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Modelling International Economic Integration: Patterns of Catching-up, Foreign Direct Investment and Migration Flows

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Michael Landesmann and *Robert Stehrer*

Modelling International Economic Integration: Patterns of Catching-up, Foreign Direct Investment and Migration Flows

Abstract

This paper develops a Schumpeterian model of international specialization and catching-up. In a previous version of the model we looked at the impact on international trade specialization 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 productivity, wage and 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 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. The model thus contributes to the literature on globalization and labour markets.

Keywords: international integration, foreign direct investment, endogenous productivity growth, trade and employment, migration

JEL classification: F15, F16, F21, F22, F43, O41

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Modelling international economic integration: patterns of catching-up, foreign direct investment and migration flows

1 Introduction

In the recent literature on the economic effects of increasing global integration (for recent contributions see Choi and Greenaway, 2000; Feenstra and Hanson, 2001; Ghose, 2003) there now seems to be a consensus that international trade affects labour market outcomes but that the effects are not very strong and other factors are at least as important as trade. These other factors include technological change (for an overview see e.g. Acemoglu, 2002), the availability of labour supply (especially of skilled labour) and the importance of labour market institutions. Further the limitations of the Heckscher-Ohlin (HO) model which has been mainly used in the analysis of trade effects on labour markets have become apparent. For example Slaughter (1998) discusses some of the shortcomings of the HO model and especially the question 'How fast does the Heckscher-Ohlin clock tick?' and argues that the issue of timing and adjustment processes must be addressed. Other limitations of the standard Heckscher-Ohlin framework are the restriction to the 2 country, 2 sectors and 2 factors case which e.g. does not allow that an advanced country may face competition from different types of less developed countries. Recent research also emphasizes the role of social and business networks in shaping trade patterns across countries and industries and may explain important hysteresis effects in bilateral trade flows (see e.g. Rauch, 2001; Eichengreen and Irwin, 1998). Furthermore, in the standard HO-model technology is assumed to be equally available for all countries which is generally seen to be an unrealistic assumption as contributions based on the product cycle and North-South technology transfer show. Technology diffusion lags exist and cannot be neglected. Another criticism which can be raised is that too little attention has been paid - in the context of applying the standard model two countries, two sectors and two factors version of the model - to different patterns of development being followed by different catching-up economies and hence advanced economies may face different pressures of international competition. Furthermore, important hysteresis effects (path dependency) have shaped trade patterns across countries. Finally, foreign direct investment flows are hardly encountered in the standard model. However, as Feenstra and Hanson (1997) have shown, the introduction of FDI flows may reverse the results expected from the Stolper-Samuelson theorem for the less advanced economy (for a recent contribution see Hanson, 2003). Freeman (2003) shows that the impact of changes in trade policy had only modest effects on labour markets and other aspects of economic integration (like migration, capital flows and technology transfer) have greater impacts.

In this paper we introduce a model which - at least in principle - avoids the criticisms summarized above. The model is a dynamic multicountry and multisector model which also allows for different skill types of workers. The dynamic adjustment processes provide room for the analysis of transitory dynamics and path dependencies which affect the structure of specialization of the world economy. Different labour market institutions are captured by wage setting and labour supply adjustment dynamics; these then in turn determine cost competitiveness and attractiveness to foreign investors.

The flows of foreign direct investment play an important role in this paper which builds on an earlier version of the model introduced by Landesmann and Stehrer (2000) and Stehrer (2002). These previous versions of the model focussed on the endogenization of the dynamics of specialization 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 much below that of the advanced economy. We spoke in this context of a 'comparative advantage switchover'.

In the present paper we endogenize FDI flows whereby the Schumpeterian feature of our model, particularly the emergence of transitory per-unit rents, leads to an interesting integration of FDI flows into our model. Global investment flows are sensitive to the emergence of per-unit rents and hence, implicitly, to the productivity- and wage-dynamics of catching up. Using furthermore a simple formulation for 'endogenizing' 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 utilization 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 utilization. We shall see that this opens up an additional dynamic where utilization patterns depend in turn on productivity-wage-price dynamics and a set of price elasticities of demand.

We start in the following with a short verbal account of the main features of the model within which we explore the impact of FDI on the dynamics on international specialization and catching-up. This is followed by a discussion of the way we specify the determinants and effects of FDI in the model. In section 3 we give a formal account of the structure of the model and in section 4 we explore some qualitative features of the impact of FDI with a number of model simulations. Section 5 concludes.

2 Endogenizing FDI flows: determinants and effects

The model is designed to present the structural features of international economic integration: it is multi-sectoral, distinguishing a range of industries and their development, so that structural change can be represented. It formulates dynamics with respect to productivity growth (differentiated across sectors) and wage and price movements, it allows for skill and wage differentiation across workers and it introduces Schumpeterian features in the form of the emergence of transitory unit rents which get eroded over time (through price-to-cost adjustments). The outcome is a trade cum growth model in which transitory dynamics drives changes in international comparative advantage.

The mechanisms inducing structural change are manifold: on the supply side, it is the uneven evolution of productivity (across sectors) which initiates changes in cost and price structures and hence causes substitution effects in the structures of demand (in final demand and in the sourcing of intermediate inputs). The opening up of price-cost gaps during the transitory dynamic which gives rise to Schumpeterian unit-rents also causes an additional investment dynamic which is financed by transitory retained earnings. Furthermore, there are two forms of endogenous productivity effects: one linked to output growth (Kaldor-Verdoorn effect), the other resulting from the investment dynamic (Schumpeter-Arrow). The endogenous productivity effects have further repercussions on the supply-side determinants of structural change. On the demand side, demand functions are specified in a traditional manner with sensitivity to relative prices (substitution effects) and the levels of real incomes (Engel effects).[1]

In an international context, it is the relative dynamic of productivity, wages, prices, and unit rents which matters in determining two types of competitiveness: competitiveness in product markets (resulting from the dynamics of relative unit costs and prices) and competitiveness on capital markets, particularly in the area of attractiveness to FDI (resulting from differential unit rents). In an integrated global economy, the two forms of competitiveness determine the evolution of relative specialization, trade structures and the global allocation of FDI. The resulting relative output and investment dynamic has further endogenous productivity growth and catching-up effects.

Now let us turn to a more explicit discussion of the determinants and effects of FDI in our model. We shall assume that the allocation of FDI flows is determined by differential per-unit rents which arise in different industrial branches and different international locations.[2] What are then the effects of FDI flows? We shall discuss three direct effects: One is a capacity effect, i.e. FDI generates additional capacity, the other is an impact on productivity, i.e. a speeding up of technology transfer, and the third could be an impact on market structure which might affect price-cost margins and/or the speed of price-to-cost adjustments.

Let us deal with the capacity effect first: FDI flows will generate additional production capacity corresponding to the real value of inputs (capital equipment and labour) which can be purchased from these flows. Furthermore we address the issue of the sourcing

[1] For a background of how these aspects of our model relate to earlier research within the broader framework of evolutionary modelling see Fagerberg (2003). Fagerberg states that 'a more general evolutionary theory of the dynamics of technology, growth and trade - whatever this might imply - is arguably still missing.'

[2] In a model with circulating capital only this amounts to the same thing as differential rates of return on invested capital. 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 (discounted) flows of returns.

structure (of inputs) associated with FDI generated production capacity. Another issue concerns the utilization of these capacities. The model will make a distinction between the build-up of capacity and its utilization. Actual production levels will be determined by demand, while capacity expansion derives from profitability of investments which is determined by per-unit earnings on capital. In phases of adjustments in which additional capacity is generated by FDI inflows there is a potential supply-demand 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 think that the approach taken here allows us to address real 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 characterize the model's behaviour during transitory phases.

Let us now address the 'endogenous productivity' effect from the point of view of a catching-up economy: We shall assume that FDI can speed up the technology transfer in such an 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). 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).

During the transitory Schumpeterian dynamics, foreign direct investment can support cumulative processes: we can have a scenario in which fast learning in technologically advanced industries combined with moderate wage increases leads to high per-unit rents in these industries (in which initial productivity gaps to the technologically leader are high). This makes them attractive for FDI inflows and this speeds up productivity growth further which can turn the comparative advantage of a catching-up economy in the direction of technologically advanced industries. 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 approach a steady-state with equal unit costs in all countries (and with an undefined specialization structure).

There are also induced labour market effects: Productivity catching-up is only one side of the story, the other is wage catching-up. Any move in the direction of specialization 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. Given the derived demand for labour which the specialization dynamic entails, the model also allows to track the major migration 'push' and 'pull' factors for different skill groups.

3 Modelling the dynamics of integrated economies

In this section we present the detailed structure of the model, which is then used in the simulation studies.

3.1 Technology

We start with a matrix of technical input coefficients for each country c, denoted by $\mathbf{A^c} = \begin{pmatrix} \tilde{\mathbf{a}}^c_{*1} & \dots & \tilde{\mathbf{a}}^c_{*i} & \dots & \tilde{\mathbf{a}}^c_{*N} \end{pmatrix}$ where $\tilde{\mathbf{a}}^c_{*i} = \begin{pmatrix} \tilde{a}^c_{1i} & \dots & \tilde{a}^c_{ji} & \dots & \tilde{a}^c_{ni} \end{pmatrix}^\top$. A typical element $\tilde{a}^c_{ji}$ denotes a *technical* input coefficient of sector i 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 for potential 'home' and 'regional bias') effects. We denote the demand coefficients for intermediate inputs supplied by country c to country r as

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

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

$$\mathbf{A} = \begin{pmatrix} \mathbf{A}^{11} & \dots & \mathbf{A}^{1C} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{C1} & \dots & \mathbf{A}^{CC} \end{pmatrix}.$$

The global sourcing matrix $\mathbf{A}$ is assumed to satisfy the conditions to guarantee economically meaningful solutions (see e.g. Gale, 1960).

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.

$$\dot{a}^c_{li,z} = \gamma^c_{a_{li,z}} \left(a^c_{li,z} - \bar{a}^c_{li,z} \right). \tag{1}$$

This formulation allows 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 (see section 3.6).

3.2 Prices and rents

Price dynamics is modeled as adjustment to unit costs using a differential equation

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

$c_i^c = \sum_j p_j^c a_{ji}^c + v_i^c$ 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 and country c. 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 equalize 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]

Another 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').[4] In the following we assume an exogenous trend for price equalization. This alters the system of differential equations for prices to

$$\dot{p}_i^c = \delta_{p_i}^c \left[p_i^c - (1+\pi) c_i^c \right] + \delta_{\bar{p}_i}^c \frac{p_i^c - \bar{p}_i}{p_i^c} \tag{2}$$

where $\bar{p}_i = \sum_r q_i^r p_i^r / \sum_r q_i^r$ is a weighted average (by outputs q_i^r) of the prices in the world market and $\delta_{\bar{p}_i}^c$ denotes the convergence parameter.

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 a (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. These transitory rents are calculated as

$$s_i^c = p_i^c - (1+\pi_i^c) c_i^c. \tag{3}$$

3.3 Labour market

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

[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 others are 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 (see below).

[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 one particular currency.

drives wages up or down; and third, we assume skill-specific wage equalization across sectors in the long-run. These three factors are formalized as follows:

$$\dot{w}_{i,z}^c = \kappa_{s,i,z}^c \frac{s_i^c}{\sum_z a_{li,z}^c} + \kappa_{u,z}^c u_z^c w_{i,z}^c + \kappa_{w,z}^c \frac{w_{i,z}^c - \bar{w}_z^c}{w_{i,z}^c} \tag{4}$$

with $\kappa_{s,i,z}^c = \kappa_{s,i}^c w_{i,z}^c / \sum_z w_{i,z}^c$. $0 \leq \kappa_{s,i}^c \leq 1$ is the proportion of per unit (transitory) rents s_i^c paid to workers (bargaining coefficient). 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 skill-specific unemployment rate is defined as $u_z^c = (h_z^c - \sum_i l_{i,z}^c)/h_z^c$ where h_z^c and $l_{i,z}^c$ 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 equalized across sectors because of labour mobility. The (weighted) average wage rate (across sectors) is defined as $\bar{w}_z^c = \sum_i l_{i,z}^c w_{i,z}^c / \sum_i l_{i,z}^c$. 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 equalized for the same skill group across sectors in the long run.

Labour demand is determined by labour productivity and the level of output. We assume that skill-specific labour supply h_z^c adjusts to labour demand according to

$$\dot{h}_z^c = \delta_{h_z^c}^c \left(l_z^c - h_z^c \right) \tag{5}$$

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]

[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).

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 or migration policies of different countries. (For modelling migration flows see section 3.7 below.) In equilibrium with no technical progress in which the economy is growing at a constant rate γ_q the growth rate of each type of labour must be $\gamma_z^c = \gamma_q$. (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.)

3.4 Quantities: Demand Components

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:

$$q_i^c = \sum_{r,j} a_{ij}^{cr} q_j^r + j_i^c + f_i^c. \tag{6}$$

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.

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

The quantity of intermediate inputs to be purchased in one period of production is $\mathbf{a}_{*j}^{*r} q_j^r$; its nominal value is $\mathbf{p}^\top \mathbf{a}_{*j}^{*r} q_j^r$. These intermediate inputs can be purchased from countries c and hence the nominal share (of total outlays on intermediate goods) spent by a sector j located in country r on an intermediate good i from country c is given by $\beta_{A,ij}^{cr} = p_i^c a_{ij}^{cr} / \mathbf{p}^\top \mathbf{a}_{*j}^{*r}$ where the (sourcing) coefficients a_{ij}^{cr} are momentarily given, but are themselves dependent on prices and may thus vary over time as we shall see below. The constraint is given by $\sum_c a_{ij}^{cr} = \tilde{a}_{ij}^r$, i.e. the sourcing coefficients of intermediate inputs must sum up to $\tilde{a}_{ji}^r$, the technical input coefficient for input i in sector j of country r (see also section 3.1 above).

We apply the following modelling strategy: First, we calculate the expenditure shares for intermediate inputs which sector i of country r spends on goods j from country c where we use the following CES specification:

$$\zeta_{ij}^{cr} = \left(p_i^c\right)^{1-\sigma_{\zeta,ij}^r} \left(\varrho_{\zeta,ij}^{cr}\right)^{\sigma_{\zeta,ij}^r} \left(\sum_s \left(p_k^s\right)^{1-\sigma_{\zeta,ij}^r} \left(\varrho_{\zeta,ij}^{sr}\right)^{\sigma_{\zeta,ij}^r}\right)^{-1}$$

where $\sigma_{\zeta,ij}^r$ denotes the elasticity of substitution and $\varrho_{\zeta,ij}^{cr}$ is a parameter reflecting a 'suppliers bias' (it can be used e.g. to include a 'home bias' or a 'regionalist bias' effect). Whereas $\sigma_{\zeta,ij}^r$ is the same across (supplier) countries, the weighting parameter $\varrho_{\zeta,ij}^{cr}$ gives weights to different countries c which may differ for sectors i and j. This formulation satisfies the condition that $\sum_c \zeta_{ij}^{cr} = 1$. Setting $a_{ij}^{cr} = \zeta_{ij}^{cr} \tilde{a}_{ij}^r$ gives the coefficients of the $\mathbf{A}$ matrix which have to satisfy $\sum_c \zeta_{ij}^{cr} \tilde{a}_{ij}^r = \sum_c a_{ij}^{cr} = \tilde{a}_{ij}^r$. 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 subsection 3.1 above.

The second step is to calculate the quantity of goods i in country c purchased by sector j of country r. Given the expenditure structures (as we have already determined the sourcing coefficients a_{ij}^{cr}) this is determined by $(1/p_i^c)\beta_{A,ij}^{cr} \mathbf{p}^\top \mathbf{a}_{*j}^{*r} q_j^r = a_{ij}^{cr} q_j^r$ which refers to demand for good i in country c bought by sector j in country r which produces q_j^r.

This formulation allows for substitution across countries when buying intermediate inputs. Please note that this 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 $\varrho_{\zeta,ij}^{cr}$ thus imply - from the cost side - efficiency losses.

Summing up over countries r and sectors j gives the total demand for intermediate inputs in sector i of country c. Thus the first component in the demand equation (6) is $\sum_{r,j} a_{ij}^{cr} q_j^r$.

3.4.2 Investment demand

Next we 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. $m_k^s = \big((1-\kappa_{s,k}^s)s_k^s + r_k^s\big)$ are entirely used for investment. Total rents plus profits in nominal terms in the economy s and sector i are then given by $m_k^s q_k^s = \big((1-\kappa_{s,k}^s)s_k^s + r_k^s\big)q_k^s$. 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 sectors and countries with relatively higher (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 k in country s invests in sector j of country r the share ν_{kj}^{sr} of total retained earnings:

$$\nu_{kj}^{sr} = \begin{cases} (m_j^r)^{\sigma_{\nu,k}^s - 1} (\varrho_{\nu,kj}^{sr})^{\sigma_{\nu,k}^s} \left(\sum_{t,l} (m_l^t)^{\sigma_{\nu,k}^s - 1} (\varrho_{\nu,kl}^{st})^{\sigma_{\nu,k}^s}\right)^{-1} & \text{for } m_l^t > 0 \\ 0 & \text{for } m_l^t \leq 0 \end{cases}$$

which again results from a CES specification.[6] Summing up over all sectors k in country s gives the investment of country s in sector j of country r. Further summing up over countries s gives total (nominal) investment in country r in sector j, i.e. $\sum_{s,k} \nu_{kj}^{sr} m_k^s q_k^s$.

[6] Specifically we set $m_l^t = 0$ if $m_l^t < 0$ when calculating the shares ν_{kj}^{sr}.

Second, one has to specify the country where the goods for investment of country c in country s are purchased. This is in general driven by cost considerations and thus by relative prices. We denote the shares by ξ_{ij}^{cr}. Again, there are various possibilities: the pattern for purchasing goods may, first, be the same as in the country in which the investment takes place (country r above) or, second, be the same as that of the investing country (country s above). The first possibility is more plausible as the investments are made in plants operating in country r. There can be arguments in favour for the second 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 first possibility.[7] These two possibilities result in different demand patterns.

In the first case the nominal sum invested from sector k in country s in sector j of country r is allocated over goods i in the same way as does sector j in the receiving country r, i.e. $\zeta_{ij}^{cr} = \xi_{ij}^{cr}$. The sourcing coefficients are then $\xi_{ij}^{cr}\tilde{a}_{ij}^{r} = a_{ij}^{cr}$, i.e. the same sourcing coefficients apply as for the intermediate inputs.[8] However, the invested sum in a specific sector has to be allocated across components for intermediate inputs and demand for workers. Analogously to the above the invested sum has to be allocated according to

$$\beta_{J,ij}^{cr} = \frac{p_i^c a_{ij}^{cr}}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r} + v_j^r} \qquad \text{and} \qquad \beta_{L,j}^{r} = \frac{w_{j,z}^r a_{l,jz}^r}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r} + v_j^r}.$$

The first term refers to the allocation of nominal investment across intermediate inputs and the second term to demand for different skill types of workers. Investment demand in sector i of country c is thus given by

$$j_i^c = \frac{1}{p_i^c} \sum_{r,j} \beta_{J,ij}^{cr} \sum_{s,k} \nu_{kj}^{sr} m_k^s q_k^s$$

which is the second component in the demand equation (6).

3.4.3 Consumption demand

For demand on consumption goods we assume in this paper that consumers maximize a Cobb-Douglas utility function $U^r = \sum_{i,c} (q_i^c)^{\alpha_i^{cr}}$ with $\sum_{c,i} \alpha_i^{cr} = 1$ from which the corresponding demand functions can be derived. Specifically this implies that the utility function is the same for different skill types of workers and that preferences are homothetic.

[7] The sourcing structure of a country may change however due to the inflow of foreign direct investment.

[8] In the second case the nominal sum invested from sector k in country s in sector j of country r is allocated over goods i in the same way as does sector j in country s, i.e. $\zeta_{ij}^{cs} = \xi_{ij}^{cs}$. This results in sourcing coefficients $\xi_{ij}^{cs}\tilde{a}_{ij}^{s} = a_{ij}^{cs}$, which results in a demand pattern with nominal shares given by $\beta_{J,ij}^{cs} = p_i^c a_{ij}^{cs}/(\mathbf{p}^\top \mathbf{a}_{*j}^{*s} + v_j^r)$ and $\beta_{L,j}^{r} = w_{j,z}^r a_{l,jz}^r/(\mathbf{p}^\top \mathbf{a}_{*j}^{*s} + v_j^r)$. Summing up gives demand for investment goods in sector i of country c $j_i^c = (1/p_i^c) \sum_{s,k,j} \beta_{J,ij}^{cs} \nu_{kj}^{sr} m_k^s q_k^s$. In this case the technology (input coefficients) of the investing country s would apply in country r, however. Thus a mixture of techniques would be operated in country r. Although this is an interesting case to be analysed in future research, we stick here to the first case.

The corresponding demand function is then given by $\alpha_i^{cr} w_{j,z}^r l_{j,z}^r / p_i^c$. Summing up over workers of skill types z employed in sectors j in countries r gives consumption demand for good i in country c, i.e.

$$f_i^c = \frac{1}{p_i^c} \sum_{r,j,z} \left(\alpha_i^{cr} w_{j,z}^r a_{lj,z}^r + \alpha_i^{cr} w_{s,j,z}^r a_{lj,z}^r \right) q_j^r.$$

The second term where $w_{s,j,z}^r = \kappa_{s,j,r} s_j^r / \sum_z a_{l,jz}^r$ results from the bargaining of workers over rents (see equation (4)). This is the third term in the demand equation (6).

3.4.4 Existence of solution

The system of equations (6) is homogenous as all components on the rhs depend on q_i^r. Thus one has to show that a nontrivial solution for q_i^r exists. In this way the model differs from a classical input-output model where the final demand vector is given (in quantity terms) and under certain conditions on the input-output matrix an economically meaningful solution exists. Under the assumption of fixed prices (which implies constant wages) the nominal shares discussed above are constant. In this case one can show that a nontrivial solution exists (see the appendix and Stehrer (2002)). The necessary condition is basically that all income (either rent or wage income) is actually spent. Further note that this result does not assume that prices are at their equilibrium values.

3.5 Output dynamics

Let us now discuss the dynamics of the output system. We first show how the growth rates of the system are calculated; second, we characterize the balanced growth path as a special case and, third, discuss potential demand-supply mismatches.

3.5.1 Growth rates

The nominal sum which is invested (out of global retained earnings) in sector j of country r is given by $\sum_{s,k} \nu_{kj}^{sr} m_k^s q_k^s$. The physical increase in capacities is made up of the set of capital goods $k = 1, \dots, N$. Under the assumptions of case one above (i.e. the investor faces the same global sourcing coefficients as the domestic producers and thus the coefficients $\beta_{J,ij}^{cr}$ are equal for both types of investors) the increase in capacity of the component i in country c of a sector k in country r derived from additional investment can be calculated as $(1/p_i^c)\beta_{J,ij}^{cr} \sum_{s,k} \nu_{kj}^{sr} m_k^s q_k^s$. Inserting for $\beta_{J,ij}^{cr}$, summing up over all countries c and dividing by the existing 'stock' of intermediate inputs gives the growth rate of all components i in sector j

$$g_j^r = \frac{1}{\tilde{a}_{ij}^r q_j^r} \frac{\sum_{s,k} \nu_{kj}^{sr} m_k^s q_k^s}{\mathbf{p}^\top \mathbf{a}_{*j}^{*r} + v_j^r} \tilde{a}_{ij}^r = \frac{\sum_{s,k} \nu_{kj}^{sr} m_k^s q_k^s}{(\mathbf{p}^\top \mathbf{a}_{*j}^{*r} + v_j^r) q_j^r}. \tag{7}$$

Analogously one can show that demand for labour is growing also at these rates. Thus the derivation of the growth rate guarantees that the increase in capacities (intermediates and labour) would be proportional in all equipment goods i and for all skill types of workers. Hence, the capacity effect in equipment good i is equivalent to the overall capacity increase in sector j. But still capacity in the particular sectors may grow at different rates. Further the two results above show that switching from one supplier country to another would not change the growth rate if both suppliers have the same price. However, switching to a cheaper supplier results in a higher growth rate as a higher quantity can be purchased. Demand out of workers income spreads across sectors and countries via the demand formula f_i^c given above. Further demand out of rents is growing also at rate g_j^r which spreads over to other sectors via the allocation of rents for investment and demand arising from these investments. The dynamics of the economy is then given by

$$\dot{\mathbf{q}} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{D}_j + \mathbf{D}_f)(\mathbf{I} + \mathbf{G})\mathbf{q} - \mathbf{q} \tag{8}$$

where $\mathbf{D}_j$ denotes a matrix with typical element $(1/p_i^c)\sum_{r,j}\beta_{J,ij}^{cr}\nu_{kj}^{sr}m_k^s$ and $\mathbf{D}_f$ denotes a matrix with typical element $(1/p_i^c)\sum_z\left(\alpha_i^{cr}w_{j,z}^r a_{lj,z}^r + \alpha_i^{cr}w_{j,z}^r a_{lj,z}^r g_j^r + \alpha_i^{cr}w_{s,j,z}^r a_{lj,z}^r\right)$. $\mathbf{G}$ denotes a diagonal matrix with the sector specific growth rates g_j^r on the diagonal.

3.5.2 Balanced growth

For a balanced growth path prices must be constant (although not necessarily at their equilibrium values). This implies that wage rates are constant as well. Thus in this section we assume that labour productivity is given and wage rates are fixed. The latter implies that in the case of rents the parameter $\kappa_s^c = 0$ and no unemployment exits. This determines not only the level of the labour supply but also the composition with regard to skill types. One can distinguish two cases. The first case is that mark-up rates are constant over time but not necessarily equal across sectors and countries. For balanced growth investment resources have to be allocated in a specific way. Thus, this case allows for different mark-up ratios (across countries and sectors) and the uneven emergence of rents. The second case - which is a more classical one - uses the assumption that profits per unit are equalized, i.e. there is a common mark-up ratio π and transitory rents are zero. Under the assumption that investment takes place only in the own sector and country, the world economy also grows at a balanced growth rate (thus this rules out foreign direct investment flows). Of course, the solution given in the first case also holds for the assumption of equalized profits.

We start with the first case and then we only shortly discuss the second one. As was shown in Stehrer (2002) the allocation of the nominal sum of retained earnings to guarantee a balanced growth path must satisfy the condition $\nu_j^r = (\mathbf{p}^\top\mathbf{a}_{*j}^{*r} + v_j^r)q_j^r/(\mathbf{p}^\top\mathbf{A}\mathbf{q} + \mathbf{v}^\top)\mathbf{q}$ which specifies how much each sector must attract from the resources available, but does not specify the specific flows across countries and sectors. Replacing ν_{kj}^{sr} in equations (7) with ν_j^r and dividing by the existing stock of intermediate inputs $a_{ki}^{rs}q_i^s$ gives the growth rate of capacities

$$g_i^s = \frac{\mathbf{m}^\top\mathbf{q}}{(\mathbf{p}^\top\mathbf{A} + \mathbf{v}^\top)\mathbf{q}}.$$

Note that this growth rate is equal for all sectors and countries as it is 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. Analogously one can show that demand for workers (and thus, capacities) are growing at the same rate. Equation (8) then collapses to

$$\dot{\mathbf{q}} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{D}_j + \mathbf{D}_f)(1 + g)\mathbf{q} - \mathbf{q}.$$

One can show easily that at the balanced growth path the term $\mathbf{D}_j\mathbf{q}$ collapses to $g\mathbf{Aq}$ and the matrix $(\mathbf{D}_j + \mathbf{D}_f)$ to $(\mathbf{I} - \mathbf{A})$ and thus we have $\dot{\mathbf{q}} = g\mathbf{q}$. Further it is satisfied that $(1+g)\mathbf{q} = \mathbf{q} + \dot{\mathbf{q}} = \mathbf{A}^{-1}(\mathbf{Aq} + g\mathbf{Aq})$ which means that the output can be produced with the available intermediate inputs $\mathbf{Aq}$ and the goods demanded for investment. 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 and the growing volume of retained profits spent on investment goods.

Under the special case of an equal profit rate π in all sectors and countries and no transitory rents the expression for the growth rate collapses to $g_i^s = \pi\mathbf{c}^\top\mathbf{q}/\mathbf{c}^\top\mathbf{q} = \pi$. In this case one may also assume that profits in each sector are only invested for building up capacities of the own sector. The growth rate can then be calculated from equation (7) as $g_j^r = m_j^r q_j^r/(\mathbf{p}^\top\mathbf{a}_{*j}^{*r} + v_j^r)q_j^r = \pi c_j^r/c_j^r = \pi$.

3.5.3 Transitory capacity-demand mismatches

In the previous section we discussed the demand side of the system and the balanced growth path. Let us now analyse the supply side of the system in order to interpret the dynamics of quantities in disequilibrium.

Imbalances arise as uneven technological progress implies uneven distribution of profits and rents. >From the CES specification this can imply that a specific country and sector attracts a high investment share although demand may not shift towards this particular sector such as to guarantee full capacity utilization. We shall look at this from the viewpoint of country r as the receiving country and sector j as the sector in which investments are being made. The capacity effect takes place in country r and sector j, i.e. the receiving country, although the demand effect will also be felt in other economies where intermediate goods are also purchased. What matters is that the capacities of sector j are expanding as a result of the allocation of FDI in the sector which in turn depends on the relative attractiveness of that sector as a destination of rents and profits made globally. The relative attractiveness of different destinations have been specified before through the 'share' coefficients ν_{kj}^{sr}. The rates at which capacities are expanding in these sectors can be determined 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.

In situations off the balanced growth path the equilibrium relations are violated. Especially there may arise a capacity-demand mismatch, as the two sides are determined by rather different variables. Thus there may arise excess capacities due to shifts in consumption demand, investment demand or changes in the sourcing matrix. In the case of supply (as determined by capacities) being higher than demand for a particular good one could either assume that the short-term productivity of the sector decreases or that there is some underutilization of capacities. In the case of excess demand on the other hand 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 regarding the adjustment processes, the arising imbalances are numerically negligible.

We interpret the dynamics of the output system in the following manner. As we have seen above, the general growth path differs from the balanced growth situation 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 these rates. 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. Specifically we assume that if this is not satisfied productivity of the system adjusts in a way that actual output is equal to demand; i.e. demand is satisfied at each point in time via (small and short-term) productivity fluctuations. 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-determined output and demand.

3.6 Weak and strong Gerschenkron effects and the impact of FDI on technology transfer

A much discussed aspect 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.

3.6.1 Exogenous catching-up

The 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 Gerschenkron's (1952, 1962) 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). We use the same specification as in equation (1) above, i.e. $\dot{a}^c_{li,z} = \gamma^c_{a_{li,z}} \left(a^c_{li,z} - \bar{a}^L_{li,z} \right)$, where $\bar{a}^c_{li}$ is replaced by $\bar{a}^L_{li}$ which denotes the labour input coefficient of the productivity leader (where technology is at the global technology frontier).

We distinguish two cases: The 'weak' Gerschenkron effect means that catching-up for the industries takes place at the same rate of convergence, i.e. the convergence parameters $\gamma^c_{a_{li,z}}$ are assumed to be equal across industries. This does not imply however that productivity growth is equal as the 'gap' from the frontier matters at each point of time. A 'strong' Gerschenkron effect takes place when the convergence parameter is higher in industries with the higher initial gap. We shall show that if there is a 'strong' Gerschenkron pattern there may be a 'comparative advantage switchover' that can take place in the course of catching up.

3.6.2 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 formalization 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 utilize 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. This last point will be introduced in this version of the model by assuming that the speed of technology transfer $\gamma^c_{a_{li,z}}$ is a function of FDI inflows.

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

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

Inserting for $\beta^{rc}_{J,ki}$ gives $FDI^c_{real,i} = \sum_{s,j} \nu^{sc}_{ji} m^s_j q^s_j / \mathbf{p}^\top \mathbf{a}^{*c}_{*i} q^c_i$ for $s \neq c$. The specific formulation used in the simulations below is

$$\dot{a}^c_{li,z} = \left(\gamma^c_{a_{li,z}} + \gamma^c_{FDI,i,z} FDI^c_{real,i} \right) \left(a^c_{li,z} - \bar{a}^L_{li,z} \right) . \qquad (9)$$

3.7 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. Additonally, one should take into account the fact that the willingness to migrate to a particular location might depend on other aspects (not explicitely considered here, such as geographic or cultural distance) and might 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 determine the changes in the labour supplies (by skill type) in the different locations according 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:

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

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, geographic and 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

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. First, we assume fixed coefficients a_{ij}^{rs} in the sourcing matrix. This also fixes the nominal shares for investment demand components ξ_{ij}^{rs}. For consumption demand we assume that $\alpha_i^{cr} = 0.125$ and $\alpha_i^{cc} = 0.375$. All 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, we do not allow for migration across countries. In all the simulations we assume that 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 $\gamma^{A}_{a_{li,u}}$ is the same for all industries and skill-types which implies that technical progress in country A is neither sector nor factor biased.

The starting values (given in table 4.1) reflect a stationary state of an integrated international economy with differences in labour productivity. The simulations start in this particular equilibrium and are then subject to, at first, exogenous productivity growth which differ between countries and across sectors. The simulations reported focus mainly on differences in parameters of the catching up economy which we shall discuss in the next section.

4.1 Weak and strong Gerschenkron effects

For the catching-up country 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 $\gamma^{c}_{a_{li,u}}$ themselves are the same across the two sectors. The strong Gerschenkron effect implies that the convergence parameter is higher in the sector where the initial gap is higher (sector 1). In the simulations reported below we only show the runs with the strong Gerschenkron effect for the catching up economy but different responses of foreign direct investment flows with regard to differences in per unit rents:

1. In the first scenario no transfer of rents (or international investments) across the countries is taking place (i.e. $\nu^{cr}_{ij} = 0.000$).
2. 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 effect.

The other parameter values can be found in table 4.2 (the second value refers to scenario 2). For country B we have both the strong Gerschenkron pattern of productivity catching-up implying that the 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.

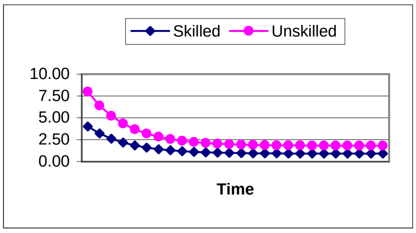
Given the structure of the starting values and the assumptions about catching-up this implies a sector-biased technical progress (but not factor-biased) in country B as can be seen in figure 4.1. This results in a much faster decrease of the relative price of industry 1 in country B than in country A 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-equalization process and the effect of lower input prices from country B (see figures 4.2 and 4.3). Furthermore there is excess demand for labour for both skill groups in country A. The reason for this is that, first, technical

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	
g_i	0.000		0.000		0.000		0.000	
	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	

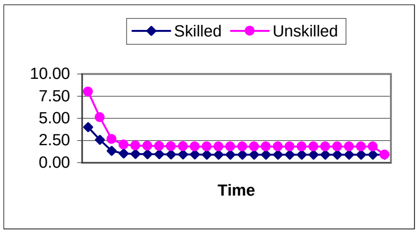
Table 4.1: Starting values used in simulations

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}	0.100		0.100		0.100		0.100	
$\sigma_{\nu,k}$	1.000/2.500		1.000/2.500		1.000/2.500		1.000/2.500	
$\varrho_{\nu,ki}^{rr}$	1.000		1.000		1.000		1.000	
$\varrho_{\nu,ki}^{rs}$	0.000/1.000		0.000/1.000		0.000/1.000		0.000/1.000	
α_i^{rr}	0.375		0.375		0.375		0.375	
α_i^{rs}	0.125		0.125		0.125		0.125	
	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	-0.030	-0.030	-0.015	-0.015
$\gamma_{FDI,i,z}$	0.000	0.000	0.000	0.000	0.000/-2.000	0.000/-2.000	0.000/-2.000	0.000/-2.000
	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	

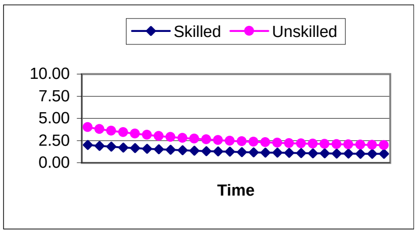
Table 4.2: Parameter values used in simulations (Scenario 1)



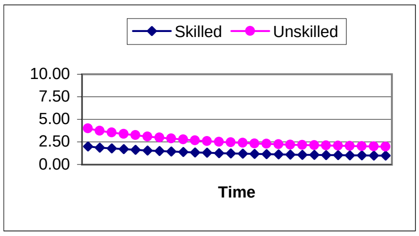
Scenario 1, industry 1



Scenario 2, industry 1

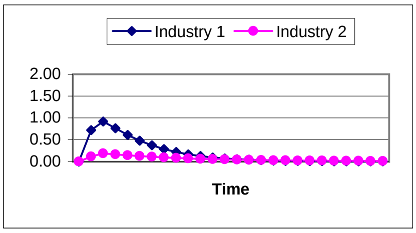


Scenario 1, industry 2

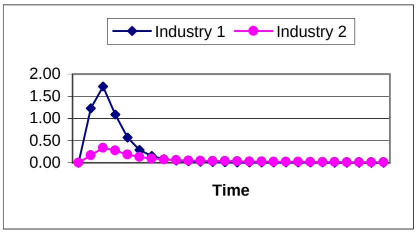


Scenario 2, industry 2

Figure 4.1: Labour input coefficients

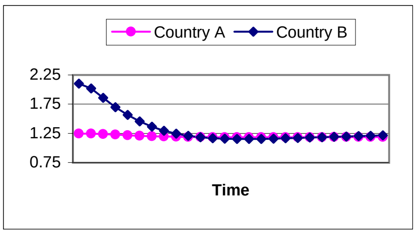


Scenario 1

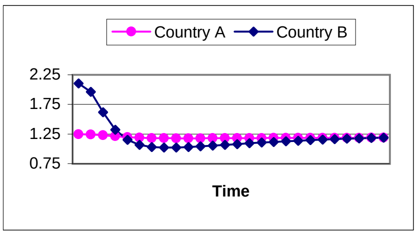


Scenario 2

Figure 4.2: Rents



Scenario 1



Scenario 2

Figure 4.3: Relative price of skill intensive industry

progress (hence the labour saving effect) is quite modest and, second, the growth process in country B creates more demand in country A (mainly for investment) because of the high rent income. 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 specialization effects).

In both countries the relative output of the skill-intensive industries (see figure 4.4) 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

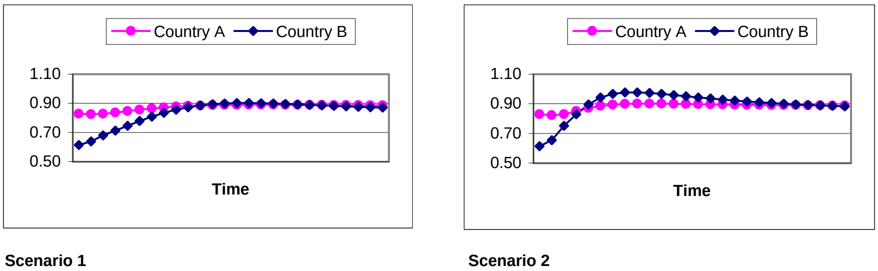


Figure 4.4: Relative output of skill intensive industry

investment flows are endogenized, 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. As a result we observe an even more dramatic improvement of the relative cost and price dynamics in favour of sector 1 and the 'switchover in comparative advantage' occurs even earlier (in period 4). There is 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). 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. Figure 4.5 shows the evolution of the relative price of the skill intensive industry in country A relative to that of country B, i.e. $(p_1^A/p_2^A)/(p_1^B/p_2^B)$.

4.2 Factor biased technical change

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

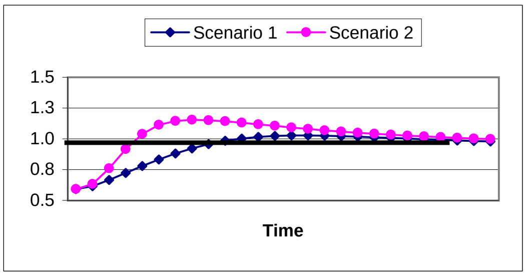


Figure 4.5: Timing of comparative advantage switchover

of the skill composition of labour demand in the different sectors which, at any point in time, are defined by the labour input coefficients and the levels of output of the different sectors. Over time, changes in the overall skill composition of labour demand in the economy result from different factors:

1. a potential 'skill (factor) bias' in the process of technical change which might differ across industries;

2. from a sector-bias of technical change, i.e. rates of non-skill specific rates of productivity growth in different industries as industries have different skill intensities;

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

4. from substitution effects due to relative wage changes (across skill groups), again the elasticities of substitution might differ across industries.

In this paper we focus on points 1.-3. above. Substitution effects due to relative wage changes are not taken into account; however, we can safely assume that either these changes or the elasticities of substitution would have to be very large to get different results in this model. Further, in this model we do not focus on changes in consumption via income elasticities which are set equal to one for all sectors as we assumed a simple Cobb-Douglas demand specification. 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 led to a 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 towards the skill intensive sector the effect of the sector biased technical progress on relative employment levels of skilled and unskilled labour was stronger.

Let us now present a scenario in which technical progress is also factor biased (i.e. in favour of skilled workers) in the catching-up economy. The assumption made here is straightforward and fits naturally into a catching-up scenario: the advanced economy starts off with a technology which requires a higher skill composition of its labour force than the catching-up economy. As the catching-up process proceeds, the catching-up economy will also adjust its technology such that it ends up using the same technology as the advanced economy. This automatically induces a skill-biased technical progress in the catching-up economy (we assume no further skill bias in the advanced economy). Given this background in exogenously given paths of labour input coefficients, we shall look at two simulations: scenario 3 allows for the skill-biased pattern of technological catching-up but does not allow for FDI, while scenario 4 allows for the skill-biased pattern of technological progress but, in addition, allows both for FDI and also for the endogenous productivity (technology transfer) effect which FDI induces. In both simulations we used the 'weak' Gerschenkron hypothesis such that differences between the two scenarios result only from endogenous factors (attraction of FDI and learning-by-doing effects). The speeding up of technology transfer means that the catching-up economy moves more speedily along the given trajectories of the labour input coefficients depicted in figure 4.6 which shows the labour input coefficients of unskilled workers in country B in sector 1 and 2. Figure 4.7 depicts the impact upon relative prices and relative output levels (of

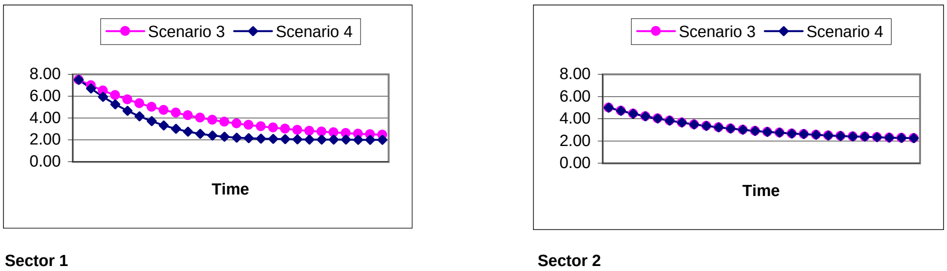


Figure 4.6: Labour input coefficients of unskilled workers in country B

the two types of industries), and on relative employment levels and relative wage rates (of workers with the two types of skills) in the catching-up economy. We can see that in these simulations, the relative price of the skill-intensive good falls in both scenarios. As was the case in the previous scenarios, this results from sector-biased technical progress in favour of the skill-intensive sector. However, this time, there is the additional factor-bias effect which means that there is relatively less saving of skilled labour compared to unskilled labour in both industries of the catching-up economy. This effect is stronger in the skill-intensive industry. Consequently, price competitiveness of that industry improves somewhat less than in the previous scenarios. Nonetheless, because of the sector bias in overall productivity growth, the industry nonetheless gains in competitiveness and the output structure moves in its favour. It is interesting to observe the differences between the scenario without FDI (scenario 3) and the one with endogenous FDI effects on productivity catching-up (scenario 4): we can see that the additional productivity enhancing effect of FDI leads to even faster productivity growth in the industry in which there is more potential for catching-up (industry 1) and hence it at first improves more strongly its price competitiveness which also entails more pronounced effects on the output structure in its favour. However, as these output effects go hand in hand with a stronger

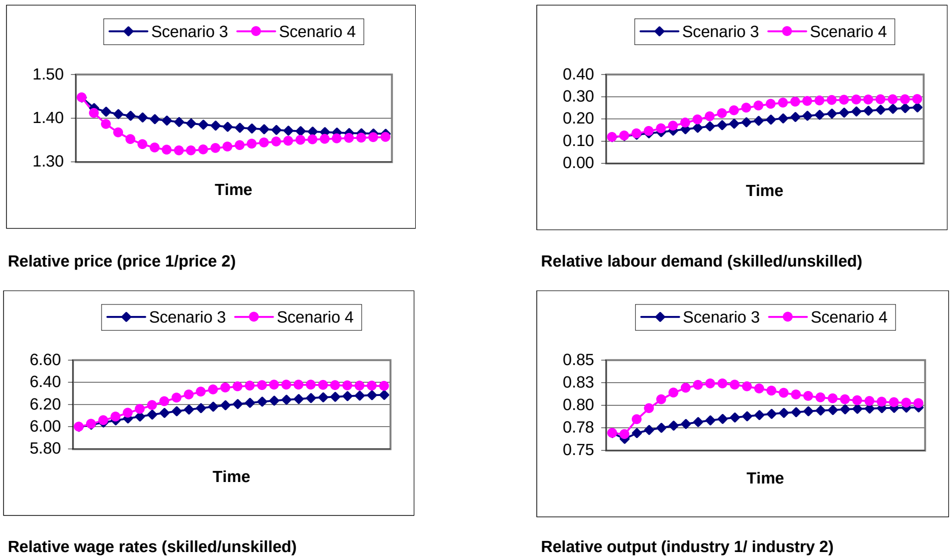


Figure 4.7: Scenarios 3 and 4

demand for skilled labour in the economy (as industry 1 is also the more skill-intensive one) there is a follow-up effect on price competitiveness. Relative scarcity of skilled labour drives up the relative wage rate of skilled labour and reverses from a certain point onwards the tendency of the more skill-intensive industry to improve its price competitiveness. The impact of this relative loss in price competitiveness then shows up in a slight shift back to the original output structure. Of course, a policy of sustained increases in the supply of skilled labour in the catching-up economy could counter-act this tendency.

5 Concluding remarks

In this paper we presented a dynamic framework for modelling the effects of international integration via trade, foreign direct investment and migration flows on specialization patterns and labour markets. Let us summarize the qualitative points revealed from the conducted simulations.

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 distinguish two patterns: one in which - despite of a weak Gerschenkron 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' (this scenario was not reported above). In this case, the catching-up economy remains (relatively) specialized 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 parameter $\gamma^c_{a_{li,z}}$ in this sector (see Landesmann and Stehrer, 2001, for an empirical investigation). In this case (Scenario 1), there may occur a 'comparative advantage switchover' i.e. the catching-up economy gains a specialization 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 as differential wage growth between skilled and unskilled workers in the catching-up economy nullifies again the transitory competitive advantage of the skill intensive sector (the long-term integrated equilibrium is always characterized by uniform prices by sectors across countries).

The introduction of foreign direct investment (scenario 2) opens another channel through which international integration affects output structures and specialization in integrated economies. Rather than being directly determined by comparative (relative price) advantages, as in the case of pure trade integration, foreign direct investment flows are determined by relative (retained) unit rents. In the simulations it is shown that the dynamics of relative unit rents introduces a shift in specialization 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 specialization. This gets strengthened when we introduce an 'endogenous productivity' effect which describes the impact which FDI has on speeding up the technology transfer in the catching up economy. The 'strong Gerschenkron' effect then gets much more pronounced and the possibility of a much faster dynamic in the upgrading 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 switchover'.

The introduction of foreign direct investment driven by relative rents also opened up an interesting dimension in our model with regard to capacity-side versus demand-side determination of production patterns. This mismatch arises if a country may attract a high investment share but may not succeed in attracting enough world demand which could lead to a capacity-demand mismatch in this particular country. This potential mismatch opens an interesting future research task.

Lastly, the labour market implications of analysing the various channels of international integration (trade, FDI, migration) 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.[9] The employment implications for skilled and unskilled labour are explicitly derived within a framework which takes account of the change in technology which a catching-up process entails and the potentially changing nature of comparative advantage in the course of catching-up. We have shown that a complex set of relationships determines the relative skill composition of the labour forces in advanced and catching-up economies.

[9] See also the analysis by Feenstra and Hanson (1997), who adopt a different framework from an Heckscher-Ohlin framework to analyse the impact of international integration on labour markets.

A Mathematical appendix

The investment goods demand vector is given by $\mathbf{j} = \mathbf{D}_j\mathbf{q}$ where $\mathbf{D}_j$ is a matrix with typical element $\sum_{s,j} \beta^{cs}_{J,ij}\nu^{rs}_{kj}m^r_k/p^c_i$. Inserting for $\beta^{cs}_{J,ij} = p^c_i a^{cs}_{ij}/c^s_j$ simplifies this element to $\sum_{s,j} a^{cs}_{ij}/c^s_j\gamma^{rs}_{kj}m^r_k$. 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 industries with $\nu^s_j = c^s_j q^s_j/\mathbf{c}^\top\mathbf{q}$. Inserting for γ^{rs}_{kj} yields $m^r_k \sum_{s,j} a^{cs}_{ij}q^s_j$. In a compact form the expression $\mathbf{D}_j\mathbf{q}$ can be rewritten as

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

The demand vector for consumption goods $\mathbf{f}$ can be represented by $\mathbf{D}_f\mathbf{q}$ where $\mathbf{D}_f$ has a typical element $\alpha^{cs}_i v^s_j/p^c_i$ with $\sum_{i,s}\alpha^{cs}_i = 1$.

We have to show that $\mathbf{q} = \mathbf{A}\mathbf{q} + g\mathbf{A}\mathbf{q} + \mathbf{D}_f\mathbf{q}$ has a nontrivial solution. This is a homogenous system of equations as $\mathbf{0} = (\mathbf{I} - \mathbf{A} + \mathbf{D}_j + \mathbf{D}_f)\mathbf{q}$. Premultiplying this equation with $\mathbf{p}^\top$ yields

$$\mathbf{p}^\top\mathbf{q} = (1+g)\mathbf{p}^\top\mathbf{A}\mathbf{q} + \mathbf{p}^\top\mathbf{D}_f\mathbf{q} = (1+g)\mathbf{p}^\top\mathbf{A}\mathbf{q} + (1+g)\mathbf{v}^\top\mathbf{q}.$$

Inserting for $g = \mathbf{m}^\top\mathbf{q}/\mathbf{c}^\top\mathbf{q}$ gives $\mathbf{p}^\top\mathbf{q} = \mathbf{c}^\top\mathbf{q} + \mathbf{m}^\top\mathbf{q}$ which is satisfied by definition. Thus there exists an output vector (for the balanced growth path) for which $(\mathbf{D}_j + \mathbf{D}_f)\mathbf{q} = (\mathbf{I} - \mathbf{A})\mathbf{q}$ is satisfied and the system has a nontrivial solution.

Engel curve effects for consumption demand can easily be included into the model by assuming that the nominal expenditure shares depend on wage rates and prices. As the model allows for industry specific wage rates of a particular skill type of workers z this can be written as $\alpha^{cs}_{i,jz}(w^s_{j,z}, \mathbf{p}^\top)$, i.e. the nominal expenditure share of a worker of skill type z in industry j in country s demanding in country c and industry i. We have to assume that $\sum_{c,i}\alpha^{cs}_{i,jz} = 1$, i.e. total income equals total expenditures. A typical element in the $\mathbf{D}_f$ matrix then becomes $\sum_z \alpha^{cs}_{i,jz}w^s_{j,z}a^s_{lj,z}/p^c_i$.

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