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Working Paper

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Thünen-Series of Applied Economic Theory - Working Paper, No. 65

Provided in Cooperation with:

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Suggested Citation: Hetze, Pascal (2006) : Economic integration, labor reallocation, and growth, Thünen-Series of Applied Economic Theory - Working Paper, No. 65, Universität Rostock, Institut für Volkswirtschaftslehre, Rostock

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Thünen-Series of Applied Economic Theory
Thünen-Reihe Angewandter Volkswirtschaftstheorie

Working Paper No. 65

**Economic Integration, Labor Reallocation, and
Growth**

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2006

Economic Integration, Labor Reallocation, and Growth

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November 27, 2006

Abstract

This paper develops an endogenous growth model with continuous labor reallocation. Economic integration increases the home availability of technologies globally developed. The wider technology pool has implications for the vintage structure of the manufacturing sector and affects the revenues earned in the two sectors R&D and manufacturing. The free exchange of technologies across the borders leads to structural change and labor reallocation within manufacturing and between the sectors. If there arises too much job destruction caused by economic integration, unemployment may be a consequence of more openness to technologies developed abroad.

JEL-classification: F43, O33, J63

Keywords: economic integration, job destruction, job creation, endogenous growth

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1 Introduction

The process of economic integration is ongoing if not accelerating during the last decade. The enlargement of regional integration blocks (NAFTA, EU, and others) and global tariff reductions, as for example the WTO Uruguay round negotiated, are supposed to stimulate growth and wealth in the contributing countries. One of the channels through which economic integration affects growth is that openness to international competition leads to efficient resource reallocation and structural and technological change. While the factor reallocation tends to increase overall productivity with positive welfare effects, this process generates costs for workers undergoing a labor turnover when their former employments fall victim to the structural change caused by the removal of former protectionism. Haltiwanger et al. (2004) and Ribeiro et al. (2004) show in their empirical studies that trade liberalization indeed increased the pace of labor reallocation with negative employment effects in Latin America and Brazil respectively.

The main argument for economic integration is that it opens up productivity potentials through efficient resource reallocation or international technology spillovers. Models of growth through innovation in the tradition of Rivera-Batiz and Romer (1991) show that a high degree of free technology exchange between the economies leads to high rates of economic growth as integrated economies enlarge the scope of available R&D products. The positive effect of openness on innovation and productivity growth is supported by empirical studies. For example, Keller (2002) concludes that R&D conducted abroad contributes up to 20 per cent to productivity increases in home industries.

However, the effects of economic integration on technological change are mixed if we consider economies with structural differences. Economic integration may enlarge those differences as it generates resource reallocation in the economies. Depending on the initial resource allocation, it might then occur that one country specializes in the highly productive, the other one in the low productive industry. This implies less growth prospects for the poorer economy. See, for example, the contributions by Grossman and

Helpman (1990), Rivera-Batiz and Xie (1993), and Feenstra (1996).

Other negative consequences of economic integration can arise in the labor market. Economic integration with skill-biased effects may result in wage inequality (Bretschger, 1997), unemployment (Davis, 1998), or both (Şener, 2001). Unemployment arises in these models if institutions, such as unions, minimum wages etc., make wages rigid.¹ This paper adds to the literature the case that, even without the skill-bias and with similar developed countries, economic integration leads to structural change and labor reallocation. The direction we consider in the relationship between economic integration and labor reallocation is that openness affects endogenous job creation and job destruction. Davidson, Martin and Matusz (1999) and Davidson and Matusz (2005) explore the implications of the reverse approach from turnover to trade, which explains trade patterns and export rates as a result of exogenously-given cross-sector differences in labor turnover. Despite the exogeneity of labor reallocation rates, their model suggests effects of trade on unemployment. With different search technologies in different sectors, sectoral shifts due to free trade may increase aggregate unemployment if a country has a comparative advantage in producing the good of the high-unemployment sector. This paper considers sectoral shifts under a different focus, which is their effects on technological change and growth. This has as one implication that, if there is a negative effect of economic integration on employment, the stimulation of growth through economic integration reduces.

The purpose of this paper is to investigate interactions between unemployment and growth in an open economy. We construct a two-sector, two-country model in which growth is driven by home and foreign R&D. Via labor reallocation, technological change has effects on the employment and the unemployment levels.² The modelling of the paper combines endoge-

¹ There are alternative approaches to introduce unemployment into trade models. For example, Matusz (1996, 1998) shows that unemployment due to efficiency wages may decline if economic integration raises real wages.

² The analysis of technological change in a matching model of unemployment goes back to Pissarides (2000) and Aghion and Howitt (1994). In a more micro-level approach, Mortensen and Pissarides (1998) show on which condition technological progress results in more labor reallocation in combination with an increase in unemployment.

nous innovation of the type developed by Aghion and Howitt (1992) with a vintage-separated manufacturing sector, in which differences in relative productivity lead to labor reallocation from old to new vintages. Economic integration tends to stimulate innovations and increases the extent of labor reallocation at the same time. On condition that frictions hinder job creation, unemployment occurs as a symptom of economic integration. The analysis shows that this effect is strong in highly protective economies and in those countries that are highly engaged in R&D. Caused by a fall in employment, the stimulating effects of openness on growth can disappear.

The paper is organized as follows. Section 2 introduces the model with endogenous innovation and explains how this is related to job destruction and job creation. Section 3 shows the equilibrium labor allocation with unemployment. In section 4, we present the effects of economic integration. Finally, section 5 concludes the paper.

2 The Model

The model analyzes the interaction between technological change and labor reallocation. From this we will derive how economic integration affects growth and employment. We construct a two-sector model with R&D and manufacturing. Equilibrium growth is driven only by new technologies developed in R&D of the two considered economies. According to the two-country analysis, we henceforth distinct variables for country $j \in [h, f]$, where h denotes the home country and f the foreign one. To keep the exposition simple, we refer to the home country if no subscript occurs.

We consider economies populated by a mass L_j of infinite living individuals. The individuals are endowed with one unit of labor which they supply inelastically. Accordingly, L_j equals the total labor supply in country j . Labor is employed in either manufacturing or R&D. Alternatively, workers can be unemployed. Labor allocation and the employment level depend on relative income opportunities and the extent of restrictions on job creation. Both will be derived in the remainder of the section.

2.1 Technological Progress

Technological progress is the only source of equilibrium growth. At any time t , R&D in both countries forms new technologies and shifts the national frontier technology $\tau_{j,t}^{\max}$. As soon as a research unit develops an innovation this adds a new technology τ to the current number of available technologies in the interval $[0, \tau_{j,t}^{\max}]$. Hence, the span of the interval increases over time. Technological progress evolves productivity gains and the embodied productivity level A_τ increases with any subsequent technology by a factor λ :

$$A_\tau = \lambda A_{\tau-1}. \quad (1)$$

Technological progress spreads out the productivity gains of innovations within a country and across the borders. However institutional or technological barriers may prevent innovations from a full diffusion. Let $\sigma_{j,j}$ denote the degree of free technology exchange, where $\sigma_{h,h} = \sigma_{f,f} = 1$ and $0 \leq \sigma_{h,f}, \sigma_{f,h} \leq 1$. While the access to home technologies at home is unrestricted, diffusion barriers, such as tariffs, restrict the flows across borders and partly exclude foreign innovations. Hence, $\sigma_{h,f}$ measures the share of foreign innovative technologies which are available at home (and $\sigma_{f,h}$ for the other way around). The range is between the closed economy case, $\sigma_{h,f}, \sigma_{f,h} = 0$, and the fully integrated economy, $\sigma_{h,f}, \sigma_{f,h} = 1$.

The total number of R&D units which undertake research at home and abroad is $L_{R,h} + L_{R,f}$. Each unit has a Poisson-distributed arrival rate ε_j of being the next innovator. As we allow for structural differences, productivity of R&D may be different in the two economies, i.e. $\varepsilon_h \leq \varepsilon_f$. A high ε_j may be an indicator for a high level of economic development if, for example, the quality of the educational system and public institutions affect the productivity of research. The number of R&D units weighted at their research productivity implies that the productivity of the current frontier technology is expected to increase by a factor $\lambda^{\varepsilon_h L_{R,h} + \sigma_h \varepsilon_f L_{R,f}}$ during a time unit. Accordingly, we can define the rate of technological progress $g_{A,t}$,

which shifts the productivity of the frontier technology over time, as:

$$g_{A,t} = \ln(\lambda) \sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}. \quad (2)$$

Technological progress³ is endogenous as the size of the R&D sector in terms of sector employment, $L_{R,j}$, will result from the equilibrium labor allocation between R&D and manufacturing. This is subject to the relative income opportunities of manufacturing and R&D, depending also on foreign demand and foreign competition, and will be analyzed next.

2.2 The Final Good Production

Firms in the manufacturing sector demand technologies and labor. They use the inputs to produce the homogenous final good in a set of different vintages. The used technology τ defines the vintage and, hence, τ denotes both the technology and the related vintage in manufacturing. As technologies are different, relative productivity $a_\tau = A_\tau/A_{\tau_t^{\max}}$ varies among the vintages. Relative productivity is equal to unity in τ_t^{\max} and lower in all other vintages. Once foreign or home R&D supplies a new technology, a new vintage τ_t^{\max} in manufacturing is created. The new vintage chooses the current maximum technology but no updating is possible afterwards. The fixed vintage technology implies a relative productivity loss, namely a_τ declines, as soon as a new technology with a higher productivity is implemented in manufacturing.

Two steps are necessary to manufacture the final good Y . First, labor transforms an intermediate good into a useful input for production. The transformation of the intermediate good follows a simple linear technology⁴ in which one employee transforms a fraction $1/\gamma$ of one unit of the intermediate good x_τ . This connects the two inputs in manufacturing simply as

³ Growth rates and therefore technology levels can diverge between the two economies. For simplicity, we assume that an innovation introduces the λ -times higher productivity level independent of the current level of $A_{\tau,j}$. This guarantees a mutual technology exchange where both countries benefit from foreign R&D.

⁴ Such as software is only beneficial with the corresponding user.

follows:

$$x_\tau = \frac{L_{M,\tau}}{\gamma}. \quad (3)$$

In the second step, the final good is created from the transformed intermediate good at a decreasing rate of return α . The production occurs with a vintage-specific productivity level A_τ . The vintage production function therefore yields:

$$Y_\tau = A_\tau x_\tau^\alpha. \quad (4)$$

All vintages in the interval $[0, \tau_t^{\max}]$ contribute to the production of total output and $Y_t = \sum_0^{\tau_t^{\max}} Y_\tau$.

The demand for the intermediate good and labor in manufacturing result from profit maximization. A vintage earns a flow of profits $\pi_{M,\tau}$. Revenues follow from the production function. The related costs arise from the input of the intermediate good. They are composed of the corresponding price p_τ paid to the intermediate good supplier and, in addition to this, the complementary labor costs as a factor γ of the wage rate w_τ . The consequent profit equation is:

$$\pi_{M,\tau} = A_\tau x_\tau^\alpha - (p_\tau + \gamma w_\tau) x_\tau. \quad (5)$$

The maximization of (5) over x_τ yields as a first-order condition the demand for the intermediate good,

$$x_\tau = \left(\alpha a_\tau \frac{A_{\tau_t^{\max}}}{p_\tau + \gamma w_\tau} \right)^{\frac{1}{1-\alpha}}. \quad (6)$$

Labor demand is γ times the input of x_τ . From this it follows that:

$$L_{M,\tau} = \gamma \left(\alpha a_\tau \frac{A_{\tau_t^{\max}}}{p_\tau + \gamma w_\tau} \right)^{\frac{1}{1-\alpha}}. \quad (7)$$

It varies with relative productivity how much of the intermediate good and labor firms demand. A highly productive technology, namely a high a_τ ,

implies c.p. a high demand for the inputs.

Given the technology level, input demand depends on p_τ and w_τ . While the price of the intermediate good is conditional on profit maximization of the monopolistic intermediate good supplier (see the following section), wages are set subject to average productivity in manufacturing. In contrast to the technology differences, the wage distribution is usually compressed and, for simplicity, we thus assume that all manufacturing workers obtain the same wage w_τ . The wage rate is fixed in such a way that the wage equals a share β of the revenues of vintage $\tilde{\tau}$ which has the average relative productivity \tilde{a} . This yields:

$$w_{\tau,t} = \beta \tilde{a} A_{\tau_t^{\max}} \left(\frac{L_{M,\tilde{\tau}}}{\gamma} \right)^\alpha. \quad (8)$$

Average relative productivity and labor input are constant. Therefore, wages increase over time with $A_{\tau_t^{\max}}$ at the rate g_A .

Finally, we set that manufacturing firms earn zero profits. Market entry with the emergence of a new vintage is associated with the implementation of the current leading technology. Suppose that this is accompanied by the payment of fixed costs F_τ . The manufacturing sector is competitive and this implies that the discounted flow of profits covers only the implementation costs, $\int_0^\infty e^{-r(t-\bar{t})} \pi_{M,\tau,t} dt = F_\tau$.

2.3 R&D and the Intermediate Good Production

Home R&D units and those abroad produce intermediate goods and develop innovations as superior technologies, which provide the intermediate good with a higher productivity level A_τ . Various R&D units compete in the development of the next innovation. As soon as an innovator appears with a new maximum technology τ_t^{\max} , the corresponding R&D unit sells the innovation in form of intermediate goods to the manufacturing sector. The flow of profits, earned from selling the intermediate good, determines the value of an innovation. This value then yields the return to labor of an R&D unit, which is the alternative income to the wage rate in manufacturing.

The R&D units produce the intermediate good at $c_\tau = cA_\tau$ marginal costs, which are proportional to the technology level. As soon as an innovation arises the previous technology becomes common knowledge and different firms compete in the supply of the intermediate good so that they set price equal to marginal costs c_τ . Hence, no profits arise for these intermediate good suppliers.

However, only the innovator has the knowledge about the leading technology τ_t^{\max} . Hence, there is no competition in the supply of technology τ_t^{\max} and its supplier earns monopolistic profits. The innovator replaces the previous monopoly and then sets the profit-maximizing price and output. Profits of the R&D unit therefore arise from serving the vintage with the highest technology level τ_t^{\max} at home and the vintage τ_t^{\max} abroad at rate $\sigma_{f,h}$:

$$\pi_{R,t} = \sum_{j=h,f} \sigma_{j,h} [p_{\tau_t^{\max},j}(x) - c_{\tau_t^{\max}}] x_{\tau_t^{\max},j} \quad (9)$$

The monopoly chooses the profit-maximizing quantity of output and sets the corresponding $p_{\tau_t^{\max},j}$. The R&D unit faces the inverse demand functions $p_{\tau_t^{\max},j} = \alpha A_{\tau_t^{\max},j} x_{\tau_t^{\max},j}^{\alpha-1} - \gamma w_{\tau,j}$ of the home and foreign manufacturing vintage τ_t^{\max} , which result from the demand function (6). With this expression for $p_{\tau_t^{\max}}$, the first-order condition of the maximization program $\max \pi_{R,\tau_t^{\max}}$ over $x_{\tau_t^{\max},j}$ produces the profit-maximizing quantity of the intermediate good

$$x_{\tau_t^{\max},j} = \left(\frac{\alpha^2}{\gamma \omega_j + c} \right)^{\frac{1}{1-\alpha}}, \quad (10)$$

where $\omega = w_{\tau^{\max}}/A_{\tau^{\max}}$ denotes the productivity-adjusted wage. The corresponding price of the intermediate good can then be written as:

$$p_{\tau_t^{\max},j} = \frac{c_{\tau_t^{\max}}}{\alpha} + \left(\frac{1}{\alpha} - 1 \right) \gamma w_\tau. \quad (11)$$

The monopolist takes a mark-up to marginal costs according to the price elasticity of demand and a term that indicates the complementarity between

labor and the intermediate good so that high wages corresponds to a high price of the intermediate good.

The optimal quantity of output and its corresponding price determine how much the R&D unit earns as long as it can realize the monopolistic profits. However, the value of an innovation is less than the infinite flow of profits. Competitors undertake R&D and will therefore replace the incumbent at some stage. This means that the flow of profits immediately stops as soon as the next innovation has been developed. This emerges stochastically at probability ε_j per labor unit in a number of $\sum_{j=h,f} L_{R,j}$ R&D units which employ one worker each. Thus, the expected present value J_τ of an innovation takes account of the flow of profits and the probability of a total loss of the asset. This leads to the following asset equation

$$rJ_\tau = \pi_{R,\tau} - J_\tau \sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}, \quad (12)$$

which indicates that the investment in R&D must bring the same expected returns as the investment in an alternative asset whose return is the constant interest rate r . Rearranging the asset equation, together with the profit equation (9) and the values $p_t^{\max,j}$ and $x_t^{\max,j}$, then yields the expression for the expected value of innovation τ :

$$J_{\tau,t} = \sum_{j=h,f} \left[\sigma_{j,h} A_{\tau_t^{\max,j}} (\gamma \omega_j + c)^{\frac{\alpha}{\alpha-1}} \right] \frac{\alpha^{\frac{2}{1-\alpha}} \left(\frac{1}{\alpha} - 1 \right)}{r + \sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}}. \quad (13)$$

One can see that the expected return from home R&D is low if foreign competitors are strong in terms of market access $\sigma_{h,j}$, productivity ε_j , or pure scale $L_{R,j}$. On the other hand, foreign demand for the intermediate good leads to a higher expected income from home R&D. The relative effect of openness, namely $\sigma_{h,f}, \sigma_{f,h} > 0$, on the returns from home R&D depends on whether the competition or the demand effect dominates. If $\sigma_{j,j}$ are variable, the countries can partly control the profitability of home R&D as long as the foreign country does not respond counteractively. Moreover, the value of an innovation is a function of time as it depends on the technology

levels $A_{\tau_t^{\max}}$ which increase over time. From this it follows that J_{τ} increases proportional to $A_{\tau_t^{\max},j}$ at the rate of technological progress.

2.4 Technology Obsolescence and Labor Reallocation

The next step is to introduce technological obsolescence as the source of job destruction and job creation to consider labor reallocation as the factor that determines the level of employment. Economic integration may have an effect on labor reallocation. This occurs via structural change in manufacturing when labor has to be reallocated from old to new vintages. In case of frictions in the reallocation, e.g. caused by the wage setting, the number of vacancies in new manufacturing firms deviates from the number of job seekers due to the dismissals in old vintages and unemployment occurs.

Technological progress creates new vintages in manufacturing and results in the disappearance of old ones. After their emergence, vintages face a gradual technological obsolescence. Technological obsolescence is accompanied by job destruction as older vintages are less productive and labor demand declines with a fall in relative productivity (see equation (7)). Only a share of the workers smaller than one remains employed in vintage τ as soon as the next innovation increases the maximum productivity by a factor λ and reduces relative productivity of all other technologies from the prior a_{τ} to a_{τ}/λ . Let ϕ denote the ratio of employees in a vintage after and before the next innovation occurs. Then divide the labor demand $L_{M,\tau}(a_{\tau}/\lambda)$ by $L_{M,\tau}(a_{\tau})$ to obtain the share of workers that remains employed:

$$\phi = \left(\frac{c + w_{\tau,t}}{c + \lambda w_{\tau,t}} \right)^{\frac{1}{1-\alpha}}. \quad (14)$$

Consequently, as soon as the next innovation emerges, a share $1 - \phi$ of the current number of manufacturing workers loses their jobs due to a gradual technological obsolescence and $1 - \phi$ represents the rate of job destruction.

The full dimension of job destruction is equal to the share $1 - \phi$ of the current jobs in manufacturing. This number of jobs yields from total labor supply minus unemployed minus workers in the R&D sector. With u as the

unemployment rate this is $L_M = (1 - u)L - L_R$. Finally, innovations emerge at the probability $\sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}$. Therefore, technology obsolescence causes the expected, or average, flow into unemployment of:

$$U = \sum_{j=h,f} [\sigma_{h,j} \varepsilon_j L_{R,j}] (1 - \phi) [(1 - u)L_h - L_{R,h}] \quad (15)$$

The emergence of a new vintage in the manufacturing sector creates new jobs. The new vintage τ_t^{\max} arises in manufacturing as soon as the corresponding innovative technology is developed. This vintage aims to employ workers in order to start production. Therefore, it opens vacancies and, thereby, generates new labor demand. How many vacancies are created follows from the input demand and monopolistic profit-maximization specified in the description of the intermediate good production. The optimal supply of the intermediate good which embodies the technology update has been shown in (10). Labor demand is a fraction γ of this number and, therefore, yields $L_{M,\tau_t^{\max}} = \gamma [\alpha^2 / (c + \gamma\omega)]^{\frac{1}{1-\alpha}}$, which is equal to the number of vacancies the vintage offers. Obviously, a high wage rate in terms of ω reduces vacancies. As an alternative expression one can write vacancies as a fraction of total employment in manufacturing. Let denote the constant ratio of labor demand of the non-leading vintages to the leading one, namely $\eta = (L_M - L_{M,\tau_t^{\max}}) / L_{M,\tau_t^{\max}}$. The total labor demand of the non-leading vintages is the sum of vintage labor demand over the interval of relative productivity up to $a = 1/\lambda$. This yield $L_M - L_{M,\tau_t^{\max}} = \gamma \sum_{a=0}^{1/\lambda} [a\alpha / (c + \gamma\omega)]^{\frac{1}{1-\alpha}}$ or $L_M - L_{M,\tau_t^{\max}} = \eta L_{M,\tau_t^{\max}}$. From this it follows that the new vintage therefore offers

$$V = \frac{L_M}{1 + \eta} \quad (16)$$

vacancies. This number is equal to job creation if the all vacancies can be filled. The number of job-worker matches may be smaller than V if there are frictions in the reallocation process. For example, firms cannot fill some of the vacancies if labor is heterogenous and some job seekers represent non-suitable skills. Let δ denote the share of non-filled vacancies as a measure

of the frictions. Then, the actual number of matches $M = \min [(1 - \delta) V, U]$ yields the extent of job creation as job creation is the minimum of either the number of filled vacancies or the number of job seekers.

2.5 Perfect and Restricted Labor Reallocation

The continuous reallocation of labor with job destruction and job creation characterizes the labor market. The labor flows generated by the reallocation are into and out of employment⁵ and must be equal in equilibrium. As the size of R&D and manufacturing in terms of sectoral employment L_R and L_M affect the extent of job destruction U and the posting of vacancies V , we must find an equilibrium intersectoral labor allocation which evens out differences between U and job creation of $M = (1 - \delta) V$. Possibly, the balance between the two flows is accompanied by unemployment. Depending on whether the value of U or $(1 - \delta) V$ is smaller, we obtain a regime with perfect labor reallocation or restricted job creation.

(I) *Perfect labor reallocation:* $U|_{u=0} \leq (1 - \delta) V$

In this regime job destruction is in any case lower than the number of new employment opportunities. Job destruction is at its maximum if all workers in the labor force are in jobs, denoted with $U|_{u=0}$. This is because dismissals due to the gradual technological obsolescence affect a fixed proportion of manufacturing workers and, hence, this number is maximum in case of full employment. From reversal conclusion follows that full employment is guaranteed only if job creation can compensate for the maximum extent of job destruction, $U|_{u=0}$. Accordingly, if $U|_{u=0}$ is smaller or equal to $(1 - \delta) V$, the number of destroyed jobs faces an equal number of newly filled vacancies and dismissed workers immediately re-enter new jobs. No unemployment occurs but if $U|_{u=0} < (1 - \delta) V$ some vacancies remain unfilled and the number of matches is restricted by the job seekers ($M = U|_{u=0}$).

(II) *Restricted job creation:* $(1 - \delta) V < U|_{u=0}$

⁵ Further moves in the interim are possible between manufacturing and R&D but we exclude the entry of unemployed into R&D.

In this regime job creation in terms of filled vacancies in the new vintage in manufacturing, is lower than than maximum job destruction of $U|_{u=0}$. Hence, this scenario is incompatible with full employment as in this case job destruction would exceed job creation. Due to a relative lack of vacancies, job creation can be equal to job destruction only if it is lower than maximum. As job destruction is proportional to employment, set $U = (1 - \delta)V$ and use (15) and (16) to see that equilibrium flows of job destruction and job creation correspond to the occurrence of unemployment

$$uL = L - L_R - \left(\frac{1 - \delta}{1 - \phi} \right) \frac{V}{\sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}}. \quad (17)$$

High rates of labor reallocation in terms of $1 - \phi$ and a high innovation rate in terms of $\sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}$ indicate high job destruction. A small V and large frictions δ are signs of low job creation. Both high job destruction and low job creation increase the extent of equilibrium unemployment. Equation (17) can also be written as $uL = L - L_R - (M/U|_{u=0})L_M$. Only if $M = U|_{u=0}$, as it applies to regime (I), we get $uL = L - L_R - L_M = 0$ because all workers are fully employed either in R&D or in manufacturing. Otherwise, employment in manufacturing is lower than under perfect labor reallocation.

Which of the two regimes (I) or (II) occurs depends on the parameter values. Not surprisingly, two examples would be that the occurrence of unemployment is more likely if frictions in labor reallocation are strong and wages are high. Given the number of vacancies and the extent of job destruction, frictions δ reduce the matching rate between job seekers and jobs so that less jobless workers can enter new employments. High wages reduce labor demand. The consequence is that a high ω increases job destruction ($\phi' < 0$) and reduces job creation as vacancies decline, $V = L_{M,\tau_t^{\max}} = \gamma [\alpha^2/c + \gamma\omega]^{\frac{1}{1-\alpha}}$ and $V' < 0$. The open economy can not be clearly associated with either regime (I) or (II). However, since openness to foreign innovations tends to increase job destruction, ongoing economic integration can change the state of the economy from regime (I) to (II) if labor reallocation is not perfectly organized.

3 Equilibrium Labor Allocation with Unemployment

Equilibrium labor allocation with constant L_M and L_R requires: First, from continuous job creation and job destruction it follows that equal flows into and out of jobs are necessary to fix the employment size. No further change in total (un)employment occurs if $U = (1 - \delta)V$ as it has been shown in the previous section. Second, it is necessary that both sectors offer identical income expectations to fix the sectoral labor allocation. Labor can be employed in either manufacturing or R&D and workers are free to move from one to the other. Moves stop in equilibrium when both alternatives offer the same expected income. This means that wages in manufacturing are equal to the expected return to R&D, which depends on the value of an innovation and the probability of arrival. This state is denoted as the income identity and yields $w_\tau = \varepsilon J_{\tau+1}$. The remainder of the section develops both conditions as a function for the R&D intensity and shows how their combination yields the solution of the model.

Equilibrium labor allocation demands that flows into and out of unemployment are even. To formulate this condition we consider the labor market identity with unemployment, $L = L_R + L_M + uL$, and use the right hand side of (17) instead of uL . This results in:

$$\mathbf{EE:} \quad L_{R,h} = \frac{1 - \delta}{\varepsilon_h (1 + \eta) (1 - \phi)} - \sigma_{h,f} \frac{\varepsilon_f}{\varepsilon_h} L_{R,f} \quad (18)$$

This is the employment equation *EE* showing those employment shares of home R&D which yield the identity between job creation and job destruction in regime (II). Here it is not competition of foreign R&D that reduces the number of researchers at home, but foreign innovations contribute to home job destruction and therefore lower the home employment base.

In addition to a constant rate of labor reallocation, no-arbitrage between the sectors must hold. While manufacturing workers earn the wage w_τ , research workers receive no income unless their firm innovates. Innovation is stochastic and research workers get an expected income of $\varepsilon J_{\tau+1}$ as a

worker develops the next innovation $\tau + 1$ at the probability ε . As long as the income identity $w_\tau = \varepsilon J_{\tau+1}$ holds, no sector attracts workers with the prospect of a higher income. The income identity can also be written as an expression of the parameters of the model and the relative labor shares of the two sectors. We substitute $J_{\tau+1}$ as it arises in the income identity by the value of an innovation according to (13), but with the future technology $\tau + 1$ instead of the current one τ . Solving for $L_{R,h}$ and simplifying then gives us:

$$\mathbf{AE:} \quad L_{R,h} = \sum_{j=h,f} \sigma_{j,h} \left(\frac{1}{\alpha} - 1 \right) \left(\gamma + \frac{c}{\omega_j} \right) \left(\frac{L_{M,j}}{1 + \eta} \right) - \sigma_{h,f} \frac{\varepsilon_f}{\varepsilon_h} L_{R,f} - \frac{r}{\varepsilon_h}. \quad (19)$$

AE is the no-arbitrage equation, in which the equilibrium employment shares of R&D and manufacturing even out the income alternatives.⁶ *AE* shows again the demand and the opposing competition effect of openness. Foreign manufacturing increases the first term of the RHS of *AE*, while foreign R&D act as a competitor for innovations and $L_{R,f}$ reduces the RHS of *AE*. If economic integration finally results in an increases (decreases) of the RHS of *AE*, the open economy makes home R&D more (less) attractive in comparison to the closed economy.

Equilibrium in regime (II) must take the flow identity according to *EE* into account in addition to no-arbitrage according to *AE*. As there is no unemployment *EE* can be omitted in regime (I) and the equilibrium is reduced to the *AE* and the simple labor market identity $L = L_M + L_R$. In regime (I) with perfect labor reallocation, the actual size of L_R and L_M follows from the magnitude of the total labor supply L . The labor market identity implies that labor is fully employed in manufacturing and R&D. This in *AE* yields the equilibrium number of employees in manufacturing, which is a function of openness and foreign demand and competition, $L_M^* = f(\sigma_{f,h}, \sigma_{h,f}, L_{R,f}, L_{M,f}, \cdot)$. See Appendix for the explicit solution.

⁶ We assume that the home country is small which allows us to ignore responses of foreign labor allocation to home labor allocation so that employment in foreign R&D, $L_{R,f}$, and foreign manufacturing, $L_{M,f}$ is fixed.

The equilibrium number of researcher follows straightforward from subtracting L_M^* from L .

Figure 1 gives a graphical illustration of the equilibrium in the $L_{M,h}, L_{R,h}$ -plane. The locus of AE starts right from the origin and slopes upwards. This indicates that a manufacturing sector of large scale increases the returns from innovations in R&D because of a broad market for the intermediate good. Higher profits then attract more R&D units. Consequently, $L_{R,h}$ increases with $L_{M,h}$. The locus of EE is parallel to the horizontal axis. Its distance from the axis is large if R&D has only small effects on job destruction. Hence, EE' which is located above EE represents an economy with less imperfections in labor reallocation. The intersection of the loci AE and EE establish equilibrium labor allocation with unemployment, from which we obtain the size of L_M and L_R . The intersection of the two curves may be right or left from the line of the labor market identity (the full employment case) $L = L_R + L_M$. The intersection is right from the line of labor market identity (point A) if job creation exceeds job destruction. However, this point is located outwards of the employment space and is therefore not attainable. Point B will be realized instead. This represents the solution of regime (I). However, labor supply is not fully engaged if EE intersects with AE left from the line of the labor market identity, such as in C . The distance between C and the line of the labor market identity yields the dimension of unemployment. Less labor is employed in both sectors in comparison to point B . This implies less output and a lower growth path because the innovation rate $g_{A,t} = \ln(\lambda) \sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}$ reduces with a low $L_{R,h}$.

Some short considerations show the stability of the equilibrium. First, the AE locus is stable. The space above the line corresponds to a relative disadvantage in income from R&D. The consequent movement of workers towards manufacturing causes a downward adjustment of $L_{R,h}$ and the employment combination approaches the AE locus. The process continues until the income differences disappear and the employment ratio corresponds to the one which follows from AE . If the adjustments takes place immediately, as it is assumed in this type of models,⁷ the economy jumps to its equilib-

⁷ We refer here to the standard growth models with endogenous innovation in the tradition

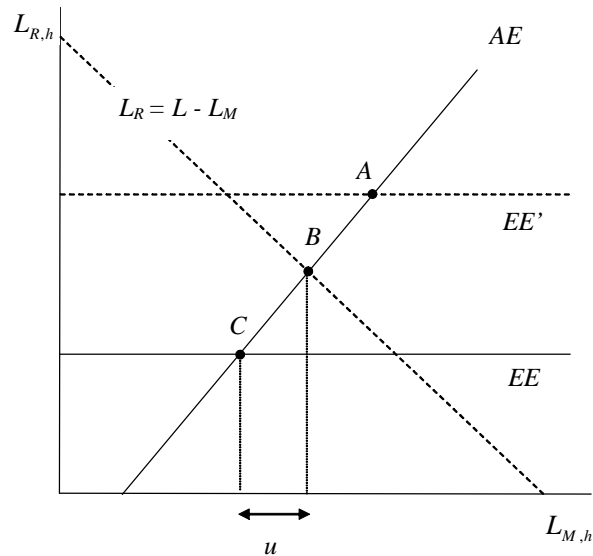


Figure 1: Equilibrium labor allocation

rium and remains there afterwards. Suppose furthermore that we start in a point above the EE curve. In this case job destruction exceeds job creation and unemployment increases. This leads to an adjustment downward and to the left, for example along AE from B to C . From the two stable loci follows that any equilibrium labor allocation, such as point C , is also stable as long as the change of positions between the sectors can be easily made.

4 The Effects of Economic Integration

Economic integration, here in terms of a higher degree of free technology exchange ($\sigma_{h,f}, \sigma_{f,h}$ increase), has an impact on growth and labor reallocation. On condition that job destruction exceeds job creation unemployment can increase as a consequence of more openness to the foreign R&D. As in Aghion and Howitt (1998, chap. 11), we can identify a direct and an indirect effect of openness on growth. The scale effect is related to the range

of Grossman and Helpman (1991) and Aghion and Howitt (1992).

of available R&D output which increases if foreign innovations can be used to a larger extent. The reallocation effect considers changes in the labor allocation if more openness augments the attractiveness of either R&D or manufacturing in terms of a higher relative income and workers consequently move from one sector to the other. If there is a gain for R&D, more innovations will stimulate growth, but the opposite is true if expected revenues from home R&D decline. The two effects imply that economic integration includes two sources of technological and structural change. First, the intra-sectoral composition of vintages in manufacturing changes if more openness accelerates the emergence of new vintages. Second, the intersectoral distribution of labor may change if one sector realizes extra profits from economic integration.

Table 1 reveals the possible effects of economic integration on employment and growth. Recall that regime (I) describes perfect labor reallocation where job creation compensates for job destruction. In contrast to this, regime (II) produces unemployment because job creation is lower than job destruction. The results are also summarized in five implications which read as follows:

Implication 1: *The scale effect of economic integration on growth is positive in regime (I) but it disappears in regime (II).*

As growth is a function of the weighted sum of the foreign and the domestic R&D sectors, $g_{A,t} = \ln(\lambda) \sum_{j=h,f} \sigma_{h,j} \varepsilon_j L_{R,j}$, the pure increase in scale of total available R&D output increases growth in regime (I) if the two economies reduce their trade barriers (i.e. if $\sigma_{h,f}$, $\sigma_{f,h}$ increase). In contrast to this, in regime (II) foreign innovations crowd out domestically developed ones. It follows from changes in the labor allocation according to *EE* that the home R&D sector shrinks if there are more foreign competitors. *EE* in the growth equation yields that $g_A = (1 - \delta) / [(1 + \eta)(1 - \phi)]$ in regime (II). This means that there is no effect of openness left in regime (II). Hence, economic integration is not accompanied by a scale effect that stimulates growth. Instead, imperfections in the labor market determine g_A and less frictions in the labor reallocation lead to more growth. One can interpret

this as a maximum of the absorptive capacity. Imperfections in the labor market limit its ability to reallocate labor to the new vintages in manufacturing. This means that the size of that part of manufacturing which demands the technology update is limited and only a fixed number of technology updates can be implemented in manufacturing. It is irrelevant whether these technology updates come from home or foreign R&D units.

Implication 2: *The scale effect of economic integration on employment is negative in regime (II).*

As soon as more foreign R&D output is available, the raise of the innovation rate leads to more structural change, the reason for job destruction in the economy. Given a constant sector allocation of labor, the equation for unemployment in regime (II), see (17), shows that less workers will be employed if $\sigma_{h,f}$ increases in an open economy. Openness increases job destruction but leaves job creation unchanged.⁸ As a consequence, unemployment increases further in the scenario with imperfect labor reallocation.

Implication 3: *In regime (I), the reallocation effect of economic integration on growth is positive (negative) if the foreign economy has a low (high) R&D intensity or if the foreign economy contributes to economic integration more (less) than the home economy.*

Economic integration is defined as allocation neutral if more openness affects only the vintage structure in manufacturing but leaves the relative employment shares of R&D and manufacturing untouched. This is true if the demand effect from foreign manufacturing is equal to the opposing competition effect of foreign R&D so that the expected income from R&D does not change. Otherwise, no-arbitrage between the sectors changes due to economic integration. On condition that the no arbitrage equation AE changes, openness amplifies or lessens the scale effect with respect to employment and growth. The analysis of the equilibrium labor allocation L_M^*, L_R^* in regime (I) yields that the employment share in home R&D increases with foreign

⁸ This result is in line with the empirical findings of Ribeiro et al. (2004) who analyzed the effects of trade liberalization on labor reallocation in Brazil.

and decreases with home openness, $\partial L_R^*/\partial\sigma_{f,h} > 0$, $\partial L_R^*/\partial\sigma_{h,f} < 0$.⁹ In a situation where the countries contribute differently to economic integration, ($\partial\sigma_{f,h} \neq \partial\sigma_{h,f}$), a relative high foreign openness tends to generate a altered labor allocation with a higher R&D share of total employment. Generally, more home innovations and growth are the consequence.

If both countries reduce their protectionism to the same extent, namely $\partial\sigma_{f,h} = \partial\sigma_{h,f}$, the overall effect of openness on home R&D is positive if

$$\frac{\varepsilon_f L_{R,f}}{\varepsilon_h L_{M,f}} < \left(\frac{1}{\alpha} - 1\right) \frac{\gamma + \frac{c}{\omega}}{1 + \eta}. \quad (20)$$

On condition of (20), economic integration increases the expected income from home R&D because the demand effect dominates the competition effect. The demand for the domestic R&D output is large if there is a broad market for technology updates because foreign manufacturing ($L_{M,f}$) is large. The foreign R&D sector is little competitive if $\varepsilon_f L_{R,f}$ is low. Hence, the demand effect dominates the competition effect if the foreign country is relatively little engaged in R&D which indicates a low ratio $L_{R,f}/L_{M,f}$. On condition that the LHS of (20) is greater than the RHS, labor reallocates from manufacturing to R&D and this generates more growth through more home innovations. Otherwise, workers move towards manufacturing which implies less future innovations and this outcome lowers the prospect of growth.¹⁰

Implication 4: *In regime (II), the reallocation effect of economic integration on employment is negative (positive) if the foreign economy has a low (high) R&D intensity or if the foreign economy contributes to economic integration more (less) than the home economy.*

An economy is highly engaged in R&D if the sector is highly productive. This is accompanied by high job destruction and leads to unemployment in regime (II). If economic integration reallocates labor further towards R&D,

⁹ See Appendix.

¹⁰ In Figure 1 the AE-curve shifts to the left (right) if economic integration is non-neutral with respect to sector labor-allocation and brings relative advantages for R&D (manufacturing) income.

the economy experiences even more job destruction in manufacturing and unemployment increases further. This scenario is more likely if foreign R&D is relative weak or if the foreign economy contributes more to economic integration when it opens the markets to foreign innovators whereas the home country keeps its protective trade barriers. This means that the demand effect dominates the competition effect and R&D becomes more attractive for home workers. The higher revenues to R&D change the former equilibrium of no-arbitrage according to *AE*. However, since the absolute number of R&D workers can not increase (their number is fixed according to *EE*), the increase in the attractiveness of R&D results in a decline in manufacturing in which less workers become employed. In contrast to this, employment increases if openness leads to a labor reallocation towards manufacturing.

Implication 5: *In regime (II), there is no reallocation effect of economic integration on growth.*

As growth is fixed to $g_A = (1 - \delta) / [(1 + \eta)(1 - \phi)]$ in regime (II), see Implication 1, labor reallocation has no effect on innovation and growth. Labor reallocation that favors R&D results in a relative increase in R&D employment. However, according to Implication 4, this happens through a reduction in manufacturing jobs. The share of workers employed in R&D increases while its size in absolute numbers, and the R&D output, remain the same.

The benefits of economic integration may be unequally distributed. Suppose, for example, that both countries are in regime (I), but country one is highly R&D intense, while country two is less. Caused by economic integration, the two countries then partly specialize in R&D and manufacturing respectively. Country one experiences an extra push in growth from an equal reduction of protectionism as home resources reallocate towards R&D and increase R&D intensity further. In contrast to this, a reciprocal effect in country two would lead to a reallocation towards manufacturing which is less beneficial in terms of future growth. However, the low R&D intense country two can avoid the loss of home innovation if it allows less inflow of technologies than country one, namely $\sigma_{1,2} > \sigma_{2,1}$.

Another example would be that country one has strong frictions in the

Table 1: The effects of integration

	regime I	regime II	
	<i>growth</i>	<i>growth</i>	<i>employment</i>
Scale effect	+	0	-
Reallocation effect			
low R&D intensity abroad	+	0	-
high R&D intensity abroad	-	0	+
$\sigma_{h,f} > \sigma_{f,h}$	-	0	+
$\sigma_{f,h} > \sigma_{h,f}$	+	0	-

+ = increase, - = decrease, 0 = no effect

labor market and is in regime (II), whereas country two manages a perfect labor reallocation and is in regime (I). On this condition, country one experiences no growth boost from more openness. Instead, economic integration will cause negative employment effects through a higher pace of labor reallocation. This effect is the stronger the more the country is engaged in R&D and the more protective the economy is (i.e. $\sigma_{1,2} < \sigma_{2,1}$) because home resources additionally move towards R&D and reinforce the labor reallocation further.

5 Conclusions

In open economies, the knowledge about best practices and technologies diffuses quickly across the borders and starts to change the prior domestic technological and organizational solutions. Therefore, economic integration of industrialized economies leads to more technological and structural change which alters the interindustry and intraindustry resource allocation as soon as more and more of the global available technologies are shared. While this tends to be gainful in terms of productivity, the structural change is mostly accompanied by a reallocation of resources, which often implies a turnover of labor. If the reallocation can not be organized perfectly, some negative

employment effects can emerge.

The empirical findings by Haltiwanger et al. (2004) suggest that trade liberalization can result in a higher pace of labor reallocation and lower employment levels. This paper provides a theoretical framework to explain how openness and free technology exchange lead to structural change in manufacturing accompanied by an increase in job destruction. The risk of a decline in employment due to economic integration is high if the prior pace of labor reallocation has been high and partly blocked by frictions. One can argue that highly R&D intense economies already show a high rate of job destruction. Consequently, these economies have a high risk of additional job losses due to a free exchange of technologies.

The combination of endogenous technological change with job destruction and job creation has some implications for the generally assumed growth effect of the removal of trade barriers. Labor markets, in which frictions lead to only imperfect labor reallocation, withstand only a maximum of structural change. From this it follows that foreign innovations substitute for home developments and, as the total technology pool remains the same, economic integration is accompanied by less productivity gains as usually expected.

Appendix

Equilibrium labor allocation $\{L_M^*, L_R^*\}$ in regime (I) yields from substituting for L_R according to the RHS of AE into the labor market identity $L = L_M + L_R$:

$$L_M^* = \frac{L + \frac{r}{\varepsilon_h} + \sigma_{h,f} \frac{\varepsilon_f}{\varepsilon_h} L_{R,f} - \sigma_{f,h} \frac{\theta\gamma}{\lambda} L_{M,f}}{1 + \theta} \quad (\text{A.1})$$

with $\theta = \frac{\lambda}{\gamma(1+\eta)} \left(\frac{1}{\alpha} - 1 \right) \left(\gamma + \frac{c_\tau}{w_\tau} \right)$, and

$$L_R^* = \frac{\theta L - \frac{r}{\varepsilon_h} - \sigma_{h,f} \frac{\varepsilon_f}{\varepsilon_h} L_{R,f} + \sigma_{f,h} \frac{\theta\gamma}{\lambda} L_{M,f}}{1 + \theta} \quad (\text{A.2})$$

From this it follows that differentiating (A.1) with respect to the level of home and foreign openness yields the competition and the demand effect:

$$\frac{\partial L_R^*}{\partial \sigma_{h,f}} = -\frac{\varepsilon_f}{\varepsilon_h (1 + \eta)} L_{R,f} < 0 \quad (\text{competition effect}) \quad (\text{A.3})$$

$$\frac{\partial L_R^*}{\partial \sigma_{f,h}} = \frac{\theta\gamma}{\lambda (1 + \eta)} L_{M,f} > 0 \quad (\text{demand effect}). \quad (\text{A.4})$$

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