Institute for Employment Research

The Research Institute of the Federal Employment Agency

IAB

IAB-Discussion Paper 19/2011

Articles on labour market issues

Trade liberalisation, technical change and skill-specific unemployment

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Trade Liberalisation, Technical Change and Skill-Specific Unemployment

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Contents

Abstract

The aim of this paper is to formalise a two-country model of trade liberalisation and technical change with heterogenous firms and search-and-matching frictions in the labour market. By considering different sectors and factors of production we allow for comparative advantages and study the trade and technology effects within and between sectors on wages and employment of skilled and low-skilled workers. Technical change together with inter-sectoral trade has distributional consequences across the labour force, favouring the skilled against the low-skilled workers. Intra-sectoral trade counteracts as it increases the demand for low-skilled workers, too. The overall effects on wages and employment of skilled and low-skilled workers depend on the extent of technical change, inter-sectoral trade and intra-sectoral trade.

Zusammenfassung

Dieser Beitrag präsentiert ein theoretisches Modell, welches die Wirkung von Handelsliberalisierung und technologischem Fortschritt auf Arbeitsmärkten zweier Länder beschreibt. Dabei werden heterogene Firmen und Sucharbeitslosigkeit unterstellt. Unterschiedliche Wirtschaftssektoren und Produktionsfaktoren gewährleisten komparative Kostenvorteile und die Analyse von Handels- und Technologiewirkungen innerhalb und zwischen den Wirtschaftssektoren auf hoch und niedrig qualifizierte Arbeitnehmer. Technologischer Fortschritt und intersektoraler Handel führen zu dem Verteilungseffekt, dass hoch qualifizierte gegenüber niedrig qualifizierten Arbeitnehmern begünstigt werden. Intrasektoraler Handel wirkt dem entgegen, da hierdurch auch die Nachfrage nach niedrig qualifizierten Arbeitnehmern steigt. Insgesamt hängen die Lohn- und Beschäftigungseffekte auf hoch und niedrig Qualifizierte vom Ausmaß technologischen Fortschritts, inter- und intrasektoralem Handel ab.

JEL classification: F12, F16, J64, O33

Keywords: trade, technology, heterogeneous firms, labour market frictions

1 Introduction

Over the last few decades the value of world trade as a share of world output has grown rapidly. Also vast developments in the fields of information technology and communication proceeded. The period was accompanied by a large increase in income inequality, measured by the rise in the relative wage of skilled to low-skilled workers, and a large increase in the relative unemployment rate of low-skilled to skilled workers in developed countries. These changes raise the important questions of how international trade and technical change interact and how these forces affect wages and employment of different skill groups.

The existence of overall gains from trade liberalisation is one of the core propositions of neoclassical trade theory despite there are both winners and losers within countries due to distributional consequences of trade. Based on the standard Heckscher-Ohlin model of international trade the distributional consequences are summarised by the Stolper-Samuelson theorem (Stolper/Samuelson, 1941). The theorem predicts that trade liberalisation will benefit an economy's relatively abundant factor of production and harm the economy's relatively scarce factor of production.

But the use of these models is accompanied by several limitations. Since factor markets of these models are supposed to be frictionless markets, equilibrium unemployment is ruled out by assumption. But unemployment is a core issue in the political and public debate about trade liberalisation. Furthermore, although the Heckscher-Ohlin model assumes profit maximising firms, operating under constant returns to scale, they have no deterministic role in determining the pattern or commodity composition of trade. Rather economic activity takes place in sectors, and international competitiveness is fashioned by relative factor endowments between potential trading partners. In addition, within neoclassical models regarding the distributional consequences of international trade and technical change, technical change is treated without effect on trade.

In this paper we present a two-country model of trade and technical change to address the questions of how these forces interact and how these forces affect wages and employment of skilled and low-skilled workers. According to the discussed limitations of neoclassical models we take account of the following issues.

First, we account for heterogeneous firms which differ in their productivity. According Melitz (2003) firms have to make a productivity draw from an exogenous distribution which determines whether they produce and export, and an endogenously determined productivity threshold determines who does and does not export. Only the most productive firms export to foreign markets, whereas less productive firms sell there products domestically.[1] By this means, trade liberalisation leads to reallocation of resources not only across industries but also across firms within industries. This is in line with the empirical evidence that much

[1] For literature concerning empirical evidence on firm selection into export markets see e.g. Dunne/Roberts/Samuelson (1989); Davis/Haltiwanger (1992); Bernard/Jensen (1995, 2004b); Roberts/Tybout (1997); Clerides/Lach/Tybout (1998); Bartelsman/Doms (2000).

of the observed reallocation occurs across firms within industries rather than between industries (see Levinsohn, 1999; Attanasio/Pinelopi/Pavcnik, 2004). Also the literature on observed heterogeneity in size and export status within sectors motivates to assume productivity differences across producers within sectors (e.g. Bernard/Jensen, 1999).

Second, we account for search-and-matching frictions in the labour market. Technical change leads, in the Schumpeter's term of creative destruction (Schumpeter, 1942), to the destruction of jobs and creation of new jobs. Furthermore, resources specialise in the comparative advantage sector. During these processes workers who lose their jobs experience a period of job search, before finding new employment. Regarding search and matching frictions in the labour market Mortensen/Pissarides (1994), and centralised in Pissarides (2000), present a framework which captures steady-state equilibrium unemployment.

Third, we consider different sectors and factors of production. In the tradition of Heckscher-Ohlin model, factors of production are mobile between sectors. This assumption together with the assumption of heterogeneous firms operating in sectors allows for reallocation of resources within and between sectors. For this reason changes in relative factor rewards are traced back also to reallocation of resources between sectors, an allowance which is rarely observed in the research on heterogeneous firms, e.g. considered by Larch/Lechthaler (2011).

Fourth, firms face productivity shocks. These shocks arise from technological progress. The way of introducing it is motivated by Schumpeter's "creative destruction" idea, in the sense that technological progress can come about through job destruction and creation of new and more productive jobs. Job destruction reveals due to obsolescence. New jobs emerge from new technological innovations which make existing jobs obsolete since wages grow in new jobs. So, jobs are created at the technological frontier and keep the same technology until job destruction. This consideration is based upon the requirement that long-run equilibrium models should be consistent with the existence of constant unemployment rates when there is balanced economic growth (see Pissarides, 2000). Moreover, the extent of productivity shock depends on the skill intensity of the sector where the firm is operating. According to the literature on skill biased technical change we assume that the productivity of a firm is positively correlated with its skill intensity. This is in line with empirical evidence that exporters and large producers in manufacturing tend to be relatively skill intensive (see Bernard/Jensen/Schott, 2006; Bustos, 2011; Verhoogen, 2008; Alcalá/Hernández, 2010; Molina/Muendler, 2009). It is also in line with various other empirical studies (e.g. Griliches, 1969) which support the idea that skilled labour is relatively more complementary to equipment capital than is unskilled labour. E.g. Nelson/Phelps (1966) contend that more educated, able or experienced labour deals better with technological change.

To feature these issues we trace back to the model of Larch/Lechthaler (2011). We make use of their framework of two asymmetric countries with two sectors and two factors of production i.e. allow for comparative advantages and of labour market frictions in a model with heterogeneous firms. Within this framework we take account of productivity changes due to technological progress. Along Pissarides (2000) we take account of the stylized fact that with balanced economic growth the rate of unemployment is constant and show that this enables to explain how technical change drives inter-sectoral trade in addition to intra-sectoral trade where some firms export and others do not. Hence, we contribute to the debate over causality between exports and productivity.

There is a large literature which refers to wage inequality and unemployment in an open economy. In Davis (1998) trade increases wage inequality in the U.S. flexible labour market and it increases unemployment in Europe facing a binding minimum wage. In this model unemployment appears among unskilled workers in Europe, rather than among skill groups of both trading partners. Moore/Ranjan (2005) distinguish between different skill groups and make use of the labour market Pissarides-Model to allow for search unemployment for each skill group. There are two tradable goods. The skilled tradable intermediate good is solely produced with skilled labour and the unskilled tradable intermediate good is solely produced with unskilled labour. Hence, the model does not allow for labour reallocation across sectors. The unemployment rate and the real wage in each sector respond to the price of sectoral output. Against it, Dutt/Mitra/Ranjan (2009) combine the Pissarides labour market search model with Heckscher-Ohlin international trade theorem and Ricardo trade model to contribute to differences across countries and factor movements across sectors. They formalise a national unemployment rate but leave for consideration of different skill groups.

In contrast, recent research on heterogeneous firms and unemployment aims to consider trade of asymmetric countries and its effect on each skill group of each trading partner. A model of heterogeneous firms and search frictions in a one-sector and closed economy is regarded by Felbermayr/Prat (2011). Felbermayr/Prat/Schmerer (2011) extend it to a symmetric-country model by considering a one-sector economy. In contrast, Bernard/Redding/Schott (2007) account for heterogeneous firms and comparative advantages i.e. asymmetric countries of a two sector and two factors of production economy but assume perfect labour markets. The results of Bernard/Redding/Schott (2007) and Felbermayr/Prat/Schmerer (2011) are combined by Larch/Lechthaler (2011) to a model of asymmetric countries with two sectors and two factors of production, heterogeneous firms and search-and-matching frictions in the labour market.

The theoretical literature points to differing performance characteristics of exporting and non-exporting firms. But there is the debate over the question whether these differences result from the decision to export or export activity. E.g. Bustos (2011) considers the concurrence of trade and technological upgrading. She studies the impact of trade liberalisation on technology upgrading and shows that firms in industries facing higher reductions in tariffs increase their investment in technology faster. The possibility of upgrading results from the increased revenues produced by trade integration. Burstein/Vogel (2010) model the interaction between skill-biased technology, international trade and wage inequality between skilled and unskilled workers and confirm that trade liberalisation increases the relative demand for skill, analogous to the effect of skill-biased technological change.[2] Stud-

[2] For further work on technology, trade and inequality see e.g. Acemoglu (2003); Yeaple (2005); Matsuyama (2007); Zeira (2007); Verhoogen (2008); Helpman/Itskhoki/Redding (2010); Costinot/Vogel (2010) and Vannoorenberghe (2011).

ies show that firm self-selection into export markets leads to productivity change through both learning by exporting and learning to export (see Greenaway/Kneller, 2007). Independent of the measure of productivity as labour productivity or TFP Bernard/Jensen (1999) and Bernard/Jensen (2004a) found that productivity growth of exporters is not significantly different from non-exporters. This implies that the growth effects from learning by exporting are not permanent. Furthermore, they provided evidence that new exporters were already among the best and differed significantly from the average non-exporter. Aw/Roberts/Winston (2007) show that investment in R&D and activity on the export market leads to higher productivity growth than just exporting. They argue that R&D investments are necessary for firms to benefit from their exposure to international markets. Similar results are given by López (2004). He finds that investment and productivity rises in the period before firms enter the export market but domestic sales are constant. He argues this is consistent with investment in technology for sales to foreign but not domestic markets. Hence, literature shows that firm self-selection into export markets leads to productivity change through both, learning by exporting and learning to export.

The main results of our model can be summarised as follows. As technological progress favours the skilled intensive sector more than the low-skilled intensive sector, the sectors face different productivity changes. With technical change wages of skilled and low-skilled workers increase in both sectors but to different extents. When trade costs decrease, the aggregate productivity differences of sectors lead to inter-sectoral trade. The within sector effects reveal as increasing wages and decreasing unemployment in the export sector and decreasing wages and increasing unemployment in the import sector. Differences in wages will cause migration of workers which results in the between sector effects of increasing unemployment in the export sector and decreasing unemployment in the import sector. The reallocation of workers between sectors reveals similar to the Heckscher-Ohlin theorem. These effects are counteracted by intra-sectoral trade as it increases the demand for low-skilled workers.

Section 2 outlines the model whereby 2.1 refers to final goods and 2.2 to intermediate goods production. The labour market equilibrium and thus the wage bargaining process is described in 2.3. Within 2.4 we take account of the rate of unemployment as well as the income of unemployment. The conditions of firm entry and exit of the markets are considered in 2.5, the between and within sector effects of inter-sectoral and intra-sectoral trade in 2.6. Section 3 concludes.

2 The Model

We consider an economy that is characterised by two different factors of production (skilled and low-skilled labour) and two different sectors of production. One of the sectors is assumed to be skill intensive. Both the skilled and unskilled workers can switch between the sectors.

As analysed in Melitz (2003) firms are heterogeneous with respect to their productivity, implying that the least efficient firms drop out of the market and only the most efficient firms take up export to a second country with iceberg transportation costs.

The labour market is characterised by search and matching frictions as in Pissarides (2000). Hence, a firm has to pay a fixed cost to post a vacancy. This vacancy will be filled with a certain probability, which depends on the tightness of the labour market, defined as the ratio of vacancies to unemployed workers.

Technological progress is embodied in new jobs, hence productivity in existing jobs does not change. With job destruction and creation of new and more productive jobs, firms face a productivity shock $I(\tau)\Delta\varphi$ where φ is the productivity of the firm and $I(\tau)$ is an indicator function with

$$I(\tau) = \left\{ \begin{array}{c} 0 \text{ if } t < \tau \\ 1 \text{ if } t \geq \tau \end{array} \right\},$$

where τ is the instant of productivity shock.[3] If technological progress and hence productivity shock takes place, then the skilled intensive sector faces a higher $\Delta\varphi$ than the low-skilled intensive sector. The following derivations apply for $t \neq \tau$.

2.1 Final Goods

There are two countries, the home country H and the foreign country F. The following equations describe the home country, whereby similar definitions apply for the foreign country. The preferences of the households for two goods which are produced by two different sectors $i = 1, 2$ are given by the utility function

$$\Psi^H = \left[\mathbb{C}_1^H\right]^{\alpha_1} \cdot \left[\mathbb{C}_2^H\right]^{\alpha_2}, \tag{1}$$

where $\alpha_1 + \alpha_2 = 1$. The total consumption of final good i in country H is denoted by $\mathbb{C}_i^H$ and the income share spend on final good i is denoted by α_i.

On the other hand, these two consumption goods are aggregates of intermediate goods, whereby the production function of the aggregate good yields as

$$Q_i^H = \left\{ [M^H]^{-\frac{1}{\sigma}} \int_{\omega_{i,j}^H \in \Omega_i^H} [q(\omega_{i,j}^H)]^{\frac{\sigma-1}{\sigma}} d\omega_{i,j}^H \right\}^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where $\sigma > 1$ denotes the elasticity of substitution between any two varieties of inputs. The mass M^H of available intermediate inputs in country H is produced by monopolistically competitive firms and the measure of the set Ω_i^H represents the mass M^H. The quantity available of intermediate input $\omega_{i,j}^H$ is denoted by $q(\omega_{i,j}^H)$. There are k_1 varieties of intermediate inputs ($j = 1, ..., k_1$) produced in sector $i = 1$ and k_2 varieties of intermediate inputs ($j = 1, ..., k_2$) produced in sector $i = 2$, hence $\omega_{i,j}^H \in \Omega_i^H$. With the normalisation M^H it follows that the rate of unemployment does not decrease with the size of the economy (see Felbermayr/Prat/Schmerer, 2011). Aggregate production covers aggregate consumption and the various costs that accumulate during production process such as fixed costs of production and costs of vacancy posting.

[3] We use ()-brackets to denote the arguments of functions, otherwise [] and {}.

The price index is given by

$$P_i^H = \left\{ \frac{1}{M^H} \int_{\omega_{i,j}^H \in \Omega_i^H} [p(\omega_{i,j}^H)]^{1-\sigma} d\omega_{i,j}^H \right\}^{\frac{1}{1-\sigma}}, \tag{3}$$

where $p(\omega_{i,j}^H)$ is the price of variety $\omega_{i,j}^H$. In the following we abstain from index j.

2.2 Intermediate Goods

According to the households utility function (1) and the production function of the aggregate good (2) the inverse demand for each intermediate good reveals as

$$p(\omega_i^H) = \left[q(\omega_i^H)\right]^{-\frac{1}{\sigma}} \left[P_i^H\right]^{\frac{\sigma-1}{\sigma}} \left[\frac{\alpha_i Y^H}{M^H}\right]^{\frac{1}{\sigma}}. \tag{4}$$

Thereby, the total income of country H is denoted by Y^H.

There is a continuum of firms, each choosing to produce a different variety of intermediate good. All firms have different productivity levels indexed by $\varphi(\omega_i^H) > 0$. Higher productivity is modeled as producing a variety at lower marginal cost. Since every variety of intermediate input ω_i^H is produced by one firm, firms are indexed by φ_i^H. In order to entry the market and to start production, firms must first make an initial investment, modeled as a sunk set-up cost $f > 0$. Beside the domestic market, producers can serve the foreign market via exports. Entry into the export market entails again a fixed investment cost $f_x > 0$. These costs reveal since an exporting firm must e.g. set up new distribution channels in the foreign country or must inform foreign buyers about the products. Trade costs are modeled as iceberg transportation costs, whereby $T \geq 1$ units of a good must be shipped in order for 1 unit to arrive at destination. At time τ the home country faces a productivity shock. That means, at time $t < \tau$ firms productivity reveals as φ_i^H and at time $t \geq \tau$ firms productivity reveals as $\varphi_i^H + \Delta\varphi_i^H$. Hence, domestic and foreign inverse demand for intermediate goods producer φ_i^H yield

$$p_d(\varphi_i^H, \tau) = \left[q_d(\varphi_i^H + I(\tau)\Delta\varphi_i^H)\right]^{-\frac{1}{\sigma}} \left[P_i^H\right]^{\frac{\sigma-1}{\sigma}} \left[\frac{\alpha_i Y^H}{M^H}\right]^{\frac{1}{\sigma}} \tag{5}$$

$$p_x(\varphi_i^H, \tau) = \left[q_x(\varphi_i^H + I(\tau)\Delta\varphi_i^H)\right]^{-\frac{1}{\sigma}} \left[P_i^F\right]^{\frac{\sigma-1}{\sigma}} \left[\frac{T\alpha_i Y^F}{M^F}\right]^{\frac{1}{\sigma}} \tag{6}$$

where $I(\tau)$ is the indicator function that takes value one when $t \geq \tau$ and zero when $t < \tau$ and indexes d and x denote the domestic and export market.

If firms decide to sell their products both on the domestic and the export market, they allocate their products so as to maximise total revenues. That means, equal marginal revenues across markets are given and tend to result in $p_d(\varphi_i^H, \tau) = p_x(\varphi_i^H, \tau)/T$. This shows that exporters have to set higher prices in the foreign market reflecting the trade costs T to serve this market. The proof is given in Appendix A.1.

The firms technology of production is represented by a Cobb-Douglas production function

$$q(\varphi_i^H,\tau) = \left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right] \cdot \left[S(\varphi_i^H)\right]^{\beta_i} \cdot \left[L(\varphi_i^H)\right]^{1-\beta_i} \tag{7}$$

where $S(\varphi_i^H)$ and $L(\varphi_i^H)$ are the number of skilled and low-skilled workers and β_i is the relative share of skilled worker in total product. $S(\varphi_i^H)$ and $L(\varphi_i^H)$ are inputs in the production process for both, the domestic and the foreign market. The firms number of skilled and low-skilled worker does not alter at time τ since new and more productive jobs displace existing jobs.

As a result of sales on the domestic market the revenues of a firm in country H with productivity φ_i^H are given by $R_d(\varphi_i^H,\tau) = p_d(\varphi_i^H,\tau)q_d(\varphi_i^H,\tau)$ and from sales on the foreign market by $R_x(\varphi_i^H,\tau) = p_x(\varphi_i^H,\tau)q_x(\varphi_i^H,\tau)/T$. Based on these equations, the total revenue of the firm is given by

$$\begin{aligned} R(\varphi_i^H,\tau) &= \left\{[\varphi_i^H + I(\tau)\Delta\varphi_i^H][S_{id}^H]^{\beta_i}[L_{id}^H]^{1-\beta_i}\right\}^{\frac{\sigma-1}{\sigma}} [P_i^H]^{\frac{\sigma-1}{\sigma}} \left[\frac{\alpha_i Y^H}{M^H}\right]^{\frac{1}{\sigma}} \\ &+ I(\varphi_i^H)\left\{[\varphi_i^H + I(\tau)\Delta\varphi_i^H][S_{ix}^H]^{\beta_i}[L_{ix}^H]^{1-\beta_i}\right\}^{\frac{\sigma-1}{\sigma}} [P_i^F]^{\frac{\sigma-1}{\sigma}} \left[\frac{T^{1-\sigma}\alpha_i Y^F}{M^F}\right]^{\frac{1}{\sigma}} \end{aligned} \tag{8}$$

whereby $I(\varphi_i^H)$ is the indicator function with value one when the firm exports and value zero when the firm only sells its intermediate inputs on the domestic market.

2.3 Wage Bargaining

Within this section we describe the labour market equilibrium, whereby the labour market is characterised by search and matching frictions. Wages are bargained individually which means the following sequence of actions. At each period, the intermediate good producer decides about the optimal number of vacancies v, taking the wage rate as given, of which only a certain share $m(\theta)$ is filled. The matching technology brings together the workers and the firm and wages are bargained before production takes place. The number of matches depends negatively on labour market tightness $\theta = V/U$, where V is the total number of vacancies posted on a specific labour market and U is the number of unemployed workers on this labour market. All payments are made at the end of each period. Before beginning of the next period, the match could be resolved due to exogenous reasons with probability ρ. The workforce's evolution of a firm is given by

$$\begin{aligned} L_i^H(t+\Delta t) &= [1-\rho]\, L_i^H(t) + m(\theta_{L_i}^H)v_{L_i}^H \\ S_i^H(t+\Delta t) &= [1-\rho]\, S_i^H(t) + m(\theta_{S_i}^H)v_{S_i}^H \end{aligned} \tag{9}$$

Solving the game by backward induction, we first characterise the firms optimal vacancy setting behaviour, and then solve the bargaining problem. The market value of an intermediate producer is given by

$$
\begin{aligned}
G_i^H(t,\tau) &= \frac{1}{1+r}\{R(\varphi_i^H,\tau) - w_{L_i}^H(t,\tau)L(\varphi_i^H) - w_{S_i}^H(t,\tau)S(\varphi_i^H) - fP_i^H \\
&- v_{L_i}^H cP_i^H - v_{S_i}^H cP_i^H - I(\varphi_i^H) f_x P_i^H + [1-\delta]G_i^H(t+\Delta t,\tau)\}, \qquad (10)
\end{aligned}
$$

where r denotes the interest rate, and $w_{S_i}^H(t,\tau)$ and $w_{L_i}^H(t,\tau)$ the wages for skilled and low-skilled workers, respectively. A firm faces fixed cost $f > 0$. The costs of posting a vacancy are given by c (measured in units of the aggregate good) and the firm will be destroyed with the exogenous probability δ. Maximisation of the value of the firm requires

$$
\frac{\partial G_i^H(t,\tau)}{\partial v_{L_i}^H} = 0 \quad \text{and} \quad \frac{\partial G_i^H(t,\tau)}{\partial v_{S_i}^H} = 0 \qquad (11)
$$

subject to production function (7), firms revenues (8) and evolution of employment (9). According these constraints it follows

$$
\begin{aligned}
\frac{\partial L_i^H(t+\Delta t)}{\partial L_i^H(t)} &= 1-\rho \quad , \quad \frac{\partial S_i^H(t+\Delta t)}{\partial S_i^H(t)} = 1-\rho \qquad (12) \\
\frac{\partial L_i^H(t+\Delta t)}{\partial v_{L_i}^H} &= m(\theta_{L_i}^H) \quad , \quad \frac{\partial S_i^H(t+\Delta t)}{\partial v_{S_i}^H} = m(\theta_{S_i}^H). \qquad (13)
\end{aligned}
$$

The first order conditions for vacancy posting read

$$
\begin{aligned}
cP_i^H &= [1-\delta]\cdot\frac{\partial G_i^H(t+\Delta t,\tau)}{\partial L_i^H(t+\Delta t)}\cdot m(\theta_{L_i}^H) \qquad (14) \\
cP_i^H &= [1-\delta]\cdot\frac{\partial G_i^H(t+\Delta t,\tau)}{\partial S_i^H(t+\Delta t)}\cdot m(\theta_{S_i}^H). \qquad (15)
\end{aligned}
$$

Substituting the constraints into the objective function of the firm, differentiating with respect to L_i^H and S_i^H and using the optimality conditions (14) and (15) yields

$$
\begin{aligned}
\frac{\partial G_i^H(t,\tau)}{\partial L_i^H(t)} &= \frac{1}{1+r}\left\{\frac{\partial R(\varphi_i^H,\tau)}{\partial L_i^H(t)} - \left[w_{L_i}^H(t,\tau) + \frac{\partial w_{L_i}^H(t,\tau)}{\partial L_i^H(t)}L(\varphi_i^H)\right] + \frac{cP_i^H}{m(\theta_{L_i}^H)}[1-\rho]\right\} \quad (16) \\
\frac{\partial G_i^H(t,\tau)}{\partial S_i^H(t)} &= \frac{1}{1+r}\left\{\frac{\partial R(\varphi_i^H,\tau)}{\partial S_i^H(t)} - \left[w_{S_i}^H(t,\tau) + \frac{\partial w_{S_i}^H(t,\tau)}{\partial S_i^H(t)}S(\varphi_i^H)\right] + \frac{cP_i^H}{m(\theta_{S_i}^H)}[1-\rho]\right\}. \quad (17)
\end{aligned}
$$

Hereby, the firm takes into account the effect of additional employment on the worker's wage. Moreover, the probability ρ with which the match could be resolved and the probability δ with which a firm will be destroyed are assumed to be independent. According this, the rate of job destruction is given by $s = \delta + \rho - \delta\rho$ and hence it follows, without using the first order conditions (14) and (15),

$$
\begin{aligned}
\frac{\partial G_i^H(t,\tau)}{\partial L_i^H(t)} &= \frac{1}{1+r}\left\{\frac{\partial R(\varphi_i^H,\tau)}{\partial L_i^H(t)} - w_{L_i}^H(t,\tau) - \frac{\partial w_{L_i}^H(t,\tau)}{\partial L_i^H(t)}L(\varphi_i^H) + [1-s]\frac{\partial G_i^H(t+\Delta t,\tau)}{\partial L_i^H(t+\Delta t)}\right\} \quad (18) \\
\frac{\partial G_i^H(t,\tau)}{\partial S_i^H(t)} &= \frac{1}{1+r}\left\{\frac{\partial R(\varphi_i^H,\tau)}{\partial S_i^H(t)} - w_{S_i}^H(t,\tau) - \frac{\partial w_{S_i}^H(t,\tau)}{\partial S_i^H(t)}S(\varphi_i^H) + [1-s]\frac{\partial G_i^H(t+\Delta t,\tau)}{\partial S_i^H(t+\Delta t)}\right\}. \quad (19)
\end{aligned}
$$

Now, we take account of the steady-state conditions. In steady-state the market value of a firm remains constant through time with $G_i^H(t,\tau) = G_i^H(t+\Delta t,\tau)$. Since optimality conditions (14) and (15) do not vary with the level of variables $v_{L_i}^H$ and $v_{S_i}^H$, the optimal firm size remains constant, so that $L_i^H(t) = L_i^H(t+\Delta t)$ and $S_i^H(t) = S_i^H(t+\Delta t)$. Furthermore, according to the optimality conditions (14) and (15) steady-state conditions are given by

$$\frac{\partial G_i^H(t,\tau)}{\partial L_i^H(t)} = \frac{\partial G_i^H(t+\Delta t,\tau)}{\partial L_i^H(t+\Delta t)} \tag{20}$$

and

$$\frac{\partial G_i^H(t,\tau)}{\partial S_i^H(t)} = \frac{\partial G_i^H(t+\Delta t,\tau)}{\partial S_i^H(t+\Delta t)}. \tag{21}$$

Thus, it follows

$$\frac{\partial R(\varphi_i^H,\tau)}{\partial L_i^H(t)} = w_{L_i}^H(t,\tau) + \frac{\partial w_{L_i}^H(t,\tau)}{\partial L_i^H(t)} L(\varphi_i^H) + [r+s]\frac{\partial G_i^H(t,\tau)}{\partial L_i^H(t)} \tag{22}$$

$$\frac{\partial R(\varphi_i^H,\tau)}{\partial S_i^H(t)} = w_{S_i}^H(t,\tau) + \frac{\partial w_{S_i}^H(t,\tau)}{\partial S_i^H(t)} S(\varphi_i^H) + [r+s]\frac{\partial G_i^H(t,\tau)}{\partial S_i^H(t)}. \tag{23}$$

Combining these two equations with the first order conditions (14) and (15) yields expressions that implicitly determine the optimal pricing behaviour of the firm, whereby marginal costs contain the effect of additional employment and expected recruitment costs

$$\frac{\partial R(\varphi_i^H,\tau)}{\partial L_i^H(t)} = w_{L_i}^H(t,\tau) + \frac{\partial w_{L_i}^H(t,\tau_i)}{\partial L_i^H(t)} L(\varphi_i^H) + \frac{cP_i^H}{m(\theta_{L_i}^H)} \cdot \frac{s+r}{1-\delta} \tag{24}$$

$$\frac{\partial R(\varphi_i^H,\tau)}{\partial S_i^H(t)} = w_{S_i}^H(t,\tau) + \frac{\partial w_{S_i}^H(t,\tau)}{\partial S_i^H(t)} S(\varphi_i^H) + \frac{cP_i^H}{m(\theta_{S_i}^H)} \cdot \frac{s+r}{1-\delta}. \tag{25}$$

The total surplus of a successful match is split between the worker and the firm. The worker's surplus is equal to the difference between the value of being employed $E_{L_i}^H(t,\tau)$ ($E_{S_i}^H(t,\tau)$) by a firm and the value of being unemployed $U_{L_i}^H(t)$ ($U_{S_i}^H(t)$). The firm's surplus is equal to the marginal increase in the firm's value $\partial G_i^H(t,\tau)/\partial L_i^H(t)$ ($\partial G_i^H(t,\tau)/\partial S_i^H(t)$) because individual bargaining implies that as in Stole/Zwiebel (1996) every worker is treated as the last worker employed by the firm, i.e. the marginal worker. Following Stole/Zwiebel (1996) we assume that the outcome of bargaining over the division of total surplus from the match satisfies the following surplus-splitting rules

$$\frac{\mu}{1-\mu} \cdot \frac{\partial G_i^H(t,\tau)}{\partial L_i^H(t)} = E_{L_i}^H(t,\tau) - U_{L_i}^H(t) \tag{26}$$

and

$$\frac{\mu}{1-\mu} \cdot \frac{\partial G_i^H(t,\tau)}{\partial S_i^H(t)} = E_{S_i}^H(t,\tau) - U_{S_i}^H(t), \tag{27}$$

where μ measures the bargaining power of a worker and thus belongs to [0, 1]. Corresponding to Pissarides (2000) the worker's surplus is given by

$$[r+s] \cdot \left[E_{L_i}^H(t,\tau) - U_{L_i}^H(t)\right] = w_{L_i}^H(t,\tau) - rU_{L_i}^H(t) \tag{28}$$

and

$$[r+s]\cdot\left[E^H_{S_i}(t,\tau)-U^H_{S_i}(t)\right]=w^H_{S_i}(t,\tau)-rU^H_{S_i}(t). \tag{29}$$

These two equations make clear that because of the risk of unemployment the permanent income of employed workers, $E^H_{L_i}(t,\tau)$ ($E^H_{S_i}(t,\tau)$), is different from the wage $w^H_{L_i}(t,\tau)$ ($w^H_{S_i}(t,\tau)$).

Solving the surplus-splitting rules (26) and (27) needs to reinsert the worker's surpluses (28) and (29) together with (22) and (23) into the rules. It follows

$$w^H_{L_i}(t,\tau)=\mu\frac{\partial R(\varphi^H_i,\tau)}{\partial L^H_i(t)}-\mu\frac{\partial w^H_{L_i}(t,\tau)}{\partial L^H_i(t)}L(\varphi^H_i)+[1-\mu]\cdot rU^H_{L_i}(t) \tag{30}$$

and

$$w^H_{S_i}(t,\tau)=\mu\frac{\partial R(\varphi^H_i,\tau)}{\partial S^H_i(t)}-\mu\frac{\partial w^H_{S_i}(t,\tau)}{\partial S^H_i(t)}S(\varphi^H_i)+[1-\mu]\cdot rU^H_{S_i}(t). \tag{31}$$

Hereby, the wages $w^H_{L_i}(t,\tau)$ and $w^H_{S_i}(t,\tau)$ are functions of $L(\varphi^H_i)$ and $S(\varphi^H_i)$, respectively. Hence, these two equations are linear differential equation in $L(\varphi^H_i)$ and $S(\varphi^H_i)$, respectively. The solutions are given by

$$w^H_{L_i}(t,\tau)=\frac{\mu\sigma}{\beta_i\mu-\beta_i\sigma\mu-\mu+\sigma}\cdot\frac{\partial R(\varphi^H_i,\tau)}{\partial L^H_i(t)}+r[1-\mu]U^H_{L_i}(t) \tag{32}$$

and

$$w^H_{S_i}(t,\tau)=\frac{\mu\sigma}{\beta_i\sigma\mu-\beta_i\mu-\mu\sigma+\sigma}\cdot\frac{\partial R(\varphi^H_i,\tau)}{\partial S^H_i(t)}+r[1-\mu]U^H_{S_i}(t). \tag{33}$$

The proof is given in Appendix A.2. Based on these solutions of linear differential equations it can proceeded with the deviation of job creation curves and wage curves.

To derive the job creation curves first we reinsert the marginal revenue functions (given in Appendix (78) and (79)) into the solutions (32) and (33) and differentiate the resulting equations with respect to $L(\varphi^H_i)$ and $S(\varphi^H_i)$, respectively. Thus, it follows

$$L^H_i\cdot\frac{\partial w^H_{L_i}(t,\tau)}{\partial L^H_i}=\mu\cdot\frac{\beta_i-\beta_i\sigma-1}{[\beta_i-\beta_i\sigma-1]\mu+\sigma}\cdot\frac{\partial R(\varphi^H_i,\tau)}{\partial L^H_i(t)} \tag{34}$$

$$S^H_i\cdot\frac{\partial w^H_{S_i}(t,\tau)}{\partial S^H_i}=\mu\cdot\frac{\beta_i\sigma-\beta_i-\sigma}{[\beta_i\sigma-\beta_i-\sigma]\mu+\sigma}\cdot\frac{\partial R(\varphi^H_i,\tau)}{\partial S^H_i(t)}. \tag{35}$$

Second we substitute the resulting functions into (24) and (25), respectively, and get

$$w^H_{L_i}(t,\tau)=\frac{\partial R(\varphi^H_i,\tau)}{\partial L^H_i(t)}\cdot\frac{\sigma}{[\beta_i-\beta_i\sigma-1]\mu+\sigma}-\frac{cP^H_i}{m(\theta^H_{L_i})}\cdot\frac{s+r}{1-\delta} \tag{36}$$

$$w^H_{S_i}(t,\tau)=\frac{\partial R(\varphi^H_i,\tau)}{\partial S^H_i(t)}\cdot\frac{\sigma}{[\beta_i\sigma-\beta_i-\sigma]\mu+\sigma}-\frac{cP^H_i}{m(\theta^H_{S_i})}\cdot\frac{s+r}{1-\delta}. \tag{37}$$

Finally, with regard of marginal revenue functions (given in Appendix (66) and (67)) the job creation curves reveal as

$$
\begin{aligned}
w^H_{L_i}(t,\tau) &= \frac{\sigma-1}{[\beta_i-\beta_i\sigma-1]\mu+\sigma}\cdot[1-\beta_i]\cdot p_d(\varphi^H_i,\tau)\left[\varphi^H_i+I(\tau)\Delta\varphi^H_i\right] \\
&\cdot \left[\frac{S(\varphi^H_i)}{L(\varphi^H_i)}\right]^{\beta_i}-\frac{cP^H_i}{m(\theta^H_{L_i})}\cdot\frac{s+r}{1-\delta}
\end{aligned} \tag{38}
$$

and

$$
\begin{aligned}
w^H_{S_i}(t,\tau) &= \frac{\sigma-1}{[\beta_i\sigma-\beta_i-\sigma]\mu+\sigma}\cdot\beta_i\cdot p_d(\varphi^H_i,\tau)\left[\varphi^H_i+I(\tau)\Delta\varphi^H_i\right] \\
&\cdot \left[\frac{S(\varphi^H_i)}{L(\varphi^H_i)}\right]^{\beta_i-1}-\frac{cP^H_i}{m(\theta^H_{S_i})}\cdot\frac{s+r}{1-\delta}.
\end{aligned} \tag{39}
$$

These equations represent the wage conditions when a firm and a searching worker meet and agree to form a match. Once the firm and the worker meet and a job is created, production continues until shocks arrive. If the economy is characterised by technological progress, it is profitable to the firm to detach from existing jobs and create new jobs at technological frontier. Then the firm faces a positive productivity shock accompanied by at $\Delta\varphi^H_i$ higher wages. The profitability of job separation stems from the fact that, because all new jobs are created on the technological frontier, outside options change with technological progress.

The job creation curves (38) and (39) are firm-specific. To express the wage curves as a function of $\theta^H_{L_i}$ and $\theta^H_{S_i}$, respectively, the solutions (32) and (33) of linear differential equations need to be reinserted into (36) and (37). The wage curves reveal as

$$
w^H_{L_i}(t,\tau)=rU^H_{L_i}(t)+\frac{\mu}{1-\mu}\cdot\frac{cP^H_i}{m(\theta^H_{L_i})}\cdot\frac{s+r}{1-\delta} \tag{40}
$$

and

$$
w^H_{S_i}(t,\tau)=rU^H_{S_i}(t)+\frac{\mu}{1-\mu}\cdot\frac{cP^H_i}{m(\theta^H_{S_i})}\cdot\frac{s+r}{1-\delta}. \tag{41}
$$

Furthermore, taking account of the value functions of employed and unemployed workers eliminates the value of unemployment of equations (40) and (41). According Pissarides (2000) the value functions of unemployed workers are given as

$$
\begin{aligned}
rU^H_{L_i}(t) &= z_{L_i}+\theta^H_{L_i}m(\theta^H_{L_i})[E^H_{L_i}(t,\tau)-U^H_{L_i}(t)] && (42)\\
rU^H_{S_i}(t) &= z_{S_i}+\theta^H_{S_i}m(\theta^H_{S_i})[E^H_{S_i}(t,\tau)-U^H_{S_i}(t)], && (43)
\end{aligned}
$$

where $\theta^H_{L_i}m(\theta^H_{L_i})$ $(\theta^H_{S_i}m(\theta^H_{S_i}))$ is the probability of an unemployed worker to find a new job and z_{L_i} (z_{S_i}) is the unemployment income. Further, the value functions of employed workers are given by

$$
\begin{aligned}
rE^H_{L_i}(t,\tau) &= w^H_{L_i}(t,\tau)+s[U^H_{L_i}(t)-E^H_{L_i}(t,\tau)] && (44)\\
rE^H_{S_i}(t,\tau) &= w^H_{S_i}(t,\tau)+s[U^H_{S_i}(t)-E^H_{S_i}(t,\tau)]. && (45)
\end{aligned}
$$

Combining the value functions of unemployed and employed workers yields

$$rU_{L_i}^H(t) = z_{L_i} + \frac{\theta_{L_i}^H m(\theta_{L_i}^H)}{r+s}\left[w_{L_i}^H(t,\tau) - rU_{L_i}^H(t)\right] \tag{46}$$

$$rU_{S_i}^H(t) = z_{S_i} + \frac{\theta_{S_i}^H m(\theta_{S_i}^H)}{r+s}\left[w_{S_i}^H(t,\tau) - rU_{S_i}^H(t)\right]. \tag{47}$$

Now, if $w_{L_i}^H(t,\tau) - rU_{L_i}(t)$ and $w_{S_i}^H(t,\tau) - rU_{S_i}(t)$ are replaced by using the wage curves (40) and (41) and the resulting equations are reinserted into (40) and (41) the wage curves reveal as

$$w_{L_i}^H(t,\tau) = z_{L_i} + \frac{\mu}{1-\mu}\left[\frac{s+r}{1-\delta}\cdot\frac{cP_i^H}{m(\theta_{L_i}^H)} + \frac{cP_i^H\theta_{L_i}^H}{1-\delta}\right] \tag{48}$$

$$w_{S_i}^H(t,\tau) = z_{S_i} + \frac{\mu}{1-\mu}\left[\frac{s+r}{1-\delta}\cdot\frac{cP_i^H}{m(\theta_{S_i}^H)} + \frac{cP_i^H\theta_{S_i}^H}{1-\delta}\right]. \tag{49}$$

The equilibrium on the labour market is determined by the job creation curve and the wage curve. The interacting of these curves gives the equilibrium wage and labour market tightness. The uniqueness of the equilibrium is ensured since the wage curve is increasing in $\theta_{L_i}^H$ $(\theta_{S_i}^H)$ and the job creation curve decreasing in $\theta_{L_i}^H$ $(\theta_{S_i}^H)$. The way that market tightness enters the wage equation is through the bargaining power of firms and workers. Analogue to Pissarides (2000) that means, a higher $\theta_{L_i}^H$ $(\theta_{S_i}^H)$ indicates that jobs arrive to workers at higher rate than workers do to vacant jobs, relative to an equilibrium with lower $\theta_{L_i}^H$ $(\theta_{S_i}^H)$. Then higher wage rates reveal, since the worker's bargaining power is higher and the firm's bargaining power lower. As in Larch/Lechthaler (2011), referring to Stole/Zwiebel (1996), the assumption that wages are bargained individually implies that every worker is treated as the marginal worker. That means, the wage of each worker represent their outside option. Workers are paid in equal measure across firms with different productivity levels. Each firm employs as many workers as are necessary to ensure that the marginal value of the last employed worker is equal to the wage.

Based on Felbermayr/Prat/Schmerer (2011), trade liberalisation raises aggregate productivity by affecting the average productivity of firms. Analogue, also technological progress raises aggregate productivity by this means. That means, because firms are on average more productive and search more intensively for workers the job creation curve shifts upwards. The wage curve also shifts upwards because unemployment income is increasing with aggregate productivity. Thus, it follows the adjustment to an equilibrium where wages $w_{S_i}^H(t,\tau)$ and $w_{L_i}^H(t,\tau)$ and labour market tightness $\theta_{L_i}^H$ and $\theta_{S_i}^H$ are higher, relative to the equilibrium before technical change and trade liberalisation took place. Hence, technological progress and trade liberalisation will affect labour market outcomes to the extent that it changes aggregate productivity by modifying the average productivity of firms.

Proposition 1 *When wages are bargained individually, the worker's wages are negotiated to their outside option. With technological progress outside options and hence wages and aggregate productivity change. Supplementary, aggregate productivity and hence wages change due to trade liberalisation. Thus, both technological progress and trade liberalisation affect labour market outcomes.*

2.4 The Rate and Income of Unemployment

Unemployment income z_{L_i} and z_{S_i} consists of two different components. These are the actual income received during unemployment, such as transfer payments, and the imputed value of time to unemployed workers. By assumption the actual-income component of z_{L_i} and z_{S_i} is proportional to average wages, since unemployment insurance benefits may be indexed to the average wage rate because the taxes used to finance them are generally proportional to wages and not lump sum. This is in line with Pissarides (2000) and confirms the adoption above that unemployment income is increasing with aggregate productivity.

By assumption there are four labour markets, for skilled and low-skilled workers of each sector. The matching function describes the probability that a vacancy is filled dependent on the tightness of the labour market $\theta^H_{L_i}$ and $\theta^H_{S_i}$. Moreover, the probability of an unemployed worker to find a new job is given by $\theta^H_{L_i} m(\theta^H_{L_i})$ and $\theta^H_{S_i} m(\theta^H_{S_i})$. Since the rate of job destruction s captures both the probability with which a match will be resolved and the probability with which a firm will be destroyed, the equilibrium rates of unemployment are given by

$$u^H_{L_i} = \frac{s}{s + \theta^H_{L_i} m(\theta^H_{L_i})} \tag{50}$$

$$u^H_{S_i} = \frac{s}{s + \theta^H_{S_i} m(\theta^H_{S_i})}. \tag{51}$$

With these conditions the flows in and out of unemployment are equal. Once workers losing their jobs they experience a period of job search before finding new employment by switching between the sectors. The rate of unemployment is a decreasing function of market tightness.

2.5 Firm Entry and Exit

Analogue to Larch/Lechthaler (2011), who refer to Felbermayr/Prat/Schmerer (2011) and further to Melitz (2003), for each sector there is a large number of prospective entrants. Prior to entry, firms are identical. To enter the market, firms have to pay a fixed and sunk entry cost $f > 0$, measured in terms of the final consumption good of the sector the firm wants to enter. Firms then draw their initial productivity φ^H_i from a common distribution $g(\varphi^H_i)$, hence they do not know their productivity until they start production and sell their goods. The cumulative distribution of $g(\varphi^H_i)$ is denoted by $G(\varphi^H_i)$. The productivity of the firm stays the same as long as the firm exists and $t < \tau$. At time τ the positive productivity shock due to technical change results in a mean value displacement of distribution $g(\varphi^H_i)$. Given that the revenues of firms are increasing in φ^H_i, there is a threshold φ^{*H}_{id} below which firms do not take up production. Similarly, there is a threshold φ^{*H}_{ix}, necessary to produce for the foreign market. Hence, with a productivity level between φ^{*H}_{id} and φ^{*H}_{ix} firms will serve only the domestic market. The mean value displacement of distribution $g(\varphi^H_i)$ at time τ involves a displacement of threshold-values, $\varphi^{*H}_i = \varphi^{*H}_i(\tau)$. The share of exporting firms is equal to

$$\zeta^H_i = \frac{1 - G(\varphi^{*H}_{ix})}{1 - G(\varphi^{*H}_{id})}. \tag{52}$$

According Melitz (2003) the average productivity of firms that sell only domestically is defined by

$$\tilde{\varphi}_{id}^{H}(\varphi_{id}^{*H},\tau)=\left[\frac{1}{1-G(\varphi_{id}^{*H})}\int_{\varphi_{id}^{*H}}^{\infty}[\varphi_{i}^{H}]^{\sigma-1}g(\varphi_{i}^{H})d\varphi_{i}^{H}\right]^{\frac{1}{\sigma-1}}, \tag{53}$$

and the average productivity of firms that also sell abroad is defined by

$$\tilde{\varphi}_{ix}^{H}(\varphi_{ix}^{*H},\tau)=\left[\frac{1}{1-G(\varphi_{ix}^{*H})}\int_{\varphi_{ix}^{*H}}^{\infty}[\varphi_{i}^{H}]^{\sigma-1}g(\varphi_{i}^{H})d\varphi_{i}^{H}\right]^{\frac{1}{\sigma-1}}. \tag{54}$$

To characterise the entry threshold φ_{id}^{*H} in the following, note that it is profitable for the firm to start production and to recruit workers when

$$[1-\delta]\frac{\pi_d(\varphi_{id}^{*H})}{r+\delta}=\frac{cP_i^H L(\varphi_{id}^{*H})}{m(\theta_{L_i}^H)}+\frac{cP_i^H S(\varphi_{id}^{*H})}{m(\theta_{S_i}^H)}+fP_i^H, \tag{55}$$

where

$$\begin{aligned}\pi_d(\varphi_i^H) &= p_d(\varphi_i^H)q_d(\varphi_i^H)-w_{L_i}^H L(\varphi_i^H)-w_{S_i}^H S(\varphi_i^H)-fP_i^H\\ &- \frac{pcP_i^H L(\varphi_i^H)}{m(\theta_{L_i}^H)}-\frac{pcP_i^H S(\varphi_i^H)}{m(\theta_{S_i}^H)}\end{aligned} \tag{56}$$

is the profit from domestic sales of the firm. Hereby, the profits are revenues minus wage payments, fixed costs and vacancy costs. With evolution of the workforce according equation (9) and the steady-state conditions $L_i^H(t)=L_i^H(t+\Delta t)$ and $S_i^H(t)=S_i^H(t+\Delta t)$ it follows $v_{L_i}^H=\rho L_i^H/m(\theta_{L_i}^H)$ and $v_{S_i}^H=\rho S_i^H/m(\theta_{S_i}^H)$. Equation (55) accounts for the fact that firms must make an initial investment to enter the market and pay vacancy costs but only a period later they recruit workers. During this period, the firm will be destroyed with exogenous probability δ so that the firm never starts production.

Similarly, it can be characterised the choice of exporting. It is profitable for the firm to produce for the foreign market when

$$(1-\delta)\frac{\pi_x(\varphi_{ix}^{*H})}{r+\delta}=\frac{cP_i^H L(\varphi_{ix}^{*H})}{m(\theta_{L_i}^H)}+\frac{cP_i^H S(\varphi_{ix}^{*H})}{m(\theta_{S_i}^H)}+f_xP_i^H \tag{57}$$

where

$$\begin{aligned}\pi_x(\varphi_i^H) &= p_x(\varphi_i^H)q_x(\varphi_i^H)\frac{1}{T}-w_{L_i}^H L(\varphi_i^H)-w_{S_i}^H S(\varphi_i^H)-f_xP_i^H\\ &- \frac{pcP_i^H L(\varphi_i^H)}{m(\theta_{L_i}^H)}-\frac{pcP_i^H S(\varphi_i^H)}{m(\theta_{S_i}^H)}\end{aligned} \tag{58}$$

is the profit of the firm when selling their products in foreign markets. This profit has to be large enough to cover the additional fixed cost f_x.

Based on these definitions the free entry condition reveals as

$$\begin{aligned} fP_i^H &= [1-G(\varphi_{id}^{*H})]\left\{[1-\delta]\frac{\pi_d(\tilde{\varphi}_{id}^H)}{r+\delta} - \frac{cP_i^H L(\tilde{\varphi}_{id}^H)}{m(\theta_{L_i}^H)} - \frac{cP_i^H S(\tilde{\varphi}_{id}^H)}{m(\theta_{S_i}^H)} - fP_i^H\right\} \\ &+ [1-G(\varphi_{ix}^{*H})]\left\{[1-\delta]\frac{\pi_x(\tilde{\varphi}_{ix}^H)}{r+\delta} - \frac{cP_i^H L(\tilde{\varphi}_{ix}^H)}{m(\theta_{L_i}^H)} - \frac{cP_i^H S(\tilde{\varphi}_{ix}^H)}{m(\theta_{S_i}^H)} - f_x P_i^H\right\} \end{aligned} \quad (59)$$

The free entry condition takes into account the behaviour of prospective entrants. Thus, entry occurs until expected profits, on the right-hand side, are equal to the entry cost, on the left-hand side. An entrant will start producing with probability $1-G(\varphi_{id}^{*H})$. Furthermore, an entrant will also export with probability $1-G(\varphi_{ix}^{*H})$. New firms will enter the market as long as profits exceed the entry cost. This leads to increased competition which drives down profits until they have reached the entry cost. Similarly, firms will exit the market if profits are too low. The equilibrium mass of firms is such that the labour market clears. Hence,

$$M_i^H[L(\tilde{\varphi}_{id}^H) + \zeta_i^H L(\tilde{\varphi}_{ix}^H)] = [1-u_{L_i}^H]\hat{L}_i^H \quad (60)$$

$$M_i^H[S(\tilde{\varphi}_{id}^H) + \zeta_i^H S(\tilde{\varphi}_{ix}^H)] = [1-u_{S_i}^H]\hat{S}_i^H, \quad (61)$$

where $\hat{L}_i^H$ $(\hat{S}_i^H)$ is the size of the labour force, equal to an exogenously given total number of people, and M_i^H is the mass of domestic producers in each country. The demand for labour is given on the left-hand side by the sum of the demand of all domestic firms for domestic and export production. The supply of labour is given on the right-hand side by the number of employed workers. Due to imports from foreign firms, the number of available varieties exceeds M_i^H and thus, given the share of exporting firms in (52), is equal to $\hat{M}_i^H = M_i^H + \zeta_i^F M_i^F$.

Proposition 2 *The average productivity of firms depends on the threshold-values φ_{id}^{*H} and φ_{ix}^{*H}, respectively. When the firm's productivity exceeds these values it starts production and exports. Technological progress raises the firm's productivity up to $\varphi_i^H + \Delta\varphi_i^H$ and thus results in a mean value displacement of the distribution of the productivity of firms $g(\varphi_i^H)$. The mean value displacement of $g(\varphi_i^H)$ involves a displacement of threshold-values φ_{id}^{*H} and φ_{ix}^{*H}.*

2.6 Between and Within Sector Effects

In the following we will point out how trade liberalisation and technical change interact and describe the impact of these two forces on wages and employment of skilled and low-skilled worker, respectively.

Technological progress expresses in a firms' productivity change from the initial value φ_i^H up to $\varphi_i^H + \Delta\varphi_i^H$. That means, it has an effect on the average productivity of firms and thus on the aggregate productivity accompanied by a shift in the productivity threshold-values φ_{id}^{*H} and φ_{ix}^{*H} that determine whether firms enter the market and export or do not. Moreover, along Felbermayr/Prat/Schmerer (2011), as long as fixed foreign distribution costs are larger than domestic ones, trade liberalisation by means of a reduction in variable trade costs or an increase in the number of trade partners raises average productivity of firms and hence aggregate productivity. Along Melitz (2003) this results in a reallocation of labour towards efficient firms and thus towards exporting firms and away from domestic firms of lower efficiency level.

Now we introduce the assumptions that country H is the skill-abundant country and it is the only country that faces a productivity change due to technical change. In addition, we suppose that the extent of productivity shock depends on the skill intensity of the sector where a firm is operating. This is in line with the literature on skill biased technical change, so that the productivity of a firm is positively correlated with its skill intensity. Empirically support comes from e.g. Bernard/Jensen/Schott (2006); Bustos (2011); Verhoogen (2008); Alcalá/Hernández (2010) or Molina/Muendler (2009) who show that exporting firms and large firms tend to be relatively skill intensive. Or as Nelson/Phelps (1966) state, more educated, able or experienced labour deals better with technological change. If sector 1 is assumed to be the skill intensive sector then these assumptions are summarised by

$$\Delta\varphi_1^H > \Delta\varphi_2^H > 0 \tag{62}$$

$$\Delta\varphi_1^F = \Delta\varphi_2^F = 0 \tag{63}$$

whereby assumption (62) states that country H faces a larger productivity change in sector 1 than in sector 2. In contrast, with (63), country F faces no alterations. In addition, we assume that both skilled and low-skilled worker can switch between the sectors within countries. Internationally, they are immobile.

Technical change in country H increases average productivity. As a result on the one hand, wages increase since jobs are created on the technological frontier (see (38) and (39)). On the other hand, since the rate of unemployment is a decreasing function of the market tightness (see (50) and (51)), it decreases unemployment. We refer to this as the within sector effects. Hence, both skilled and low-skilled workers get higher wages in both sectors of country H, but because of assumption (62) to a larger extent in sector 1. As skilled and low-skilled workers are fully mobile, this leads to movements of workers to sector 1, until the values of them are equalised between the sectors. Due to these migration flows, unemployment increases in sector 1. Unemployment in sector 2 goes down since leaving this sector leads to an increase of the prospects of the remaining workers to find a job. We refer to this as the between sector effects.

As trade costs decrease, inter-sectoral trade between the two countries rises. With trade liberalisation, competition increases whereby driving out the least productive firms and rising average productivity. That means, it leads to selection of efficient firms into exporting and of inefficient firms into exit (analogue to Melitz, 2003). Country H specialises in the production of the skill intensive good 1, since this sector is characterised by productivity advantages relative to sector 2 because of assumption (62) as well as it is the comparative advantage-sector. Hereby, it becomes a net-exporter of goods from sector 1 and a net-importer of goods from sector 2. The specialisation implies changes in relative prices. The price in the export sector 1 goes up and the price in the import sector 2 goes down. This will tend to increase wages and decrease unemployment in the export sector and decrease wages and increase unemployment in the import sector - the within sector effects. The specialisation results in reallocation of workers between sectors, similar to the traditional Heckscher-Ohlin model. Differences in wages will cause migration of workers to sector 1 until the values of the workers are equalised between the sectors, and further, has the consequence of increasing unemployment in sector 1 and decreasing unemployment in sector 2 - the between sector effects. As the home country is the skill-abundant country, overall the skilled workers should gain whereas the low-skilled workers should lose both in terms of wages and employment. But these effects can be overlaid by the effects of intra-sectoral trade.

The rise of intra-sectoral trade can be discussed also due to decreasing trade costs. Analogue to Larch/Lechthaler (2011), the consideration is as follows. If trade costs become sufficiently low, the consumers love for variety becomes more important, implying that the demand of country F for goods of sector 2 of country H rises. Despite the fact that country F can produce these goods relatively cheaper than country H, country H starts to export these good, too. This results in a increased competition in this sector, whereby the least productive firms are driven out of the market. This increases average productivity in sector 2, raises wages and thus enhances the desire to work in this sector.

Overall, there are diverse effects on wages and unemployment of skilled and low-skilled workers. The results give a theoretical foundation of the interaction of technological progress and trade between countries with the various labour market effects. Hereby, it depends on the extent of technical change, inter-sectoral and intra-sectoral trade to describe the overall effects on skilled and low-skilled workers.

3 Conclusion

During the last decades, developed countries have become more and more characterised by increasing wage inequality and unemployment inequality among different skill groups. As for wage inequality, neoclassical general equilibrium models mainly trace back to the two demand-side causes of international trade and technical change. Besides, unemployment remained on the sidelines. In these models, it can only come from factor market distortions.

Recent research points to the analysis of trade liberalisation by taking account of equilibrium unemployment due to search and matching frictions in the labour market. Moreover, this literature refers to the fact that exporting and non-exporting firms co-existed in the same industry. Entry to and survival in export markets are traced back to the interaction of sunk costs and productivity heterogeneity of firms.

In this paper we presented a model which applied for equilibrium unemployment due to search and matching frictions in the labour market and heterogeneous firms, differing in their productivity. We took account of two different sectors and factors of production. Within this framework, we analysed the effects of technological progress on wages and unemployment of the two factors, skilled and low-skilled workers. Motivated by Schumpeter's idea of 'creative destruction', technological progress comes about through job destruction and creation of new and more productive jobs. Thereby, it raises aggregate productivity by modifying the average productivity of firms. As trading partners experience technical change, and hence productivity shocks, among their sectors at different extents, technology effects on worker's wages and employment differ across sectors. The skilled intensive sector is the favoured sector and therefore it becomes the export sector when trade liberalisation takes place. As trade liberalisation raises aggregate productivity by modifying the average productivity of firms, both, technological progress and trade liberalisation affect labour market outcomes. Inter-sectoral trade favours the skilled against the low-skilled workers regarding both, wages and employment. Intra-sectoral trade counteracts as it favours low-skilled workers, too. The overall effects on wages and employment of skilled and low-skilled workers depend on the extent of technical change, inter-sectoral trade and intra-sectoral trade.

The introduction of productivity changes due to technological progress gives rise to new insights concerning the effects of technical change on international trade. As long as it affects the economies' sectors to different extents, it raises inter-sectoral trade if trade costs are sufficiently low. An useful direction for further research would be to evaluate the theory by empirical data.

A Appendix

A.1 Equalisation of Marginal Revenues

The firms revenues from sales on the domestic market are given by

$$R_d(\varphi_i^H,\tau) = p_d(\varphi_i^H,\tau)\cdot q_d(\varphi_i^H,\tau). \tag{64}$$

Using the domestic inverse demand for intermediate good (5) and Cobb-Douglas production function (7) the firms domestic revenues reveal as

$$R_d(\varphi_i^H,\tau) \;=\; \left[\left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right]\left[S(\varphi_i^H)\right]^{\beta_i}\left[L(\varphi_i^H)\right]^{1-\beta_i} P_i^H\right]^{\frac{\sigma-1}{\sigma}}\left[\frac{\alpha_i Y^H}{M^H}\right]^{\frac{1}{\sigma}}. \tag{65}$$

The partial derivatives with respect to $L(\varphi_i^H)$ and $S(\varphi_i^H)$ reveal as

$$\frac{\partial R_d(\varphi_i^H,\tau)}{\partial L(\varphi_i^H)} \;=\; \frac{\sigma-1}{\sigma} p_d(\varphi_i^H,\tau)\cdot[1-\beta_i]\cdot\left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right]\cdot\left[\frac{S(\varphi_i^H)}{L(\varphi_i^H)}\right]^{\beta_i} \tag{66}$$

$$\frac{\partial R_d(\varphi_i^H,\tau)}{\partial S(\varphi_i^H)} \;=\; \frac{\sigma-1}{\sigma} p_d(\varphi_i^H,\tau)\cdot\beta_i\cdot\left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right]\cdot\left[\frac{S(\varphi_i^H)}{L(\varphi_i^H)}\right]^{\beta_i-1}. \tag{67}$$

The firms revenues from sales on the export market are given by

$$R_x(\varphi_i^H,\tau) = p_x(\varphi_i^H,\tau)\cdot q_x(\varphi_i^H,\tau)\cdot\frac{1}{T}. \tag{68}$$

Using the foreign inverse demand for intermediate good (6) and Cobb-Douglas production function (7) the firms export revenues reveal as

$$R_x(\varphi_i^H,\tau) \;=\; \left[\left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right]\left[S(\varphi_i^H)\right]^{\beta_i}\left[L(\varphi_i^H)\right]^{1-\beta_i} P_i^F\right]^{\frac{\sigma-1}{\sigma}}\left[T^{1-\sigma}\frac{\alpha_i Y^F}{M^F}\right]^{\frac{1}{\sigma}}. \tag{69}$$

The partial derivatives with respect to $L(\varphi_i^H)$ and $S(\varphi_i^H)$ reveal as

$$\frac{\partial R_x(\varphi_i^H,\tau)}{\partial L(\varphi_i^H)} \;=\; \frac{\sigma-1}{\sigma}\cdot p_x(\varphi_i^H,\tau)\cdot\frac{1}{T}\cdot[1-\beta_i]\cdot\left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right]\cdot\left[\frac{S(\varphi_i^H)}{L(\varphi_i^H)}\right]^{\beta_i} \tag{70}$$

$$\frac{\partial R_x(\varphi_i^H,\tau)}{\partial S(\varphi_i^H)} \;=\; \frac{\sigma-1}{\sigma}\cdot p_x(\varphi_i^H,\tau)\cdot\frac{1}{T}\cdot\beta_i\cdot\left[\varphi_i^H + I(\tau)\Delta\varphi_i^H\right]\cdot\left[\frac{S(\varphi_i^H)}{L(\varphi_i^H)}\right]^{\beta_i-1} \tag{71}$$

If firms equalise marginal revenues across domestic and foreign markets

$$\begin{aligned}\frac{\partial R_d(\varphi_i^H,\tau)}{\partial L(\varphi_i^H)} &= \frac{\partial R_x(\varphi_i^H,\tau)}{\partial L(\varphi_i^H)}\\ \frac{\partial R_d(\varphi_i^H,\tau)}{\partial S(\varphi_i^H)} &= \frac{\partial R_x(\varphi_i^H,\tau)}{\partial S(\varphi_i^H)}\end{aligned} \tag{72}$$

it follows

$$p_d(\varphi_i^H,\tau) = p_x(\varphi_i^H,\tau)\cdot\frac{1}{T}. \tag{73}$$

A.2 Solution of Linear Differential Equations

The solutions of the surplus-splitting rules revealed as

$$w_{L_i}^H(t,\tau) = \mu\frac{\partial R(\varphi_i^H,\tau)}{\partial L_i^H(t)} - \mu\frac{\partial w_{L_i}^H(t,\tau)}{\partial L_i^H(t)}L(\varphi_i^H) + [1-\mu]\cdot rU_{L_i}^H(t) \tag{74}$$

and

$$w_{S_i}^H(t,\tau) = \mu\frac{\partial R(\varphi_i^H,\tau)}{\partial S_i^H(t)} - \mu\frac{\partial w_{S_i}^H(t,\tau)}{\partial S_i^H(t)}S(\varphi_i^H) + [1-\mu]\cdot rU_{S_i}^H(t), \tag{75}$$

known as equations (30) and (31) above, which are linear differential equation in $L(\varphi_i^H)$ and $S(\varphi_i^H)$, respectively. In the following we abstain from indexes and do not denote the arguments of functions. To solve these equations it needs taking account of the marginal revenues of the firm with respect to L and S. According (8) with $S_d = S_x = S$ and $L_d = L_x = L$ total revenues are given by

$$\begin{aligned} R \;=\; & \left\{[\varphi + I(\tau)\Delta\varphi]S^{\beta}L^{1-\beta}\right\}^{\frac{\sigma-1}{\sigma}}\\ \cdot\; & \left\{[P^H]^{\frac{\sigma-1}{\sigma}}\left[\frac{\alpha Y^H}{M^H}\right]^{\frac{1}{\sigma}} + I(\varphi)[P^F]^{\frac{\sigma-1}{\sigma}}\left[\frac{T^{1-\sigma}\alpha Y^F}{M^F}\right]^{\frac{1}{\sigma}}\right\}. \end{aligned} \tag{76}$$

Denoting

$$\Gamma = [P^H]^{\frac{\sigma-1}{\sigma}}\left[\frac{\alpha Y^H}{M^H}\right]^{\frac{1}{\sigma}} + I(\varphi)\cdot[P^F]^{\frac{\sigma-1}{\sigma}}\left[\frac{T^{1-\sigma}\alpha Y^F}{M^F}\right]^{\frac{1}{\sigma}}, \tag{77}$$

whereby Γ is independent on L and S, marginal revenues reveal as

$$\begin{aligned} \frac{\partial R}{\partial L} &= \left\{[\varphi + I(\tau)\Delta\varphi]S^{\beta}\right\}^{\frac{\sigma-1}{\sigma}} \cdot \Gamma \cdot \frac{[\sigma-1][1-\beta]}{\sigma} L^{\frac{\beta-\beta\sigma-1}{\sigma}} && (78) \\ \frac{\partial R}{\partial S} &= \left\{\varphi + I(\tau)\Delta\varphi]L^{1-\beta}\right\}^{\frac{\sigma-1}{\sigma}} \cdot \Gamma \cdot \frac{[\sigma-1]\beta}{\sigma} S^{\frac{\beta\sigma-\beta-\sigma}{\sigma}}. && (79) \end{aligned}$$

Hence, for (74) and (75) it follows

$$\mu \frac{\partial w_L}{\partial L} L + w_L = \mu \left\{[\varphi + I(\tau)\Delta\varphi]S^{\beta}\right\}^{\frac{\sigma-1}{\sigma}} \Gamma \frac{[\sigma-1][1-\beta]}{\sigma} L^{\frac{\beta-\beta\sigma-1}{\sigma}} + r[1-\mu]U_L \quad (80)$$

$$\mu \frac{\partial w_S}{\partial S} S + w_S = \mu \left\{[\varphi + I(\tau)\Delta\varphi]L^{1-\beta}\right\}^{\frac{\sigma-1}{\sigma}} \Gamma \frac{[\sigma-1]\beta}{\sigma} S^{\frac{\beta\sigma-\beta-\sigma}{\sigma}} + r[1-\mu]U_S. \quad (81)$$

Thereby, w_L, w_S, U_L, U_S, L and S are independent of each other and w_L and w_S are considered to be functions only of L and S, respectively. Otherwise it would be a system of differential equations or partial differential equations. Thus, the differential equations are ordinary linear nonhomogeneous first-order differential equations for w_L and w_S. The general solutions to the linear differential equations are the sum of the general solutions of the related homogeneous equations and the particular solutions. The solutions of nonhomogeneous equations are obtained by finding the particular solutions by the method of variation of parameters.

The general solutions of the related homogeneous equations, w_L^h and w_S^h, respectively, are obtained by

$$\mu \frac{dw_L^h}{dL} L + w_L^h = 0. \quad (82)$$

Separation of variables yields

$$\begin{aligned} \frac{dw_L^h}{w_L^h} &= -\frac{1}{\mu}\frac{dL}{L} \\ \int \frac{dw_L^h}{w_L^h} &= -\frac{1}{\mu}\int \frac{dL}{L} && (83) \end{aligned}$$

and integrating yields

$$\begin{aligned} \ln w_L^h &= -\frac{1}{\mu}\ln L + c = \ln L^{-\frac{1}{\mu}} + c \\ w_L^h &= C \cdot L^{-\frac{1}{\mu}} && (84) \end{aligned}$$

with $0 \leqq C < \infty$.
Analogue for

$$\mu \frac{dw_S^h}{dS} S + w_S^h = 0 \quad (85)$$

it reveals

$$w_S^h = C \cdot S^{-\frac{1}{\mu}}. \quad (86)$$

The method of variation of parameters yields particular solutions of nonhomogeneous equations (80) and (81), denoted by w_L^p and w_S^p, respectively. That means, inserting

$$\begin{aligned} w_L^p &= C(L) \cdot L^{-\frac{1}{\mu}} \\ \frac{dw_L^p}{dL} &= \frac{dC(L)}{dL} \cdot L^{-\frac{1}{\mu}} - \frac{1}{\mu} C(L) \cdot L^{-\frac{1}{\mu}-1} \end{aligned} \tag{87}$$

and

$$\begin{aligned} w_S^p &= C(S) \cdot S^{-\frac{1}{\mu}} \\ \frac{dw_L^p}{dS} &= \frac{dC(S)}{dS} \cdot S^{-\frac{1}{\mu}} - \frac{1}{\mu} C(S) \cdot S^{-\frac{1}{\mu}-1} \end{aligned} \tag{88}$$

into (80) and (81) yields

$$\begin{aligned} C(L) &= \left\{[\varphi + I(\tau)\Delta\varphi] S^{\beta}\right\}^{\frac{\sigma-1}{\sigma}} \cdot \Gamma \cdot \frac{[\sigma-1][1-\beta]\mu}{[\beta-\beta\sigma-1]\mu+\sigma} \\ &\cdot \quad L^{\frac{\beta-\beta\sigma-1}{\sigma}+\frac{1}{\mu}} + r[1-\mu] U_L L^{\frac{1}{\mu}} \end{aligned} \tag{89}$$

$$\begin{aligned} C(S) &= \left\{[\varphi + I(\tau)\Delta\varphi] L^{1-\beta}\right\}^{\frac{\sigma-1}{\sigma}} \cdot \Gamma \cdot \frac{[\sigma-1]\beta\mu}{\beta\sigma\mu-\beta\mu-\mu\sigma+\sigma} \\ &\cdot \quad S^{\frac{\beta\sigma\mu-\beta\mu-\mu\sigma+\sigma}{\mu\sigma}} + r[1-\mu] U_S S^{\frac{1}{\mu}}. \end{aligned} \tag{90}$$

Hence, the particular solutions of nonhomogeneous equations reveal as

$$\begin{aligned} w_L^p &= \left\{[\varphi + I(\tau)\Delta\varphi] S^{\beta}\right\}^{\frac{\sigma-1}{\sigma}} \cdot \Gamma \cdot \frac{[\sigma-1][1-\beta]\mu}{[\beta-\beta\sigma-1]\mu+\sigma} \\ &\cdot \quad L^{\frac{\beta-\beta\sigma-1}{\sigma}} + r[1-\mu] U_L \end{aligned} \tag{91}$$

$$\begin{aligned} w_S^p &= \left\{[\varphi + I(\tau)\Delta\varphi] L^{1-\beta}\right\}^{\frac{\sigma-1}{\sigma}} \cdot \Gamma \cdot \frac{[\sigma-1]\beta\mu}{\beta\sigma\mu-\beta\mu-\mu\sigma+\sigma} \\ &\cdot \quad S^{\frac{\beta\sigma-\beta-\sigma}{\sigma}} + r[1-\mu] U_S. \end{aligned} \tag{92}$$

Using (78) and (79) yields

$$w_L^p = \frac{\mu\sigma}{\beta\mu-\beta\sigma\mu-\mu+\sigma} \cdot \frac{\partial R}{\partial L} + r[1-\mu] U_L \tag{93}$$

$$w_S^p = \frac{\mu\sigma}{\beta\sigma\mu-\beta\mu-\mu\sigma+\sigma} \cdot \frac{\partial R}{\partial S} + r[1-\mu] U_S. \tag{94}$$

The general solutions to the linear differential equations are now the sum of the general solutions of the related homogeneous equations (84) and (86) and the particular solutions of nonhomogeneous equations (93) and (94). Thus, it follows

$$w_L = w_L^h + w_L^p = C \cdot L^{-\frac{1}{\mu}} + \frac{\mu\sigma}{\beta\mu-\beta\sigma\mu-\mu+\sigma} \cdot \frac{\partial R}{\partial L} + r[1-\mu] U_L \tag{95}$$

$$w_S = w_S^h + w_S^p = C \cdot S^{-\frac{1}{\mu}} + \frac{\mu\sigma}{\beta\sigma\mu-\beta\mu-\mu\sigma+\sigma} \cdot \frac{\partial R}{\partial S} + r[1-\mu] U_S \tag{96}$$

with $0 \leqq C < \infty$. If $C \neq 0$ the wage equations contained a component larger than zero which is only dependent on L, S and μ, independent on the production (independent on

Γ). Hence, by assumption $C = 0$ and thus the solutions of the two differential equations reveal as

$$w_L = \frac{\mu\sigma}{\beta\mu - \beta\sigma\mu - \mu + \sigma} \cdot \frac{\partial R}{\partial L} + r[1-\mu]U_L \tag{97}$$

$$w_S = \frac{\mu\sigma}{\beta\sigma\mu - \beta\mu - \mu\sigma + \sigma} \cdot \frac{\partial R}{\partial S} + r[1-\mu]U_S \tag{98}$$

known as equations (32) and (33) above.

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