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A (nearly) comprehensive model of the dynamics of international economic integration

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FLOWENLA DISCUSSION PAPER

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FLOWENLA Discussion Paper

A (nearly) comprehensive model of the dynamics of international economic integration

Michael A. Landesmann *
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ABSTRACT

This paper develops a Schumpeterian model of international specialisation and catching-up. In a previous version of the model we looked at the impact on international trade specialisation when different patterns of technological catching-up are followed. One of these is a Gerschenkron pattern at the industrial level, where the largest initial gaps in productivity give rise to the fastest relative productivity growth rates. Depending on the wage, productivity, profits dynamic there can be ´comparative advantage switchovers` in which a catching-up economy turns its competitive advantage towards medium- to high-tech areas. In this paper we follow up the impact of the unit profit or ´rent` patterns on foreign direct investment and through that on the speed of technology transfer and hence on differential productivity growth. We show again that labour market dynamics, productivity catching-up and investment patterns all combine to determine the evolution of the international division of labour. We point also to the impact on labour demand and wage structures (between skilled and unskilled workers) both in the lead and the catching-up economies; These in turn are used to explain ´push` and ´pull` factors of migration flows. The model thus contributes to the literature on globalisation and labour markets.

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A (NEARLY) COMPREHENSIVE MODEL OF THE DYNAMICS OF INTERNATIONAL ECONOMIC INTEGRATION

M. Landesmann and R. Stehrer

1 Introduction

This paper builds on a model introduced by Landesmann and Stehrer (2000) and Stehrer (2002) In the present paper we endogenise FDI flows and bring in a number of issues which show how FDI flows may play an important role in codetermining international specialisation and catching-up patterns. In fact, the causality runs both ways: the nature of catching-up determines the overall quantity and industrial allocation of FDI across branches of a catching-up economy and FDI in turn affects the pattern of catching-up. The previous version of the model focussed on the endogenisation of the dynamics of specialisation in a global economy which depended on the detailed modelling of sectoral patterns of productivity growth as well as wage dynamics in both the (technologically) advanced and the catching-up economies. It could be shown that, adopting a Gerschenkron pattern of catching-up at the sectoral level (i.e. industries with a higher initial productivity gap have a greater scope for productivity growth), can turn the comparative advantage of catching-up economies towards technologically advanced industries, even if the absolute level of productivity of the catching-up economy remains below that of the advanced economy. We spoke in this context of a 'comparative advantage switchover'. The Schumpeterian feature of our model, particularly the emergence of transitory per-unit rents allows an interesting integration of FDI flows into our model. Global investment flows are sensitive towards the emergence of per-unit rents and hence, implicitly, to the productivity- and wage-dynamics of catching up. Using a simple formulation for 'endogenising' productivity growth as a function of FDI flows (representing the impact of FDI on technology transfer) we show that FDI flows in turn impact upon the sectoral patterns of catching-up and hence on the dynamics of comparative advantage.

On the technical side, the integration of FDI into our model reveals a feature of disequilibrium dynamics: the building-up of capacities becomes both demand- and supply-determined. The latter refers to the impact which high unit-rents (Schumpeterian profits) have upon the attractiveness to expand capacities in particular sectors and locations/countries. The utilisation of such capacities is, on the other hand, demand-determined, and hence a function of whether such sectors and locations are able to attract the additional demand required for such utilisation. We shall see that this opens up an additional dynamic where utilisation patterns depend in turn on productivity-wage-price dynamics and a number of price elasticities of demand. In the following, we shall proceed in two steps:

(i) Endogenising FDI flows

(ii) Impact of FDI on 'endogenous productivity growth'

1.1 Endogenising FDI flows

We assume that FDI flows are reacting to the differential in per-unit rents[1] to be obtained in different industrial branches and different international locations. In general, FDI should be forward looking and not be just dependent upon current per-unit profits, but we shall have to assume this as long as we do not implement a forward looking integral about expected flows of returns. The chosen specification will allow us to introduce also investment incentives which would reduce unit costs.

The next step is to allow FDI inflows to affect international market shares which will allow those additional production capacities to be utilised as additional demand is generated. We intend to allow FDI to also have an impact on the parameter of price-to-cost adjustment so that (even without an impact on endogenous productivity growth) there would also be a direct impact of FDI on international market shares as long as there are disequilibrium price-cost margins. The rationale for this is that FDI flows imply an opening of markets (to new entrants) and thus increase the competitive pressure in domestic markets (leading to a faster price-to-cost adjustment). Of course, it does not always have to work in this direction: There could e.g. be trade (and other entry) barriers so that the foreign investor who 'jumps' over the existing barriers would find a rather protected domestic market and has little incentive to forego a profit margin. If he is a 'contested' new entrant (i.e. no entry barriers for other new entrants), then the pressure to behave competitively will be there, but there might still be high fixed costs to cover in the first phase of entry so that the foreign investor will have to keep the margin to cover the fixed costs (typical situation in endogenous growth models).

In the model there is not an automatic adjustment of supply (the build-up of additional capacities through FDI and home investments) and demand (which evolves as a function of the growth of market shares and additional income generation in the domestic market where more workers are hired, possibly paid higher wages, etc.). In phases of adjustments resulting from the additional capacity-generating FDI flows there is a potential demand-supply mismatch. The model converges to a long-run equilibrium where prices equal (average) costs plus a (long-run) mark up and supply equals demand. We do not however specify an immediate (and necessarily infinitely fast) price-setting mechanism to equilibrate demand and supply, given capacities. We think that the approach taken here is more flexible and allows us to bring in real phenomena (problems of adjustment) which are not dealt with in neoclassical (equlibrium spot market) models. This, however, comes at the cost of temporary (supply-demand) imbalances which characterise the model's behaviour during transitory phases.

[1] In a model with circulating capital only, this amounts to the same thing as differential rates of return on invested capital (with wages paid ex ante).

1.2 Endogenous productivity effects of FDI

The next step is to model the impact of FDI on endogenous productivity growth. We shall assume that FDI can speed up the technology transfer in the catching-up economy but not allow the country to shift the technology frontier itself (the latter is defined by the productivity level of the more advanced economy). This reduces the possibility of a cumulative process where competitiveness may be improved to a level which drives out the advanced economy completely. If only technology transfer is speeded up, there is a limitation of the degree to which a catching-up economy can benefit (technologically) from increased FDI inflows (i.e. it can maximally reach the productivity level of the more advanced economy).

There is also an empirical rationale behind this specification in that MNCs do not set up sites in less developed economies which are technologically superior to the ones in the home base. A real process of technological 'overtaking' could occur if there is a building up of human capital stock and R&D infrastructure superior to that of the technological leader; this could occur as a function of domestic public policy and - under certain circumstances - be the result of the ways how factor markets operate in different economies.

Once FDI affects productivity growth, we shall have the scenario that fast learning in the technologically advanced industries combined with moderate wage increases leads to high per-unit rents in these industries; this makes them attractive for FDI inflows and this speeds up productivity growth further. There will be a limitation in this productivity growth push in that the Gerschenkron mechanism (advantage of backwardness) can be exhausted and hence at some point productivity growth in spite of FDI inflows will slow down as productivity levels of the more advanced economy are approached. In the long-run we again approach a steady-state with equal unit costs in all countries (and with an undefined specialisation structure).

Before this long-run steady-state is reached however, specialisation advantages in the high-tech branches by the catching-up country are enforced by FDI productivity effects. Of course, as always, productivity catching-up is only one side of the story, the other is wage catching-up. And we know that any move in the direction of specialisation towards high tech branches, requires an increased relative demand for skilled workers and hence increases the pressure (given the composition of the labour force) on the wage rates of the skilled workers.

1.3 Migration

TO BE INSERTED

2 The model

In this section we present the detailed structure of the model, which is used afterwards in simulation studies. The model is based on a paper by Landesmann and Stehrer (2000) and a more extended version by Stehrer (2002). The version of the model presented in this paper brings in the role of FDI as an important mover in the dynamics of catching-up and in the evolution of comparative advantage.

2.1 Technology

2.1.1 Input-output matrix

We start with a matrix of technical input coefficients for each country c, denoted by

$$\mathbf{A^c} = \begin{pmatrix} \tilde{\mathbf{a}}^c_{*1} & \dots & \tilde{\mathbf{a}}^c_{*j} & \dots & \tilde{\mathbf{a}}^c_{*N} \end{pmatrix}$$

where

$$\tilde{\mathbf{a}}^c_{*j} = \begin{pmatrix} \tilde{a}^c_{1j} & \dots & \tilde{a}^c_{ij} & \dots & \tilde{a}^c_{nj} \end{pmatrix}^\top$$

and the typical element $\tilde{a}^c_{ji}$ denotes a *technical* input coefficient of sector j in country c. These technical coefficients are assumed to be stable over time (i.e. determined by technological considerations). The technical coefficients must be distinguished from the demand matrix for intermediate inputs as goods may be purchased from different suppliers; we shall refer to this demand matrix as the 'sourcing matrix'; the elements of that matrix will be price sensitive as we shall allow for substitution (as well as 'home' and 'regional bias') effects. We denote the demand coefficients for intermediate inputs supplied by country r to country c as

$$\mathbf{A^{rc}} = \begin{pmatrix} a^{rc}_{11} & \dots & a^{rc}_{1N} \\ \vdots & \ddots & \vdots \\ a^{rc}_{N1} & \dots & a^{rc}_{NN} \end{pmatrix}$$

These demand (or 'sourcing') coefficients have to satisfy the technological given constraint $\tilde{a}^c_{ji} = \sum_r a^{rc}_{ji}$. The overall world sourcing matrix is then given by

$$\mathbf{A} = \begin{pmatrix} \mathbf{A}^{11} & \dots & \mathbf{A}^{1C} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{C^1} & \dots & \mathbf{A}^{CC} \end{pmatrix} = \begin{pmatrix} \mathbf{a}^{*1}_{*1} & \dots & \mathbf{a}^{*C}_{*N} \end{pmatrix} = \begin{pmatrix} (\mathbf{a}^{1*}_{1*})^\top \\ \vdots \\ (\mathbf{a}^{C*}_{N*})^\top \end{pmatrix}$$

The integrated $\mathbf{A}$ matrix further satisfies the conditions to guarantee economically meaningful solutions.

2.1.2 Labour input coefficients

Leontief production function The goods produced require different types of workers denoted by $z = 1, \dots, Z$. We denote the vector of labour input coefficients by

$$\mathbf{a}^c_{li} = \begin{pmatrix} a^c_{li,1} & \dots & a^c_{li,Z} \end{pmatrix}$$

where $a^c_{li,z}$ denotes the labour input coefficient of skill tpye z in industry i in country c. We do not allow for substitution effects between different types of labour, although we allow for changes in the composition of labour due to technological change (e.g. skill-biased technological change).

Technological progress is introduced through changes in labour input-coefficients as a steady decrease to an exogenous (stationary) level, i.e.

$$\dot{a}^c_{li,z} = \gamma^c_{a_{li,z}} \left(a^c_{li,z} - \bar{a}^c_{li,z} \right)$$

This simple formulation allows both for differences in the rates of productivity growth, firstly, due to inital 'distance' from the stationary state productivity level and, secondly, due to differences in the speed of adjustment (parameter $\gamma^c_{a_{li,z}}$) to that level. The same distinction will be used later on to differentiate between a 'weak' and a 'strong' Gerschenkron effect when productivity catching-up processes are considered from the point of view of a catching-up economy. Finally, we should also mention here that we shall also employ more complicated specifications, such as a logistic formulation. These allow the characterisation of more differentiated patterns of productivity growth across industrial branches and also of catching-up patterns across economies.

Substitution effects We follow the following modeling strategy: As a benchmark we model technical progress in the way that labour productivity for the skilled workers are following an exogenous path. Connected to the level of productivity of the skilled workers we have an unambigously defined level of productivity for the unskilled workers if the relative wage of both types of workers reflects the relative productivity level. This means the skilled to unskilled ratio follows an exogenous path (see figure). The curvature of the path reflects the factor bias of the technical progress. Each point at this path reflects the factor ratio for a Leontief production function (i.e. no substitution effects across factors). However, to each of these points we construct a CES production function which has its optimal point (i.e. the cost minimisation point) at exactly this point of the path if the relative wage reflects relative average productivity of the workers. This means that the assumption of cost minimisation given a more general production function and given relative wage rates reflecting the average productivity we have the same outcome (factor ratio) for both types of production functions. The latter however allows to implement substitution effects in a well defined way. Given the relative wage rate differs from that of the relative productivity levels, this allows for substition effects. Figure 2.1.2 shows

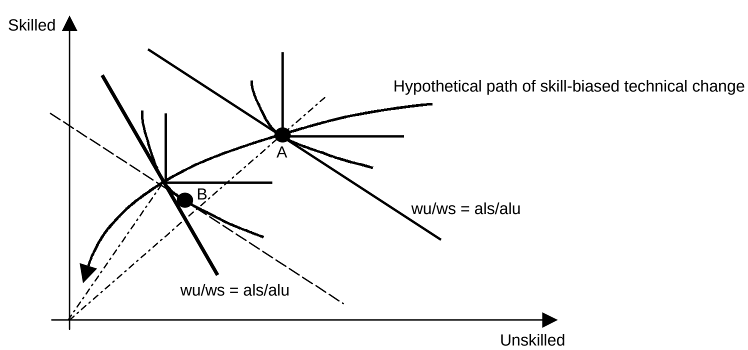


Figure 2.1: Path of technical progress

the the path of one particular industry. Point A is a long-term equilibrium where relative wage rates reflect relative productivity levels. Over time technology changes (i.e. the production function shifts inwards); in the figure we assumed that technical progress is biased against the unskilled workers. If relative wages are stable there is a substitution effect towards the unskilled workers as the relative wage rates of unskilled workers do not change accordingly to relative productivity increases. Given the flexible production function the skilled to unskilled ratio is given by point B. If, however, relative wage rates changes in the way to reflect average productivity levels (as would be given by the Leontief function) the technology would shift to the hypothetical path.

2.2 Prices and rents

Prices Prices are modeled as adjustment to unit costs

$$\dot{p}_i^c = -\delta_{p_i}^c \left[p_i^c - (1 + \pi_i^c) c_i^c \right]$$

where $c_i^c = \sum_j p_j^c a_{ji}^c + v_i^c$ are the costs of production and $v_i^c = \sum_z w_{i,z}^c a_{li,z}^c$ denote the unit labour costs in a particular sector i.[2]

We assume that wage rates (by skill-types) $w_{i,z}^c$ need not be equal across sectors, although we shall assume that wage rates for each particular skill-group tend to equalise in the long run as we shall see below. The parameter $0 < \delta_{p_i}^c \leq 1$ gives the speed of adjustment of prices to (equilibrium) unit labour costs. There exists a long run mark-up on prices with π_i^c being the mark-up ratio. This assumption leads to equal per unit profitability across sectors in the long run simply through the price-to-cost adjustment mechanism.[3][4]

Rents As there is a constant long-run mark-up ratio on prices π_i^c there are long-run per unit profits r_i^c defined as

$$r_i^c = \pi_i^c c_i^c$$

As prices do not adjust immediately to unit costs plus (long-run) mark-up, there arise *transitory rents* s_i^c depending on the speed of technological progress, the price-to-cost adjustment parameter $\delta_{p_i^c}$ and the dynamics of wages as we shall see below:

$$s_i^c = p_i^c - (1 + \pi_i^c) c_i^c = p_i^c - c_i^c - \pi_i^c c_i^c = p_i^c - c_i^c - r_i^c$$

[2]The price equation could be extended to allow for an excess supply/excess demand term; we shall not do this in this paper.

[3]In addition, there will be other mechanisms at work in the model which lead to long-run equilibration: one is the pressure on wage rates when a sector has above-average unit-rents; the other is the allocation (see below) of additional investment flows into a sector with high per-unit rents which increases labour demand and thus provides another mechanism for wage (and hence unit cost) pressure in that sector.

[4]At this stage we do not introduce exchange rate dynamics and assume the exchange rates to be constant. This means that all nominal values are expressed in a particular currency.

2.3 Labour market

Wage rates Nominal wages are growing or falling for three reasons: First, transitory rents are partly distributed to workers; second, excess supply (demand) of workers in the labour market drives wages up or down; and third, we assume skill-specific wage equalisation across sectors in the long-run. These three factors are formulated as follows:

$$\dot{w}_{i,z}^c = \kappa_{s_i,z}^c \frac{s_i}{\sum_z a_{li,z}^c} + \kappa_{u_z^c} u_z^c w_{i,z}^c + \kappa_{w_z^c} \frac{w_{i,z}^c - \bar{w}_z^c}{w_{i,z}^c} \qquad \text{with} \qquad \kappa_{s_i,z}^c = \kappa_{s_i}^c \frac{w_{i,z}^c}{\sum_z w_{i,z}^c}$$

$0 \leq \kappa_{s_i}^c \leq 1$ is the proportion of per unit (transitory) rents s_i^c paid to workers. The specification of the first term on the rhs of the wage equation implies that wage rates of different types of workers are absorbing a certain proportion of sector-specific rents (the latter are defined per unit of output). This means that wage rates can (temporarily) be different across sectors and skill-groups as rents are, in the first instance, distributed only to workers in the respective sector where the rents arise.

The second term on the rhs of the wage dynamics equation reflects the impact of unemployment on the dynamics of the wage rates ($\kappa_{u_z}^c \leq 0$). The unemployment rate is defined as

$$u_z^c = \frac{h_z^c - \sum_i a_{li,z}^c q_i^c}{h_z^c} = \frac{h_z^c - \sum_i l_{i,z}^c}{h_z^c}$$

where h_z^c and l_z^c denote labour supply and demand, respectively.

Third, there is an impact on the wage dynamics if wage rates (for the same skill-type of worker) differ across sectors. This reflects the common assumption that wage rates get equalised across sectors because of labour mobility. The (weighted) average wage rate (across sectors) is defined as $\bar{w}_z^c = \frac{\sum_i l_{i,z}^c w_{i,z}^c}{\sum_i l_{i,z}^c}$. If the average wage $\bar{w}_z^c$ is higher than the sectorial wage $w_{i,z}^c$ the wage in sector i will rise, in the other case fall. This term works across all sectors. Thus in the formulation used in the simulations, there are two sector specific terms and one economy wide term having an influence on wage rates in each sector. Skill-specific wage differentiation can occur across sectors in the short run, but wage rates are equalised for the same skill group across sectors in the long run.

Labour supply Skill-specific labour supply h_z^c is assumed to adjust to labour demand according to

$$\dot{h}_z^c = \delta_{h_z^c}^c \left(l_z^c - h_z^c \right)$$

where

$$\delta_{h_z^c}^c = \begin{cases} \delta_{h_z^c,IN} > 0 & \text{for } h_z^c > l_z^c \\ \delta_{h_z^c,OUT} \geq 0 & \text{for } h_z^c \leq l_z^c \end{cases}$$

This formulation implies that labour supply adjusts to labour demand if there is excess demand or excess supply of labour; adjustment occurs at different rates, however. In the first case workers are entering the labour market, in the second case workers leave the labour market in case of unemployment, so that high unemployment leads to a falling participation rate.[5]

In the case of an exogenous inflow (or an exogenous constant growth rate) of workers the labour supply equation is

$$\dot{h}_z^c = \delta_{h_z^c}^c \left(l_z^c - h_z^c \right) + \gamma_z^c h_z^c$$

which may reflect human capital policies of different countries. The implications for the long term structure of the economy are discussed below. (Of course, the maximum of the work force cannot exceed the stock of this skill type in the population times a long-term participation rate.)

3 International economic linkages

3.1 Quantities: Demand Side

Following on from the discussion of the price system, the quantity system must be specified. Demand for goods consists of three different components which can be summarized in the following demand equation:

$$q_i^c = \sum_{s,k} a_{ik}^{cs} q_k^s + j_i^c + f_i^c \tag{3.1}$$

The first term is demand for intermediate goods used in production, the second term is (net) investment demand (financed - by assumption - out of profit and rent income) and the third term reflects consumption demand (at this stage assumed to come from workers' incomes). j_i^c and f_i^c therefore denote investment and consumption demand respectively for good i. We discuss each of these items in turn.

3.1.1 Demand for intermediate inputs and the 'global sourcing' matrix

The quantity of intermediate inputs to be purchased in one period of production is $\mathbf{a}_{*i}^{*c} q_i^c$; its nominal value is $\mathbf{p}^\top \mathbf{a}_{*i}^{*c} q_i^c$. These intermediate inputs can be purchased from countries r and hence the nominal share (of total outlays on intermediate goods) spent by a sector i located in country c on an intermediate good k from country r is given by

$$\beta_{ki}^{rc} = \frac{p_k^r a_{ki}^{rc}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*c}}$$

where the (sourcing) coefficients a_{ki}^{rc} are momentarily given, but are themselves dependent on prices and may thus vary over time. The constraint is given by $\sum_r a_{ki}^{rc} = \tilde{a}_{ki}^c$, i.e.

[5]We do not, at this stage, make the labour supply a function of the real wage - contrary to a typical neo-classical formulation - but a function of the excess-demand for labour, as we think that this mechanism has been shown to be empirically more relevant than the neoclassical mechanism; see e.g. Elmeskov and Pichelmann (1993).

the sourcing coefficients of intermediate inputs must sum up to $\tilde{a}^c_{ki}$, the technical input coefficient for input k in sector i of country c (see also section 2.1 above).

We suggest the following modeling strategy: First, we calculate the expenditure shares for intermediate inputs which sector i of country c spends on goods k from country r. We use the following CES specification:

$$\zeta^{rc}_{ki} = (p^r_k)^{1-\sigma^{\ c}_{(\zeta)ki}} (\varrho^{rc}_{(\zeta)ki})^{\sigma^{\ c}_{(\zeta)ki}} \left(\sum_s (p^s_k)^{1-\sigma^{\ c}_{(\zeta)ki}} (\varrho^{sc}_{(\zeta)ki})^{\sigma^{\ c}_{(\zeta)ki}} \right)^{-1}$$

where $\sigma^{\ c}_{(\zeta)ki}$ denotes the elasticity of substitution and ϱ^{rc}_{ki} is a parameter reflecting a 'suppliers bias' (it can be used e.g. to include a 'home bias' or a 'regionalist bias' effect). Whereas $\sigma^{\ c}_{(\zeta)ki}$ is the same across countries, the weighting parameter $\varrho^{rc}_{(\zeta)ki}$ gives weights to different countries r which may differ for sectors i and k. This satisfies the condition that $\sum_r \zeta^{rc}_{ki} = 1$. Setting $a^{rc}_{ki} = \zeta^{rc}_{ki}\tilde{a}^c_{ki}$ gives the coefficients of the $\mathbf{A}$ matrix which have to satisfy

$$\sum_r \zeta^{rc}_{ki}\tilde{a}^c_{ki} = \sum_r a^{rc}_{ki} = \tilde{a}^c_{ki}$$

These coefficients give the structure of purchases of intermediate input goods across countries and sectors. In fact, this defines the 'global sourcing matrix' $\mathbf{A}$ introduced in section 2.1 above.

The second step is to calculate the share of the nominal value spent on goods k. Given the expenditure structures (as we have already determined the sourcing coefficients a^{rc}_{ki}) this is determined by

$$\frac{1}{p^r_k}\beta^{rc}_{ki}\mathbf{p}^\top\mathbf{a}^{*c}_{*i}q^c_i = \frac{1}{p^r_k}\frac{p^r_k a^{rc}_{ki}}{\mathbf{p}^\top\mathbf{a}^{*c}_{*i}}\mathbf{p}^\top\mathbf{a}^{*c}_{*i}q^c_i = a^{rc}_{ki}q^c_i$$

which refers to demand for good k in country r bought by sector i in country c which produces q^c_i.

The above formulation allows for substitution across countries when buying intermediate inputs. Please note that the above implies that a higher physical amount of intermediate inputs can be purchased as expenditures are allocated more efficiently over countries. Or, alternatively, the same bundle of technologically determined inputs can be purchased at lower costs as expenditures are allocated more efficiently over countries. Positive values for the 'suppliers bias' terms $\varrho^{rc}_{(\zeta)ki}$ thus imply - from the cost side - efficiency losses.

Summing up over countries c and sectors i gives the total demand for intermediate inputs in sector k of country r:

$$\sum_{c,i} a^{rc}_{ki}q^c_i$$

This is exactly the first component in the demand equation (3.1).

3.1.2 Consumption demand

Demand for consumption goods in general depends on preferences, income and prices (or real income). We assume a simple two-stage budgeting process. In the first stage income is allocated across products, in the second stage the expenditures for each good are allocated across suppliers from different countries.

Let the nominal share of expenditures for good k of country c spent on goods produced in countries $r = 1, \ldots, C$ be given by

$$\mu_k^{rc} = (p_k^r)^{1-\sigma_{(\mu)}^c} (\varrho_{\mu,k}^{rc})^{\sigma_{(\mu)}^c} \left(\sum_r (p_k^r)^{1-\sigma_{(\mu)}^c} (\varrho_{(\mu)k}^{rc})^{\sigma_{(\mu)}^c} \right)^{-1}$$

which results from a CES utility function. Similar to above $\sigma_{\mu,i}^c$ is the elasticity of substitution for goods across countries for consumption demand. The parameters $\varrho_{(\mu)k}^{rc}$ are again parameters which should reflect 'suppliers bias' effects. Given the nominal shares allows to calculate the price index for each consumer in a specific country. Consumers within each country differ as wage income differs across skill-types and industries. For simplicity we assume that the parameters $\sigma_{\mu,i}^c$ and $\varrho_{(\mu)k}^{rc}$ are equal for all consumers in country c. The (average) price for good k in country c is then given by

$$\tilde{p}_k^c = \left(\sum_r (p_k^r)^{1-\sigma_{(\mu)}^c} (\varrho_{(\mu)k}^{rc})^{\sigma_{(\mu)}^c} \right)^{\frac{1}{1-\sigma_{(\mu)}^c}}$$

which results from the compensated demand function. This average price can be interpreted as the price of good k in country c.[6]

In general the expenditure share on a specific good k is a function of the nominal wage income and the price vector $(\tilde{p}_1^c, \ldots, p_N^c)$.

Given any specific demand system (e.g. an Almost Ideal Demand System) one can calculate the nominal expenditure shares for good j of each skill-type of worker z in a specific industry i receiving a nominal wage of $w_{i,z}^c$. We denote these shares by $\alpha_{j(i,z)}^c$ with $\sum_j \alpha_{j(i,z)}^c = 1$ for products j.

Consumption demand for good k in country r purchased from country c is then given by

$$\sum_{j,z} \mu_k^{rc} \alpha_{k(j,z)}^c \frac{w_{j,z}^c}{p_k^r} a_{lj,z}^c q_j^c$$

Summing up over all countries c gives consumption demand for good k in country r:

$$f_k^r = \sum_{c,j,z} \mu_k^{rc} \alpha_{k(j,z)} \frac{w_{j,z}^c}{p_k^r} a_{lj,z}^c q_j^c$$

which is the third term in the demand equation (3.1).

[6] If one would assume that paramters $\sigma_{\mu,i}^c$ and $\rho_{(\nu)k}^{rc}$ are e.g. different for skill groups one would have to calculate a price p_k^c for each skill group.

3.1.3 Investment demand

Finally we have to specify how income out of retained earnings is spent. We assume that per unit profits and rents which are not distributed to workers, i.e. $\big((1-\kappa_{s_i^c})s_i^c + r_i^c\big) = m_i^c$ are entirely used for investment. Total rents plus profits in nominal terms in the economy c and sector i are then given by

$$m_i^c q_i^c = \big((1-\kappa_{s_i^c})s_i^c + r_i^c\big)q_i^c$$

In an integrated economy investors have to make two decisions: First, in which country and sector to invest, and second in which country to buy the goods for investment. These questions are guided by different considerations: The first one is motivated by relative per unit rents (and profits), the second by relative prices for purchases of investment goods.

Let us adress the first question. It is reasonable to assume that investments are made in the sectors and countries with the highest (expected) per unit rents. Second, there are also sector specific investment patterns, i.e. profits made in a sector i are more likely to be invested in a sector which is 'closer' in terms of sector-specific knowledge (of its technology, its markets, types of industrial relations, etc.). To account for these considerations we assume the following specification. A specific sector i in country c invests in sector j of country s the share ν_{ij}^{cs} of total retained earnings:

$$\nu_{ij}^{cs} = \begin{cases} (m_j^s)^{\sigma^c_{(\nu)i}-1}(\varrho^{cs}_{(\nu)ij})^{\sigma^c_{(\nu),i}} \left(\sum_{t,l}(m_l^t)^{\sigma^c_{(\nu)i}-1}(\varrho^{ct}_{(\nu)il})^{\sigma^c_{(\nu)i}}\right)^{-1} & \text{for } m_l^t > 0 \\ 0 & \text{for } m_l^t \le 0 \end{cases}$$

This again results from a CES specification. Summing up over all sectors i in country c gives the investment of country c in sector j and country s:

$$\sum_i \nu_{ij}^{cs} m_i^c q_i^c$$

Further summing up over countries c gives total investment in country s in sector j:

$$\sum_{c,i} \nu_{ij}^{cs} m_i^c q_i^c$$

Second, we have to specify the country where the goods for investment of country c in country s are purchased. This is in general driven by relative prices. We denote the shares by ξ_{ki}^{rc}. Again, there are various possibilities: the pattern for purchasing goods may, firstly, be the same as that of the investing country (country c above); or, secondly, it may be the same as in the country in which the investment takes place (country s above). The second possibility is more plausible as the investments are made in plants operating in country s. There can be arguments in favour for the first alternative, e.g. if a multinational keeps its structure of suppliers. But even in this case, one would consider this a transitory phenomenon, as increasingly the sourcing structure might move towards the new location. In the simulations reported below, we shall restrict ourselves to the second possibility.

In the first case the nominal sum invested from sector i in country c in sector j of country s is allocated over goods k as does sector j in country c:

$$\zeta_{kj}^{rc} = \xi_{kj}^{rc}$$

In the second case the nominal sum invested from sector i in country c in sector j of country s is allocated over goods k as does sector j in the receiving country s:

$$\zeta_{kj}^{rs} = \xi_{kj}^{rc}$$

This results in different demand patterns. Let us discuss the two cases separately:

First case In the first case the nominal sum of country c and sector i invested in country s and sector j is given by

$$\nu_{ij}^{cs} m_i^c q_i^c$$

Summing up over all countries c and industries i give total investment in industry j of country s.

To calculate the demand effects we have to include the expenditure patterns across countries which are in this case:

$$\zeta_{kj}^{rc}(\nu_{ij}^{cs} m_i^c q_i^c)$$

This represents the demand in sector k and country r as country c invests in country s and sector j. Taking sums over all investing countries c, across all sectors i, and all receiving countries s, determines total (nominal) demand (from global profit income) for good k in country r

$$\sum_{c,i,s} \zeta_{kj}^{rc}(\nu_{ij}^{cs} m_i^c q_i^c)$$

In real terms this is then given by

$$j_k^r = \frac{1}{p_k^r} \sum_{c,s,i} \zeta_{kj}^{rc}(\nu_{ij}^{cs} m_i^c q_i^c)$$

This is the second component in the demand equation (3.1). From a technical point of view this would also imply that country s uses a mixture of technology of countries c as the column vectors $\tilde{\mathbf{a}}_{*1}^c$ would apply.

Second case In this case the expenditure patterns across countries are given by

$$\zeta_{kj}^{rs}(\nu_{ij}^{cs} m_i^c q_i^c)$$

which gives demand in sector k and country r as country c invests in country s and sector j. Again, summing up over all countries c and s, and sectors i give

$$j_k^r = \frac{1}{p_k^r} \sum_{c,s,i} \zeta_{kj}^{rs}(\nu_{ij}^{cs} m_i^c q_i^c)$$

3.2 Supply side: capacity effects and transitory disequilibria

In the previous section we discussed the demand side of the system. In this section we analyse the supply side of the system. Before going to disequilibrium dynamics we look at a special case, i.e. the balanced growth path of the world economy.

3.2.1 Capacity effects

Apart from this demand effect one can calculate the capacity effect. The capacity effect takes place in country s, i.e. the receiving country (although the demand effect will also be felt in other economies where intermediate goods are also purchased.) We shall look at this from the viewpoint of country s as the receiving country and sector i as the sector in which investments are being made. What matters is that the capacities of sector i are expanding as a result of the allocation of FDI in the sector which in turn depends on the attractiveness of that sector as a destination of rents and profits made globally. The relative attractiveness of different destinations (sectors i in countries s) have been specified through the 'share' coefficients ν_{ji}^{cs}. The rates at which capacities are expanding in these sectors can be calculated by calculating the physical purchases (of equipment goods) which can be bought with a particular (nominal) FDI allocation of investments. This in turn depends on the sourcing structure discussed earlier.

Hence, in the first place, the nominal sum which is invested (out of global profits and rents) in sector i of country s is given by

$$\sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c$$

The physical increase in capacities is made up of the set of capital goods $k = 1, \ldots, n$ and the real increase in capacity of a capital good k derived from additional investment can be calculated as

$$\frac{1}{p_k^r} \beta_{ki}^{rs} \sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c$$

Inserting for $\beta_{ki}^{rs} = \frac{p_k^r a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}}$ gives

$$\frac{1}{p_k^r} \frac{p_k^r a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}} \sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c = \frac{a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}} \sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c$$

While this is the growth rate (in real terms) of 'capacity' for one capital good k in sector i of country s, we have in our derivations guaranteed (see section 2.4.1) that the increase in capacity would be proportional in all equipment goods k. Hence, the capacity effect in equipment good k is equivalent to the overall capacity increase in sector i.

3.2.2 Balanced growth

For discussing balanced growth we use a result derived in that the allocation of the nominal sum of retained earnings must satisfy the following condition as argued in Stehrer (2002):

$$\nu_i^s = \frac{\mathbf{p}^\top \mathbf{a}_{*i}^{*s} q_i^s}{\mathbf{p}^\top \mathbf{A}\mathbf{q}}$$

which assumes that investment behaviour is the same for all industries and countries.

Inserting in the expression for the physical increase in capacities above gives

$$\begin{aligned}
\frac{a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}} \sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c &= \frac{a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}} \sum_{c,j} \frac{\mathbf{p}^\top \mathbf{a}_{*i}^{*s} q_i^s}{\mathbf{p}^\top \mathbf{A}\mathbf{q}} m_j^c q_j^c \\
&= \frac{a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}} \frac{\mathbf{p}^\top \mathbf{a}_{*i}^{*s} q_i^s}{\mathbf{p}^\top \mathbf{A}\mathbf{q}} \sum_{c,j} m_j^c q_j^c \\
&= a_{ki}^{rs} \frac{q_i^s}{\mathbf{p}^\top \mathbf{A}\mathbf{q}} \sum_{c,j} m_j^c q_j^c \\
&= a_{ki}^{rs} q_i^s \frac{\sum_{c,j} m_j^c q_j^c}{\mathbf{p}^\top \mathbf{A}\mathbf{q}}
\end{aligned}$$

Dividing by the existing stock of intermediate inputs $a_{ki}^{rs} q_i^s$ gives the growth rate of capacities

$$g_i^s = \frac{\sum_{c,j} m_j^c q_j^c}{\mathbf{p}^\top \mathbf{A}\mathbf{q}}$$

Note that this growth rate is equal for all sectors and countries as it is just the ratio of the sum of retained earnings and the nominal value of the intermediate inputs, i.e. $g_i^s = g$ for all i, s.

The dynamics of the output of good i in country c is modeled by:

$$\dot{q}_i^c = (1+g) \sum_j \overline{a}_{ij}^c \left(j_j^c + f_j^c \right) - q_i^c$$

where $\overline{a}_{ij}^c$ denotes a typical element of the Leontief inverse $[\mathbf{I} - \mathbf{A}]^{-1}$. In equilibrium supply equals demand and we have

$$\mathbf{q} = \mathbf{A}\mathbf{q} + \mathbf{j} + \mathbf{f}$$

satisfied. Inserting gives

$$\dot{\mathbf{q}} = g\mathbf{q}$$

Further it is satisfied that

$$\mathbf{q} + \dot{\mathbf{q}} = \mathbf{A}^{-1}(\mathbf{j} + \mathbf{A}\mathbf{q}) = \mathbf{A}^{-1}\mathbf{j} + \mathbf{q}$$

which means that the output can be produced with the available intermediate inputs $\mathbf{A}\mathbf{q}$ and the goods demanded for investment.

At each point in time $\mathbf{j}$ and $\mathbf{f}$ is demanded which implies that $(\mathbf{I}-\mathbf{A})^{-1}(\mathbf{j}+\mathbf{f})$ should be available as intermediate inputs. As however $\mathbf{j}$ is not consumed, this investment is additionally available for production and thus allows for a growing economy.

The stock of intermediate inputs available at the beginning of the production period is thus augmented by the investments. This allows the economy to grow at the rate g without constraint on the supply side of goods as at each point in time $g\mathbf{Aq}$ is added to capacities. The demand side is satisfied by consumption demand from either a growing work force and/or - if labour productivity increases - from consumption spending from growing earnings (of workers and capitalists) and the growing volume of retained profits spent on investment goods.

3.2.3 Disequilibrium interpretations

In general it is however likely that the equilibrium behaviour is violated, especially in the case of integrated economies. Thus there may arise excess capacities due to shifts in consumption demand, investment demand or changes in the sourcing matrix. In the case of excess supply being higher than demand for a particular good one could either assume that the goods vanish or that the short-term productivity of the sector decreases or that there is some underutilisation of capacities. On the other hand in the case of excess demand one could either assume that the productivity of this sector increases or that capacities get stretched which allows us to focus on the long-term behaviour of our model rather than to focus on the detailed adjustment to short-term imbalances. Further, as we formulate our analysis in continuous time and given the (numerical) assumptions in our simulations on the adjustment processes, the arising imbalances are negligible.

Expressed in terms of growth rates, the growth rate of capacities is defined as

$$\frac{a_{ki}^{rs}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s}} \sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c / a_{ki}^{rs} q_i^s = \frac{\sum_{c,j} \nu_{ji}^{cs} m_j^c q_j^c}{\mathbf{p}^\top \mathbf{a}_{*i}^{*s} q_i^s}$$

which in equilibrium equals the growth rate of demand. However this equality need not hold in general, i.e. there can be a capacity-demand mismatch, as the two sides are determined by rather different variables.

We interpret the dynamics of the output system in the following manner. The equation for output dynamics is given by

$$\dot{q}_i^c = (1+g_i^c) \sum_j \overline{a}_{ij}^c \left(j_j^c + f_j^c\right) - q_i^c$$

which differs from the balanced growth situation only as the common growth rate is replaced with sector and country specific growth rates g_i^c. In fact, this gives the 'capacity' output path which would be equal to actual output if consumption and investment demand would also grow at this rate. However, as the latter are driven mainly by expenditure structures which are sensitive to relative prices and relative unit rents in a global economy this is not satisfied in general. As mentioned above we assume that if this is not satisfied productivity of the system adjusts in a way that actual output is equal to demand.

This does not rule out that there can be a path of overinvestment or underinvestment in particular sectors until the system reaches a steady state. For the moment, we take recourse to the 'productivity assumption' (or stretching of intermediate inputs) which requires a certain flexibility of the productive system to deal with a mismatch between capacity output and demand.

Before coming to the discussion of catching-up patterns and the impact which FDI has on the speed of technology transfer, we still introduce the price side.

3.3 Price convergence in the long-run

The last effect of international (market) integration we wish to introduce into our model is the long run tendency of the prices of the same type of goods to converge to the same (weighted) average price ('law of one price'). In the following we assume an exogenous trend for price equalisation. This alters the system of differential equations for prices to

$$\dot{p}_i^c = \delta_{p_i}^c \left[p_i^c - (1+\pi)c_i^c\right] + \delta_{\bar{p}_i}^c \frac{p_i^c - \bar{p}_i^c}{p_i^c}$$

where $\bar{p}_i^c$ is a weighted average of the prices of the trading partners of c.

3.4 International convergence patterns: strong and weak Gerschenkron effects and the impact of FDI on technology transfer

Another much discussed aspects of the linkages which emerge from international economic integration is that countries can learn from each other, i.e. that there are 'knowledge spillovers'. This greatly facilitates the catching-up of technologically backward countries with more advanced countries.

3.4.1 Exogenous catching-up

The simplest modelling strategy, which will be used in this paper, is that countries are catching-up with the leading country (or the technology frontier). Different paths of catching-up processes were investigated in Landesmann and Stehrer (2001) and this discussion will not be repeated here. In the simulations below we assume that a (technologically) lagging country will experience higher rates of productivity growth in those industries which start off with a higher initial productivity gap relative to the leader (this amounts to an application of Gershenkron's famous thesis of the 'advantage of backwardness' at the industrial level; see also Landesmann and Stehrer (2001) for a theoretical discussion and empirical analysis of this use of the Gerschenkron hypothesis). The specific equations for the catching-up processes are similar to the closed economy case:

$$\dot{a}_{li,z}^c = \gamma_{a_{li,z}}^c \left(a_{li,z}^c - \bar{a}_{li,z}^L\right) \tag{3.2}$$

where $\bar{a}_{li}^L$ denotes the labour input coefficient of the productivity leader (i.e. associated with the global technology frontier)

We distinguish to cases: The 'weak' Gerschenkron effect means that catching-up for the industries takes place at the same rate of convergence, i.e. the convergence parameter is equal across industries. This does not mean however that productivity growth is equal. The 'strong' Gerschenkron effect means that the convergence parameter is higher in one or a subset of industries. As we shall show below if the industries with the higher initial gap show a 'strong' Gerschenkron pattern there may a 'comparative advantage switchover' can take place in the course of catching up.

3.4.2 Endogenous catching-up

In a more sophisticated setting, the speed of catching-up could also depend on various proxies of 'social or technological capabilities' in the catching-up economy (this approach is associated with the arguments put forward in Abramovitz (1986); a formalisation and a partial test of this hypothesis is provided in Verspagen (1992). Proxies for such capabilities (i.e. reflecting the ability of a catching-up economy to absorb and utilise more advanced technology) could be the country-wide or industry-specific skill-structure, exogenously specified learning parameters, the structure and volume of imports and exports (reflecting the embodied part of technology transfer, particularly with respect to imports of capital goods and the incentive effects on technology up-grading which a high export orientation provides, particularly towards high-income markets) and, finally but very importantly, the intensity of flows of foreign direct investments, i.e. FDI. This last point will be introduced in this version of the model by assuming that the speed of technology appropriation $\gamma^c_{a_{li,z}}$ is a function of FDI inflows.

Thus, we endogenise productivity growth as a function of inward FDI flows. We normalise the effect of FDI by using the physical inflow of foreign direct investment in country c and sector i relative to the capacities:

$$FDI^c_{real,i} = \left(\frac{1}{p^r_k} \beta^{rc}_{ki} \sum_{s,j} \nu^{sc}_{ji} m^s_j q^s_j \right) / a^{rc}_{ki} q^c_i$$

Inserting for

$$\beta^{rc}_{ki} = \frac{p^r_k a^{rc}_{ki}}{\mathbf{p}^\top \mathbf{a}^{*c}_{*i}}$$

gives

$$FDI^c_{real,i} = \frac{\sum_{s,j} \nu^{sc}_{ji} m^s_j q^s_j}{\mathbf{p}^\top \mathbf{a}^{*c}_{*i} q^c_i} \qquad \text{for } s \neq c$$

which collapses to a nominal ratio. The specific formulation used in the simulations is

$$\dot{a}^c_{li,z} = (\gamma^c_{a_{li,z}} + \gamma^c_{FDI,i,z} FDI^c_{real,i}) \left(a^c_{li,z} - \bar{a}^L_{li,z} \right) \tag{3.3}$$

3.4.3 Substitution effects across skill groups

Accordingly to the discussion above the industries follow a hypothetical path as shown in figure 2.1.2 above. This means that the hypothetical skilled to unskilled ratio is determined by the level of labour productivity of the skilled workers. Allowing for substition effects an economy may deviate from the path in the above specified manner.

3.5 Migration (and commuting)

A third path of international integration is via migration of workers. Given the set up of the model this can be introduced via the labour supply equations given above.

Generally, there are two important variables for migration: The first is the differential in real wage rates (for a given skill group or even skill/industry specific) and the differential in unemployment rates (again for a particular skill group) between two countries. Third, one has to take into account that the migration potential in each country may differ across skill groups. For migrants we have to determine to which country the people want to move to (or stay); we assume the relative attractiveness of different (destination) locations s from a host location c to be expressed by shares θ_z^{sc}. Then the resulting flows determines the changes in the labour supplies (by skill type) in the different locations accordingly to

$$\dot{h}_z^c = \delta_{h_z^c}^c \left(l_z^c - h_z^c\right) + \sum_s \theta_z^{sc} h_z^s - \sum_s \theta_z^{cs} h_z^c$$

The shares θ_z^{cs} are assumed to be determined by a CES function:

$$\begin{aligned}\theta_z^{rc} \quad = \quad & \lambda_z^c (\tilde{w}_z^{rc})^{1-\sigma_{(\theta)z}^c} \left(\varrho_{(\theta)z}^{rc}\right)^{\sigma_{(\theta)z}^c} \left(\sum_s (\tilde{w}_z^{sc})^{1-\sigma_{(\theta)z}^{sc}} \left(\varrho_{(\theta)z}^{sc}\right)^{\sigma_{(\theta)z}^c}\right)^{-1} + \\ & (1-\lambda_z^c)(\tilde{u}_z^{rc})^{1-\sigma_{(\theta)z}^c} \left(\varrho_{(\theta)z}^{rc}\right)^{\sigma_{(\theta)z}^c} \left(\sum_s (\tilde{u}_z^{sc})^{1-\sigma_{(\theta)z}^{sc}} \left(\varrho_{(\theta)z}^{sc}\right)^{\sigma_{(\theta)z}^c}\right)^{-1}\end{aligned}$$

where $\tilde{w}_z^{rc}$ and $\tilde{u}_z^c$ are appropriate measures of real wage and unemployment differentials and λ_z^c denotes a weighting parameter for the relative importance of these two variables in the migration decision. The parameters $\sigma_{(\theta)z}^c$ are the elasticities by which migration flows respond to differences in the characteristics across locations (they can be skill specific) and the parameters $\varrho_{(\theta)z}^{rc}$ reflect further preferences across locations (which may also include policy measures, geographical/cultural distance, etc.).

We assume that the immigrants are immediately adjusting to the consumption behaviour of the host country. The number and structure of immigrants into a country then have an effect on labour markets via the unemployment term in the wage equations and via the demand effects on output.

4 Simulation studies

4.1 Weak and strong Gerschenkron effects

In this section we present three simulations to show the effects of

1. trade integration and 'weak' Gerschenkorn pattern of catching-up;

2. trade integration with 'strong' Gerschenkron pattern of catching-up;

3. the additional impact of FDI inflows with additional 'endogoenous' productivity ('speeding up of technology transfer') effects.

The simulations are undertaken in a two-sector version of our model including two countries and two skill-types of workers. Country A is the technological leader and country B is the catching-up country. Sector 1 is the skill-intensive sector which also experiences faster productivity growth. In all the simulations we allow for trade in intermediate inputs, trade in investment goods and trade in consumption goods. However no transfer of rents (or international investments) across the countries is taking place. In the second scenario we allow for foreign direct investment with a high sensitivity to relative unit rents and we also introduce the endogenous productivity (speeding up of technoogy transfer) effect.

In the previous sections we presented the model in very general terms. In the simulations however we shall make some specific assumptions which allow a better understanding of the ongoing dynamics. In most cases we let the CES-specifications collapse to a Cobb-Douglas specification, i.e. the price elasticity equals -1 and thus nominal shares remain invariant to changes in prices (i.e. $\sigma \rightarrow 1$). First, we assume fixed coefficients in the sourcing matrix. Second, we use constant nominal shares for the demand components: Specifically we assume that 75 % of the spending on each good for investment or consumption 25 % percent is purchased abroad. The expenditure pattern for consumption across two sectors is assumed to be $\alpha_k^c = 0.5$.

In Scenario 2 we use the CES specification for the allocation of rents given in the equation above with a high sensitivity on relative rents. The other parameters can be found in table 4.1. The starting values are given in table 4.2. The starting values in all the simulations reflect a stationary state of an integrated international economy as given in table 4.2. The simulations start in this particular equilibrium and are then subject to, at first, exogenous productivity growth effects; these differ between countries (the aggregate Gerschenkron effect) and across sectors (the sectoral Gerschenkron effect).

Country A succeeds in moderate labour productivity gains over time as labour input coefficients are falling to a level of 90 per cent of the starting values. We further assume that the parameter $\gamma_{a_{li,u}}^A$ is the same for all industries and skill-types which implies that technical progress in country A is neither sector nor factor biased.

For country B we have both the aggregate and the sectoral Gerschenkron pattern of productivity catching-up implying that rate of catching-up is considerably higher in the sector in which the initial productivity gap is higher (sector 1); this sector is also more intensive in the use of skilled labour.[7] Given the structure of the starting values and the assumptions about catching-up this implies a sector-biased technical progress (but not factor-biased) in country B.

[7] We distinguish between a weak and a strong Gerschenkron effect at the sectoral level: In the first case productivity growth would be higher in sector 1 simply because the initial gap is higher than in sector 2 but the convergence parameters $\gamma_{a_{li,u}}^c$ themselves are the same across the two sectors. The strong Gerschenkron effect implies that also the convergence parameter is higher in the sector where the initial gap is higher. We shall see later on that we need the strong Gerschenkron effect in order to obtain a 'comparative advantage switchover'. In the simulations discussed we only show the runs with the strong Gerschenkron effect.

Parameter	Country A		Country B	
	Sector specific		Sector specific	
	Sector 1	Sector 2	Sector 1	Sector 2
a_{ii}^{rr}	0.300	0.300	0.300	0.300
a_{ij}^{rr}	0.075	0.075	0.075	0.075
a_{ii}^{rs}	0.100	0.100	0.100	0.100
a_{ij}^{rs}	0.025	0.025	0.025	0.025
π_i	0.000	0.000	0.000	0.000
δ_{p_i}	0.100	0.100	0.250	0.250
$\delta_{\bar{p}_i}$	0.010	0.010	0.150	0.150
κ_{s_i}	0.000	0.000	0.000	0.000
$\sigma_{(\zeta)ki}$	1.000	1.000	1.000	1.000
$\vartheta_{(\zeta)ki}^{rr}$	0.750	0.750	0.750	0.750
$\vartheta_{(\zeta)ki}^{rs}$	0.250	0.250	0.250	0.250
α_k	0.500	0.500	0.500	0.500
σ_μ	1.000	1.000	1.000	1.000
$\vartheta_{(\mu)ki}^{rr}$	0.750	0.750	0.750	0.750
$\vartheta_{(\mu)ki}^{rs}$	0.250	0.250	0.250	0.250
σ_ν	1.000	1.000	1.000	1.000
$\vartheta_{(\nu)ki}^{rr}$	0.750	0.750	0.750	0.750
$\vartheta_{(\nu)ki}^{rs}$	0.250	0.250	0.250	0.250

Parameter	Country A				Country B			
	Sector and skill specific				Sector and skill specific			
	Sector 1		Sector 2		Sector 1		Sector 2	
	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled
$\bar{a}_{li,z}$	1.800	0.900	0.900	1.800	1.800	0.900	0.900	1.800
$\gamma_{a_{li,z}}$	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015
$\gamma_{(FDI)a_{li,z}}$	0.000	0.000	0.000	0.000	-2.000	-2.000	-2.000	-2.000

Parameter	Country A		Country B	
	Economy wide, skill specific		Economy wide, skill specific	
	Skilled	Unskilled	Skilled	Unskilled
$\delta_{h_{z,IN}}^c$	1.000	1.000	1.000	1.000
$\delta_{h_{z,OUT}}^c$	0.000	0.000	0.000	0.000
κ_{u_z}	0.100	0.100	0.100	0.100
κ_{w_z}	0.010	0.010	0.010	0.010

Table 4.1: Parameter values used in simulations (Scenario 1)

Variable	**Country A**				**Country B**			
	Sector and skill specific				**Sector and skill specific**			
	Sector 1		**Sector 2**		**Sector 1**		**Sector 2**	
	Skilled	**Unskilled**	**Skilled**	**Unskilled**	**Skilled**	**Unskilled**	**Skilled**	**Unskilled**
$a_{li,z}$	2.000	1.000	1.000	2.000	8.000	4.000	2.000	4.000
$w_{i,z}$	1.000	0.500	1.000	0.500	0.500	0.100	0.500	0.100
$l_{i,z}$	2.000	1.000	1.207	2.414	6.852	3.426	2.792	5.583
	Sector specific				**Sector specific**			
	Sector 1		**Sector 2**		**Sector 1**		**Sector 2**	
v_i	2.500		2.000		4.400		1.400	
p_i	5.231		4.202		7.569		3.598	
c_i	5.231		4.202		7.569		3.598	
r_i	0.000		0.000		0.000		0.000	
s_i	0.000		0.000		0.000		0.000	
j_i	0.000		0.000		0.000		0.000	
f_i	0.489		0.609		0.365		0.767	
q_i	1.000		1.207		0.856		1.396	
	Economy wide, skill specific				**Economy wide, skill specific**			
	Skilled		**Unskilled**		**Skilled**		**Unskilled**	
l	3.207		4.414		9.643		9.009	
h	3.207		4.414		9.643		9.009	
u	0.000		0.000		0.000		0.000	
	Economy wide				**Economy wide**			
g	0.000				0.000			

Table 4.2: Starting values used in simulations

This results in a much faster decrease of the relative price of industry 1 in country B than in country A which means that country B becomes more competitive in the skill intensive sector. Due to the much faster technical progress in sector 1 per unit rents are also higher in this sector in country B. In country A (where technical progress is not biased) rents are almost equal in both sectors. They are a little bit higher in industry 1 which shows the effect of the price-equalisation term and the effect of lower input prices from country B. Unemployment in country A is even negative (meaning excess demand for labour) for both skill groups. The reason for this is that, first, technical progress (hence the labour saving effect) is quite smooth and, second, that the growth process in country B creates more demand from country B (mainly for investment). As mentioned above, country B undergoes a rapid rate of labour-saving technical progress and thus undergoes a phase of transitory unemployment at the beginning. The unemployment rate is a little higher for the skilled workers as the rate of productivity growth is particularly high in the skill-intensive sector and the weight of this sector increases in the economy (due to substitution and trade specialisation effects). In both countries the relative output of the skill-intensive industries is rising as this industry becomes relatively cheaper. In the particular simulation selected the relative comparative advantage moves in such a way that we observe a 'comparative advantage switchover' around period 10.

In the second scenario in which foreign direct investment flows are endogenised, these are set to be very sensitive to the differences in per-unit rents. Given our catching-up assumptions (i.e. fast unit cost reductions in the skill-intensive sector in country B) this implies very high relative unit rents in sector 1 and hence most foreign investment flows into sector 1 of country B. Next comes the additional impact of FDI on endogenous productivity growth. The result is even stronger productivity growth and cost reductions in sector 1. The result is that we observe an even more dramatic improvement of the relative cost and price dynamics in favour of sector 1 and that the 'switchover in comparative advantage' occurs even earlier (in period 4). There is something of a 'cumulative' process going on: The Gerschenkron assumption on catching-up at the sectoral level leads to an improvement in the comparative advantage position of the skill-intensive sector (the one with the higher initial gap) and this is accentuated by the beneficial unit rent dynamic in favour of that sector which attracts disproportional amounts of FDI and leads to a further endogenous disproportionate productivity dynamics and thus pushes the comparative advantage pattern forward in time.

4.2 Labour market implications

The dynamics of comparative advantages of course has impliciations on the demand for different skill groups. In this model the demand for different skill groups is a function of

1. the skill composition of labour demand in the different sectors which are defined by the labour input coefficients and in the more generalized model also by substitution effects (level effect)

2. changes in the skill composition which result, on the one hand from 'skill bias' in the process of technical change as well from substitution effects due to relative wage

changes (across skill groups) - the factor bias of technical change

3. the sector-bias of technical change, i.e. rates of non-skill specific rates of productivity growth in different sectors

4. the evolution of output levels (driven by domestic and foreign consumption via income and price elasticities, investment and trade structures) of different sectors

5. migration flows has an effect on labour demand via the wage equations leading to effects on output structure and substitution effects

6. finally, there is an overall growth effect of output which may is stronger than the labour saving effect of technical progress and thus hinders technological unemployment

As mentioned above, the scenarios presented in the previous section assumed that technical progress was neither factor nor sector biased in the lead country and - due to the weak and strong Gerschenkron effects - sector biased in the catching up country. This lead to an fall in the skilled to unskilled ratio in the catching up country as technical progress was faster in the skill intensive sector. Although the structure of output shifted to the skill intensive sector this effect of sector biased technical progress was stronger.

In this section we present a scenario in which technical progress is also factor biased (i.e. against the unskilled workers).

TO BE INSERTED

5 Concluding remarks

The three simulations conducted reveal the following qualitative points:

- given particular catching-up patterns, combined with wage behaviour across sectors, there is a whole spectrum of possible dynamics of comparative advantages. In particular, we can distinguish two patterns: one in which - in spite of a weak Gerschenkron/Barro pattern of catching-up which favours the industry with the higher initial productivity gap - there is an improvement in the competitiveness of the catching-up economy in the high-skill intensive sector, but there is no 'comparative advantage switchover'. In this case (Scenario 0), the catching-up economy remains (relatively) specialised in the low skill intensive branch. In the second case, we assume a 'strong' Gerschenkron pattern of catching-up in which the faster productivity growth in the skill-intensive sector stems not only from the higher initial productivity gap but also from a higher convergence parameters $\gamma^c_{a_{li,z}}$ in this sector. In this case (Scenario 1), there is a 'comparative advantage switchover' i.e. the catching-up economy gains a specialisation advantage over the more advanced economy (which still keeps its 'absolute' productivity advantage) in the skill-intensive (higher tech) industry. As any comparative advantage in our model is purely a feature of transitory dynamic, there is a wage dynamic which over the longer time horizon erodes this comparative advantage over time (differential wage growth between skilled and unskilled workers in the catching-up economy erode the competitive advantage of the skill intensive sector).

- The introduction of foreign direct investment opens another channel through which international integration affects output structures and specialisation in integrated economies. Rather than being directly determined by comparative (relative price) advantages, as in the case of pure trade integration, FDI flows are determined by relative unit rents. In the simulations it is shown that the dynamics of relative unit rents introduces a shift in specialisation which is related but not synonymous with the dynamic in comparative cost dynamics; hence this additional determinant of international production structures changes somewhat the extent and timing of international specialisation. This becomes much more pronounced when we introduce the 'endogenous produtivity' effect or the impact which FDI has on speeding up the technology transfer in the catching up economy. The 'strong Gerschenkron effect' then gets much more pronouned and the possibility of a much faster dynamic in the up-grading process of a catching-up economy in the international division of labour arises. This feature emerged clearly in the figure on the 'timing of the comparative advantage switchoever'.

- The introduction of FDI also opened up an interesting dimension in our model with regard to supply-side versus demand-side determination of production patterns.

- Lastly, the labour market implications of analysing the various channels of the international integration ('globalisation') process are of particular interest. While the traditional approaches to this question adopted mostly a Heckscher-Ohlin framework of analysis, the set-up of our model comes to quite different insights and conclusions to this question (see also the analysis by Feenstra and Hanson (1997), who also adopt a different framework from an Heckscher-Ohlin analysis to analyse the impact of international integration on labour markets.

A Mathematical appendix

A.1 Equilibrium

Before discussing the model in disequilibrium let us first summarize the properties of the model in equilibrium. Demand is split into three components. Demand for intermediate inputs is given by

$$\mathbf{A}\mathbf{q} = \begin{pmatrix} a_{11}^{11} & \dots & a_{1N}^{11} & \dots & a_{11}^{1C} & \dots & a_{1N}^{1C} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{N1}^{11} & \dots & a_{NN}^{11} & \dots & a_{N1}^{1C} & \dots & a_{NN}^{1C} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{11}^{C1} & \dots & a_{1N}^{C1} & \dots & a_{11}^{CC} & \dots & a_{1N}^{CC} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{N1}^{C1} & \dots & a_{NN}^{C1} & \dots & a_{N1}^{CC} & \dots & a_{NN}^{CC} \end{pmatrix} \begin{pmatrix} q_1^1 \\ \vdots \\ q_N^1 \\ \vdots \\ q_1^C \\ \vdots \\ q_N^C \end{pmatrix}$$

where $\mathbf{A}$ denotes the global sourcing matrix and $\mathbf{q}$ the world output vector. In the case that prices are constant the sourcing matrix is fixed as well. Demand for investment goods is given by

$$\begin{aligned} \mathbf{j} &= \mathbf{D}_j \mathbf{q} = \\ &= \mathbf{P}^{-1} \begin{pmatrix} \sum_{s,j} \beta_{1j}^{1s}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \beta_{1j}^{1s}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \beta_{1j}^{1s}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \beta_{1j}^{1s}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \beta_{Nj}^{1s}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \beta_{Nj}^{1s}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \beta_{Nj}^{1s}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \beta_{Nj}^{1s}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \beta_{1j}^{Cs}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \beta_{1j}^{Cs}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \beta_{1j}^{Cs}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \beta_{1j}^{Cs}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \beta_{Nj}^{Cs}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \beta_{Nj}^{Cs}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \beta_{Nj}^{Cs}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \beta_{Nj}^{Cs}\gamma_{Nj}^{Cs} m_N^C \end{pmatrix} \begin{pmatrix} q_1^1 \\ \vdots \\ q_N^1 \\ \vdots \\ q_1^C \\ \vdots \\ q_N^C \end{pmatrix} \end{aligned}$$

Inserting for $\beta_{kj}^{ts} = p_k^t a_{kj}^{ts} / \mathbf{p}^\top \mathbf{a}_{*j}^{*s}$ (which allocates a given amount of investment in sector j of country s given the global sourcing matrix such that each component rises at the same rate) yields

$$\mathbf{j} = \mathbf{P}^{-1} \begin{pmatrix} \sum_{s,j} \frac{p_1^1 a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{p_1^1 a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{p_1^1 a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{p_1^1 a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \frac{p_N^1 a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{p_N^1 a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{p_N^1 a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{p_N^1 a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \frac{p_1^C a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{p_1^C a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{p_1^C a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{p_1^C a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \frac{p_N^C a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{p_N^C a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{p_N^C a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{p_N^C a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \end{pmatrix} \begin{pmatrix} q_1^1 \\ \vdots \\ q_N^1 \\ \vdots \\ q_1^C \\ \vdots \\ q_N^C \end{pmatrix}$$

Simplifying gives

$$\mathbf{j} = \begin{pmatrix} \sum_{s,j} \frac{a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{a_{1j}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \frac{a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{a_{Nj}^{1s}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \frac{a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{a_{1j}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \sum_{s,j} \frac{a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{1s} m_1^1 & \dots & \sum_{s,j} \frac{a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{1s} m_N^1 & \dots & \sum_{s,j} \frac{a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{1j}^{Cs} m_1^C & \dots & \sum_{s,j} \frac{a_{Nj}^{Cs}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*s}}\gamma_{Nj}^{Cs} m_N^C \end{pmatrix} \begin{pmatrix} q_1^1 \\ \vdots \\ q_N^1 \\ \vdots \\ q_1^C \\ \vdots \\ q_N^C \end{pmatrix}$$

A solution for the equilibrim balanced growth path in the global economy is that the total sum of profits (and rents) $\mathbf{m}^\top\mathbf{q}$ is allocated across countries and industris with

$$\gamma_j^s = \frac{\mathbf{p}^\top \mathbf{a}_{*j}^{*s} q_j^s}{\mathbf{p}^\top \mathbf{A}\mathbf{q}}$$

This is not necessarily the only investment behaviour which leads to this result; but for balanced growth investment behaviour must satisfy this condition. Inserting above gives

$$\mathbf{j} = (\mathbf{p}^\top\mathbf{A}\mathbf{q})^{-1} \begin{pmatrix} m_1^1 \sum_{s,j} a_{1j}^{1s} q_j^s & \dots & m_N^1 \sum_{s,j} a_{1j}^{1s} q_j^s & \dots & m_1^C \sum_{s,j} a_{1j}^{1s} q_j^s & \dots & m_N^C \sum_{s,j} a_{1j}^{1s} q_j^s \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_1^1 \sum_{s,j} a_{Nj}^{1s} q_j^s & \dots & m_N^1 \sum_{s,j} a_{Nj}^{1s} q_j^s & \dots & m_1^C \sum_{s,j} a_{Nj}^{1s} q_j^s & \dots & m_N^C \sum_{s,j} a_{Nj}^{1s} q_j^s \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_1^1 \sum_{s,j} a_{1j}^{Cs} q_j^s & \dots & m_N^1 \sum_{s,j} a_{1j}^{Cs} q_j^s & \dots & m_1^C \sum_{s,j} a_{1j}^{Cs} q_j^s & \dots & m_N^C \sum_{s,j} a_{1j}^{Cs} q_j^s \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ m_1^1 \sum_{s,j} a_{Nj}^{Cs} q_j^s & \dots & m_N^1 \sum_{s,j} a_{Nj}^{Cs} q_j^s & \dots & m_1^C \sum_{s,j} a_{Nj}^{Cs} q_j^s & \dots & m_N^C \sum_{s,j} a_{Nj}^{Cs} q_j^s \end{pmatrix} \begin{pmatrix} q_1^1 \\ \vdots \\ q_N^1 \\ \vdots \\ q_1^C \\ \vdots \\ q_N^C \end{pmatrix}$$

In a compact form this can be rewritten as

$$\begin{aligned} \mathbf{D}_j\mathbf{q} = \mathbf{j} &= (\mathbf{p}^\top\mathbf{A}\mathbf{q})^{-1} \left[\mathbf{m}^\top \otimes \begin{pmatrix} \mathbf{a}_{1*}^\top \mathbf{q} \\ \vdots \\ \mathbf{a}_{N*}^\top \mathbf{q} \end{pmatrix} \right] \mathbf{q} \\ &= (\mathbf{p}^\top\mathbf{A}\mathbf{q})^{-1} (\mathbf{m}^\top \otimes \mathbf{A}\mathbf{q})\mathbf{q} \\ &= \frac{\mathbf{m}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} \mathbf{A}\mathbf{q} \\ &= g\mathbf{A}\mathbf{q} \end{aligned}$$

That means, that at the balanced growth path each sector (j,s) has to attract the share γ_j^s of total world 'retained earnings'. This does not give a mechanism by which this is guaranteed but states only the condition. Using $\gamma_{ji}^{rc} = \gamma_i^c = \frac{\mathbf{p}^\top \mathbf{a}_{*i}^{*c} q_i^c}{\mathbf{p}^\top\mathbf{A}\mathbf{q}}$ one gets

$$\frac{1}{a_{ki}^{sc} q_i^c} \frac{a_{ki}^{sc}}{\mathbf{p}^\top \mathbf{a}_{*i}^{*c}} \sum_{j,r} \frac{\mathbf{p}^\top \mathbf{a}_{*i}^{*c} q_i^c}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} m_j^r q_j^r = \frac{\sum_{j,r} m_j^r q_j^r}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} = \frac{\mathbf{m}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} = g$$

i.e. the equilibrium growth rate (but now derived from the investment (supply) side).

We have to analyse the relationship between the demand (and supply) for investment goods $\mathbf{j}$ and the vector of growth rates g. In equilibrium the investment vector is given by $\mathbf{j} = \frac{\mathbf{m}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}}\mathbf{A}\mathbf{q}$. The system is constant (in the case $m_i^c = 0$, or $\pi_i^c = 0$ and $s_i^c = 0$ for all $i = 1, \dots, N$ and all $c = 1, \dots, C$) or is growing at

$$\mathbf{g} = \text{diag}(\mathbf{q})^{-1}\mathbf{A}^{-1}\mathbf{j} = \frac{\mathbf{m}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} \text{diag}(\mathbf{q})^{-1}\mathbf{A}^{-1}\mathbf{A}\mathbf{q} = \frac{\mathbf{m}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} \boldsymbol{\iota}$$

One can easily see that the growth rate is equal for all industries as $\frac{\mathbf{m}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}}$ denotes a scalar. In equilibrium (i.e. with $\mathbf{s} = \mathbf{0}$ or at equilibrium prices $\mathbf{p}^\top$) this can be reformulated as

$$g^* = \frac{\mathbf{r}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} = \frac{\mathbf{r}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{q}} \frac{\mathbf{p}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}} = \frac{\mathbf{c}^\top\mathbf{\Pi}\mathbf{q}}{\mathbf{c}^\top(\mathbf{I}+\mathbf{\Pi})\mathbf{q}} \frac{\mathbf{p}^\top\mathbf{q}}{\mathbf{p}^\top\mathbf{A}\mathbf{q}}$$

The economy is growing in equilibrium exactly at the rate g^*.[8] Given preferences or a specific demand system one can derive the nominal share $\alpha_j^c(w_{i,z}^c, \mathbf{p})$ spent on a specific good j of country c. As this can be derived for all workers one can

[8] In the case that there is a unique maximum profit rate, $\pi^{max} = \frac{1}{\lambda_{\mathbf{A}}^{max}} - 1$, and under the assumption that the whole surplus is reinvested this gives

$$g^{max} = \frac{\pi^{max}}{1+\pi^{max}} \frac{1}{\lambda_{\mathbf{A}}^{max}} = \pi^{max}$$

This is a simple form of the von Neumann result in which the economy grows at the maximum rate of profit.

calculate the aggregate demand vector. The nominal expenditure shares of a particular worker in country r in industry i of skill-type z for consumption of goods in country s of good j are denoted $\alpha_j^s(i,z,r)$.

Demand for consumption goods can be represented by the following equation where $\mathbf{q} = (q_1^1, \ldots, q_N^1, \ldots, q_1^C, \ldots, q_N^C)^\top$ denotes the world output vector:

$$
\begin{aligned}
\mathbf{f}_z &= \mathbf{D}_{f_z}\mathbf{q} \\
&= \mathbf{P}^{-1}\begin{pmatrix}
\alpha_1^1(1,z,1)v_{1,z}^1 & \ldots & \alpha_1^1(N,z,1)v_{N,z}^1 & \ldots & \alpha_1^1(1,z,C)v_{1,z}^C & \ldots & \alpha_1^1(N,z,C)v_{N,z}^C \\
\vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\
\alpha_N^1(1,z,1)v_{1,z}^1 & \ldots & \alpha_N^1(N,z,1)v_{N,z}^1 & \ldots & \alpha_N^1(1,z,C)v_{1,z}^C & \ldots & \alpha_N^1(N,z,C)v_{N,z}^C \\
\vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\
\alpha_1^C(1,z,1)v_{1,z}^1 & \ldots & \alpha_1^C(N,z,1)v_{N,z}^1 & \ldots & \alpha_1^C(1,z,C)v_{1,z}^C & \ldots & \alpha_N^C(N,z,C)v_{N,z}^C \\
\vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\
\alpha_N^C(1,z,1)v_{1,z}^1 & \ldots & \alpha_N^C(N,z,1)v_{N,z}^1 & \ldots & \alpha_N^C(1,z,C)v_{1,z}^C & \ldots & \alpha_N^C(N,z,C)v_{N,z}^C
\end{pmatrix}\mathbf{q}
\end{aligned}
$$

Using $v_{i,z}^r = w_{i,z}^r a_{li,z}^r$ and calculating the matrix product yields

$$
\mathbf{Pf}_z = \begin{pmatrix}
\sum_{i,r}\alpha_1^1(i,z,r)v_{i,z}^r q_i^r \\
\vdots \\
\sum_{i,r}\alpha_N^1(i,z,r)v_{i,z}^r q_i^r \\
\vdots \\
\sum_{i,r}\alpha_1^C(i,z,r)v_{i,z}^r q_i^r \\
\vdots \\
\sum_{i,r}\alpha_N^C(i,z,r)v_{i,z}^r q_i^r
\end{pmatrix} = \begin{pmatrix}
\sum_{i,r}\alpha_1^1(i,z,r)w_{i,z}^r a_{li,z}^r q_i^r \\
\vdots \\
\sum_{i,r}\alpha_N^1(i,z,r)w_{i,z}^r a_{li,z}^r q_i^r \\
\vdots \\
\sum_{i,r}\alpha_1^C(i,z,r)w_{i,z}^r a_{li,z}^r q_i^r \\
\vdots \\
\sum_{i,r}\alpha_N^C(i,z,r)w_{i,z}^r a_{li,z}^r q_i^r
\end{pmatrix} = \begin{pmatrix}
\sum_{i,r}\alpha_1^1(i,z,r)w_{i,z}^r l_{i,z}^r \\
\vdots \\
\sum_{i,r}\alpha_N^1(i,z,r)w_{i,z}^r l_{i,z}^r \\
\vdots \\
\sum_{i,r}\alpha_1^C(i,z,r)w_{i,z}^r l_{i,z}^r \\
\vdots \\
\sum_{i,r}\alpha_N^C(i,z,r)w_{i,z}^r l_{i,z}^r
\end{pmatrix}
$$

In the case that the nominal expenditure shares are independent of wage rates and prices and the same for all skill-types of workers in all countries this reduces to

$$
\mathbf{Pf}_z = \begin{pmatrix}
\alpha_1^1 \\ \vdots \\ \alpha_N^1 \\ \vdots \\ \alpha_1^C \\ \vdots \\ \alpha_N^C
\end{pmatrix}\mathbf{v}_z\mathbf{q} = \begin{pmatrix}
\alpha_1^1 \\ \vdots \\ \alpha_N^1 \\ \vdots \\ \alpha_1^C \\ \vdots \\ \alpha_N^C
\end{pmatrix}\mathbf{w}_z\mathbf{l}_z
$$

Summing up over all skill-groups $z = 1, \ldots, Z$ then yields the final demand vector for consumption

$$
\mathbf{f} = \mathbf{P}^{-1}\sum_z \mathbf{f}_z
$$

In equilibrium (balanced world) growth several conditions are satisfied. First, at each point in time we have that demand equals supply

$$
\mathbf{q} = \mathbf{Aq} + \mathbf{j} + \mathbf{f} = (\mathbf{A} + \mathbf{D}_j + \mathbf{D}_f)\mathbf{q}
$$

from which it follows that

$$
\mathbf{q} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{j} + \mathbf{f})
$$

i.e. given the demand vectors one can calculate the necessary output given the global sourcing matrix. For the second condition let us define the 'stock' of intermediate inputs $\mathbf{Aq} = \mathbf{k}$ from which it follows that

$$
\mathbf{q} = \mathbf{A}^{-1}\mathbf{k}
$$

For the third condition we can rewrite

$$\mathbf{AQ} = \begin{pmatrix} a_{11}^{11}q_1^1 & \dots & a_{1N}^{11}q_N^1 & \dots & a_{11}^{1C}q_1^C & \dots & a_{1N}^{1C}q_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{N1}^{11}q_1^1 & \dots & a_{NN}^{11}q_N^1 & \dots & a_{N1}^{1C}q_1^C & \dots & a_{NN}^{1C}q_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{11}^{C1}q_1^1 & \dots & a_{1N}^{C1}q_N^1 & \dots & a_{11}^{CC}q_1^C & \dots & a_{1N}^{CC}q_N^C \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{N1}^{C1}q_1^1 & \dots & a_{NN}^{C1}q_N^1 & \dots & a_{N1}^{CC}q_1^C & \dots & a_{NN}^{CC}q_N^C \end{pmatrix}$$

$$= \begin{pmatrix} k_{11}^{11} & \dots & k_{1N}^{11} & \dots & k_{11}^{1C} & \dots & k_{1N}^{1C} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ k_{N1}^{11} & \dots & k_{NN}^{11} & \dots & k_{N1}^{1C} & \dots & k_{NN}^{1C} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ k_{11}^{C1} & \dots & k_{1N}^{C1} & \dots & k_{11}^{CC} & \dots & k_{1N}^{CC} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ k_{N1}^{C1} & \dots & k_{NN}^{C1} & \dots & k_{N1}^{CC} & \dots & k_{NN}^{CC} \end{pmatrix} = \mathbf{K}$$

By definition it is satisfied that

$$a_{ij}^{rc}q_j^c = k_{ij}^{rc} \qquad \text{or} \qquad q_j^c = \frac{k_{ij}^{rc}}{a_{ij}^{rc}}$$

for all components $i = 1, \dots, N$ in countries $r = 1, \dots, C$ of sector j in country c. In the equilibrium growth context we have that the 'stocks' k_{ij}^{rc} are rising as investment j_{ij}^{rc} is added. Investment j_{ij}^{rc} (i.e. the physical inflow of goods) is given by

$$\dot{k}_{ij}^{rc} = \frac{1}{p_k^t}\sum_{i,c}\beta_{kj}^{tr}\gamma_{ij}^{cr}m_i^c q_i^c$$

Inserting for $\beta_{kj}^{tr} = \frac{p_k^t a_{kj}^{tr}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}}$ gives

$$\begin{aligned} \dot{k}_{ij}^{rc} &= \frac{1}{p_k^t}\sum_{i,c}\frac{p_k^t a_{kj}^{tr}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}}\gamma_{ij}^{cr}m_i^c q_i^c \\ &= \sum_{i,c}\frac{a_{kj}^{tr}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}}\gamma_{ij}^{cr}m_i^c q_i^c \end{aligned}$$

Dividing by the 'stock' of intermediate inputs gives the growth rate of sector j in country r

$$\begin{aligned} \frac{\dot{k}_j^r}{k_j^r} &= \frac{\sum_{i,c}\frac{a_{kj}^{tr}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}}\gamma_{ij}^{cr}m_i^c q_i^c}{a_{kj}^{tr}q_j^r} \\ &= \frac{\sum_{i,c}\gamma_{ij}^{cr}m_i^c q_i^c}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}q_j^r} \\ &= g_j^r \end{aligned}$$

which is the ratio of the nominal value of investment in sector j of country r and the nominal value of the 'stock' of intermediate inputs. This term is equal for all components of sector j. If retained earnings are allocated by $\gamma_j^r = \frac{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}q_j^r}{\mathbf{p}^\top \mathbf{A}\mathbf{q}}$ this term reduces to

$$\begin{aligned} \frac{\dot{k}_j^r}{k_j^r} &= \frac{\sum_{i,c}\gamma_{ij}^{cr}m_i^c q_i^c}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}q_j^r} \\ &= \frac{\sum_{i,c}\frac{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}q_j^r}{\mathbf{p}^\top \mathbf{A}\mathbf{q}}m_i^c q_i^c}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r}q_j^r} \\ &= \frac{\sum_{i,c}m_i^c q_i^c}{\mathbf{p}^\top \mathbf{A}\mathbf{q}} = \frac{\mathbf{m}^\top \mathbf{q}}{\mathbf{p}^\top \mathbf{A}\mathbf{q}} \\ &= g \end{aligned}$$

i.e. the world balanced growth rate. Assuming that capacities are growing at this rate output is growing as well at rate g,

$$(1+g)\mathbf{A}^{-1}\mathbf{k} = (1+g)\mathbf{A}^{-1}\mathbf{A}\mathbf{q} = (1+g)\mathbf{q}$$

This also implies that demand for intermediate inputs is growing at rate g. As matrices $\mathbf{D}_{f_z}$ and $\mathbf{D}_j$ are constant in equilibrium one gets

$$(1+g)\mathbf{q} = (1+g)\mathbf{A}\mathbf{q} + (1+g)\mathbf{D}_j\mathbf{q} + (1+g)\mathbf{D}_f\mathbf{q} = (1+g)(\mathbf{A} + \mathbf{D}_j + \mathbf{D}_f)\mathbf{q}$$

Rearranging gives

$$\begin{aligned} (1+g)\mathbf{q} - (1+g)\mathbf{A}\mathbf{q} &= (1+g)\mathbf{D}_j\mathbf{q} + (1+g)\mathbf{D}_f\mathbf{q} \\ (1+g)(\mathbf{I} - \mathbf{A})\mathbf{q} &= (1+g)\mathbf{D}_j\mathbf{q} + (1+g)\mathbf{D}_f\mathbf{q} \\ (1+g)\mathbf{q} &= (1+g)(\mathbf{I} - \mathbf{A})^{-1}\mathbf{D}_j\mathbf{q} + (1+g)\mathbf{D}_f\mathbf{q} \end{aligned}$$

Setting $g\mathbf{q} = \dot{\mathbf{q}}$ this can be rewritten as

$$\begin{aligned} \dot{\mathbf{q}} &= (1+g)(\mathbf{I} - \mathbf{A})^{-1}(\mathbf{D}_j + \mathbf{D}_f)\mathbf{q} - \mathbf{q} \\ &= (1+g)(\mathbf{I} - \mathbf{A})^{-1}(\mathbf{j} + \mathbf{f}) - \mathbf{q} \end{aligned}$$

Interpretation may also be turned around: If demand is growing at rate g then output and capacities also must grow at this rate.

A.2 Unbalanced growth

TO BE INSERTED

A.3 Disequilibrium

TO BE INSERTED

References

Abramovitz, M. (1986). Catching up, forging ahead and falling behind. *Journal of Economic History 46*, 385–406.

Elmeskov, J. and K. Pichelmann (1993). Unemployment and labour force participation - trends and cycles. *OECD Working Paper 130*.

Feenstra, R. and G. Hanson (1997). Foreign direct investment and relative wages: Evidence from mexico's maquiladoras'. *Journal of International Trade 42*(3-4), 371–393.

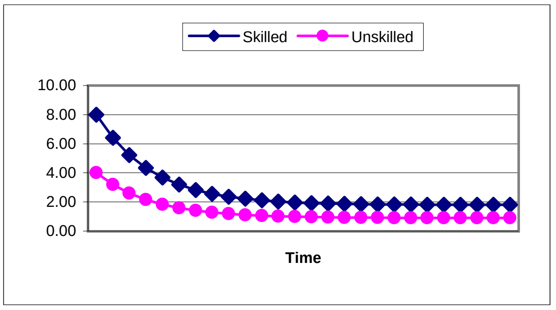
Landesmann, M. and R. Stehrer (2000). Industrial specialisation, catching-up and labour market dynamics. *Metroeconomica 51*(1), 67–101.

Landesmann, M. and R. Stehrer (2001). Convergence patterns and switchovers in comparative advantage. *Structural Change and Economic Dynamics 12*, 399–423.

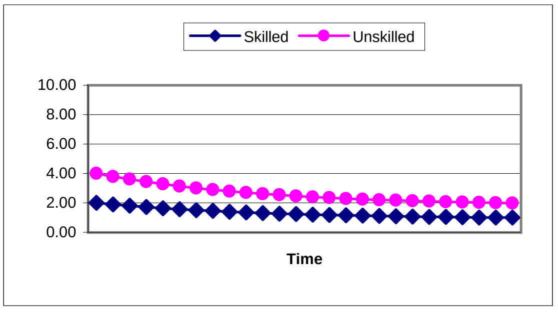
Stehrer, R. (2002). Dynamics of trade integration and technological convergence. *Economic Systems Research 14*(3), 219–244.

Verspagen, B. (1992). A new empirical approach to catching up or falling behind. *Structural Change and Economic Dynamics 2*(2), 359–380.

SCENARIO 1



Country B, industry 1



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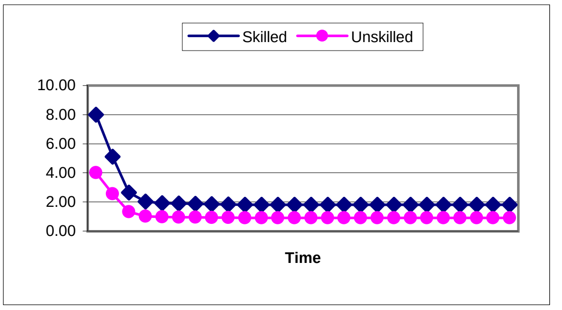
SCENARIO 2



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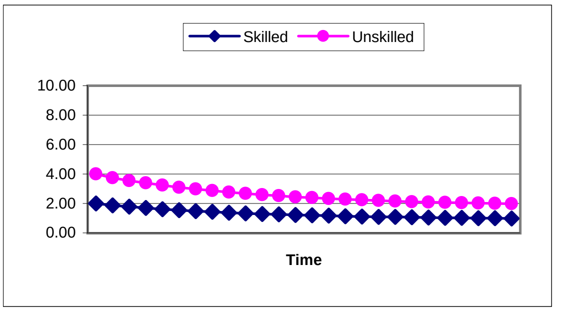

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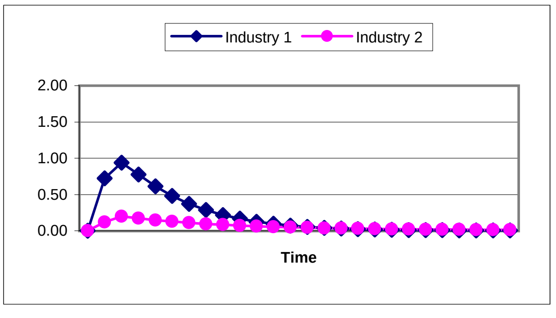
Figure 1: Labour input coefficients



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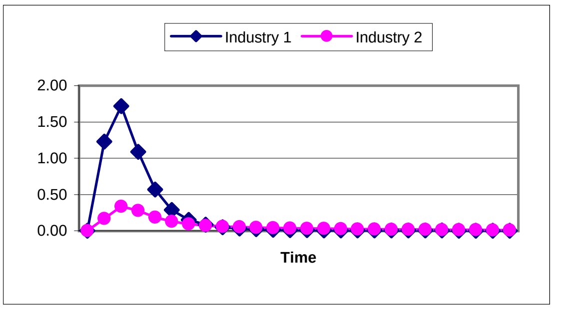
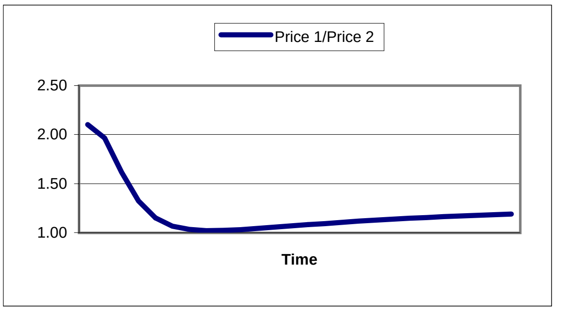


Country B

Figure 2: Rents

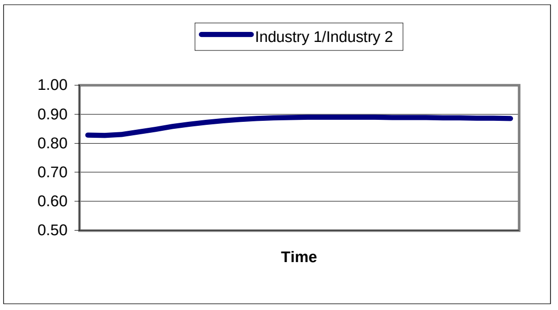
Country B

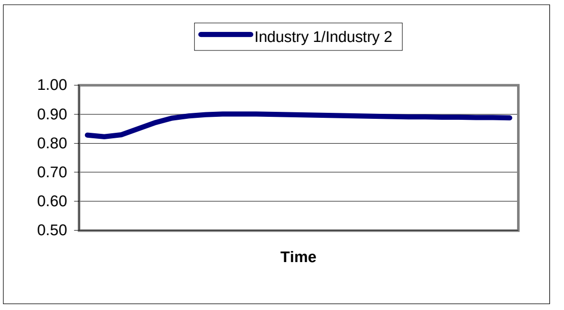


Country B

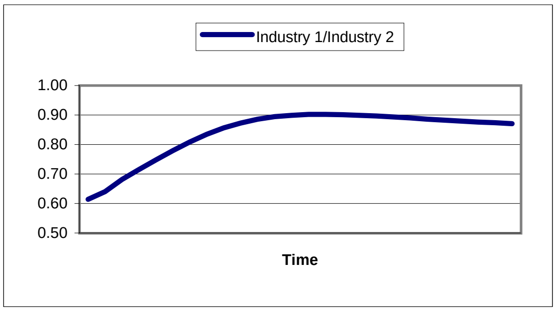
Figure 3: Relative price of skill-intensive industry

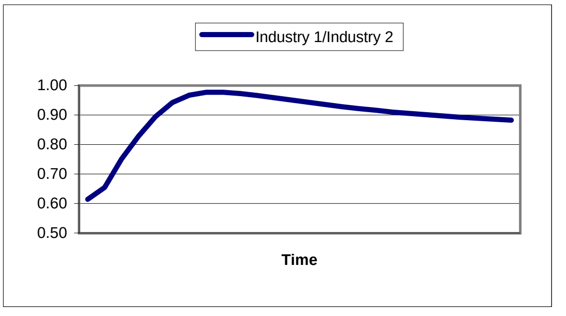
SCENARIO 1 **SCENARIO 2**





Country A **Country A**





Country B **Country B**

Figure 4: Relative output of skill-intensive industries

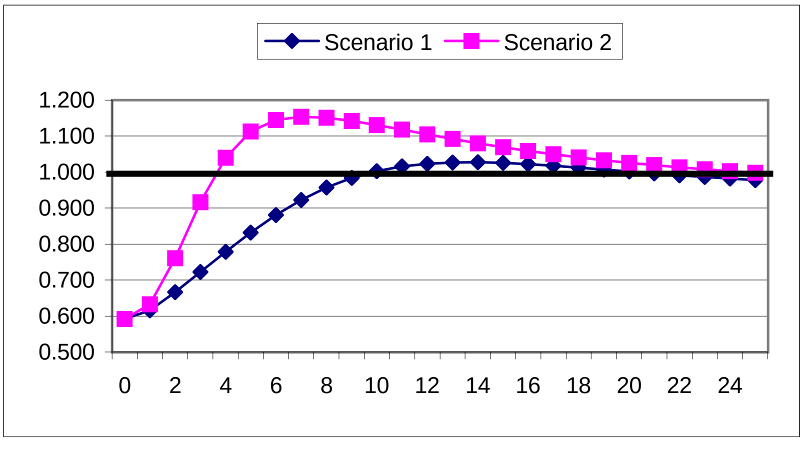


Figure 5: Timing of 'comparative advantage switchover'