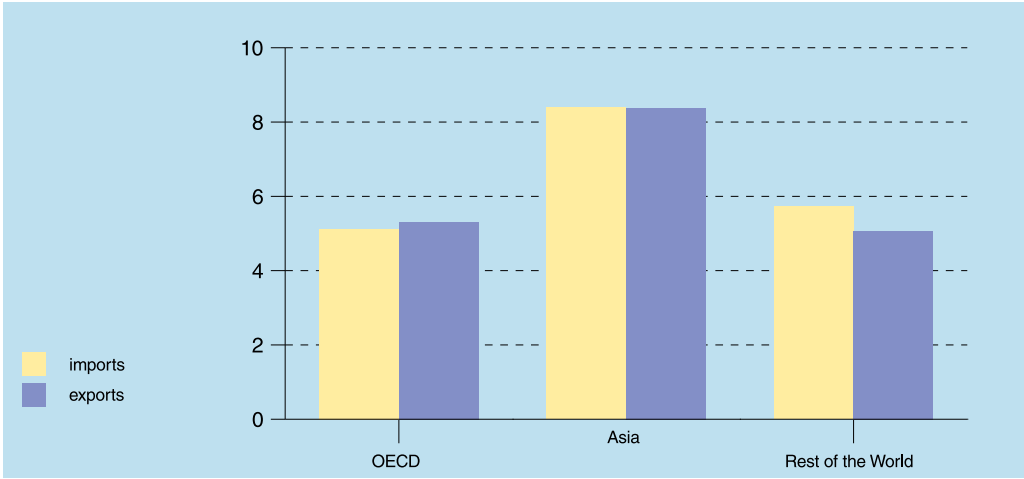
The first important consequence is that demand in the non-OECD area for agricultural products increases compared to the baseline. Technological development in agricultural sectors is the same in both simulations. Higher demand thus results in both more domestic resources devoted to agricultural production and more imports of agricultural products. The effect is a sharp increase in net agricultural exports from the OECD to the non-OECD area. Because of the deterioration of export possibilities for the non-OECD regions, intra-industry trade in agricultural products declines.

The increased demand for agricultural products drains away resources from other sectors, especially from Consumer Goods, because that sector is also low-skilled labour-intensive. The declining capacity to produce Consumer Goods is apparent in the international trade pattern. The net exports of Consumer Goods by the non-OECD area decline. Net imports of Capital Goods by the non-OECD area also decline. Figure 6.5 shows this as a positive change on net exports. There are at least two reasons for this decline in net imports of Capital Goods. First, investment demand decreases as a result of the shift away from capital-intensive sectors. Second, the surge in imports of agricultural products and the drop in net exports of Consumer Goods diminishes the potential to import Capital Goods.

Compared to the baseline, overall trade increases for all sectors, as is shown in Figure 6.6. The reason is the shift from the sheltered service sector towards more exposed sectors. Even if in each sector the trade intensity remains the same, this sectoral shift would imply an increase in the macro trade intensity.

Apart from the impact on trade flows, the sectoral shift provokes many domestic dynamics. Increased demand for agricultural products, for example, leads to a rise in their relative price. One of the consequences is an increase in income in the informal sector, leading to a smaller inflow of employment in the formal sector. This is one of the reasons why per capita income declines compared to the baseline. However, we will not elaborate on this issue because comparison of such declines is not allowed since the utility function differs in both simulations.

Figure 6.6 *Cumulated changes in volume of imports and exports as a result of fixed consumption patterns in non OECD*



6.4 Sensitivity analysis

This section explores how sensitive WorldScan's results are to the so-called Armington elasticities in the trade relations. WorldScan contains rather high long-run price elasticities of demand for foreign goods. To assess the impact of these high elasticities, we calibrate the model again with long-run elasticities that are half as large as the original ones. With the alternative model we construct a baseline scenario similar to the one described in Chapter 5. After that, we run the trade liberalization simulation from the previous section. By comparing both simulations we will analyse how the impact of trade liberalization depends on the chosen Armington elasticities.

Many econometric studies have reported price elasticities in trade flows of around -2 (see *e.g.* Goldstein and Khan (1985) for an overview). At CPB this elasticity is referred to as the 'Tinbergen two', because Tinbergen used that number in the first models he built at CPB. Also Harberger (1957) noted that the consensus export-price elasticity was near or above -2. In a general equilibrium model of the Dutch economy, this elasticity is close to two (see Nieuwenhuis and Boone (1998)).

Modern trade theories, however, based on Dixit and Stiglitz' love of variety utility function, have an infinite long-run price elasticity. Economies may grow by producing new varieties of a product, which they can sell abroad without any loss in terms of trade, because the supply of varieties creates its own demand. The infinite long-run price elasticity also corresponds to the footloose character of many industrial activities nowadays. This means that demand for goods does not depend on the country

of origin, contrary to what Armington assumed by suggesting finite elasticities.

It is obvious that the choice of price elasticities in demand for foreign goods is crucial in long-term scenario analysis and policy simulations. In case of relatively small price elasticities, emerging countries can grow only relatively fast, at the cost of large terms-of-trade losses. Small elasticities also give governments the opportunity to generate terms-of-trade gains by imposing import tariffs. To avoid these consequences of low price elasticities, WorldScan assumes much larger long-run elasticities than most econometric models do. In WorldScan, the elasticities vary between -5 and -17, depending on the sector. Because we do not provide a thorough empirical justification for this choice, a sensitivity analysis is appropriate.

6.4.1 A new baseline

In the calibration of WorldScan, the so-called preference parameters in the demand for foreign goods will change if the Armington long-run price elasticities are changed. These preference parameters indicate the preferred demand for goods from different countries of origin in case all prices are equal. In other words, the market shares are equal to the preference parameters if all prices are equal. In the presence of import tariffs and transport costs, the price of foreign goods exceeds the price of domestic goods. Actual market shares of foreign producers can then be explained by allowing the preference parameters to differ from the observed market shares. This difference is larger if the price elasticity is high. In that case the parameters will show less home bias in the demand function, because a large market share of domestic producers on the domestic market can already be explained by relatively low domestic prices. That means that in the new baseline not only are price elasticities lower, but also the home bias in demand is larger.

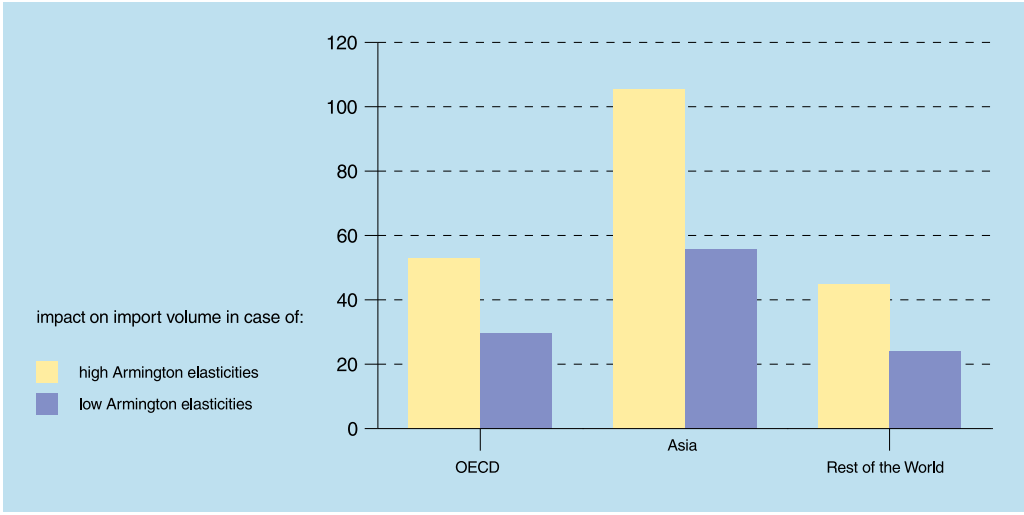
The main difference between the new and the old baseline is the development of the terms of trade. In the new baseline, the drop in export prices of fast-growing economies is sharper than in the old baseline. The emerging economies in Asia now have to lower their prices more to create enough export possibilities in 2020. This leads to an additional 6% decline in the ratio between Asian export prices and Asian import prices. As a percentage of Asia's national income, this is an additional terms-of-trade loss of 2½%. The mirror image of that loss is a terms-of-trade gain by OECD economies. Because their economy is much larger, that gain is only ½% of the OECD's national income.

The relative prices within Asia also change. Capital Goods, which are imported to a large extent, become expensive in terms of domestic output. As a result, capital accumulation in Asia slows down. The worsening of the terms-of-trade can be seen as a productivity slowdown in the formal sector. Consequently, the inflow of labour into the formal sector is slightly below the level in the original baseline.

6.4.2 *Trade liberalization*

As was described in section 6.3, the direct impact of lower trade barriers is an increase in the volume of trade. In the alternative model with lower price elasticities, this increase is smaller than in the original version. Figure 6.7 shows the cumulated impact on the volume of imports in the two model versions. It appears that when long-run elasticities are twice as large, the impact on trade volumes is also twice as large. Note that in section 6.3 we have seen that exports and imports of a region remain within a narrow range of each other.

Figure 6.7 *Cumulated changes in the volume of trade due to trade liberalization with different Armington elasticities*



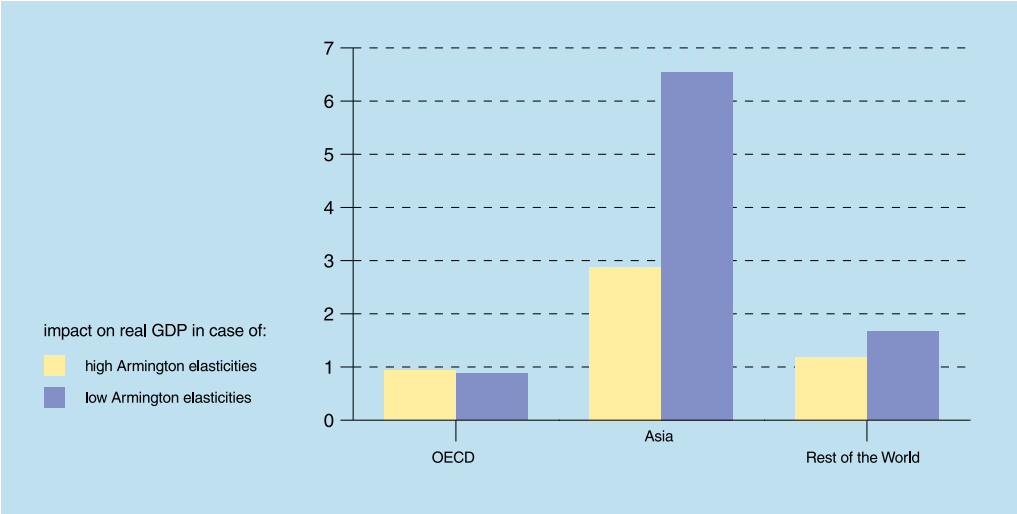
More surprising is to see how price elasticities influence the income effect of trade liberalization. In case of high price elasticities and large impacts on trade flows, Figure 6.8 shows that the positive income effect of lower trade barriers is relatively small. Intuitively, this is not immediately obvious. At first glance, one would expect the opposite result: small income effects in case of low price elasticities, for two reasons.

First, positive income effects originate from a more efficient allocation of endowments over sectors. If the sectoral shift is only marginal, the reallocation has a negligible impact, since the marginal yield of endowments does not differ between sectors. Only in case of considerable shifts may the income effect become substantial. One would therefore expect that the income effect is larger when the trade effect is larger.

Second, import tariffs may lead to a terms-of-trade gain. That gain is negatively

related to the price elasticity. In case of low price elasticities, *i.e.* products are poor substitutes, tariffs may enforce considerable shifts in relative prices, and thus considerable terms-of-trade gains. This means that the abolishment of tariffs leads to relatively large terms-of-trade losses in case of low price elasticities. Because of this negative income effect, one would expect the net positive effect to be relatively small if price elasticities are low.

Figure 6.8 *Cumulated effects on real GDP induced by trade liberalization with different Armington elasticities*



Why do we find the opposite result? Why is the income effect small in case of high Armington elasticities? The reason is related to the impact that intra-industry trade has on utility. The previous section has shown that especially intra-industry trade increases if trade barriers are eliminated. If goods produced in different countries can be easily substituted, intra-industry trade hardly affects utility in the standard Armington specification. Box 6.1 elaborates on this mechanism.

This sensitivity analysis shows that the choice of long-run price elasticities is crucial in the analysis of trade policies. Since it is very uncertain what the true long-run elasticities are, one may find this a weakness of the scenario approach. However, with even more force one may defend the stance that this example shows the relevance of scenario analysis. Only formal analysis may help to uncover the elements most crucial for the outcome. Especially with scenario analysis one can think through alternative assumptions. This seems to be a more attractive approach than relying on specific estimates of long-run elasticities.

Box 6.1 Armington elasticities and income effects of tariffs

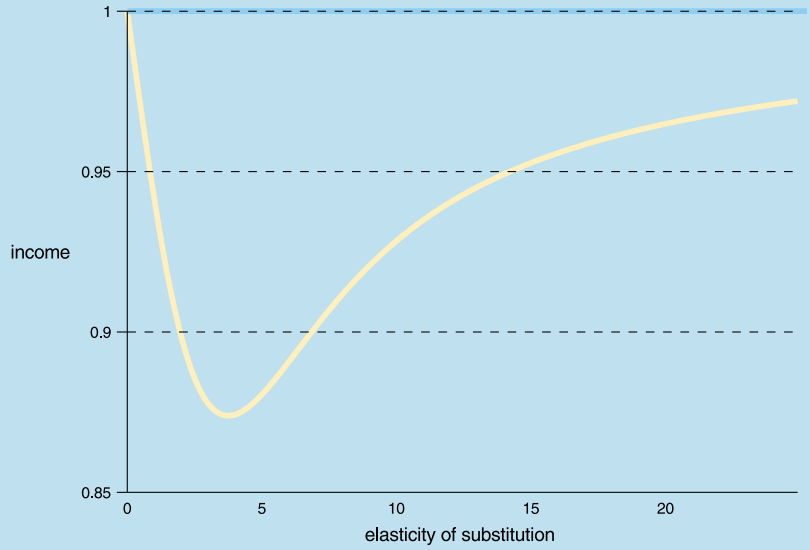
The sensitivity analysis with WorldScan shows that the impact of tariffs on income is smaller in case of higher trade elasticities, while the impact on trade flows is larger. The reason is that high price elasticities imply that foreign and domestic products are good substitutes. Substitution of foreign products by domestic counterparts does not change utility dramatically if these products can be easily substituted. So, even if substitution is large, and subsequently the effect on trade is large, then the impact on real income measured as utility is modest.

To illustrate this point, let us assume a world with two identical countries. Both countries own an endowment normalized at one. The endowments can be traded. Both countries have the same CES utility function from which demand for the two endowments is derived. There is no home bias, so that if the two endowments have the same price, each country wants to consume half of its own endowment and half of the foreign endowment. Total utility is then one in both countries, irrespective of the elasticity of substitution.

Assume that both countries impose the same import tariff. Because the domestic endowment becomes relatively cheap, each country will consume more than half of its own endowment. The own consumption share is then positively related to the elasticity of substitution, which also influences total utility. The figure below shows the relation between the elasticity and total utility in the presence of a common import tariff.

If the elasticity approaches infinity, and products become perfect substitutes, then the income effect of tariffs will disappear and utility will approach one — the same as without tariffs. On the other hand, if the elasticity is zero, and thus the goods are completely complementary, then the income effect of tariffs is also zero.

The change in relative prices caused by the tariffs has no effect on the amounts consumed and therefore has no effect on trade flows. If the elasticity of substitution becomes positive, then tariffs affect trade flows. This effect is positively related to the elasticity, and the trade effect has a negative impact on utility. If the elasticity is still relatively small, this negative impact is positively related to the elasticity of substitution. After a certain value of the elasticity, the income effect becomes smaller again — and disappears completely if the elasticity approaches infinity.



The elasticities in WorldScan exceed the value at which the income effect reaches its maximum, since in WorldScan a larger trade effect coincides with a smaller income effect.

7 Extensions and applications

WorldScan is an applied general equilibrium model of the world economy. It focusses on long-term growth and trade between developed and developing regions. The characteristics of the model and its properties have been described in chapters 2 and 3. Chapters 5 and 6 have presented and highlighted the main mechanisms using various simulations. Thus far, we have ignored extensions of the model and applications. This chapter will compensate for this to some extent by discussing some of the extensions and applications. Section 7.1 outlines some modified model versions with simplifications or extensions. Section 7.2 describes the role of labour reallocation in economic growth in developing regions and the spill-overs to the OECD regions. Section 7.3 discusses the impact of climate change policies as agreed upon in the Kyoto protocol. Section 7.4 gives a short overview of other applications that have recently been carried out or that will be carried out in the near future. Finally, we will summarise the previous chapters.

7.1 Extensions

The version of the model presented thus far is the basic version of the model. New research questions may call for other versions of the model with modified economic mechanisms, other sectoral structures or another regional classification. In principle, the basic version of the model is the starting point for each project. Depending on the requirements of the project, the model can be modified.

One of the simplest modifications possible is another sectoral or regional structure. We often reduce the number of regions. A three-region model containing the OECD, Asia and the Rest of the World is convenient to analyse the global impact of the rise of the Asian economies. A four-region model with Western Europe, the Rest of the OECD, the transition countries and the Rest of the World (in terms of the Kyoto protocol: the Non-Annex 1) is useful for the analysis of climate change policies. The current sectoral structure is too rough for the study of strategies targeting CO_2 reductions. For this purpose, the sector Raw Materials is split up in Oil, Natural Gas and Coal and Other Raw

Materials. Electricity Non-fossil Fuels are taken apart from the services sector. The model version for environmental studies thus contains eleven sectors. Electricity is used by consumers and firms, whereas the other energy sectors are only used for intermediary demand. The production structure is also adjusted for this sectoral classification. The nest of intermediary goods is divided into two nests: one for Electricity, Oil, Natural Gas, Coal and Other Raw Materials, and a second nest for other intermediary goods. This split enables more substitution between the energy carriers. The elasticity of substitution between these inputs is set at two.

A modified production structure may also be necessary. Recently, we developed a putty-clay vintage production structure for environmental applications. There are two vintages: one new and one old. The introduction of new environmental technologies affects only new investments. Old vintages are left unaffected. Input intensities of a vintage remain constant once the vintage is installed.

In globalization scenarios it is often implicitly assumed that outward-looking policies in developing regions foster the dissemination of new technologies from OECD regions. A new research project aims to endogenise this relation in WorldScan. This research will be linked to the literature on the spill-overs of new technologies to other countries. Coe, Helpman and Hofmeister (1997) relate the benefits of technologies developed abroad to the openness of countries. The level of technology depends on the amount of trade with other countries and the level of their technologies. We will incorporate such a mechanism in WorldScan. Trade and trade policies will thus affect the level of technology and thereby influence economic growth, particularly in developing regions and transition countries. This can be called endogenous catching up, because higher technology levels induced by trade facilitate economic growth in developing countries. We will incorporate this mechanism in WorldScan at a sectoral level, such that new sector-specific technologies in a certain region will produce spill-over effects in the same sectors in other regions.

7.2 Labour reallocation in developing regions

WorldScan is often used to analyse the effects of developments in the non-OECD regions on the OECD regions. Our collaborative study with the OECD (1997a) is an example of that. More recently, Lejour and Tang (1999) have analysed sectoral restructuring in developing regions, with a focus on the informal sector.

The informal sector in developing regions can be an important source of growth in developing regions. Labour reallocation from low to high-productivity sectors results in a productivity gain and an expansion of low-skilled labour-intensive goods in these regions. Section 2.4 discusses the concept of the informal sector and quantifies its size.

Lejour and Tang (1999) analyse the economic effects of the informal sector within WorldScan. Two simulations highlight the effects of declining informal sectors. The first one holds constant the allocation of workers across low- and high-productivity sectors. The second simulation is similar to the Globalization scenario in Chapter 5 and thus assumes an outflow from low- to high-productivity sectors. Comparison of the two simulations reveals the effects of labour reallocation. Here, we first describe the impact on economic growth. Then, we discuss production and trade patterns and relative wages.

Labour reallocation enhances economic growth. An important part of this mechanism can be explained by a growth-accounting exercise such as the one performed in Figure 5.1. This covers, however, only the direct effects of labour reallocation. There is also an indirect effect of labour reallocation on growth, as part of the additional income is saved and invested again, which causes future production and income to rise again. The total growth effect of labour reallocation follows from a comparison of annual growth rates in a simulation with and without labour reallocation. This is done in Figure 7.1.

Figure 7.1 *The growth effect of labour reallocation in Asia simulations with and without labour reallocation annual GDP growth 1996-2020*

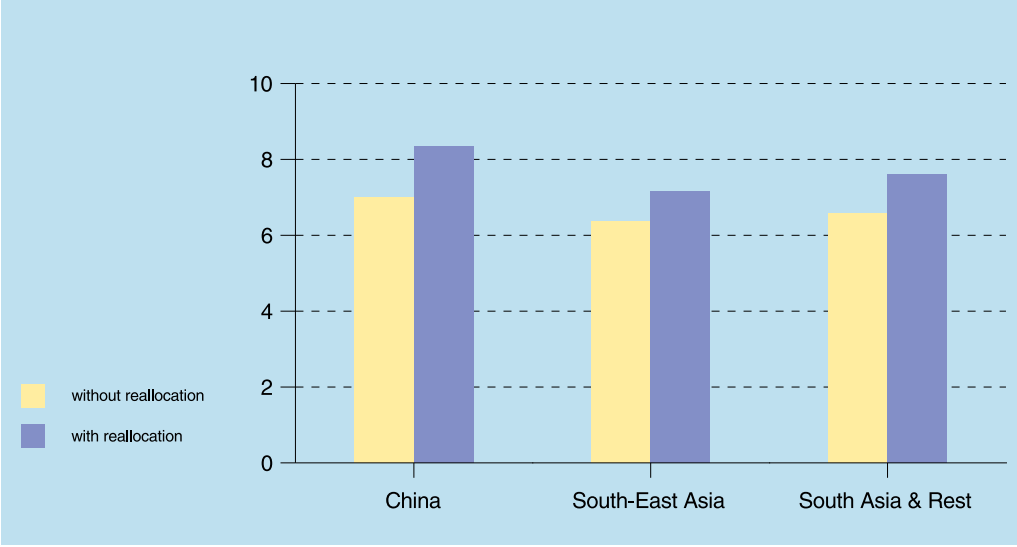


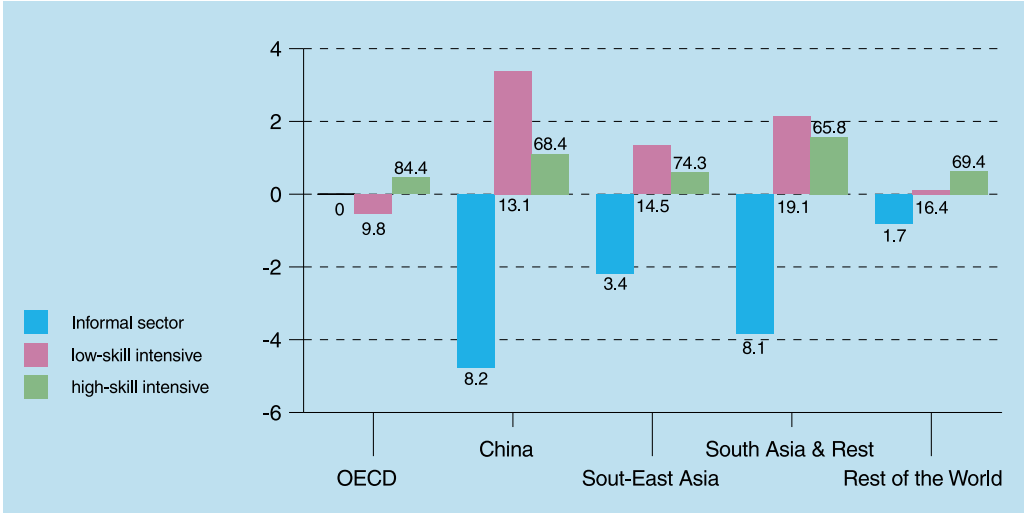
Figure 7.1 indicates that labour reallocation contributes to economic growth in both South-East Asia and South Asia & Rest for about 1 percentage point per year. In the case of China, the contribution is nearly 1.5 percentage points. When we combine the

information from Figures 7.1 and 5.1, we are able to conclude that the contribution of capital accumulation to growth is about 0.5 percentage points per year. This result reflects the observation that the share of capital costs in production is approximately 40%; see Figure 3.6.

The finding that direct labour reallocation leads on average to 1 percentage point extra growth, corresponds with other estimates. The Worldbank (1996) claims that reallocation from the agricultural sector to the more productive (manufacturing) sectors raised economic growth in China annually by about 1%, between 1978 and 1994. Approximately 20% of the total labour force was reallocated during this period. This is comparable, on average, to the labour reallocation that we assume in our simulations. These WorldScan simulations indicate that labour reallocation has been and will be an important source of growth.

The informal sector can be viewed as a large pool of reserve labour. The inflow into the high-productivity sectors exerts a downward pressure on wages and production costs. For that reason, we expect labour reallocation not only to improve the production opportunities, but also to further specialization in especially low-skilled labour-intensive goods.

Figure 7.2 *Production patterns in various regions*
simulations with and without labour reallocation. Differences of value-added shares in 2020(%). Numbers near the columns refers to value-added shares in 2020 in the simulation without labour reallocation.



The relative value-added of the informal sector is lower than in 1995, even if labour reallocation is not taken into account (compare Table 2.1). This is the result of increasing productivity differences between low- and high-productivity sectors over time.

Figure 7.2 presents the value-added shares of three aggregated sectors in various regions. These aggregated sectors are informal, formal and low-skilled labour intensive and formal and high-skilled labour intensive. Agriculture and Consumer Goods make relatively intensive use of low-skilled labour. Capital, International Transport, and Services are high-skilled labour intensive. In the first simulation labour reallocation does not take place, whereas in the second it does. Figure 7.2 shows the different production patterns in the two simulations.

From the value-added shares in the simulation without reallocation, it is clear that the Asian regions specialise in the production of low-skilled labour-intensive goods, while the OECD specialises in production of high-skilled labour-intensive goods. Labour reallocation intensifies this specialization pattern. Note that the decline of the informal sectors raises the share of the other two sectors. However, the increase in the share of low-skilled labour-intensive goods is larger than the increase in share of high-skilled labour-intensive goods. The results of the simulation neatly fit the traditional Heckscher-Ohlin analysis.

Labour reallocation lowers employment in the low-productivity sector and exerts a downward pressure on low-skilled wages in the high-productivity sectors. Figure 7.3 presents the effects on wages for the Asian regions. The other regions are less interesting because reallocation is not as important for them as it is in Asia.

Figure 7.3 *Wages and employment in Asia simulations with and without labour reallocation in 2020 (%)*

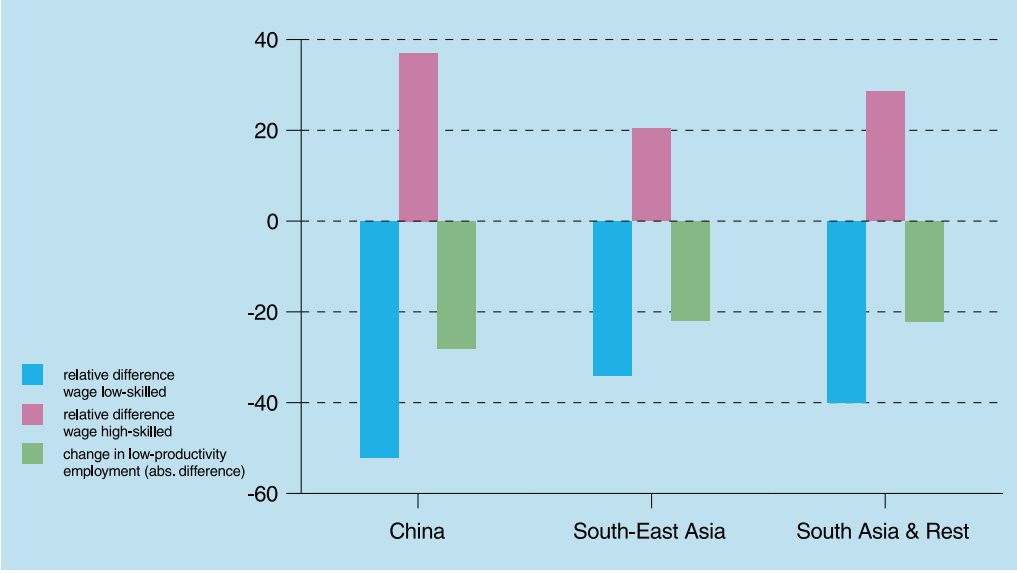


Figure 7.3 shows that the reduction in low-productivity employment by about 20 percentage points lowers the wages of low-skilled workers in the formal sector by about 35 to 40 percentage points in South-East Asia and South Asia & Rest. The extra inflow in the formal sectors makes the high-skilled workers more productive. As a result, their wages go up. The outflow is higher in China due to a higher GDP growth per capita. Consequently, the effects on wages in the formal sectors are larger.

Lejour and Tang (1999) show the macroeconomic effects of labour reallocation from the low- to the high-productivity sectors. A reallocation of approximately 20% of the total labour force in 25 years time implies a boost of economic growth by a percentage point per annum in developing regions. It also exerts a downward pressure on wages, especially those of low-skilled workers. Developing regions specialise more in labour-intensive sectors that are skill-extensive. The effects on the OECD, on the other hand, are very modest. Nevertheless, since developing regions specialise in low-skilled labour-intensive goods, the OECD further specialises in the production of high-skilled labour-intensive goods.

7.3 The Kyoto Protocol

WorldScan has been and will be applied to analyse policy options for the implementation of the Kyoto Protocol on Climate Change. The main feature of the Protocol is that the "Annex-1 Parties" accepted quantified emissions limitations of greenhouse gases. The group of Annex-1 countries consists of the OECD, Eastern Europe and the countries of the Former Soviet Union. On average, the agreement would result in emissions of greenhouse gases from Annex-1 countries in 2008-2012 being about 5% below their 1990 level. However, the obligations differ by country.

There are three mechanisms for transferring the emissions internationally under the protocol: Joint Implementation (JI), International Emission Trading (IET) and Clean Development Mechanism (CDM) . The first two instruments can reduce the total costs of emission reductions within the Annex-1 region because they create the option to realise reductions in those countries in which marginal abatement costs are lowest. From an Annex-1 perspective, the third instrument can be seen as an extension of this flexibility to the global level. Since costs of emission reduction are relatively low outside the Annex-1 area, this global flexibility should further reduce costs for Annex-1 Parties.

Bollen *et al.* (1999) analyse a number of policy cases. Table 7.1 gives an overview of them. On one side of the spectrum is the No Trading case (NTR). Without permit trading, all reductions have to be realised on a domestic scale. On the other side is the Annex-1 Trading case (A1T) . This case is the most flexible and efficient, which ensures uniform marginal abatement costs throughout the Annex-1 group. Cases with

ceilings on trade lie between these two extremes. Both uniform import (Mx) and export restrictions (Xx) are considered with more or less stringent ceilings. Each region is allowed to import or export permits as long as it does not exceed a certain percentage of its assigned target. For the Annex-1 group as a whole, relaxation of restrictions is just a gradual movement from the No Trading case to the Annex-1 Trading case. For individual countries, however, further relaxation may constitute a qualitative difference between binding and non-binding restrictions.

Table 7.1 Policy cases in the Kyoto protocol

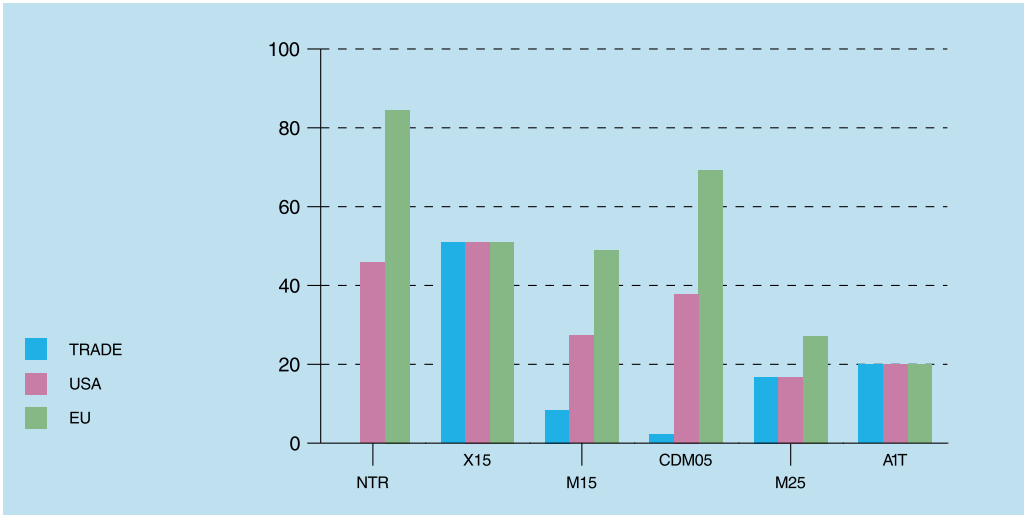
Case	*Abbreviation*	*Description*
No Trading	*NTR*	Each Annex-1 region needs to realize its own target.
Annex 1 Trading	*A1T*	The Annex-1 group as a whole needs to remain within the Kyoto quotas. Unrestricted permit trade leads to transfers of quotas. One global emission price evolves.
Restricted Import	*Mx*	Import constraints on the A1T case, *i.e.* each region may import permits up to x% of its quota.
Restricted Export	*Xx*	Export constraints on the A1T case, *i.e.* each region may import permits up to x% of its quota.
Clean Development Mechanism	*CDM05*	95% of the Kyoto targets need to be realized locally within the Annex-1 regions. Among Annex-1 countries no trade is allowed. On top of that, there are investment subsidies from Annex-1 to non-Annex-1 regions to reduce emissions.

Finally, Bollen *et al.* investigate the potential effects of the CDM. According to the Protocol, Annex-1 countries are allowed to invest in non-Annex-1 countries in order to reduce emissions in those countries. The certified reductions can be added to the domestic targets of Annex-1 countries. This flexibility mechanism extends permit trading beyond the Annex-1 regions. The CDM case leads to unilateral actions for all Annex-1 countries, and therefore to different regional marginal costs. It will, however, lead to a uniform carbon price level in non-Annex-1. The CDM case that is considered in Bollen *et al.* assumes trade between Annex-1 and non-Annex-1 regions to a maximum of 5% of the amounts assigned to the Annex-1 regions. No trade is allowed within Annex-1.

We now turn to the main results of the simulation of these cases. Macroeconomic and sectoral changes are not explicitly shown, but they do determine the distribution of emissions and the level of carbon prices. Figure 7.4 presents the unilateral marginal costs of reduction for the USA and the EU and, in those cases where trade is allowed, the traded carbon price. Figure 7.5 shows the change in emissions compared to the

baseline in different regions. A comparison between the NTR case and the A1T case reveals the efficiency of permit trading. The uniform carbon price equals 20 US$/tC, which is much lower than the unilateral price under no trading (82 US$/tC and 44 US$/tC for the EU and the USA, respectively). The A1T case leads to increased burden sharing through the side payments. See Gielen and Koopmans (1998), and Gielen and Bollen (1997) for a discussion of these topics.

Figure 7.4 Carbon prices in all cases, in 1995 US $/tC in 2010

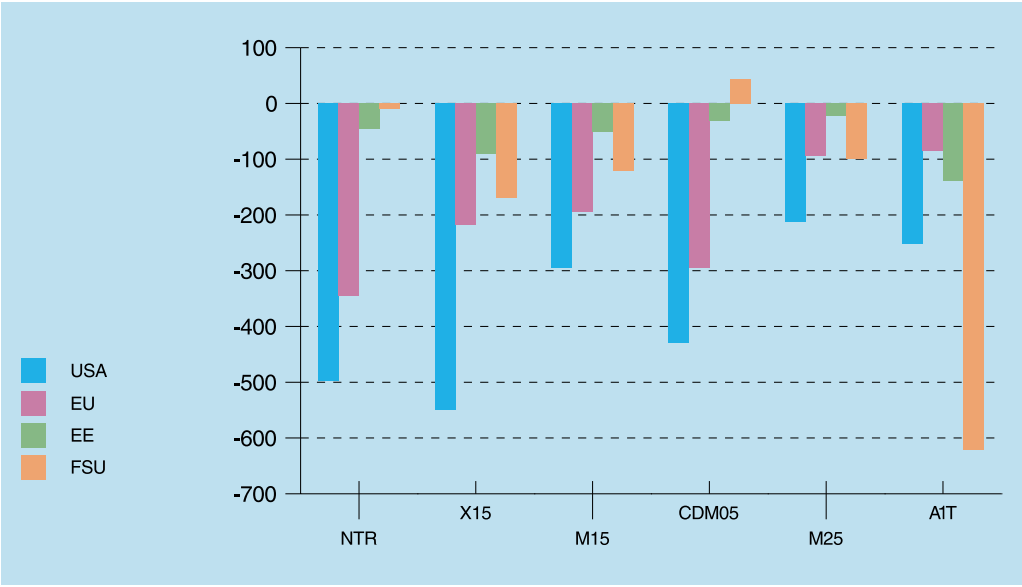


Restricted trade constrains exports and imports of permits. The X15 case assumes that exports are restricted to 15% of the emission target. This reduces overall trade in permits to 71% of the trade in the A1T case. The supply-side restriction is binding for all exporting regions. The demand for traded emission permits will decrease because the permit price increases. This price will rise until it is equal to the marginal abatement costs in the importing countries. Importers will compete for permits and Eastern Europe and the Former Soviet Union will acquire market power as permit suppliers. Because of higher prices, they will experience a terms of trade gain, but they will export less in value terms, a 28% reduction compared to the A1T case. Countries that are importers both in the A1T and in the X15 case (the Rest of the OECD, Japan and the European Union) will experience a loss. Their marginal costs will more than double (see Figure 7.4), and they will have to make greater domestic efforts to reduce emissions (see Figure 7.5). The United States has relatively low abatement costs and has become a non-rationed exporter of emission

permits. The reason is that their permits can be sold at a higher price on the international market. Because of these exports, their domestic reduction efforts will increase.

Now we turn to the import restriction cases M15 and M25. The restrictions apply mainly to the OECD regions because they are importers in the A1T case. Their relative market power increases because the suppliers are not constrained and remain fully competitive. As stated before, regional marginal costs of the constrained players will differ, and the carbon price of the imported permits will equal the marginal costs of the unconstrained exporters. This is illustrated in Figure 7.4, in which the M15 and M25 trade prices are significantly lower than the trade prices in the A1T case.

Figure 7.5 Change in emissions compared to baseline in 2010 (MtC)



Because most OECD importers are constrained, they increase their own efforts to reduce domestic emissions (see Figure 7.5). The United States is an exception in the M25 case. The import restriction is not binding for them and their domestic reduction effort declines. The United States increases its imports because the price of traded permits declines. This allows the country a smaller domestic reduction effort. This case shows that a restriction can be beneficial for the United States. Restrictions will always harm the European Union, because it will increase its domestic marginal costs drastically. The increasing costs outweigh the advantage of lower prices of

imported permits. The exporting countries will suffer from the import restrictions. They will export less at a lower price and thus incur a terms-of-trade loss.

Summarising, import restrictions will have different impacts on importing countries. They turn out to be relatively beneficial for the United States and harmful for the European Union. The exporters Eastern Europe and the Former Soviet Union will suffer due to terms-of-trade losses.

Finally, CDM has been analysed assuming that there is no trade within the Annex-1 region. Looking at Figure 7.4, we see that the CDM projects offer opportunities to earn certified reductions that increase domestic emission allowances. Because the marginal abatement costs are lower outside the Annex-1, this leads to a situation in which even Eastern Europe and the Former Soviet Union import permits. Carbon prices in the NTR case are higher than in the CDM case. This is due to the realization of targets through CDM investments outside the Annex-1 countries. Prices decline for all regions because domestic targets are less stringent.

Figure 7.6 Emissions in 2010 compared to NTR — selected regions

Figure 7.6 presents the carbon emissions in CDM compared to NTR. With CDM, global emissions increase relative to no trading. This phenomenon, the shift of energy-

intensive production from Europe to other regions with less stringent environmental policies, is called carbon leakage. In the CDM case, the nature of this leakage is rather different than in the other cases, in which it is fuelled by a lower global demand for energy and higher prices of energy-intensive products in the Annex-1 region. The use of efficient instruments, such as unrestricted trade, reduces carbon leakage because it reduces the price of energy-intensive products in Annex-1 regions. However, in the CDM case the price of energy-intensive products is lowered as well because the Annex-1 regions impose lower carbon taxes. The leakage in this case should therefore have another reason. The reason is the existence of local energy markets. CDM causes energy demand to increase in the Annex-1 region and to decrease outside it. The decreases occur mainly in China, which hosts the bulk of the CDM projects. Emission reduction in China is therefore substantial. However, the input factors allocated to the Chinese energy supply sector will not easily move towards other sectors. This results in downward pressure on local energy prices. Transport costs and other impediments to trade prevent energy prices from equalising across borders. As a result, China and other hosting countries will experience lower energy prices, even if global energy use increases, or if energy-intensive sectors in those countries increase their energy demand.

7.4 Overview of other applications

WorldScan emphasises the linkages between OECD and non-OECD regions. For this reason it is a useful tool to analyse such issues as the rise of Asia (see Van de Klundert *et al.*, 1996) and the consequences of globalization. In a collaborative study with the OECD (OECD, 1997a) we constructed a so-called High Growth scenario, in which the linkages between developed and developing regions become much stronger. These linkages are intense in order to study the spillovers on the industrial countries of high economic growth in developing regions like Brazil, the Former Soviet Union, China, Indonesia and India. High economic growth affects the demand for energy, and is therefore a major explanation for the levels of CO_2 emissions. Moreover, growth induces shifts in sectoral production patterns, which affects the position of workers in different ways, depending on their skills.[1] Tang (1999) analyses this issue using simulation results of WorldScan. He concludes that the position of low-skilled workers is affected in only a marginal way, even when the intensified linkages and high growth rates in the non-OECD regions are taken into account.

[1] The effects of trade on the position of low-skilled workers in the OECD is heavily debated, see among others Lawrence (1996) and Wood (1994).

Box 7.1 Overview of WorldScan applications

Bollen, J.C. and A.M. Gielen (1998), Economic Impacts of Multilateral Emission Reduction Policies, in Carraro (1998).

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Van de Klundert, T., B. Geurts, and H.R. Timmer (1996), The European economy in an expanding world, *De Economist 144,* p. 165-193.

Van de Klundert, T. and R. Nahuis (1998), Economic development and trade in the world economy, *Economic Modelling,* 15, pp 287-305.

Another application is the analysis of international aspects of ageing. Here, WorldScan will be brought into action within an international project initiated by the Brookings Institute. This Institute has brought together a group of economists from universities and international and national organisations. The aim is a study of the global consequences of ageing. Our contribution to this project will be an analysis of the interaction between ageing and schooling. We will explore trends in schooling levels of the labour force, especially in the context of demographic changes. Schooling policies will also be analysed as instruments that raise future productivity. Financial burdens caused by ageing may be alleviated by higher productivity levels that can be expected to result from education. The analysis will be supported by WorldScan simulations. For this purpose, the description of the schooling *vs.* productivity relation in WorldScan will be modified. This extension is scheduled for the second half of 1999 and 2000.

Recently, we constructed four scenarios for a project that will be performed in collaboration with the Institute for Environmental Studies (IVM) at the Free University of Amsterdam and with the Netherlands Research School for Transport, Infrastructure and Logistics (TRAIL). These scenarios will be part of a project that is focussed on the effects that globalization and international transport have on the global environment.[2] The scenarios contain varying degrees of globalization, technological progress, energy-saving technologies and environmental targets. WorldScan provides economic content to the scenarios, and delivers forecasts of energy demand and emissions between 1995 and 2050. The scenario outcomes indicate that the emission level will quadruple when economic growth is high and when no attempts are made to create energy-efficient technologies or to impose environmental legislation. However, global emissions hardly increase in a ecological scenario that combines energy-efficient technologies, environmental legislation and a modest economic growth. The results will be used to construct transport scenarios, which quantify the amount of CO_2 emitted by international transport.

The recent interest in the reduction of greenhouse gas emissions through the implementation of environmental taxes has lead to quite a few projects in which we analyse the economic effects of such taxes. Tang *et al.* (1998) investigate the consequences of unilateral taxes by the EU. They explore the effects of alternative tax schemes on the competitiveness of EU economies, their sectoral structures and their macro-economic performance. They also investigate the carbon-leakage problem. Tang *et al.* (1998) show that import tariffs and export subsidies can be used to restore competitiveness and to alleviate the problems of carbon leakage.

The endogenous catching-up mechanism described earlier makes it possible to analyse the spillovers of more energy-efficient technologies. If barriers are put up against imports from developing countries that do not have CO_2 policies, this will not help those countries to adopt energy-efficient foreign technologies. As a result, trade

[2] This project is sponsored by NOP, the Dutch National Research Programme on Global Air Pollution and Climate Change.

measures might be a less efficient weapon against carbon leakage. Moreover, the leakage problem itself may prove less severe if the endogeneity of technology is taken into account. If energy-efficient firms in high-income countries move their production towards countries that do not join climate agreements, they will transfer more energy-efficient technologies than those originally used in these countries.

In the longer term, more countries may join the Annex-1 group and agree to impose global constraints on CO_2 emissions. In a new project we will analyse both the macro-economic impacts and effects on energy markets of such carbon coalitions, using WorldScan. We will show how different burden-sharing rules yield different regional target profiles. Moreover, a system of tradeable permits, which aims at achieving a global constraint, may attract new partners that join the abatement coalition. However, some countries within the abatement coalition might block the entry of new partners.

Another relevant issue is the stabilization of greenhouse gasses. In a new cooperative project with the National Institute of Public Health and the Environment (RIVM),[3] we develop stabilization scenarios and analyse the policy options under the restriction that greenhouse gasses are stabilised. These scenarios serve as inputs to the Third Assessment Report of the International Panel on Climate Change (IPCC). They will be included in the IPCC Special Report on Emission Scenarios. The analyses are carried out in scenarios that run until 2100. Given this time span, we are interested not only in the question which countries will reduce their emissions but also at which point in time they will do so, given an environmental target in 2100. The answer to the latter question depends on the developments of new environmentally-friendly techniques, discount factors and adjustments costs in the production process, but also on consumer behaviour.

7.5 Summary

WorldScan is built on neo-classical theories of economic growth and trade. It contains a number of characteristic elements compared to standard applied general equilibrium models. First of all, our Armington specification, which models two-way trade, is modified in such a way that it exhibits a tendency to the law of one price. Second, we distinguish high- and low-productivity sectors in developing regions. Low-productivity sectors are mostly traditional sectors, in which people are self-employed and have no access to capital and modern technologies. In the process of economic development, labour will reallocate from these traditional sectors to the high-productivity sectors. Third, regional consumption patterns, which describe the allocation of budgets to the various categories of goods, develop towards a universal pattern as per capita consumption rises. The most important characteristic of this process is a consumption shift from agriculture to services in developing regions. Fourth, we classify labour into

[3] See footnote 2.

two skills: high and low. This distinction permits us to describe specialization patterns of OECD regions, where high-skilled labour is relatively abundant, and of developing regions, where low-skilled labour is relatively abundant. Fifth, we model regional capital markets, which are imperfectly integrated. This specification allows for a description of foreign investment and of further integration of these markets.

In addition to these mechanisms, the model contains some general properties. One of them is the expectation structure. Expectations are not always realised because some of them are backward-looking. However, our way of modelling expectations does not lead to systematic errors. We do not require the model to exhibit steady-state properties. Differences between the regions in our calibration year 1995 are huge. Future differences will therefore remain large for a long time, even in simulations more than fifty years ahead of us. A steady state is characterised by equal growth rates for all regions and sectors and would thus not be a desirable characteristic of our model and scenarios. Nevertheless, the model provides some mechanisms that lead to convergence between regions where it concerns labour reallocation, the development of consumption patterns and the tendency to the law of one price. Complete convergence, however, is not our aim.

WorldScan's calibration year is 1995. The most important data source is the GTAP data base, version 4 (see McDougall *et al.* (1998)). This database contains data on production, investment, consumption and trade for about 50 sectors and regions in the world. We aggregate these data to seven sectors and twelve regions. The data are used to derive capital stocks and the return on capital, and to calibrate the parameters in the production and consumption functions, and in the demand relations. Our data and projections on labour supply are derived from the demographic projections by United Nations (1995) and those on participation rates by ILO (1996). The skill split is based on data and projections on human capital by Ahuja and Filmer (1995) and Barro and Lee (1996). The data on the informal sector are derived from WorldBank (1995) and ILO (1998). Monetary data originate from De Jong *et al.* (1993) and are used to calibrate the portfolio for international diversification of investments.

The characteristic elements of the model are highlighted by simulations that are compared to a basic scenario. This scenario is a globalization scenario. It is characterised by intensified linkages between developed and developing regions and by high growth in particularly the latter regions. Together with the simulations in Chapter 6, this scenario emphasises the importance of schooling, labour reallocation and technical progress as keys to economic growth. The analysis of trade liberalization shows the increased specialization in the production of high-skilled labour-intensive goods by OECD countries and the specialization in low-skilled labour-intensive goods in non-OECD countries (Asia, in particular). Intra-industry trade within the OECD increases substantially.

These characteristic elements of the model are useful to construct scenarios, to analyse events, and to perform policy analysis. The applications discussed in this chapter are examples of the role WorldScan plays in these three kinds of studies. More specific details can be found in the publications themselves.

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