Four Essays on International Trade and Labour Markets

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Meiner Mutter und meinem Vater († 1981)

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Introduction and Executive Summary

The following dissertation is a collection of four stand-alone research papers, written during my time as a research assistant at the University of Konstanz between October 2002 and October 2004 and during my time at the Justus–Liebig–University Gießen between November 2004 and January 2007. The major focus of my research is on the interaction between human–capital investment of individuals and international trade in goods and factors as well as its labour market consequences.

Without going too much into detail, the following gives a short summary of the four different contributions. The common theme of all papers is the analysis of the decision of heterogeneous individuals about investing in education. The first paper analyses how these decisions affect the impact of globalisation or technological change on the income distribution. The second and the third paper focus on the distributional effects of human-capital investments in the presence of immigration. The fourth paper discusses the interplay of globalisation and alternative formulations of the institutional framework of the educational system. Again, central to this paper is the analysis of decisions of heterogenous individuals about education.

Chapter 1 is a reproduction of the article *Globalization, Technical Change, and the Skill Premium: Magnification Effects from Human–Capital Investments*, co-authored by Jürgen Meckl, and published in the "*Journal of International Trade and Economic Development*", Vol.12 (4) in December 2003. The paper discusses the interplay of globalisation or technological change and the income distribution. A huge body of the literature attributes the rise in wage differentials in favour of high-skilled labour to changes in relative goods prices. These changes in relative prices can be caused by globalisation as well as by specific forms of technological progress. These explanations, however, have been disputed, because empirical evidence for relative price changes that are strong enough to explain the observed change in wage differentials is rather small. In our theoretical analysis we argue that human capital investments can magnify the effect of relative price changes on wage differentials under quite plausible conditions. These composition effects arise from decisions of individuals with heterogeneous inherent abilities about acquiring human capital. They reinforce the well–known Stolper–Samuelson effect on the measured skill premium in countries with a sufficiently high relative supply of skilled labour, but compensate them otherwise. As a result, the model can account for the observation of a worldwide increase in the skill premium during the last two decades.

Chapter 2 is based on the research paper *Immigration, Education, and Labour Market Institutions*, co-authored by Christian Lumpe. Conventional wisdom tells us that immigration is beneficial for the host country under competitive markets and can serve as a disciplining tool in unionised labour markets. Additionally, immigration has distributional consequences for native workers of different skill groups. Typically, we expect, e.g., a deteriorating wage income for those skill groups which directly compete with immigrants. We extend the existing literature by considering heterogeneity among workers of different skill groups as well as endogenous skill acquisition. In this framework, immigration does not only generate a change of the existing relative labour supply, but also affects the incentives of natives to invest into education. The model is used to study the effect of immigration on the labour market prospects of natives of the different skill groups. It is shown that the conventional wisdom concerning distributional issues is oversimplified. We argue that the distributional consequences of immigration crucially depend on the host country's level of education. More precisely, in course of low skilled immigration, the wage differential between high- and low skilled native workers can decline if educational attainment is low while the opposite is true if educational attainment is high. This result is in contrast to the existing literature where low skilled immigration unambiguously increases the wage differential between high- and low skilled workers. We extend our model to show that this major result is robust irrespective of existing labour market institutions like, e.g, a binding minimum.

Chapter 3 is based on the research paper *Immigration Policy, Equilibrium Unemployment, and Underinvestment in Human Capital*, co-authored by Christian Lumpe. In this paper we analyse the impact of different immigration policies on human capital investment in a search-theoretic model of the labour market. This class of model features unemployment and underinvestment in human capital. We show that an immigration policy aiming at well educated immigrants leads to rising educational attainment of natives and can be Pareto-improving. In combination with education subsidies, underinvestment in human capital can be resolved such that Pareto-optimal investment levels for natives is reached. Additionally, we discuss bimodal immigration with respect to skills, a pattern that is observed, e.g., in the US. To that end, we extend our model to labour markets of different skill groups.

The last chapter is based on the research paper *Educational Systems and Globalisation*. This contribution brings together the discussions about educational institutions on the one side and globalisation on the other. To this end, we construct a 2-factors–2-goods model of international trade featuring three different kinds of educational systems. We analyse both the polar cases of an exclusively privately funded system of higher education and a system of publicly funded higher education. The third case is that of a mixed system with an active private and a public system side by side. Within this framework, the institutional arrangement in the educational sector constitutes the comparative advantage of a country. Countries lacking a well developed public system of higher education and imperfect credit markets – a scenario, that applies to many less developed countries – will have a comparative advantage in low-skilled intensive production. Furthermore, we find that trade liberalisation can evoke the emergence of private universities in a country with a public system leading to a mixed system. Importantly, during the transition from a public to a mixed educational system, the congestion effect in the public system is partially reduced. Therefore, our analysis indicates that globalisation might be a driving factor behind recent emergence of private universities in countries like, e.g., Germany. Additionally, our model generalises many of the existing distinct models in the literature on trade and education which allows us to relate different models and their results to specific educational institutions.

Einleitung und Zusammenfassung

Die vorliegende Dissertation beinhaltet vier unterschiedliche Forschungsarbeiten. Diese entstanden während meiner Tätigkeit als wissenschaftlicher Mitarbeiter an der Universität Konstanz von Oktober 2002 bis Oktober 2004 sowie an der Justus–Liebig–Universität Gießen von November 2004 bis Januar 2007. Das Hauptaugenmerk meiner Forschung liegt auf der Wechselwirkung von individuellen Bildungsentscheidungen und dem internationalen Handel von Gütern sowie Immigration und deren Einfluss auf den Arbeitsmarkt.

Im Folgenden soll ein kurzer Überblick über die vier verschiedenen Forschungsarbeiten gegeben werden. Trotz der Unterschiedlichkeit der verschiedenen Arbeiten haben doch alle eines gemeinsam. In allen Modellen sind es heterogene Individuen mit unterschiedlichen Fähigkeiten, die Entscheidungen über ihre Ausbildung treffen. Im ersten Beitrag wird untersucht, in welcher Weise sich diese Ausbildungsentscheidungen auf den Zusammenhang zwischen Globalisierung oder technologischen Wandel und der Einkommensverteilung auswirken. Im zweiten und dritten Beitrag wird die Wechselwirkung zwischen der Ausbildungsentscheidung und Immigration untersucht. Der Einfluss der konkreten Ausgestaltung des Bildungssystem auf die Bildungsentscheidung in einer globalen Welt wird schließlich im vierten Beitrag untersucht.

Kapitel 1 beinhaltet eine gemeinsame Arbeit mit Jürgen Meckl mit dem Titel *Globalization, Technical Change, and the Skill Premium: Magnification Effects from Human–Capital Investments*. Diese Arbeit wurde im Dezember 2003 im "*Journal of International Trade and Economic Development*", Vol.12 (4) veröffentlicht. In der einschlägigen Literatur gibt es Begründungen, die die Veränderung der qualifikatorischen Lohnstruktur auf Änderung der relativen Güterpreise zurückführt. Veränderungen der relativen Güterpreise können ihrerseits durch Globalisierung, als auch durch bestimmte Formen des technologischen Fortschritts hervorgerufen werden. Kritiker werfen Vertretern dieser Erklärungshypothese vor, dass die empirisch beobachteten Relativpreisänderungen quantitativ wohl zu unbedeutend sind, um die beobachtete quantitative Veränderung der qualifikatorischen Lohnstruktur zu erklären. Vor diesem Hintergrund versucht unser Beitrag theoretisch zu klären, ob die endogene Ausbildungsentscheidung die Wirkungen von Relativpreisänderungen auf die Lohnstruktur verstärken kann. Zu diesem Zweck wird ein Modell entwickelt, in dem sich Individuen mit unterschiedlicher Begabung für oder gegen eine weitergehende Ausbildung entscheiden. Sie tun dies in Abhängigkeit von den aus der Ausbildung zu erwartenden Erträgen. Es zeigt sich, dass sowohl dem technologischen Wandel als auch der Globalisierung der Charakter eines Katalysators zukommt. Die durch die genannten Ursachen ausgelöste Faktorpreisanpassung führt zu einer Veränderung der individuellen Ausbildungsentscheidungen und damit zur Änderung der Zusammensetzung der Qualifikationsgruppen. Unter der für Industrieländer plausiblen Voraussetzung, dass bereits ein relativ großes Angebot an hochqualifizierten Arbeitnehmern vorhanden ist, verstärkt die veränderte Ausbildungsentscheidung der Individuen die nachfrageseitig bedingte Entwicklung des qualifikatorischen Lohndifferentials.

Kapitel 2 enthält eine gemeinsame Forschungsarbeit mit Christian Lumpe. Der Titel der Arbeit lautet *Immigration, Education, and Labour Market Institutions* und befasst sich mit den Verteilungswirkungen von Immigration im Gastland. In der ökonomischen Literatur über Immigration wird der Einfluss von Immigration auf das Gastland herausgearbeitet. Dabei zeigt sich, dass Immigration vielfach vorteilhaft für das Einwanderungsland ist. Dies kann sowohl für Arbeitsmärkte unter vollkommener Konkurrenz gezeigt werden, als auch, unter bestimmten Bedingungen, für gewerkschaftlich organisierten Arbeitsmärkte. Im letztgenannten Fall kommt der Immigration gering qualifizierter Arbeiter eine besondere Rolle zu, da die zusätzliche Konkurrenz durch Einwanderer disziplinierend auf die Lohnpolitik der Gewerkschaft wirkt. Zudem löst die Immigration erhebliche Verteilungseffekte aus, da einige Qualifikationsgruppen Einkommensgewinne verzeichnen, während andere von Einkommensverlusten betroffen sind. In unserem Beitrag erweitern wir die klassische Analyse um zwei wesentliche Punkte: Einerseits berücksichtigen wir explizit die Heterogenität der Arbeitskräfte und andererseits endogenisieren wir das qualifikatorische einheimische Arbeitsangebot. In einer Erweiterung des in Kapitel 1 entwickelten Grundmodells zeigen wir, dass die landläufige Meinung über die Verteilungswirkung von Immigration teilweise zu kurz greift. In unserer Analyse zeigt sich, dass die Verteilungswirkung vor allem von der Anzahl der hoch qualifizierten Arbeiter im Gastland abhängt. Im Zuge gering qualifizierter Immigration wird der gemessene Lohnaufschlag für hoch qualifizierte Arbeiter sinken, sofern deren Anteil vergleichsweise gering ist. Umgekehrt steigt der gemessene Lohnaufschlag, wenn sehr viele hoch qualifizierte Arbeiter im Gastland vorhanden sind. Dieses Ergebnis steht im Gegensatz zur "klassischenÏmmigrationsliteratur, die im Fall gering qualifizierter Immigration eine eindeutige Erhöhung des Lohnaufschlags prognostiziert. Unser qualitatives Ergebnis bleibt selbst dann erhalten, wenn wir unser Modell um einen Arbeitsmarkt mit bindenden Mindestlöhnen erweitern.

Kapitel 3 ist ebenfalls eine gemeinsame Forschungsarbeit mit Christian Lumpe zum Thema Immigration. Unter dem Titel *Immigration Policy, Equilibrium Unemployment, and Underinvestment in Human Capital* befassen wir uns mit der Frage, welchen Einfluss Immigration auf die Bildungsinvestitionen von Einheimischen hat, wenn der Arbeitsmarkt durch Suchfriktionen gekennzeichnet ist. Suchfriktionen auf dem Arbeitsmarkt führen zu Arbeitslosigkeit und mithin zu einem ineffizienten Niveau von privaten Bildungsinvestitionen. In unserer Analyse zeigen wir, dass eine selektive Einwanderungspolitik, mit der versucht wird, gezielt gut ausgebildete Einwanderer zu attrahieren, zu verstärkten Bildungsinvestitionen bei Einheimischen führt. Damit kann eine derart ausgestaltete Politik zu Pareto-Verbesserungen der Einheimischen führen. Sollte die Einwanderungspolitik mit Ausbildssubventionen für die einheimische Arbeiter kombiniert werden, dann ist es sogar möglich, die Ineffizienz der Bildungsinvestitionen vollständig zu beseitigen und das Pareto-optimale Bildungsniveau zu erreichen. In einem letzten Schritt erweitern wir unser Modell, um zusätzliche Qualifikationsgruppen. Dadurch können wir den Einfluss von sogenannter bimodaler Immigration auf Humankapitalinvestitionen, die Arbeitslosigkeit und das Lohndifferential diskutieren.

Kapitel 4 beinhaltet eine eigene Forschungsarbeit mit dem Titel *Educational Systems and Globalisation*. Diese Arbeit widmet sich der Diskussion von länderspezifischen Institutionen und deren Auswirkungen auf den komparativen Vorteil eines Landes. Speziell wird dabei der Versuch unternommen, den Zusammenhang zwischen der institutionellen Ausgestaltung des Bildungswesens und der Globalisierung zu untersuchen. Zu diesem Zweck wird ein 2-Güter–2-Faktoren Außenhandelsmodell formuliert mit einem explizit modellierten Bildungssektor der für die Bereitstellung von qualifizierten

Arbeitern verantwortlich ist. Dabei werden drei unterschiedliche institutionelle Ausgestaltungen des Bildungssektors betrachtet. Zum einen wird ein rein privatwirtschaftlich organisiertes Bildungssystem mit privaten Universitäten analysiert und zum anderen ein rein staatliches Bildungssystem mit öffentlichen Universitäten. Weiterhin wird ein gemischtes Bildungssystem untersucht, in dem sowohl öffentliche als auch private Universitäten existieren. Mit Hilfe dieses Modells ist es möglich, den komparativen Vorteil eines Landes auf die konkrete institutionelle Ausgestaltung des Bildungssystem zurückzuführen. Entwicklungsländer, die typischerweise kaum öffentliche Universitäten und keinen funktionierenden Markt für Ausbildungskredite besitzen, haben einen komparativen Vorteil bei der Produktion solcher Güter, die unqualifizierte Arbeit intensiv nutzt. Das zentrale Ergebnis meiner Arbeit ist, dass Globalisierung von Ländern mit öffentlichem Bildungssystem einen Systemwechsel provozieren kann. Globalisierung kann die Ausbildungsanreize so stark erhöhen, dass ein zusätzliches Bildungsangebot durch private Universitäten bereitgestellt wird. Durch die Globalisierung wandelt sich das rein öffentliche System zu einem gemischten. Zudem wird durch das zusätzliche Angebot privater Universitäten der Übernutzung des öffentlichen Bildungssystems entgegengewirkt. Meine Analyse deutet somit darauf hin, dass Globalisierung eine mögliche Erklärung für die in Deutschland beobachtete Entwicklung im Hochschulsektor ist. Denn gerade in den letzten 15 Jahren kam es in Deutschland zu einer Fülle von Neugründungen von privaten Hochschulen. In der bisherigen Literatur existieren bereits verschiedenste Ansätze um Ausbildung und Humankapital in entsprechende Außenhandelsmodelle zu integrieren. Mit meiner Arbeit können durch die spezielle Berücksichtigung von Bildungssystemen viele dieser Ansätze sowie deren Ergebnisse konkret einem Bildungssystem zugeordnet werden.

CHAPTER 1

Globalisation, Technical Change, and the Skill Premium: Magnification Effects from Human–Capital Investments

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1.1 Introduction

The development of wage inequality by skills has been studied extensively in the recent literature. Many industrialised countries have experienced sharp shifts in labour rewards favoring skilled labour since the beginnings of the 1980ies. For the United States, e.g., Katz and Autor (1999) report an increase in the skill premium – the wages of skilled workers (college graduates) relative to wages of unskilled workers – of about 25 percent between 1979 and 1995, despite of the fact that the relative supply of skilled labour expanded considerably over this time period. Additionally, they find that wage inequality within the different skill groups also increased considerably. Similar qualitative findings characterise the development of wage inequality in other industrialised countries, except for the unskilled's residual wage inequality which declined in countries like Germany (cf. Fitzenberger, 1999).

There are two popular theoretical explanations for rise in the skill premium. Standard trade theory predicts that increased international trade with newly industrialised or less developed countries, which typically have a comparative advantage in goods using unskilled labour intensively, should increase the demand for skilled labour in industrialised countries. Specifically, the rise in the industrialised countries' terms of trade resulting from globalisation induces more than proportionate increases in skilled wages, whereas unskilled wages should decline (Stolper–Samuelson effects). As a result, several trade theorists emphasise globalisation as the principal cause for the increase in wage inequality in that countries (cf. for example, Wood, 1994, 1998). This explanation, however, was challenged by empirical studies according to which changes in relative commodity prices are at best of minor size.[1] Thus, the scope for international trade as the cause of increasing wage inequality seems rather limited.[2]

[1]Cf. Slaughter (1998) for an overview of earlier empirical studies, and Harrigan and Balaban (1999) for a more recent study.

[2]The trade–based explanation has been criticised on other reasons as well. E.g., the theory predicts that the change in relative factor prices should induce all industries to adopt less skill–intensive techniques, which is also contrary to fact. The trade–based explanation also implies that developing countries should experience a decline in wage inequality due to the improvements of their terms of trade. These counterfactual implications have been taken up by an alternative explanation of rising wage inequality based on globalisation developed by Feenstra and Hanson (1999, 1996). They emphasise specialisation effects by increased fragmentation of production generating an increase in the relative demand for skilled labour in each country and thus similar developments in wage inequality for all trading partners. For the purpose of our paper it is inessential whether the change in relative factor prices is caused by trade or by international direct investment. We want to emphasise that the empirically measured skill premium is affected by composition effects in the labour supply which are caused by changes in relative factor prices. The force driving the change in factor prices is of no special interest here. For sake of simplicity, we draw on the standard trade approach.

The rival explanation (supported especially by labour economists but also by a group of trade theorists) argues that pervasive skill–biased technological change (SBTC) should induce all industries to apply more skill–intensive techniques and thus to raise the demand for skilled labour. Although there seems to be some empirical support for this thesis from several industry studies (e.g., Machin and Van Reenen, 1998), this argument is not conclusive from a general–equilibrium perspective. In a multi–sectoral economy, *pervasive SBTC* per se, i.e. technical change that is complementary to skilled labour, but does not favor particular sectors of an economy[3] raises factor prices but does not affect relative factor prices. At unaltered commodity prices, pervasive adoption of more skill–intensive techniques only alters the composition of the production sector by generating a relative expansion of sectors using unskilled labour intensively. Only endogenous commodity–price adjustments that equilibrate commodity markets correct for this implication about an economy's sectoral adjustments, which is counterfactual as well.[4] As a result, SBTC affects wage inequality only as far as it generates changes in relative commodity prices, and therefore the scope of the SBTC hypothesis in explaining the observed rise in the skill premium seems rather limited as well.

The present paper argues that changes in relative commodity prices affect the skill premium measured in empirical studies not only through the Stolper–Samuelson effects on factor prices, but also through adjustments in the composition of skilled and unskilled labour induced by that changes in factor prices. We emphasise the term 'measured skill premium', because wage incomes within skilled and unskilled labour obviously differ. Consequently, the skill premium is typically calculated using some average wage income for each group of labour. Such average wage incomes, however, crucially depend on the composition of each group. As we will show, Stolper–Samuelson effects generate changes in the composition of each group that can reinforce the impact of changes in relative prices on the measured skill premium. Furthermore, from the perspective of theory, there is no limit about the size of this magnification effect. Since the above mentioned analyses do not account for this selection effect, the role of global market integration and/or SBTC for the rise in wage inequality has been underestimated.

[3]Cf. Xu (2001), and Haskel (2000) for a clear–cut distinction of possible forms of technical progress.

[4]Note that these endogenous adjustments of commodity prices do not occur in a small open economy. Cf. Krugman (2000) for a discussion about the small–open–economy perspective in that context.

In order to clarify how this composition effect contributes to measured wage inequality, suppose that wage earnings are determined by the following regression function (cf. Taber, 2001)

$$Y_t = \alpha_t(s) + \gamma_t a + \epsilon_t \,,$$

where Y_t, a variable measuring earnings, is explained by years of schooling s, ability a, and a zero–mean stochastic disturbance term ϵ. The wage differential between two groups with different educational attainments s_H (skilled labour) and s_L (unskilled labour) is then described by

$$\begin{aligned} \mathrm{E}(Y_t|s = s_H) - \mathrm{E}(Y_t|s = s_L) = \alpha_t(s_H) - \alpha_t(s_L) \\ + \gamma_t \left[\mathrm{E}(a|s = s_H) - \mathrm{E}(a|s = s_L)\right] . \end{aligned} \tag{1.1}$$

In (1.1), $\alpha_t(s_H) - \alpha_t(s_L)$ measures earning differences arising from different skills, while $\gamma_t \left[\mathrm{E}(a|s = s_H) - \mathrm{E}(a|s = s_L)\right]$ is the wage differential generated by differences in abilities across groups. This 'ability bias' depends on the returns to ability γ_t and on the distribution of abilities within skill groups. Changes in the skill premium as measured by (1.1) can then result from variations in the returns to education or to ability, and from alterations of $\mathrm{E}(a|s = s_H) - \mathrm{E}(a|s = s_L)$, for which the selection of abilities into skill groups is crucial. Whereas the direct impact of changes in commodity prices (the Stolper–Samuelson effect) shows up in the differences arising from different skills, the magnification effect is comprised by the sorting effect which, moreover, impacts on the extent of inequality within skill groups through its influence on the degree of heterogeneity of the members.[5] The empirical relevance of the ability bias has been demonstrated by Taber (2001).[6] He has shown that the 'ability bias' explains a greater share of the rise in the US skill premium than the change in returns to education. Hence, the scope of the magnification effect seems important.

Our explanation of within–group wage differentials draws on heterogeneities of individuals with respect to their effective labour endowments.[7] Specifically, agents are assumed to differ in their inherent abilities that determine the individuals' effective labour

[5] Acemoglu (2002, 2003) analyses an alternative magnification effect that works through endogenous skill–biased technological change. Thus, his magnification effect works through changes in the composition of labour demand. In contrast, the present approach emphasises magnification arising from changes in the composition of labour supply.

[6] Of course, it is impossible to identify the components of the ability bias. We concentrate on the composition effect exclusively.

[7] The model developed in the paper is extension of Meckl and Zink (2002). It introduces imperfect substitutability of both types of labour thus opening up a channel through which commodity–price changes affect

supply, both for the skilled and the unskilled labour force. Individual wage incomes then differ, even though the prices of each effective unit of skilled or unskilled labour (factor prices) are identical. This allows for some explanation of residual wage inequality as well.

Differences in individual wage incomes also generate differences in the individuals' incentives to invest in education, thereby endogenising the supply of skilled and unskilled labour. With the decision to become educated depending on relative factor prices, there is an additional channel through which changes in relative commodity prices affect the measured skill premium. Any increase in the skill premium causes additional skill acquisition. Counterintuitively, that induced growth of the relative supply of skilled labour can reinforce the Stolper–Samuelson effect on the measured skill premium.[8]

The paper now proceeds as follows. Section 1.2 analyses the decisions about acquiring education of heterogeneous individuals and shows how the composition of labour supply affects our measure of the skill premium. In section 1.3, we derive the impact of exogenous changes in relative commodity prices on the measured skill premium. Section 1.4 concludes by shortly discussing the model's implications about within–group wage inequality and presenting possible extensions of the model that can account for the diverging empirical evidence with respect to this problem.

1.2 The model

We consider an otherwise standard two–sector model of the production sector with skilled and unskilled labour as the only factors of production. We denote the price of the good that uses skilled labour relatively intensively by p and normalise the price of the other good to unity. Furthermore, we abstract from factor–intensity reversals thus ensuring that factor prices are uniquely determined by commodity prices as long as production is diversified. Diversification is assumed throughout the analysis.

the composition of skilled and unskilled labour. This allows for an analysis of the impact of globalisation and SBTC on wage inequality.

[8]Of course, an increase in the relative wage of skilled labour could also raise the relative supply of skills in an otherwise neoclassical model. However, this adjustment of relative labour supply does not affect wage inequality as long as production is fully diversified. Once the economy is driven into complete specialisation or driven into another cone of diversification, an increase in the relative supply of skilled labour always *reduces* the effect of changes in commodity prices on wage inequality (cf. Haskel, 2000).

The composition of labour supply is endogenously determined by decisions of individuals with heterogeneous inherent abilities. The economy is populated by a continuum of agents indexed by their ability a with the mass normalised to 1. Inherent abilities are distributed according to some density function $f(a)$ on the interval $[0, 1]$. An individual with ability a can either enter the labour force as unskilled thereby supplying $(1 + a)$ units of unskilled labour and earn the wage rate w_L per unit of effective labour. Alternatively, an individual can choose to spend a exogenously given fraction λ of time in training to become a skilled worker. Education is assumed to raise individual abilities. For simplicity, we assume individual abilities of skilled workers to be ba, where $b > 1$ can be interpreted as a measure of the efficiency of the educational system. Thus, a skilled worker with ability a supplies $(1 - \lambda)(1 + ba)$ units of skilled labour and earns the wage rate w_H per unit of effective labour. The wage income of an individual with ability a then either is $(1 + a)w_L$ as an unskilled worker, or $(1 - \lambda)(1 + ba)w_H$ as a skilled worker.

An individual chooses to become skilled iff its ability is not smaller than some threshold value t determined by

$$t(p) = \{a : (1 + a) - (1 + ba)(1 - \lambda)\omega(p) = 0\} , \qquad \omega(p) := \frac{w_H}{w_L}(p) . \tag{1.2}$$

Given our assumptions about factor intensities, ω is a function of p with $\omega'(p) > 0$. Figure 1.1 illustrates the determination of the threshold value $t(p)$. Provided that $2/(1 + b) \leq (1 - \lambda)\omega(p) \leq 1$, there exists a unique threshold value $t \in [0, 1]$.[9] We assume this condition to be fulfilled in the following. Otherwise, either all or no individuals choose to become educated, a situation which is clearly contrary to fact.

The education decision determines the aggregate supplies of unskilled and skilled labour (L and H) as functions of p:

$$L(p) = \int_0^{t(p)} (1 + a)f(a)\, da\, , \qquad H(p) = \int_{t(p)}^{1} (1 - \lambda)(1 + ba)f(a)\, da\, , \tag{1.3}$$

with $L'(p) < 0$, and $H'(p) > 0$. As a result, relative labour supply $h(p) := H(p)/L(p)$ depends on relative factor prices. Throughout our analysis, we assume that $h(p)$ lies in the cone of diversification bounded by $\underline{h}(p)$ and $\overline{h}(p)$.

[9] This condition can be easily checked using figure 1.1

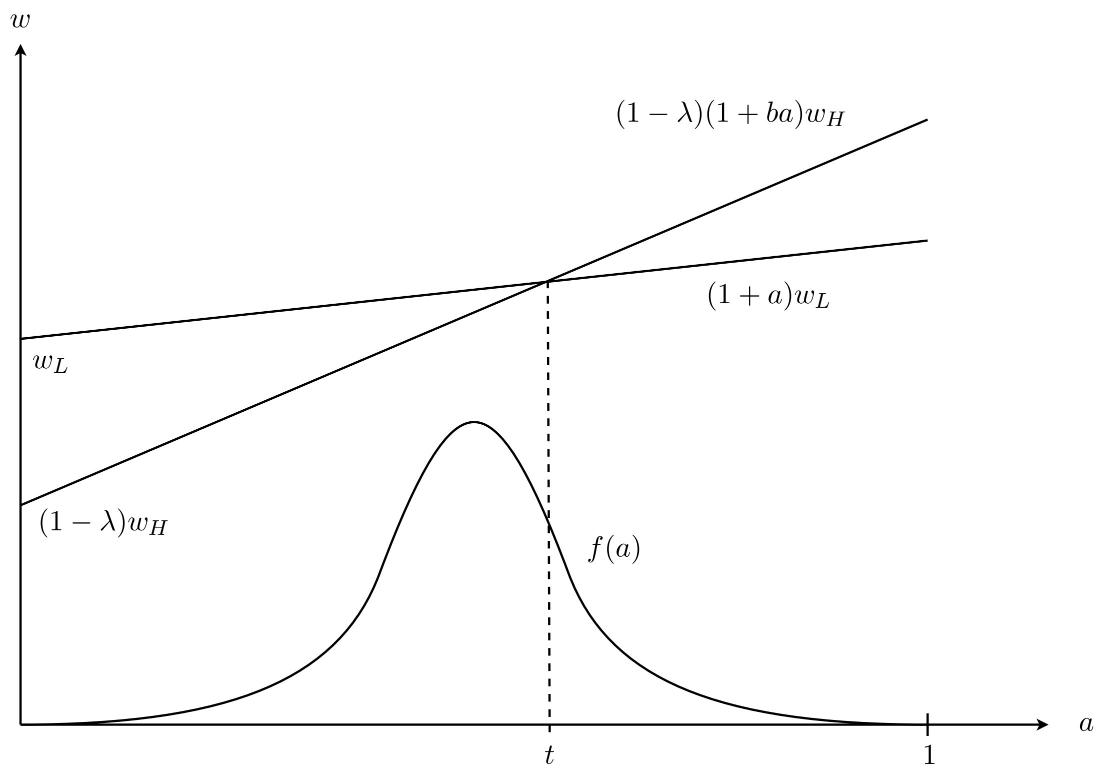

Figure 1.1: Determination of the threshold value $t(\omega)$

In order to discuss the impact of a change in relative commodity prices on the skill premium we need to define a measure for the skill premium. Due to within–group heterogeneity there is no unique wage for workers of one educational group that naturally applies. Equation (1.1) suggests to use the ratio of the mean wage of skilled and unskilled workers. A major drawback with respect to practical application arises, since the mean is vulnerable to outliers. This might pose a serious problem in our model, because the wage distribution of the two groups is given by the upper or lower truncated distribution of inherent abilities which will most likely result in skewed distributions. Using the mean wage alone might overstate the measured skill premium. To tackle this problem we additionally use another measure of central tendency: the median wage of the skilled and unskilled workers.

We define the skill premium $x(p)$ as the ratio of the representative wage $m(w|s = s_i)$ $(i = L, H)$ of the skilled to the unskilled workers given by one of our measures of central tendency. Since the wage function is a linear transformation of abilities, we express the mean/median wage as a function of the mean/median ability of the respective group:

$$x(p) := \frac{m(w|s = s_H)}{m(w|s = s_L)} = \frac{1 + bm(a|a > t(p))}{1 + m(a|a \leq t(p))}(1 - \lambda)\omega(p)\,. \tag{1.4}$$

The skill premium decomposes into the relative wage (in efficiency units) of skilled labour, $\omega(p)$, weighted by the ratio of the representative efficiency units of skilled and unskilled labour. Since the international price ratio influences both the relative wage of skilled labour *and* the relative supply of skilled labour, there are two channels through which commodity–price changes affect the skill premium. First, $x(p)$ is affected directly via the change in $\omega(p)$; this is the Stolper–Samuelson effect known from the standard neoclassical model with fixed factor endowments. Second, $x(p)$ is affected by the change of the relative effective supply of skilled labour through the composition of the labour force as reflected by changes in $m(a|a > t(p))$ and $m(a|a \leq t(p))$. As we will show in the following, the resulting change in relative labour supply can affect the skill premium in a counterintuitive way (cf. footnote 7): an increase in the relative supply of labour can *raise* the skill premium. Furthermore, the impact of a change in the composition of the labour force can be substantial even for minor changes in commodity prices. Slight changes in relative commodity prices are thus sufficient for a significant change of the skill premium.

1.3 Price changes and the skill premium

We model global market integration or SBTC as a change in relative commodity prices. As long as the economy remains fully diversified, factor prices are completely determined by commodity prices. The effects of trade or SBTC on factor prices are given by the Stolper–Samuelson theorem: An increase in the relative price of the skilled–labour intensive product—this is thought to be the typical consequence of either global market integration for industrialised countries or of pervasive SBTC in a world (resp. closed) economy—raises the relative wage of skilled labour. According to empirical studies, however, this direct effect of international trade on the skill premium explains only a minor part of the observed rise in the skill premium.

With endogenous education, changes in commodity prices also alter relative labour supplies. From (1.2), a change in relative factor prices alters the threshold value $t(p)$ according to

$$t'(p) = \frac{(1-\lambda)\left[1+bt(p)\right]}{1-(1-\lambda)b\omega(p)}\omega'(p) < 0. \tag{1.5}$$

Obviously, t declines as p increases as long as the the denominator is smaller than zero which is true as long as $t \in [0,1]$. Note that the change in t can be substantial even for minor changes in relative factor prices. This is the case, if the marginal wage difference $w_L - b(1-\lambda)w_H$ is small.

The following proposition then follows immediately from (1.3) and (1.5):

Proposition 1.1. *An increase in the relative price of the skill–intensive good raises both the relative factor price ω and the relative supply of skilled labour.*

The adjustment in relative labour supply represented by a change in $t(p)$ affects the wage income of the skilled and unskilled workers since the representative quality of labour or amount of efficiency units will change. Calculating the complete effect of a change in p on x from (1.4) gives:[10]

$$x'(p)\frac{p}{x} = \omega'(p)\frac{p}{\omega} + \left|t'(p)\right| pG(t) \tag{1.6}$$

where

$$G(t) := \left[\frac{m'(a|a<t)}{1+m(a|a<t)} - \frac{bm'(a|a \geq t)}{1+bm(a|a \geq t)}\right] \tag{1.7}$$

The function $G(t)$ measures the difference in the rate of change of the representative supply of effective labour units for both skill groups that is caused by a change in the threshold value $t(p)$. Changes in relative labour supply magnify (compensate) the effect of a change in relative factor prices on the skill premium iff the term $G(t)$ is positive (negative). The greater the difference in mean supply growth rates, the greater is the magnification effect of adjustments in $h(p)$.[11]

Magnification occurs, iff $G(t) > 0$, which essentially depends on the underlying distribution of abilities $f(a)$ and on the efficiency of the educational system b. Of course,

[10] For notational convenience we drop the functional argument p in $t(p)$ in the following.

[11] Deardorff (2000) also endogenises the decision about acquiring education in a similar setting of individuals with heterogeneous inherent abilities. However, he assumes that abilities do not affect effective labour supplies of the unskilled. As a result, endogenous adjustment of labour supply always compensates the effect of a change in relative factor prices.

there exist combinations of specific distribution functions and specific values of b such that $G(t) > 0$ holds. In the following we discuss two specific examples that do not rely on extreme assumptions on the distributional functions of inherent abilities in order to demonstrate that maginfication occurs under quite plausible conditions. In each case, we analyse our two measures of central tendency, the mean and the median.

Magnification with uniformly distributed abilities

We first suppose that inherent abilities are distributed uniformly within the interval $[0, 1]$. This assumption is primarily made because it turns out to be the limiting case of more plausible distributions of innate abilities.[12] It implies $f(a) = 1 \, \forall \, a \in [0, 1]$, and $F(a) = a$, where $F(a)$ is the distribution function of abilities. The truncated distributions are also uniform, and the mean and the median coincide. Thus, we concentrate on the mean.

The mean abilities of the respective groups are given by $E_L = t/2$ and $E_H = (1+t)/2$. Calculating $G(t)$ gives us the following condition for magnification:

$$b < 2. \tag{1.8}$$

We arrive at the following proposition:

Proposition 1.2. *With abilities distributed uniformly over the admissible support, an increase in the relative supply of skilled labour raises the skill premium iff the returns to education in terms of effective labour supply are not too great. In this case, the effect of price changes on skill premium are magnified by endogenous labour supply reactions.*

Note that (1.5) implies that the smaller the value of b, the greater is *ceteris paribus* the change in t in absolute terms, and the less is the growth rate of the high–skilled mean effective labour supply. Hence, the greater is the magnification effect on the skill premium.

Magnification with symmetric and unimodal distribution of abilities

In our second example we discuss a more general class of distributional functions that includes our first example as a special limiting case. Assume inherent abilities to be

[12] Although the assumption of uniformly distributed abilities is by no means realistic, it is frequently applied in theoretical analyses(cf., e.g., Galor and Moav, 2000) on grounds of its tractability.

distributed in the interval $[0,1]$ according to a symmetric and unimodal distribution with the following properties:

$$f(0) = f(1) = c \geq 0 \text{ and } \lim_{a\to 0} f'(a) = -\lim_{a\to 1} f'(a) > 0$$

We have to analyse the mean and the median separately, because the upper (lower) truncated distribution will be left (right) skewed. Obviously, the skill premium is always higher when measured by the mean wage income rather the medians' wage income.

The median ability of unskilled $a_L(t)$ and skilled $a_H(t)$ labour is implicitly defined by:

$$a_L(t) := F^{-1}\left[\frac{F(t)}{2}\right], \qquad a_H(t) := F^{-1}\left[\frac{1-F(t)}{2}\right].$$

The change of the median position resulting from changes in the threshold can be calculated as

$$\frac{da_L(t)}{dt} = \frac{1}{2}\frac{f(t)}{f(a_L(t))}, \qquad \frac{da_H(t)}{dt} = \frac{1}{2}\frac{f(t)}{f(a_H(t))}.$$

Since the median positions rise as t increases, the sign of $G(t)$ is ambiguous in general. After replacing $m(\cdot)$ and $m'(\cdot)$ in (1.7), factor–price changes are magnified iff

$$G(t) = \frac{1}{2}\left[\frac{f(t)}{f(a_L(t))}\frac{1}{1+a_L(t)} - \frac{f(t)}{f(a_H(t))}\frac{b}{1+ba_H(t)}\right] > 0.$$

We arrive at the following proposition:

Proposition 1.3. *With abilities distributed symmetrically and single peaked over the admissible support with $f(0) = f(1) = c \in [0, 1/2)$, and using the median as a representative measure of the skill premium, the effect of price changes on the skill premium is magnified by endogenous labour–supply reactions iff the relative supply of skilled labour is sufficiently high.*

Proof. The proof is in two steps. We first prove that the function $G(t)$ can have at most one root. We then show that both $\lim_{t\to 0} G(t) > 0$ and $\lim_{t\to 1} G(t) < 0$ hold for all $c \in [0, 1/2)$. In order to simplify the first part of our proof, we define the function

$$Q(t) := \frac{1+ba_H(t)}{b\,(1+a_L(t))} - \frac{f(a_L(t))}{f(a_H(t))}.$$

Obviously, the sign of the function $Q(t)$ determines the sign of $G(t)$. We now show that $Q(t)$ can have at most one root $\tilde{t} \in [0,1]$. Symmetry and single peakedness of f guarantee that $d[f(a_L)/f(a_H)]/dt > 0$. Furthermore, we have

$$d\left(\frac{1+ba_H}{b\,(1+a_L)}\right)/dt = -\frac{f(t)}{2\,(1+a_L)\,f(a_L)}\left[\frac{(1+ba_H)}{b\,(1+a_L)} - \frac{f(a_L)}{f(a_H)}\right].$$

This implies that

$$sgn\left[d\left(\frac{1+ba_H}{b\,(1+a_L)}\right)/dt\right] = -sgn[Q(t)].$$

Combining these results yields that for all t with $Q(t) \geq 0$ we have $Q'(t) < 0$. Consequently, the function $Q(t)$—and hence the function $G(t)$—can have at most one root.

For the second part we consider the limit of $G(t)$ at the lower and upper bound of the support:

$$\lim_{t\to 0} G(t) = \left[1 - \frac{zb}{1+b/2}\right]/2$$
$$\lim_{t\to 1} G(t) = \left[\frac{2z}{3} - \frac{b}{1+b}\right]/2\,,$$

where $z := c/f(1/2)$. Single peakedness of f implies $f(1/2) > 1$ and therefore $z \in [0,c)$. Hence, the condition $c < 1/2$ is sufficient for $\lim_{t\to 0} G(t) > 0$ and $\lim_{t\to 1} G(t) < 0$ to hold.

Together with our result that there can be at most on root, and since $G(t)$ is a continuous function, the intermediate value theorem guarantees the existence of $\tilde{t}$ such that $G(\tilde{t}) = 0$. We then have $G(t) \geq 0 \;\forall\, t \leq \tilde{t}$, and $G(t) < 0 \;\forall\, t > \tilde{t}$. □

Note that the constraint $c < 1/2$ is not very restrictive, because it is most unlikely that extremes of high and low abilities are very frequent within a population.[13] Allowing for $c \geq 1/2$ gives us two additional cases where either only magnification or only compensation occurs for all admissible t. Which of these cases applies depends on the return to education, b. We can dispense with an in–depth analysis of these cases because they give us quite similar results as the analysis of the uniform distribution.[14] It is note-

[13]This point will be clearer at the end of the section where we calculate the function $G(t)$ for a specific distribution using empirical estimates of its parameters.

[14]Indeed, the condition $b < 2$ is sufficient, though not necessary, for magnification to occur.

worthy that for a symmetric distribution with plausible upper–bound and lower–bound weights the return to education has no influence whether magnification or compensation can occur in general. The parameter b, however, directly controls the determination of relative labour supply.

Next we consider the function $G(t)$ for the mean–wage–income formulation:

$$G(t) = \frac{E_L'(t)}{1 + E_L(t)} - \frac{bE_H'(t)}{1 + bE_H(t)},$$

where $E_L(t)$ and $E_H(t)$ are the mean ability of the respective groups:

$$E_L(t) = \frac{1}{F(t)} \int_0^t af(a)da, \qquad E_H(t) = \frac{1}{1 - F(t)} \int_t^1 af(a)da.$$

The derivatives $E_L'(t)$ and $E_H'(t)$ can be calculated as

$$E_L'(t) = \frac{f(t)}{F(t)} \left[t - E_L(t)\right], \qquad E_H'(t) = \frac{f(t)}{1 - F(t)} \left[E_H(t) - t\right]$$

Both derivatives are positive over the whole support.

Magnification requires $G(t) > 0$, which leads us to the next proposition:

Proposition 1.4. *With abilities distributed symmetrically and single peaked over the admissible support with $f(0) = f(1) = c \in [0, 1/2)$, and using the mean as a representative measure of the skill premium, the effect of price changes on the skill premium is magnified by endogenous labour–supply reactions iff relative labour supply of skilled labour is sufficiently high.*

Proof. We again derive the limits of $G(t)$:

$$\begin{aligned} \lim_{t \to 0} G(t) &= E_L'(0) - \frac{b}{1 + b/2} \frac{c}{2} \\ \lim_{t \to 1} G(t) &= \frac{c}{3} - \frac{b}{1 + b} E_H'(1), \end{aligned}$$

with $E_L'(0) = E_H'(1)$ amounts to $2/3$ for $c = 0$, and to $1/2$ for $c > 0$ (cf. Appendix). For $c \in [0, 1/2)$ we get $\lim_{t \to 0} G(t) > 0$ and $\lim_{t \to 1} G(t) < 0$, independent of b. Since $G(t)$

is a continuous function, the intermediate value theorem guarantees the existence of at least one t^* such that $G(t^*) = 0$. □ □

As for the median, allowing for $c \in [1/2, 1]$ gives rise to two additional cases with either $G(0) < 0$ and $G(1) < 0$, or $G(0) > 0$ and $G(1) > 0$, depending on the value of b. Similar to the median wage income formulation, we always have magnification *and* compensation as long $c < 1/2$, depending on the relative supply of skilled labour. With the mean as representative wage income, however, there is a theoretical possibility of more than one root, i.e., we have an alternating pattern of magnification and compensation as t changes. But the following numerical calculations of $G(t)$ provide considerable support for the existence of only one root for plausible distributions of inherent abilities.

We illustrate the graph $G(t)$ for the two different measures of the representative wage used to calculate the skill premium with the abilities distributed according to a truncated normal distribution represented by

$$f(a) = \frac{\phi(a, \sigma)}{\Phi(1, \sigma) - \Phi(0, \sigma)},$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are the density and the distribution function of the normal distribution with parameters $\mu = 0.5$ and $\sigma > 0$, respectively. The applied distribution has positive weights at the lower and upper support, these are approximately zero when the standard deviation is sufficiently small. We use a standard deviation of $\sigma = 0.075$ corresponding to the normal distribution usually found in IQ-Studies.[15] In figures 1.2 and 1.3 on the facing page, G_1 and G_2 represent the calculation of $G(t)$ by the median with $b = 1.3$ and $b = 100$, respectively. G_3 and G_4 represent the calculation of $G(t)$ by the mean using the same parameter values for b. Using these extreme values for b lets us sketch the upper and lower bound of $G(t)$. As one easily observes, using the median results in higher absolute values for both magnification and compensation than using the mean. This is due to faster change of the median compared to the mean. Our computations also show that a higher b slightly compresses the interval for magnification. However, as equation (1.5) indicates, this movement in b lowers the threshold t significantly.

[15] To describe the distribution of abilities within a population, Wechsler (1939) used the normal distribution which is standard in psychology today. The mean is standardised to 100. Typical estimates for the standard deviation are 10 or 15. Our $\sigma = 0.075$ used in the simulation corresponds to a standard deviation of 15.

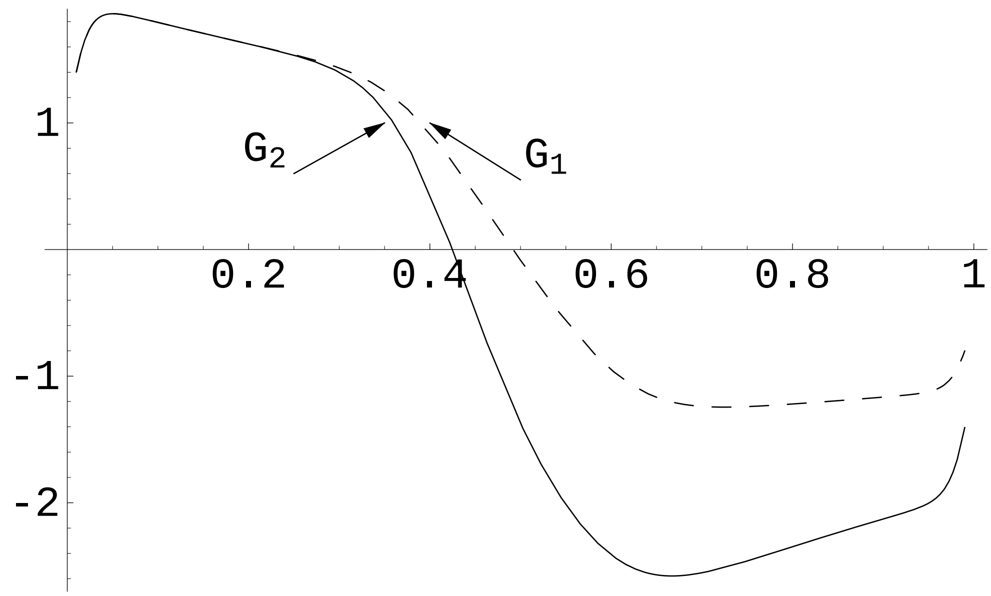

Figure 1.2: $G(t)$ using the median wage representation. The graph G_1 uses b=1.3 and G_2 uses b=100

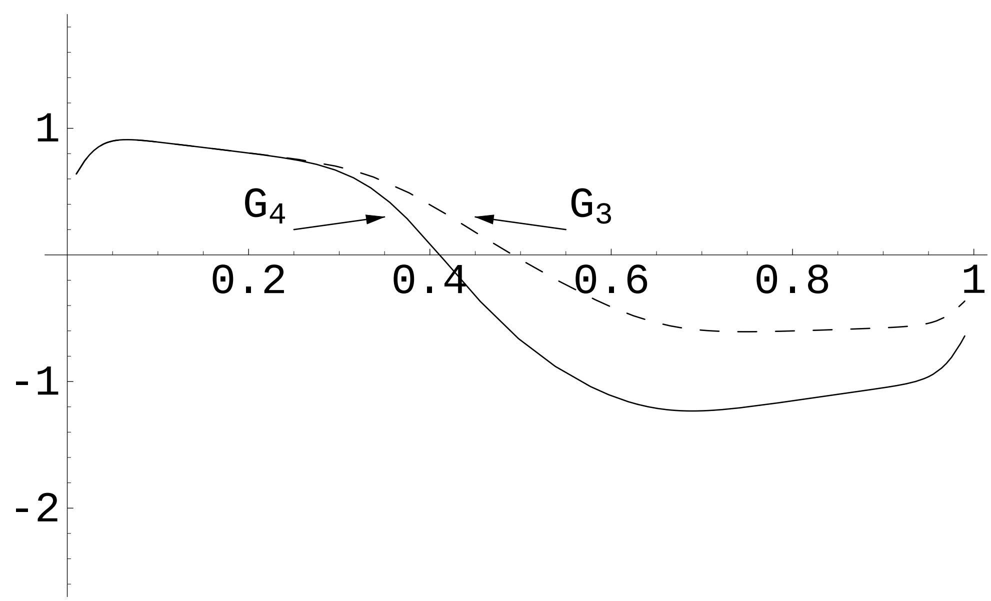

Figure 1.3: $G(t)$ using the mean wage representation. The graph G_3 uses b=1.3 and G_4 uses b=100

1.4 Conclusions

This paper has emphasised endogenous adjustment of relative labour supply as an additional channel through which changes in relative commodity prices caused by globalisation or SBTC affect the empirically measured skill premium. These composition effects arise from decisions of individuals with heterogeneous inherent abilities about acquiring human capital. Under plausible conditions, they magnify the traditional Stolper–Samuelson effect implying that even minor changes in relative prices can generate substantial changes in the skill premium. According to our analysis, magnification is comprehensible for countries with high relative supplies of skilled labour. Thus, we should expect considerable increases in the skill premium in the US and other highly industrialised countries. On the other hand, endogenous labour–supply adjustments are likely to work against the Stolper–Samuelson effect in developing countries, where the relative supply of skilled labour typically is rather low. Since this counteracting effect arising from labour–supply adjustment is in no way limited by the extent of the change in factor prices, it clearly can dominate the Stolper–Samuelson effect on measured skill premium. As a result, the skill premium in developing countries does not necessarily decline when these countries experience adjustments of commodity prices in the process of globalisation that are exactly the opposite of those in industrialised countries.

Our model also gives some first results on wage inequality within different groups of labour (residual wage inequality). As globalisation or SBTC drive down the threshold ability, the group of skilled labour becomes more heterogeneous, and residual wage inequality (measured by, e.g., the Gini coefficient) increases. This may explain the observed rise in wage inequality within the group of skilled labour. On the other hand, the group of unskilled labour becomes less heterogeneous, and residual wage inequality declines. Although this is contrary to empirical observations, one must bear in mind that the evidence for an increase in within–group wage inequality is less strong for the unskilled. Additionally, within–group wage inequality for unskilled labour may have been primarily affected by institutional changes (cf., e.g. DiNardo et al., 1996).

1.A Appendix

We assume that the distribution of abilities is given by the following unimodal and symmetric distribution:

$$f(0) = f(1) = c \quad c \in [0,1) \text{ and } \lim_{a\to 0} f'(a) = -\lim_{a\to 1} f'(a) > 0.$$

We can use the following properties of the truncated mean to derive the limit of the first derivative of mean wage for skilled and unskilled workers with respect to the threshold value:

$$\lim_{t\to 0} E'_L(t) = \lim_{t\to 1} E'_H(t)$$
$$\lim_{t\to 1} E'_L(t) = \lim_{t\to 0} E'_H(t)\,.$$

Therefore we concentrate on the derivation of $\lim_{t\to 0} E'_L(t)$ and $\lim_{t\to 1} E'_L(t)$. We start with the $\lim_{t\to 0} E'_L(t)$:

$$\lim_{t\to 0} E'_L(t) = \lim_{t\to 0} t\frac{f(t)}{F(t)} - \lim_{t\to 0} \frac{f(t)}{F(t)^2}\int_0^t af(a)da\,. \tag{1.A.1}$$

The limit of the first term in (1.A.1) $\lim_{t\to 0} t\frac{f(t)}{F(t)}$gives us after applying L'Hospitals rule:

$$\lim_{t\to 0} t\frac{f(t)}{F(t)} = \lim_{t\to 0} \frac{f(t)+tf'(t)}{f(t)}\,.$$

For $c > 0$ we get $\lim_{t\to 0} t\frac{f(t)}{F(t)} = 1$. For $c = 0$ we have to apply L'Hospitals rule a second time:

$$\lim_{t\to 0} t\frac{f(t)}{F(t)} = \lim_{t\to 0} \frac{f(t)+tf'(t)}{f(t)} = \lim_{t\to 0} \frac{2f'(t)+tf''(t)}{f'(t)} = 2\,.$$

Collecting things we get for the first term in (1.A.1) the following result:

$$\lim_{t\to 0} t\frac{f(t)}{F(t)} = \begin{cases} 2 & \text{for } c = 0 \\ 1 & \text{for } c > 0 \end{cases} \tag{1.A.2}$$

Next we turn to the second term in (1.A.1):

$$\lim_{t\to 0}\frac{1}{F(t)^2}f(t)\int_0^t af(a)da = \lim_{t\to 0}\frac{f'(t)\int_0^t af(a)da}{2F(t)f(t)} + \frac{1}{2}\lim_{t\to 0}\frac{tf(t)}{F(t)}\,. \tag{1.A.3}$$

The limit of the second term in (1.A.3) is the same as in (1.A.2) but the first term is undecidable. Therefore we have to apply L'Hospitals rule again for that expression

$$\lim_{t\to 0}\frac{f'(t)\int_0^t af(a)da}{2F(t)f(t)} = \lim_{t\to 0}\frac{f''(t)\int_0^t af(a)da + f'(t)tf(t)}{2\left[F(t)f'(t)+f(t)^2\right]}\,.$$

For $c > 0$ the limit of that expression is zero but for $c = 0$ the limit is again undecidable and we get:

$$\lim_{t\to 0}\frac{2f''(t)tf(t) + f'''(t)\int_0^t af(a)da + f'(t)f(t) + f'(t)^2 t}{2\left[F(t)f''(t)+3f(t)f'(t)\right]}\,.$$

Since the limit of this term is again undecidable, we once again apply L'Hospital's rule. Dropping all expressions that include $f(t)$, t, $F(t)$ and $\int_0^t af(a)da$ after differentiation (since they are equal to zero), we arrive at

$$\lim_{t\to 0}\frac{2f'(t)^2}{6f'(t)^2} = \frac{1}{3}$$

As a result the limit of the second term in (1.A.1) is:

$$\lim_{t\to 0}\frac{f(t)}{F(t)^2}\int_0^t af(a)da = \begin{cases}\frac{4}{3} & \text{for } c = 0\\ \frac{1}{2} & \text{for } c > 0\,.\end{cases} \tag{1.A.4}$$

Collecting terms from (1.A.2) and (1.A.4), we finally derive the limit $\lim_{t\to 0} E_L'(t)$:

$$\lim_{t\to 0} E_L'(t) = \begin{cases}\frac{2}{3} & \text{for } c = 0\\ \frac{1}{2} & \text{for } c > 0\,.\end{cases}$$

The limit $\lim_{t\to 1} E_L'(t)$ is given by:

$$\lim_{t\to 1} E_L'(t) = \lim_{t\to 1} \frac{f(t)}{F(t)}[t - E_L]$$
$$= \frac{1}{2} \lim_{t\to 1} f(t) = \begin{cases} 0 & \text{for } c = 0 \\ \frac{c}{2} & \text{for } c > 0\,. \end{cases}$$

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CHAPTER 2

Immigration, Education, and Labour Market Institutions

2.1 Introduction

Large and steady inflows of (il)legal immigrants into the US and Western Europe are a striking fact of the last four decades. While the workforce of those countries is relatively high skilled, the overwhelming part of their immigrants are low skilled workers.[1] Conventional wisdom of low skilled immigration is that it is beneficial for the host country as long as labour markets are competitive, though there might arise unintended distributional effects.[2] However, when labour markets are not fully competitive as in the case of Central Europe, the effects of immigration of low skilled workers depend on the labour market institutions. In both settings it is shown, that the wage of low skilled workers has to fall. In contrast to these clear-cut theoretical results, empirical evidence of the quantitative influence of immigration of low skilled workers on the labour market is somehow mixed: Borjas et al. (1997) and Borjas (2003) argue that the influence of immigration on the labour market outcome of natives is quite substantial. However, many studies find only a slight influence of immigration (cf. LaLonde and Topel, 1996; Card, 2001) or no influence of immigration (cf. Altonji and Card, 1991).[3]

In this paper we show that this conventional wisdom is maybe misleading if workers are heterogeneous and the level of education is endogenous. Our findings can be summarised as follows: Firstly, the impact of immigration on the skill premium crucially depends on the initial level of education in an economy. Consequently, a country's "tradition" of immigration is a relevant determinant for the labour market outcome for natives. Thus we can give a theoretical explanation of the mixed empirical results: recent empirical studies mostly consider a rather "short" period of time while we take a more long term perspective. Secondly, the influence of immigration on the evolution of the skill premium remains valid even with the introduction of labour market rigidities. This might account for the different European experiences concerning the evolution of the skill premium.[4]

[1] See Borjas (1994) for legal immigration and Warren and Passel (1987); Espenshade (1995) for illegal immigration.

[2] See Berry and Soligo (1969); Borjas et al. (1997).

[3] The different results perhaps are due to the different empirical methods used in these studies. The studies by Card (2001); Altonji and Card (1991); Card (1990) are looking for the impact of immigration on local labour markets. The studies of Borjas (2003); Borjas et al. (1997) are concentrating on the impact of immigration on the aggregated national level. Borjas (2005) consolidates to a certain degree the both strands of literature: he finds that the internal migration decision of natives might explain these differing results.

[4] The evolution of the skill premium is mixed within Continental Europe: we observe decreasing, constant or slightly rising skill premia (cf. Siebert, 1997).

In the early theoretical literature, immigration is modeled by assuming fixed labour endowments and competitive labour markets in the host country. Within this framework the assumptions on capital mobility solely determine which kind of immigration is optimal for the host country. Nevertheless it is shown that immigration is never detrimental and therefore there exists an immigration surplus for the native population. These classical results will not fully apply when the assumption of undistorted labour markets is removed. Schmidt et al. (1994) show that both – higher native unemployment or increased employment – might arise depending on the substitutability or complementarity of low skilled and high skilled workers. Most important, immigration of low skilled workers may induce unions to lower their wage claim. Most related to our approach is the analysis of Fuest and Thum (2001). They introduce an endogenous labour supply within an efficient bargaining model. It is shown that the reaction of the labour supply to the expected future immigration internalises the negative effect of immigration on the labour market outcome for workers. Since their result depends on the incorporated bargaining process, our results are different concerning unemployment and the evolution of wage dispersion.

We introduce a general equilibrium model with heterogeneous individuals who decide on education and thereby forming the aggregate labour supply of low skilled and high skilled workers. Heterogeneity is introduced by an ability distribution. The skill premium – measured by the ratio of median or mean income between the educational groups – depends on the relative wage and on the ability composition of both groups. Hence, the influence of immigration on the labour market is twofold: Firstly, by changing the relative wage, immigration directly increases the skill premium. We call this channel the direct wage effect of immigration. Secondly, a changing relative wage will induce natives to revise their educational decisions. This will modify the ability composition of the respective educational groups and constitutes what we call the compositional effect of immigration. We show that immigration of low skilled labour magnifies the aforementioned direct wage effect if the level of education is sufficiently high in the host country. However, with a lower level of education this direct effect is likely to be compensated. The basic mechanism of magnification or compensation remains valid even when accounting for rigidity of wages. In this economic environment the change of the skill premium is accompanied by an increase of the unemployment of low skilled workers. Furthermore, we show that countries with sustained low skilled immigration have higher levels of education. We argue that these countries show a higher tendency for magnification of the skill premium. This remains true for countries characterised by rigid wages.

The remainder of the paper is organised as follows. In Section 2.2, we present the basic model, discuss the labour market equilibrium and our measure of skill premium. Immigration and its influence on the economy with flexible and rigid wages will be analysed in section 2.3. Section 2.4 concludes.

2.2 The model

2.2.1 Technology

We consider an economy in which competitive firms produce a single homogeneous consumption good Y using two different factors of production: high skilled labour H and low skilled labour L each measured in efficiency units.[5] The production technology $Y(H, L)$ is assumed to be neo-classical.[6] Normalising the price of the final product to one, profit maximisation leads to the following first order conditions:

$$\partial Y/\partial H = w_H, \qquad \partial Y/\partial L = w_L, \tag{2.1}$$

The marginal product for each type of labour equals the wage rate $w_i \quad (i = H, L)$ per efficiency unit of labour. Taken together, the first order conditions in (2.1) define the aggregate relative labour demand $g(\omega)$ as a function of the relative factor price $\omega \equiv w_H/w_L$:

$$\frac{H}{L} = g(\omega). \tag{2.2}$$

Given our assumption on the production technology, the relative labour demand depends negatively on the relative wage ω: $g'(\omega) < 0$.

[5]Capital as a third factor can be ignored as long as capital is assumed as perfectly mobile internationally with an exogenously given global interest rate. Otherwise the capital income of natives also depends on the relative inflow of immigrants and one has to analyse the wealth- and the wage distribution simultaneously. By ignoring capital as third factor, we are not concentrating on the issue of substitutability or complementarity of skill groups (cf. Borjas, 1995).

[6]This technology has to satisfy the following requirements: (i) $\partial Y/\partial i > 0$ and $\partial^2 Y/\partial i^2 < 0$ (ii) $\lim_{i\to 0} \partial Y/\partial i = \infty$ $\lim_{i\to\infty} \partial Y/\partial i = 0$ for $i = H, L$ (iii) $\gamma Y = Y(\gamma H, \gamma L)$.

2.2.2 Households

Individuals are assumed to be heterogeneous with respect to their abilities a.[7] Abilities are continuously distributed on the support $[0, 1]$ according to a general density function $f(a)$. The total native population is normalised to mass one.

Given his ability a, an agent has to decide whether he invests in education or not. A worker with ability a without any further education supplies $(1 + a)$ efficiency units of low skilled labour and earns a total wage income of $W_L(a) = (1 + a)w_L$. Alternatively he can spend an exogenously given fraction λ of time on further education, to supply $(1 + ba)(1 - \lambda)$ efficiency units of high skilled labour. The parameter $b > 1$ measures the gross effect of education on marginal efficiency units of a trained worker with ability a. Hence, a trained worker earns a total wage income of $W_H(a) = (1 + ba)(1 - \lambda)w_H$.[8] We assume that both types of labour are *qualitatively* different: a low skilled worker cannot work as high skilled and vice versa. The wage for each skill group is a linear affine function of the ability a as depicted in figure 2.1.

Preferences are defined over the consumption of the homogeneous good Y and are identical for all workers. Thus, an agent maximises his total wage income and chooses to invest in training if his ability is higher than some threshold value t defined by:

$$(1 + bt)(1 - \lambda)w_H = (1 + t)w_L. \tag{2.3}$$

Workers with ability t are indifferent between investing in education or not. The threshold value depends on the relative factor price ω as well as on the exogenous parameters b and λ. Graphically the threshold is given by the intersection of the two wage functions (see figure 2.1 on the next page) and can be calculated as:

$$t = \frac{(1 - \lambda)\omega - 1}{1 - b(1 - \lambda)\omega}. \tag{2.4}$$

The parameters b, λ and the relative wage ω have to satisfy the following condition: $2/(1 + b) \leq (1 - \lambda)\omega \leq 1$, such that t lies in the interval $[0, 1]$. For the remainder of the

[7] We interpret abilities as a mixture of innate abilities and knowledge acquired during compulsory schooling. The educational choice modeled in our paper is therefore a choice of further education.

[8] The model can be transfered into a dynamic framework if we would apply an OLG model: in the first period, the households would either acquire education (in the case of a high skilled native) or work (as a low skilled native). In the second period, both households would work and consume their life time income.

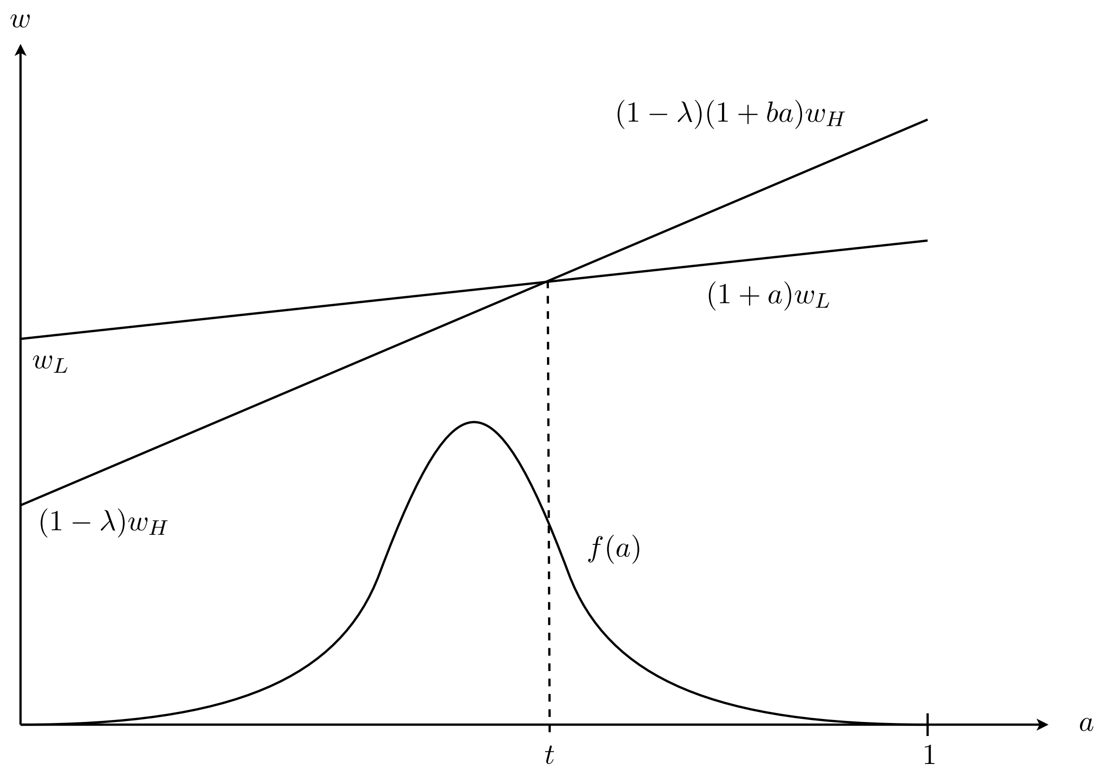

Figure 2.1: Determination of the threshold value $t(\omega)$

paper we assume that this condition is fulfilled. If the relative wage changes, the threshold value changes according to:

$$t'(\omega) = \frac{(1-\lambda)(1+tb)}{1-b(1-\lambda)\omega} < 0. \tag{2.5}$$

The rationale behind the negative sign is that a higher relative wage makes it favourable for agents with lower ability to invest in training. Even a small change in ω might result in a large reaction of t if the denominator is close to zero.

The economy's total supply of low skilled labour and high skilled labour corresponds to the weighted sum of efficiency units of the respective group and therefore depends directly on the training decisions made by households:

$$L(\omega) = \int_0^{t(\omega)} (1+a)f(a)da, \qquad H(\omega) = \int_{t(\omega)}^{1} (1-\lambda)(1+ba)f(a)da. \tag{2.6}$$

Obviously $L'(\omega) < 0$ and $H'(\omega) > 0$ since a higher relative wage decreases the threshold value thereby expanding the ability interval of the high skilled workers while at the same time narrowing that of the low skilled workers. Relative labour supply $h(\omega) \equiv H(\omega)/L(\omega)$ can be written as a function of the relative wage ω:

$$\frac{H}{L} = h(\omega). \tag{2.7}$$

Given the properties of the respective labour supply functions the relative labour supply is positively sloped: $h'(\omega) > 0$. The relative labour supply is determined by the structural parameters b, λ and the relative wage ω.

2.2.3 *Labour market equilibrium and the skill premium*

The properties of the relative labour supply and the relative labour demand guarantee a unique labour market equilibrium $\{\omega^*, (H/L)^*\}$ in terms of efficiency units.[9]

In order to discuss the influence of immigration on the income of individuals and the respective skill groups we need to define some wage measure. Because the economy is populated by heterogeneous agents, an unique wage does not exist for every skill group but a wage distribution for both groups. An apparent measure for the wage of the respective group would be the mean wage. But there is a major drawback in using the mean wage alone. The wage distribution of each group is a linear transformation of the assumed skill distribution, which turns out to be a skewed distribution. This can lead to over- or underestimation of the reaction of the representative wage. To address the problem, we also use the median wage as a representative wage.[10] We define the native's skill premium x as the ratio of the representative wage of high and low skilled workers m_H and m_L:

$$x = \frac{m_H(t)}{m_L(t)} = \frac{m(w \mid a \geq t)}{m(w \mid a < t)} = \frac{(1 + bm(a \mid a \geq t))\,(1 - \lambda)}{1 + m(a \mid a < t)}\omega. \tag{2.8}$$

The skill premium is the product of two terms: The first term is the ratio of mean/median efficiency units of labour and the second term is the relative wage. Obviously, a change of the equilibrium relative wage ω resulting from immigration will change the skill

[9]Throughout the paper asterisks denote equilibrium values.

[10]The ratio of the median/mean wage as a measure of premia of different skill groups has been used extensively in empirical research (cf. Greiner et al., 2004).

premium directly via the second term. We call this change the direct wage effect. However, a change of the relative wage will also change the incentives to educate and thus the ratio of representative efficiency units. We call the change of the incentives to educate the compositional effect. As we will show, the overall impact of a change of the relative wage on the wage structure is ambiguous in general because both effects can offset each other. Figure 2.2 shows the labour market with LD denoting the labour demand and LS denoting the labour supply. Point A represents the labour market outcome without immigration.

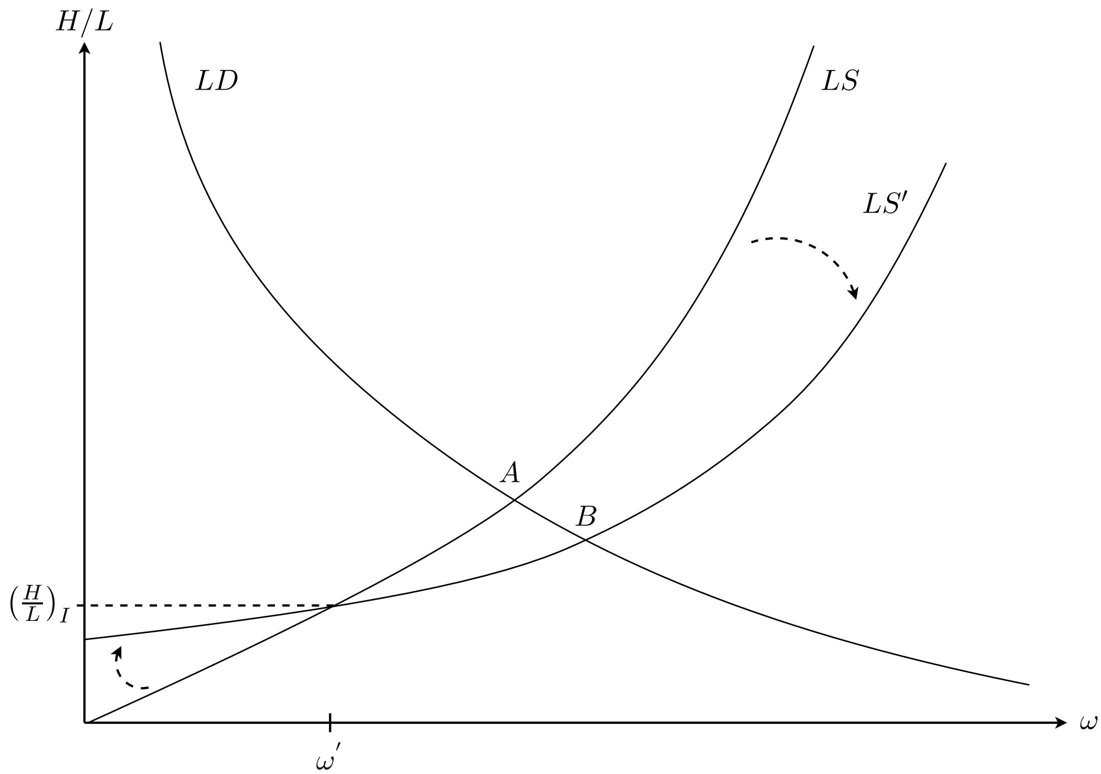

Figure 2.2: The labour market equilibrium with relatively low skilled immigration

2.3 Immigration and the labour market

2.3.1 *Immigration under flexible wages*

We model immigration as an inflow of efficiency units of labour denoted by H_I and L_I. We abstract from the consideration of the total number of immigrants entering the country and of the distribution of abilities among immigrants. To keep matters simple we assume that immigrants are not allowed to invest in education in the host country.

The influence of immigration on the labour supply is reflected by the immigration augmented labour supply function:

$$\frac{H}{L} = \frac{H_I + H(\omega)}{L_I + L(\omega)} \equiv h_I(\omega). \tag{2.9}$$

Using this representation allows us to discuss both the impact of first time ($L_I, H_I = 0$) and sustained immigration ($L_I, H_I > 0$). With exclusive low (high) skilled immigrants, the supply curve shifts to the right (left). But with both, positive immigration of low and high skilled workers – which is the typical case –, the labour supply curve LS in figure 2.2 on the preceding page will rotate clockwise around the point H_I/L_I, leading to a less elastic supply curve. The influence of immigration on the equilibrium relative wage ω^* can be derived as:[11]

$$d\omega^* = \frac{h_I(\omega^*)}{g'(\omega^*) - h_I'(\omega^*)} \left(\frac{dH_I}{H_I + H(\omega^*)} - \frac{dL_I}{L_I + L(\omega^*)} \right). \tag{2.10}$$

As the first term on the right hand side is always negative the second term determines the sign of $d\omega^*$: The equilibrium relative wage rate increases (decreases) if the immigration includes relatively less (more) high skilled efficiency units in comparison to the existing equilibrium relative labour supply in the host country. This result is in line with the standard immigration literature summarised by Borjas (1999, 1995). As we are interested in the experiences made in the US or Western Europe, we limit the discussion to the case of relatively low skilled immigration ($dH_I/dL_I < h_I(\omega^*)$) for the rest of the paper.[12]

Due to heterogeneity of the labour force, the change of the relative wage ω is not sufficient to discuss the distributional consequences of low skilled immigration. We analyse the percentage change of the measured skill premium (2.8) to determine the distributional consequences of immigration. As indicated above the change of the skill premium can be decomposed into a direct wage effect and into a compositional effect.

[11] See the appendix 2.A.1.

[12] The case for immigration of low skilled workers is even stronger if we take illegal immigration into account. For the US, at the beginning of the 1990ies the size of the population of illegal immigrants was estimated to be 3 Mio. people. . Most of this population was of Mexican origin, see Espenshade (1995) and Warren and Passel (1987). For estimates of the population of illegal immigrants in Europe see Entorf (2002).

Thus the net impact of low skilled immigration on the wage distribution is not as clear cut as it might seem at first sight. It crucially depends on the educational level in the host economy.

The elasticity of the skill premium $\varepsilon_{x,\omega}$ with respect to the relative wage change can be computed as:

$$\varepsilon_{x,\omega} = x'\left(\omega^*\right)\frac{\omega^*}{x\left(\omega^*\right)} = 1 - \left|t'(\omega^*)\right|\omega^* G(t^*), \tag{2.11}$$

$$\text{with } G(t) = \left(\frac{bm'_H(t)}{1+bm_H(t)} - \frac{m'_L(t)}{1+m_L(t)}\right).$$

The first term in equation (2.11) (the one) represents the direct wage effect by which the skill premium is influenced. The compositional effect ($|t'(\omega^*)|\,\omega^* G(t^*)$) stems from the fact that individuals react to the change of the relative wage. The sign of the compositional effect depends on the function $G(t)$ which measures the difference in the rate of change of the representative labour supply of the two educational groups. The sign of the function $G(t)$ is ambiguous in general. Hence the total effect of immigration on the measured skill premium is also ambiguous. As the threshold value is only another way of expressing relative labour supply, there are cases in which $G(t) < 0$ and immigration will magnify the direct wage effect.

In the following we will show that whether magnification $G(t) < 0$ or compensation $G(t) > 0$ occurs, will crucially depend on the initial relative labour supply and on the distribution of abilities $f(a)$.

The skill premium with symmetric and unimodal distribution of abilities

Assumption 2.1. *Abilities are distributed according to a symmetric and unimodal distribution with mean, median and modus at* $1/2$. *The following boundary conditions are also imposed:*

$$f(0) = f(1) = c \geq 0 \quad \textit{and} \quad \lim_{a\to 0} f'(a) = -\lim_{a\to 1} f'(a) > 0.$$

We will proceed as follows: Firstly, we calculate the compositional effect $G(t)$ for our two measures of the representative wage and show under which conditions the direct wage effect is magnified or compensated. Secondly, we discuss the difference between both measures and illustrate our findings.

The median ability of the low skilled workers $a_L(t)$ and the high skilled workers $a_H(t)$ are defined by:[13]

$$a_L(t) \equiv F^{-1}\left[\frac{F(t)}{2}\right], \quad a_H(t) \equiv F^{-1}\left[\frac{1-F(t)}{2}\right].$$

Considering the derived formula for $G(t)$ in (2.11), we need to compute the change of the median abilities due to a change in the threshold value t:

$$\frac{da_L(t)}{dt} = \frac{1}{2}\frac{f(t)}{f(a_L(t))}, \quad \frac{da_H(t)}{dt} = \frac{1}{2}\frac{f(t)}{f(a_H(t))}.$$

Using those derived formulas above in the definition of $G(t)$ (equ. (2.11)) gives us the condition for magnification:

$$G(t) = \frac{1}{2}\left[\frac{f(t)}{f(a_H(t))}\frac{b}{1+ba_H(t)} - \frac{f(t)}{f(a_L(t))}\frac{1}{1+a_L(t)}\right] < 0,$$

and we arrive at the following proposition:

Proposition 2.1. *Under assumption 2.1 and the additional requirement that* $f(0) = f(1) = c$, $c \in [0, 1/2)$, *the effect of a change in the relative wage on the skill premium – measured by median wages – through immigration is magnified (compensated) by an endogenous labour-supply reaction, iff the relative labour supply before immigration is sufficiently high (low).*

Proof. Please consult the appendix. □

The requirement that $f(0) = f(1) = c \in [0, 1/2)$ is not very restrictive because even a boundary weight of $1/2$ is rather implausible. Especially, if one thinks of abilities as some kind of measurable IQ the usual distribution used in IQ studies is the normal distribution with a mean of 100 and a standard deviation of 10 to 15. Applied to our chosen standardisation of abilities between zero and one this would give us an approximate weight of zero for the lower and upper bound of the ability interval.

[13] The median for the respective groups is calculated using the conditional ability distribution: $(1/F(t))\int_0^t f(a)da$ and $(1/(1-F(t)))\int_t^1 f(a)da$.

Next , we analyse the change of the skill premium using the mean as a representative wage. The mean wage of the low and high skilled group are defined by:

$$E_L(t) = \frac{1}{F(t)} \int_0^t af(a)da \quad \text{and} \quad E_H(t) = \frac{1}{1-F(t)} \int_t^1 af(a)da.$$

Taking the derivative of the mean wage with respect to the ability threshold t leads to:

$$E_L^{'}(t) = \frac{f(t)}{F(t)}[t - E_L(t)] \quad \text{and} \quad E_H^{'}(t) = \frac{f(t)}{1-F(t)}[E_H(t) - t].$$

Using the mean and its derivative in the expression for $G(t)$ gives the following condition for magnification:

$$G(t) = \left[\frac{bE_H^{'}(t)}{1 + bE_H(t)} - \frac{E_L^{'}(t)}{1 + E_L(t)}\right] < 0,$$

and we get the following proposition:

Proposition 2.2. *Under assumption 2.1 and the additional requirement that $f(0) = f(1) = c$, $c \in [0, 1/2)$, the effect of a change of the relative wage on the skill premium – measured by mean wages – through immigration is magnified (compensated) by an endogenous labour-supply reaction, iff the relative labour supply before immigration is sufficiently high (low).*

Proof. Please consult the appendix. □

As propositions 2.1 and 2.2 show there is no qualitative difference in using the median or the mean wage as the representative wage. But as illustrated in figure 2.3 on the facing page, where we simulated the function $G(t)$ for the triangle distribution setting $b = 1.4$, the magnification (compensation) effect is even stronger by using the median.

What both propositions indicate is quite surprising. The existing educational level of the economy before immigration is the main cause for magnification or compensation. Hence countries with a high level of education (a small value of t) are very prone to

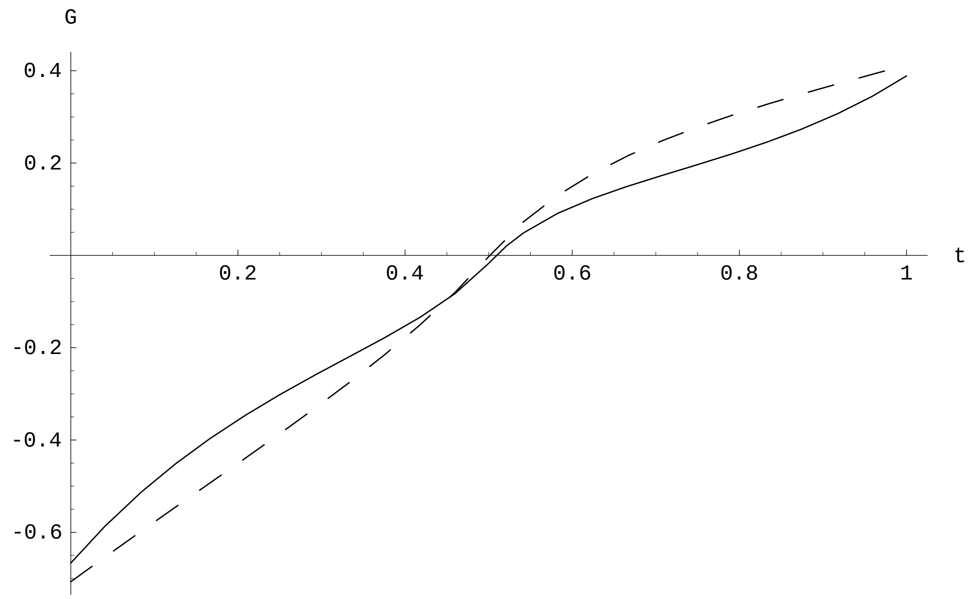

Figure 2.3: The function $G(t)$ assuming a triangle distribution and $b = 1.4$. The dashed line depicts the median and the solid line depicts the mean.

magnification of the rising relative wage. This can be explained as follows: a high degree of educational attainment leaves a rather small group of low skilled workers compared to the total workforce. An increase of the relative wage adds only a few (compared to the existing high skilled workers) to the lower ends of the high skilled income distribution. This leads to nearly no change of the mean/median wage income of the high skilled workers. Compared to the existing small group of low skilled workers, the drain of those few leads to a significant change of the median/mean wage income of the group of low skilled workers. Both effects add up to an increase of the skill premium.

Sustained immigration can also be a source of a high level of education in the host country. A country like the US with a long tradition of mostly low skilled immigration will experience an increase of the skill premium. Countries with a small relative supply of high skilled labour which experience first time immigration are rather likely to observe a decreasing skill premium. As we argue in the next section this result even holds if we replace the assumption of an undistorted labour market by that of a labour market with a binding minimum wage. The binding minimum wage may be the result of union power or fair-wage considerations.

2.3.2 *Immigration under rigid wages*

In this subsection we analyse the influence of immigration on the measured skill premium with a real minimum wage. By introducing a minimum wage we are aiming at the experiences made in Continental Europe.[14]

Consider a real minimum wage $\overline{w}$ per physical unit of labour, which is binding only for the group of low skilled workers.[15] Then there exists an ability threshold $\overline{a}(w_L;\overline{w})$ representing the least employable ability:

$$\overline{a}(w_L;\overline{w}) = \{a : \overline{w} = (1+a)w_L, \overline{w} > w_L\}. \tag{2.12}$$

Any worker with abilities lower than $\overline{a}(w_L;\overline{w})$ will not be employed by firms because the minimum wage income $\bar{w}$ is larger that the marginal productivity of the worker. The native unemployment rate resulting from such a binding minimum wage is given by all workers with abilities lower than the threshold value $\overline{a}(w_L;\overline{w})$:

$$U(w_L;\overline{w}) = \int_0^{\overline{a}(w_L;\overline{w})} f(a)da. \tag{2.13}$$

A lower wage rate in efficiency units for low skilled workers drives the ability threshold $\overline{a}$ up and leaves more low skilled workers unemployed: $d\overline{a}/dw_L < 0$.

With minimum wage legislation we have to differentiate between the relative labour supply and the employable relative labour. The relative labour supply results from educational decisions of individuals at a given relative wage ω. However, a binding minimum wage leaves all workers $a < \overline{a}$ unemployed. This leads to higher employable relative labour with a binding minimum wage. Both, relative labour supply and the employable labour supply coincide in the case of a non-binding minimum wage. Given our assumptions about the technology, the low skilled wage rate is a function of the relative labour used in production. Therefore we can define η as the specific relative labour

[14] The evolution of the skill premium is rather mixed within Continental Europe: we observe decreasing, constant or slightly rising skill premia (cf. Siebert, 1997).

[15] Two different scenarios are possible: a binding minimum wage before and after immigration or an initially non binding minimum wage which then becomes a binding one after immigration of low skilled labour. We analyse only the first scenario since the second is just the transition from the flexible wage case to that of a binding minimum wage case.

used in production leading to a wage rate of low skilled w_L which equals the minimum wage:

$$\eta = \left\{ \frac{H}{L} : \frac{\partial Y}{\partial L} = \overline{w} \right\}.$$

We define the employable relative labour including the supply of immigrants of both skill groups as:

$$\frac{H}{L} = \begin{cases} h_I(\omega) & h_I(\omega) \geq \eta \\ \frac{H_I + H(\omega)}{L_I + L(\omega) - U(w_L; \overline{w})} & h_I(\omega) < \eta \end{cases} \tag{2.14}$$

A wage rate w_L higher than the minimum wage does not change the relative labour supply in comparison to the flexible wage case and is still defined by (2.9). Whenever the wage rate for low skilled labour is smaller than the minimum wage $w_L < \overline{w}$, unemployment increases the employable relative labour supply as represented by the second term.

Figure 2.4 on the next page illustrates the relative labour supply with a minimum wage. The curve LS represents the relative labour supply whereas eLS illustrates the employable relative labour. As the minimum wage binds at the level η the labour supply curve eLS becomes less elastic. The flexible wage equilibrium at point A depicted in figure 2.4 on the following page cannot be supported as a market equilibrium with a minimum wage $\overline{w}$, because all workers with abilities lower than $\overline{a}$ will not be hired due to the minimum wage legislation. The equilibrium prevailing with a binding minimum wage is depicted as point B. The equilibrium relative wage rate will be lower than in the flexible wage case but the employed relative labour is higher. Compared to a country with flexible wages, we observe less education but higher relative employment of high skilled labour.

When it comes to our measure of the skill premium the wage of the high skilled group is the same as in the flexible wage case. But with a binding minimum wage we have to revise the representative wage of the low skilled group because part of the low skilled are unemployed and without any wage income:

$$m_L = m(w \mid \overline{a} \leq a < t) = 1 + m(a \mid \overline{a} \leq a < t). \tag{2.15}$$

Due to the minimum wage, the wage distribution is truncated at $\overline{w}$ leading to a higher representative wage than under flexible wages. If we use the representative wage in

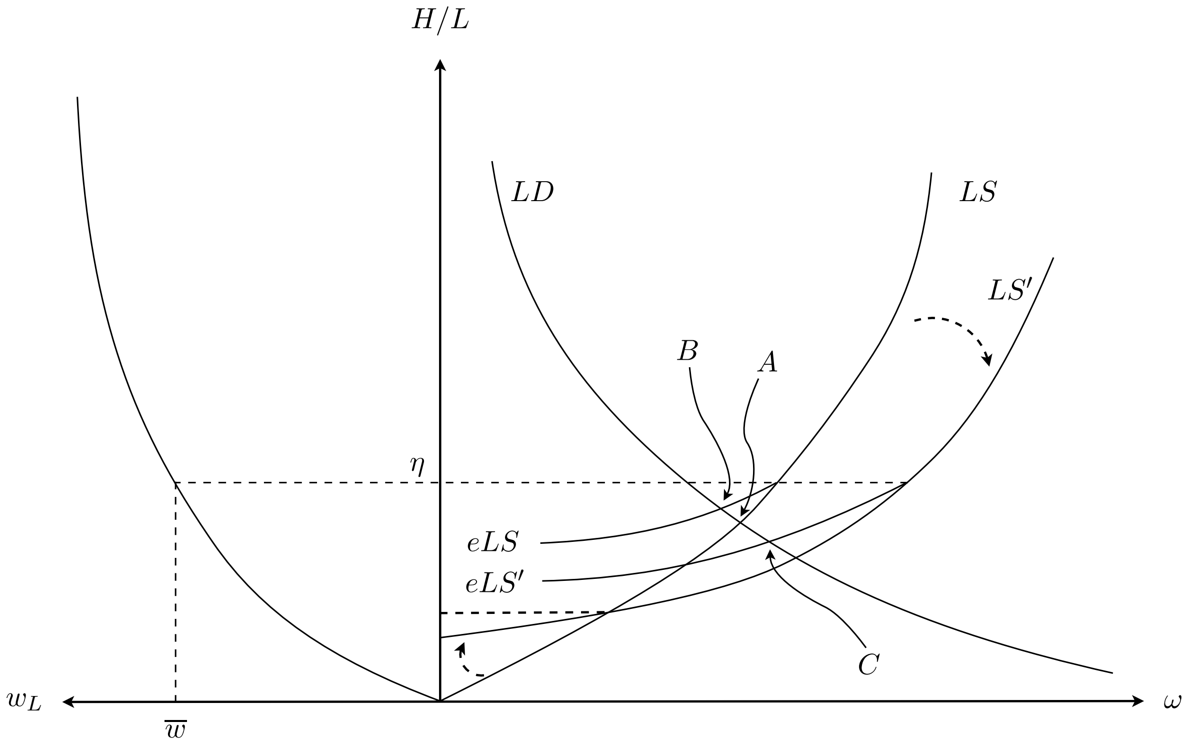

Figure 2.4: The labour market equilibrium with a binding minimum wage $\overline{w}$

equation (2.15), we end up with the measured skill premium with a binding minimum wage:

$$x = \frac{1 + bm(a \mid a \geq t)(1-\lambda)}{1 + m(a \mid \overline{a} \leq a < t)}\omega. \tag{2.16}$$

Now the measured wage differential by education does not only depend directly on ω and the educational threshold $t(\omega)$ but also on the minimum wage $\overline{w}$ via the least employable ability $\overline{a}$. Note that there might be significant differences in the skill premium among countries with rigid wages depending on the absolute value of minimum wages. The skill premium under rigid wages can be lower or higher in comparison to the flexible wage case. As the discussion of the change of the skill premium in the flexible wage case has shown the qualitative results are indifferent concerning the use of the median or mean wage. Therefore we limit our discussion of rigid wages to the median wage.

Consider an immigration of low skilled workers $dH_I/dL_I < (H/L)^*$ into a country with a binding minimum wage, where we assume that a part of the low skilled immigrants have abilities high enough to be employed in the pre-immigration economy.[16] Figure 2.4 on the preceding page illustrates the impact of immigration of low skilled workers on the labour market.[17] The economy's initial equilibrium point is given by point B. Immigration of low skilled labour leads to a clockwise rotation of the labour supply curve (from LS to LS'). Therefore the effective labour supply curve also changes its position (from eLS to eLS'). Note that the effective labour supply still becomes less elastic at the specific relative labour level η. The new equilibrium is represented by point C. The equilibrium relative wage $\overline{\omega}^*$ has increased and the relative employment of high skilled labour has fallen even though more natives invested into training (originating from a lower threshold t). At the same time even more low skilled workers will be pushed into unemployment due to decreased wages for the low skilled workers thereby driving up the least employable abilities $\overline{a}$.

When it comes to the change in the measured skill premium, results differ strongly from the flexible wage case. With binding minimum wages the percentage change of the skill premium resulting from a one percent change of the relative wage can be calculated as:

$$\varepsilon^R_{x,\omega} = 1 - \left|t'(\overline{\omega}^*)\right| \overline{\omega}^* G_R(t^*) - \overline{\omega}^* \frac{1}{1+m_L(\overline{a}^*,t^*)} \frac{\partial m_L(\overline{a}^*,t^*)}{\partial \overline{a}} \frac{d\overline{a}}{dw_L} \frac{dw_L}{d\omega}, \tag{2.17}$$

$$\text{with } G_R(t) = \left(\frac{b}{1+bm_H(t)} \frac{\partial m_H(t)}{\partial t} - \frac{1}{1+m_L(\overline{a},t)} \frac{\partial m_L(\overline{a},t)}{\partial t} \right),$$

where R denotes the rigid wage regime. In comparison to the flexible wage case, the change in the skill premium with a binding minimum wage is augmented by a third term. This term measures the change of the representative wage of low skilled workers due to a change in the least employable abilities $\overline{a}$. This term has a positive sign as long as $dw_L/d\omega < 0$ which is fulfilled given our assumption about the production technology. Therefore the change in the unemployment of low skilled workers always counteracts the direct wage effect.

To grasp the wage effects of immigration under minimum wage legislation, we will consider two different formulations of a minimum wage: i) $\overline{w} = \gamma w_L$ for some constant $\gamma > 1$ and ii) $\overline{w} = \delta w_H$ for some constant $\delta > 0$. The first formulation captures the

[16] If all immigrants have abilities below $\overline{a}$ nothing changes in the economy because they are not employable.

[17] The formal derivation can be found in the appendix.

idea that the social security system offers an outside option which is for some workers more valuable than their wage income. The second specification can be interpreted as a minimum wage negotiated by a labour union. As to some extent a union tries to reduce the wage dispersion across skill groups by increasing the wage of the lower skill groups (cf. Booth, 1995, pp. 179). We use these simplifying assumptions because we are not interested in modelling the union's decision but in the educational decision of natives.[18] Both specifications represent extremal cases. The first case leads to a constant unemployment rate because $\overline{a}$ is independent of any wage measure, while the second case implies an unemployment threshold $\overline{a}$ proportional to the relative wage ω. However, analysing both cases allows us to draw inferences about any intermediate case.

Starting with formulation i) the third term in (2.17) vanishes because $\frac{d\overline{a}}{dw_L} = 0$ holds and we arrive at the following proposition:

Proposition 2.3. *Under assumption 2.1 and a binding minimum wage given by $\overline{w} = \gamma w_L$ the impact of immigration on the skill premium is more likely to be compensated than under flexible wages if the educational threshold $t \in [\overline{a}, 1 - \overline{a}]$.*

Proof. Consider the difference

$$\Delta \equiv G_R(t) - G(t) = 1/\left[f(m_L)\left(1 + m_L\right)\right] - 1/\left[f(m_L^R)\left(1 + m_L^R\right)\right]$$

where we used the fact that the representative wages of high skilled workers and its derivatives are the same in both regimes. We only need to show under which circumstances $\Delta > 0$ holds. As $m_L \leq m_L^R$, the sign of Δ depends on the density f evaluated at both median positions. Unimodality and symmetry guarantee that $f(m_L) \leq f(m_L^R)$ as long as $t \in [\overline{a}, 1 - \overline{a}]$. □

The claim of proposition 2.3 is that the chance of compensation increases with the existence of a minimum wage. This confirms the intuition of wage rigidity, which concludes that the change of wage inequality is dampened compared to flexible wages.

[18] Fuest and Thum (2001) model the decision problem of the union but neither the educational decision nor unemployment has been explicitly described.

However, the basic mechanism of compensation and magnification which we sketched within a flexible wage framework still exists. Figure 2.5 illustrates the difference between the flexible and the rigid wage regime. Obviously the intersection of $G(t)$ with the t axis moves to the left, leaving a larger interval for magnification. However, the possibility of magnification is still present. Considering case ii) means that the third term in (2.17) is positive which leaves the results derived in proposition 2.3 unaltered.

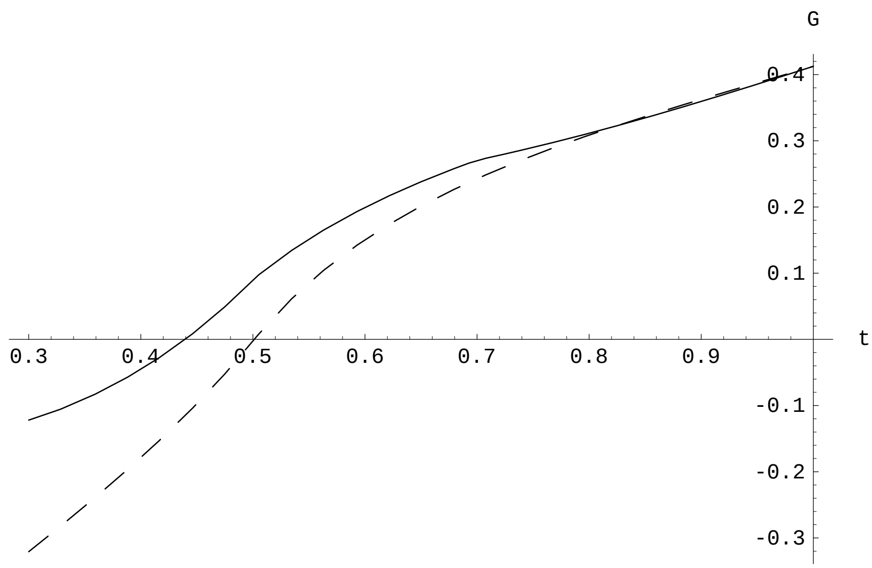

Figure 2.5: The function $G(t)$ assuming a triangle distribution and $b = 1.4$. The dashed line depicts the flexible wage case and the solid line depicts the minimum wage case assuming a fixed unemployment threshold $\overline{a} = 0.3$.

Thus, the main result of our analysis of immigration within the framework of rigid wages is that the mechanism of compensation and magnification is robust. This result differs to the conventional wisdom: under rigid wages we can not exclude the possibility of magnification of the direct wage effect. More precisely, there is only a higher chance of compensation to arise. Labour market rigidities are likely to generate higher unemployment rates and as our analysis indicates *either* increasing or decreasing skill premia. But the differences in the development of the unemployment rate and the skill premium between the US and Continental Europe (the often cited two sides of the same coin) do not seem to be as clear cut as the literature may suggest.[19] Depending on the structural

[19]See Nickell et al. (2005) for empirical support of doubts on this conventional wisdom.

parameters of the economy low skilled immigration can lead to a strong increase of the skill premium with flexible and rigid wages alike.

2.4 Conclusions

We argued that immigration generates two effects: a direct wage effect but also a compositional effect which influences the decision of heterogeneous agents to invest in education. Taking this compositional effect into account, we can show that under reasonable conditions the direct wage effect is either magnified or compensated depending on the initial relative labour employed in production. The magnification results from the revised human capital investment decision of the native population. A higher fraction of natives invests in education making the group of high skilled more heterogeneous and at the same time the group of low skilled more homogeneous.

Within this model, the existing relative labour supply of a country is the decisive determinant for magnification or compensation of the skill premium. Furthermore the results of the model are robust to changing labour market institutions. These two findings are partially in contrast to the existing literature. We can show that the magnification effect on the skill premium in the flexible wage case which corresponds to the increasing skill premia in the US or the UK. But we can not exclude the possibility of magnification of the skill premium in the case of rigid wages considering immigration of low skilled workers. Labour market rigidities may therefore lead to increasing skill premia.

Furthermore there is an influence through the length of education λ because it influences t. Countries with a higher λ (Germany could serve as an example) are prone to compensation and countries with a lower λ are prone to magnification.

The analysis also provides a possible explanation of the mixed results of empirical studies on the labour market impact of immigration. Several empirical studies come to the conclusion that immigration has none or only a relatively small negative impact on the wages of native workers[20], whereas others studies suggest a stronger effect of immigration.[21] These puzzling results may come from the revised educational decision of

[20] See Card (2001) among others for the US as an example for flexible wages and Pischke and Velling (1997) for Germany as an example of unionised wages.

[21] Borjas (2003) finds that immigration has an significant negative impact on the wage earnings of the natives: a ten percent increase in immigration reduces the native wage by three to four percent.

natives which depend on immigration of low skilled workers and the structural parameters of the economy. Borjas (1994) presents evidence that there was a stronger attainment of higher education of US natives in the respective period. We see two possibilities for future research. First, there could be a possible empirical analysis of the influence of immigration on educational attainment. This channel could serve as a further explanation of the differing results between the analysis of local and national labour markets (compared to the proposed explanation of internal migration decisions of Borjas (2005)). Second, it might be important to introduce intergenerational effects. Card (2005), for example, describes the assimilation success of the children of immigrants through education. These children have higher education as the comparable native children.

2.A Appendix

2.A.1 Comparative statics of ω^* under minimum wages

Next, we derive the comparative statics of the labour market for binding and nonbinding minimum wage legislation. Labour market equilibrium $(\omega^*, (H/L)^*)$ with immigration is given by:

$$\left(\frac{H}{L}\right)^*_{LD} = g(\omega^*) \tag{2.A.1}$$

$$\left(\frac{H}{L}\right)^*_{LS} = \frac{H_I + (1-\lambda)\int_{t(\omega^*)}^{1}(1+ba)f(a)da}{L_I + \int_{\overline{a}(w_L^*;\overline{w})}^{t(\omega^*)}(1+a)f(a)da} \tag{2.A.2}$$

$$\overline{a}(w_L^*;\overline{w}) = \begin{cases} \frac{\overline{w}-w_L^*}{w_L^*} & \text{if } \overline{w} > w_L^* \\ 0 & \text{otherwise} \end{cases} \tag{2.A.3}$$

$$w_L^* = f((H/L)^*) - f'((H/L)^*)(H/L)^* \tag{2.A.4}$$

in which the first and second equation constitute the labour supply and demand which are equal in equilibrium $(H/L)_{LD} = (H/L)_{LS}$. The third and the fourth equation give the lowest employable ability at the given minimum wage $\overline{w}$ and the resulting low skilled wage per efficiency units at the equilibrium ratio of high to low skilled labour. Since we are interested in the equilibrium change of the skill premium and of the relative physical labour supply through immigration, we take the total differential of labour demand and supply:

$$d\left(\frac{H}{L}\right)^*_{LD} = g'(\omega^*)d\omega^* \tag{2.A.5}$$

$$\begin{aligned} d\left(\frac{H}{L}\right)^*_{LS} = & \frac{\partial\,(H/L)_{LS}}{\partial\omega}d\omega^* + \frac{\partial\,(H/L)_{LS}}{\partial\overline{a}}\frac{d\overline{a}}{dw_L}dw_L^* \\ & + \frac{\partial\,(H/L)_{LS}}{\partial H_I}dH_I + \frac{\partial(H/L)_{LS}}{\partial L_I}dL_I \end{aligned} \tag{2.A.6}$$

$$dw_L^* = -f''((H/L)^*)(H/L)^* d\left(\frac{H}{L}\right)^* \tag{2.A.7}$$

Since the equilibrium requires equality of the labour supply and demand, the comparative statics of the equilibrium requires: $d(H/L)^* = d(H/L)_{LS} = d(H/L)_{LD}$. The term dw_L^* in (2.A.6) can be substituted with (2.A.7). After substitution of $d(H/L)^*$ with the demand relation (2.A.5) we arrive at:

$$\left(1 - \frac{\partial\,(H/L)_{LS}}{\partial \overline{a}} \frac{d\overline{a}}{dw_L} \left|f''((H/L)^*)\right| (H/L)^*\right) g'(\omega^*) d\omega^* = \frac{\partial\,(H/L)_{LS}}{\partial \omega} d\omega^* + \frac{\partial\,(H/L)_{LS}}{\partial H_I} dH_I + \frac{\partial (H/L)_{LS}}{\partial L_I} dL_I \quad (2.A.8)$$

We use the results from the text for the partial effects of immigration of low and high skilled labour to solve for $d\omega^*$:

$$d\omega^* = \frac{\frac{1}{L_I + \int_{\overline{a}(w_L^*;\overline{w})}^{t(\omega^*)} (1+a) f(a) da} \left(dH_I - \left(\frac{H}{L}\right)^* dL_I\right)}{\left(1 - \frac{\partial (H/L)_{LS}}{\partial \overline{a}} \frac{d\overline{a}}{dw_L} \left|f''((H/L)^*)\right| (H/L)^*\right) g'(\omega^*) - \frac{\partial (H/L)_{LS}}{\partial \omega}} \lesseqqgtr 0 \quad \text{if } \frac{dH_I}{dL_I} \gtreqqless \left(\frac{H}{L}\right)^* \quad (2.A.9)$$

The relative wage change coincides with the flexible wage case derived in the text by setting $\partial\,(H/L)_S\,/\partial \overline{a}$ equal to zero. All results from the flexible wage regime apply because there is no principal difference between the minimum wage regime and the flexible wage regime. The main difference is that with binding minimum wage for the group of low skilled workers, there exists no competitive relative labour supply. But there exists a supply relation which already incorporates demand effects.

2.A.2 Proof of Proposition 2.1

First, we proof that the limit of the function $G(t)$ at the lower (upper) bound is always negative (positive): $\lim_{t\to 0} G(t) < 0, \lim_{t\to 1} G(t) > 0$. Then we show that $G(t)$ has at most one root. Taking the limit of $G(t)$ at the lower and upper bound of the ability interval gives the following expressions:

$$\lim_{t\to 0} G(t) = \frac{1}{2}\left(\frac{f(0)}{f(a_H(0))} \frac{b}{1+ba_H(0)} - \frac{f(0)}{f(a_L(0))} \frac{1}{1+a_L(0)}\right) = \frac{1}{2}\left(\frac{c}{f(1/2)} \frac{b}{1+b/2} - 1\right) \quad (2.A.10)$$

$$\lim_{t\to 1} G(t) = \frac{1}{2}\left(\frac{f(1)}{f(a_H(1))} \frac{b}{1+ba_H(1)} - \frac{f(1)}{f(a_L(1))} \frac{1}{1+a_L(1)}\right) = \frac{1}{2}\left(\frac{b}{1+b} - \frac{c}{f(1/2)} \frac{2}{3}\right) \quad (2.A.11)$$

Because of $f(1/2) > 1$, the term $c/f(1/2) \in [0, c)$ and therefore $c < 1/2$ is a necessary and sufficient condition for $\lim_{t\to 0} G(t) < 0$ and $\lim_{t\to 1} G(t) > 0$ to hold independent of the value of b. Note that a $b \ll \infty$ also allows for $c > 1/2$. To get the unambiguous result, that only magnification occurs with relative labour sufficiently high (t small), we need to rule out more than one root. We define the root of $G(t)$ as the value t^* leading to: $G(t^*) = 0$. Simplifying the function of $G(t)$ leads to:

$$\widetilde{G}(t) = \frac{f(a_L(t))}{f(a_H(t))} - \frac{1 + ba_H(t)}{b\,(1 + a_L(t))}.$$

The sign of $G(t)$ and $\widetilde{G}(t)$ are the same, therefore it is sufficient to show that $\widetilde{G}(t)$ has at most one root because this result will also apply to $G(t)$. Taking the derivative of $\widetilde{G}(t)$ gives us:

$$\widetilde{G}'(t) = \frac{df(a_L(t))/f(a_H(t))}{dt} - \frac{d\,(1 + ba_H(t))\,/b\,(1 + a_L(t))}{dt}. \tag{2.A.12}$$

The first term in (2.A.12) is positive because we assumed single peakness and symmetry of the distribution. The second term can be further calculated as:

$$\frac{d\,(1 + ba_H(t))\,/b\,(1 + a_L(t))}{dt} = \frac{f(t)}{2\,(1 + a_L(t))\,f(a_L(t))}\left(\frac{f(a_L(t))}{f(a_H(t))} - \frac{1 + ba_H(t)}{b\,(1 + a_L(t))}\right),$$

implying that the sign of the second term in (2.A.12) is given by:

$$sgn\left(\frac{d\,(1 + ba_H(t))\,/b\,(1 + a_L(t))}{dt}\right) = sgn\left(\widetilde{G}(t)\right).$$

As a consequence we get that whenever $\widetilde{G}(t) \leq 0$ holds, we know that $\widetilde{G}'(t) > 0$ and therefore the function $\widetilde{G}(t)$ – and also $G(t)$ – can have at most one root. Together with the result of $\lim_{t\to 0} G(t) < 0$ and $\lim_{t\to 1} G(t) > 0$, we establish the result that $G(t)$ has one unique root. Furthermore we have proofed for t sufficiently low that magnification occurs ($G(t) < 0$).

2.A.3 Proof of Proposition 2.2

We calculate the limit of the first derivatives of the mean wage for the respective educational groups with the following properties of the truncated mean:

$$\lim_{t\to 0} E_L^{'}(t) = \lim_{t\to 1} E_H^{'}(t),$$

$$\lim_{t \to 1} E_L^{'}(t) = \lim_{t \to 0} E_H^{'}(t).$$

First, we derive $\lim_{t \to 0} E_L^{'}(t)$:

$$\lim_{t \to 0} E_L^{'}(t) = \lim_{t \to 0} t \frac{f(t)}{F(t)} - \lim_{t \to 0} \frac{f(t)}{F(t)^2} \int_0^t af(a)da. \tag{2.A.13}$$

Applying L'Hôpital's rule on the first term of the equation (2.A.13) gives:

$$\lim_{t \to 0} t \frac{f(t)}{F(t)} = \lim_{t \to 0} \frac{f(t) + tf^{'}(t)}{f(t)}.$$

Applying L'Hôpital's rule a second time for $c = 0$:

$$\lim_{t \to 0} t \frac{f(t)}{F(t)} = \lim_{t \to 0} \frac{f(t) + tf^{'}(t)}{f(t)} = \lim_{t \to 0} \frac{2f^{'}(t) + tf^{''}(t)}{f^{'}(t)} = 2.$$

We arrive then at the following result for the first term:

$$\lim_{t \to 0} t \frac{f(t)}{F(t)} = \begin{cases} 2 & \text{for } c = 0 \\ 1 & \text{for } c > 0 \end{cases}. \tag{2.A.14}$$

We are now looking at the second term of equation (2.A.13):

$$\lim_{t \to 0} \frac{f(t)}{F(t)^2} \int_0^t af(a)da = \lim_{t \to 0} \frac{f^{'}(t) \int_0^t af(a)da}{2F(t)f(t)} + \frac{1}{2} \lim_{t \to 0} t \frac{f(t)}{F(t)}. \tag{2.A.15}$$

The second term of equation (2.A.15) has the same limit as equation (2.A.14) but the first term is still undecidable $(c = 0)$.

Applying l'Hôpital's rule twice and with $t = 0$, $f(t) = 0$, $F(t) = 0$, we get the following expression:

$$\lim_{t\to 0} \frac{2f'(t)^2}{6f'(t)^2} = \frac{1}{3}.$$

The limit of the second term of (2.A.13) is therefore:

$$\lim_{t\to 0} \frac{f(t)}{F(t)^2} \int_0^t af(a)da = \begin{cases} \frac{4}{3} & \text{for } c = 0 \\ \frac{1}{2} & \text{for } c > 0 \end{cases}. \tag{2.A.16}$$

We can derive $\lim_{t\to 0} E_L'(t)$ from the equations (2.A.13) and (2.A.16):

$$\lim_{t\to 0} E_L'(t) = \begin{cases} \frac{2}{3} & \text{for } c = 0 \\ \frac{1}{2} & \text{for } c > 0 \end{cases}, \tag{2.A.17}$$

and with the relation $\lim_{t\to 1} E_L'(t) = \lim_{t\to 1} \frac{f(t)}{F(t)}(t - E_L)$, we get:

$$\lim_{t\to 1} E_L'(t) = \begin{cases} 0 & \text{for } c = 0 \\ \frac{c}{2} & \text{for } c > 0 \end{cases}.$$

Taking again the limit of $G(t)$ at the lower and upper bound of the ability interval gives the following expressions:

$$\lim_{t\to 0} G(t) = \left[\frac{bE_H'(0)}{1 + bE_H(0)} - \frac{E_L'(0)}{1 + E_L(0)}\right] = \left[\frac{b}{1 + b/2}\frac{c}{2} - E_L'(0)\right],$$

$$\lim_{t\to 1} G(t) = \left[\frac{bE_H'(1)}{1 + bE_H(1)} - \frac{E_L'(1)}{1 + E_L(1)}\right] = \left[\frac{b}{1 + b}E_H'(1) - \frac{c}{3}\right].$$

As we have shown in equation (2.A.17), $E'(0) = E'(1)$ have the value $2/3$ for $c = 0$ and $1/2$ for $c > 0$. Therefore, we conclude that the limit of the function $G(t)$ at the lower (upper) bound is always negative (positive): $\lim_{t\to 0} G(t) < 0, \lim_{t\to 1} G(t) > 0$ for $c \in [0, 1/2)$. Furthermore this is a necessary and sufficient condition for $\lim_{t\to 0} G(t) < 0$ and $\lim_{t\to 1} G(t) > 0$ to hold independent of the value of b.

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CHAPTER 3

Immigration Policy, Equilibrium Unemployment, and Underinvestment in Human Capital

3.1 Introduction

The impact of immigration on the labour market prospects of natives has been subject of a public and academic discussion. Most of the discussion is about the influence of actual immigration flows and how to choose immigration policy optimally. In fact, in some countries (e.g. Canada, Australia) immigration policy explicitly aims at augmenting the domestic labour supply of skilled workers by a certain quality (in terms of skills) and volume to support economic development of the host country. Moreover, in other countries like Germany, the UK and the US, the discussion is about reforming immigration policy in favour of a more selective immigration in terms of skills. Our subsequent analysis shows that such an immigration policy is indeed able to foster human capital acquisition of natives and we can also show that this kind of policy is Pareto-improving. If at the same time, domestic education is subsidised, even a Pareto-optimal investment level can be reached. Therefore, our analysis gives a theoretical underpinning for a skill selective immigration policy.

We present a search-theoretic model with endogenous human capital investment. As the human capital investment decision is taken before workers enter the labour force and because of the existence of search frictions, this class of models features underinvestment in human capital (cf. Acemoglu, 1996; Moen, 1998; Sato and Sugiura, 2003). Our model extends this literature by including immigration in terms of the total flows (amount of immigrants) and its characteristics (amount of human capital). This modelling approach of the labour market contrasts sharply with the existing literature on immigration because its major focus has been mostly on stocks and its composition in a static context (Borjas, 1995, 1999). One of the few articles which analyses migration in a search-theoretic context is Ortega (2000). However, he analyses migration patterns in a two country model and the impact of migration on employment and wages in the host and origin country. We differ from his paper in the consideration of the impact of immigration on human capital investments and its impact on wages and employment in the host country. The solely consideration of the host country gives us the opportunity to compare our results with the results from previous studies on immigration, human capital and labour market frictions (cf. Fuest and Thum, 2001; Schmidt et al., 1994)

Our modelling approach accounts for the fact that immigrants return to their home country with a positive probability.[1] Introducing this positive probability of returning home leads to a higher job destruction rate (shorter employment spells) for immigrants than for natives. As a partial result, our model can explain two stylised facts of economies with immigration: first, immigrants with the same human capital endowment earn lower wages than natives. Second, the unemployment rate of immigrants is higher than the unemployment rate of natives. Immigrants are therefore discriminated ex-post against natives because of their higher probability to leave the match.[2] This has to be distinguished from ex-ante discrimination because in our model firms do not offer vacancies which are specific to immigrants or natives.

Our main result is that an immigration policy aiming at well educated immigrants increases the number of vacancies which in turn increases the wage paid by firms. Therefore high skilled immigration leads to rising educational attainment of natives. This is in contrast to the exisiting literature of immigration and human capital which shows that low skilled immigration may rise educational attainment of natives (cf. Fuest and Thum, 2001). Therefore, our result supports a rather skill selective immigration policy (e.g. Australia and Canada) which is opposite to the actual immigration policies of most Europeen countries. Furthermore, relying on appropriate education subsidies, the distortion generating underinvestment in human capital can be removed such that a Pareto-optimal investment level is reached. As an additional result, we demonstrate that either the appropriate number of immigrants (the flows) or the appropriate educational attainment (its characteristics in terms of human capital stocks) of immigrants can have the same effect as unemployment benefits proposed by Sato and Sugiura (2003).

The remainder of the paper is structured as follows: in section 3.2 we present the basic structure of the model. In section 3.3 we derive both the solution of the individual human capital investment decision problem and the market equilibrium. In section 3.4 we analyse the efficiency of the market outcome and discuss different immigration policies which are appropriate to overcome the underinvestment. Section 3.5 presents an extension of the basic model by including a labour market of different skill groups. Section 3.6 concludes.

[1] For a detailed theoretical and empirical discussion on return migration see Dustmann (2003). Müller (2003) also introduces return migration in an efficiency-wage model.

[2] This kind of discrimination is similar to the analysis of Müller (2003) .

3.2 Basic model

3.2.1 *Households*

We develop an equilibrium matching model of the Diamond-Mortensen-Pissarides type (cf. Pissarides, 2000) . The economy is populated by a mass one of identical risk-neutral native workers $N = 1$ and foreign workers (immigrants) $I \geq 0$ adding to a total population $L = 1 + I$.[3] All individuals and firms discount future payments at the common discount rate ρ. Native workers enter and exit the labour market at a constant rate $\delta_N > 0$ such that the number of native workers is constant over time.[4] The number of *potential* immigrants is normalised to one which simplifies the exposition of the model. Immigrants enter a country's labour market at rate $\mu > 0$ and leave the labour market due to retirement ($\delta_N > 0$) or migration back to the home country ($r > 0$). The total exit rate of immigrants adds to: $\delta_I = \delta_N + r$.[5] The net flow of immigrants can therefore be calculated as $\dot{I} = \mu - \delta_I I$. The steady state number of immigrants ($\dot{I} = 0$) in the host country is $I = \mu/\delta_I$. To simplify the exposition of the model we denote the immigrants share in total population by $\eta_L = I/(1 + I) = \mu/(\delta_I + \mu)$.

Both native and immigrant workers start their working life in the unemployment pool. Before entering the unemployment pool, native workers have to decide about their human capital investment $z_N > 0$. Once taken the educational decision is irreversible. The cost per unit of human capital z_N amounts to c and the total cost of education cz_N will be borne by workers.

Immigrants entering the labour market are assumed to be endowed with human capital z_I which they already acquired in their home country. We assume that there exists no principal difference between the quality of human capital of natives and immigrants.[6] The acquired human capital can be used by any firm meaning that firms make no differences between an immigrant and a native worker.[7] The difference of endowments of

[3]Throughout the paper subscript N denotes natives and subscript I denotes immigrants.

[4]The rate δ_N is the birth and retirement rate in the economy.

[5]In our model the return rate r is assumed to be exogenous. Typically, the decision to return to the home country is taken by the immigrant. However, in most industrialised countries we observe a large return migration which justifies our assumption of $r > 0$.

[6]At least at the beginning, the human capital quality of immigrants will differ from the human capital of natives (e.g. by language proficiency) but including this assimilation process would only strengthen the results of the model.

[7]See Bowlus and Eckstein (2002) or Black (1995) for discrimination in search models.

human capital between natives and immigrants will only be reflected in the wages paid by firms.

Natives and immigrants can be in two different states: they are either working or searching for a job. Hence we abstract from on-the-job search.

3.2.2 Matching

We denote the number of unemployed workers by u and the number of vacancies searching for a worker by v. The ratio $\theta = v/u$ is then called labour market tightness. The random process by which vacancies and unemployed workers find each other is represented by a matching function: $m(u, v) > 0$ with $u, v > 0$. The matching function denotes the number of matched vacancies and workers per unit of time.[8] The application arrival rate for vacant jobs $q(\theta)$ can then be written as: $q(\theta) = m(u, v)/v = m(1/\theta, 1)$ with $q'(\theta) < 0$ and $\lim_{\theta\to 0} q(\theta) = \infty$, $\lim_{\theta\to\infty} q(\theta) = 0$. An unemployed worker meets a vacant job at the rate $p(\theta) = m(u, v)/u = \theta q(\theta)$ with $p'(\theta) > 0$ and $\lim_{\theta\to 0} p(\theta) = 0$, $\lim_{\theta\to\infty} p(\theta) = \infty$. Native workers and immigrants meet a vacant job at the same rate. Note that potential firms cannot directly search either a native worker or an immigrant worker. Whether it is a native worker or an immigrant will be revealed when a firm and a worker meet.

The Beveridge curve

The flow equation of umployment $\dot{u}$ which characterises the labour market is the difference between the inflows into unemployment and the outflows from unemployment. With both natives and immigrants being in the pool of unemployed workers we have two different flow equations for each group: $\dot{u}_N$, $\dot{u}_I$. Inflows into unemployment occur if a job is closed or new workers enter the labour market. Any filled job can be destroyed due to two different reasons: either the job is hit by an exogenous negative productivity

[8] The matching function $m(u, v)$ is assumed to be twice continuously differentiable, homogeneous of degree one and exhibits the following properties: $m(0, v) = m(u, 0) = 0$, $\partial m/\partial u$, $\partial m/\partial v > 0$, $\partial^2 m/\partial u^2, \partial^2 m/\partial v^2 < 0$ and $\partial m/\partial u$, $\partial m/\partial v > 0$.

shock at rate s or the job is closed because the employee leaves the labour market completely which occurs at rate δ_i, $i = I, N$. Note that only the former increases the number of unemployed. The respective dynamics of unemployment are given by:

$$\dot{u}_N = \delta_N + s(1 - u_N) - p(\theta)u_N - \delta_N u_N, \tag{3.1}$$

$$\dot{u}_I = \mu + s(I - u_I) - p(\theta)u_I - \delta_I u_I. \tag{3.2}$$

In the steady state, $\dot{u}_i = 0 \; i = I, N$, we obtain the following *number* of unemployed native[9] and immigrant workers:

$$u_N = \frac{\delta_N + s}{s + p(\theta) + \delta_N}, \quad u_I = \frac{\mu}{\delta_I}\frac{\delta_I + s}{s + p(\theta) + \delta_I} \tag{3.3}$$

with $u_N \in [0, 1]$ and $u_I \in [0, \mu/\delta_I]$. The aggregated Beveridge curve of the economy is then given by the sum of unemployed natives and immigrants:

$$u = \frac{\delta_N + s}{s + p(\theta) + \delta_N} + \frac{\mu}{\delta_I}\frac{\delta_I + s}{s + p(\theta) + \delta_I}. \tag{3.4}$$

Comparing the unemployment *rates* of natives and immigrants we arrive at the following result:

Corollary 3.1. *The unemployment rate of immigrants is always higher than the unemployment rate of natives:* $u_N < u_I/I$.

Proof. Using equation (3.3) together with the definition of the unemployment rate it follows that $u_N < u_I/I$. □

Consequently, the immigrants' share in unemployment is always greater than the immigrants share in total population: $\eta_U(\theta) = u_I/(u_I + u_N) > I/(1 + I) = \eta_L(\theta)$. Therefore our model features a well documented fact of labour markets in most industrialised countries (cf. Hatton and Williamson, 2005, pp.325 table 15.3).[10]

[9] Because the number of natives is standardised to one, the number of unemployed natives is also the unemployment rate of natives.

[10] Interestingly, most of the empirical literature concentrates on the explanation of wage differentials between natives and immigrants. There are very few papers analysing immigrants incidence of unemployment (cf. McDonald and Worswick (1997) for Canada, Arai and Vilhelmsson (2004) for Sweden).

Match formation and wage setting

Let $U_i,\ W_i$, $i = I, N$, be the expected present value of unemployment and employment, respectively. Then the flow value (asset value) of unemployment is given by:

$$\rho U_i = b + p(\theta)(W_i - U_i) - \delta_i U_i, \quad i = I, N. \tag{3.5}$$

An unemployed worker receives the instantaneous value of leisure b, and will meet a vacant job at rate $p(\theta)$, thereby swapping the value of unemployment U_i with the value of employment W_i. At the rate δ_i an unemployed worker is expected to leave the labour market and therefore loses the value of unemployment U_i.[11] By the same argument the flow value of an employed worker can be written as:

$$\rho W_i = w_i + s(U_i - W_i) - \delta_i W_i, \quad i = I, N. \tag{3.6}$$

While being employed a worker receives instantaneously the wage w_i. The job is expected to be closed at rate s and the worker enters the unemployment pool. Additionally, a job is randomly closed according to the retirement rate δ_i, $i = I, N$.

Now, we look at the expected present value of firms, which are either producing or searching for a worker. A firm searching for an applicant incurs search cost $k > 0$ at each instant of time. Note that a job can either be filled with a native worker or an immigrant worker. As mentioned before, apart from the differing retirement rates, the only potential difference between both types of workers is the endowment with human capital z_i, $i = I, N$.

The output of a job-worker pair is generated according to a general production function $f : \mathbb{R}^+ \rightarrow \mathbb{R}^+$ with human capital z being the only input of production. The production function has the following properties: $f'(z) > 0$, $f''(z) < 0$, $\lim_{z\rightarrow 0} f'(z) = \infty$ and $\lim_{z\rightarrow\infty} f'(z) = 0$. Furthermore, we assume that for any $z \geq 0$ the value of output is strictly greater than the value of leisure b: $f(z) > b$.[12]

[11] For simplicity we assume that the value of returning to the home country is zero for immigrants . In any case, the value of returning home should be smaller than the value of unemployment.

[12] Without this requirement a situation can arise where no individual chooses to educate and work.

Let V, J_i, $i = I, N$ be the expected present value of a vacant job and a filled job, respectively. The flow value of a producing firm with worker $i = I, N$ is given by:

$$\rho J_i = f(z_i) - w_i + (s + \delta_i)(V - J_i) \quad i = I, N.$$

The flow value consists of the flow profits of a match $f(z_i) - w_i$ and the potential loss caused by either the destruction of the job (with rate s) or the retirement of the respective worker (with rate δ_i).

For the derivation of the flow value of a vacancy ρV it is important to bear in mind, that ex-ante a firm does not know whether it will produce with a native worker or an immigrant worker. The share of unemployed immigrants of the pool of unemployed workers $\eta_U(\theta)$ also reflects the conditional probability of meeting an immigrant job searcher. The effective rate of meeting an unemployed immigrant is $q(\theta)\eta_U(\theta)$ while the effective rate of meeting an unemployed natives is given by: $q(\theta)\,(1 - \eta_U(\theta))$. We assume that the effective rate for any group is negatively correlated with labour market tightness θ such that $dq(\theta)(1 - \eta_U(\theta))/d\theta < 0$ and $dq(\theta)\eta_U(\theta)/d\theta < 0$ holds.[13] Any firm offering a vacant job considers the expected present value of a filled job $J^e = \eta_U J_I + (1 - \eta_U)J_N$.[14] The flow value of a vacant job can then be written as:

$$\rho V = -k + q(\theta)(J^e - V).$$

and consists of the flow costs of searching k and the potential change from a vacant to a productive job $(J^e - V)$. Free entry of firms generates an asset value of a vacancy of zero: $V_i = 0$. Thus we can calculate the job creation condition of firms as:

$$J^e = \frac{k}{q(\theta)}. \tag{3.7}$$

Free entry leads to an expected present value of a filled job J^e which is equal to the expected costs of finding a worker. We also get the following expression for a filled job of type i:

$$J_i = \frac{f(z_i) - w_i}{\rho + \delta_i + s}, \quad i = I, N. \tag{3.8}$$

[13]This assumption ensures that the composition effect in the pool of unemployed cannot dominate the effect of an increased labour market tightness. Otherwise, an increase in labour market tightness might decrease the effective rate of meeting an unemployed immigrant while at the same time increasing the effective rate of meeting an unemployed native.

[14]For notational convenience we drop the functional argument θ in $\eta_U(\theta)$ when this causes no confusion.

We assume that wages are negotiated between a matched worker-firm pair according to Nash-bargaining. This means that the wage for worker type i solves the following optimisation problem:

$$w_i = \arg\max \left(W_i(w_i) - U_i\right)^{\beta} \left(J(w_i) - V\right)^{1-\beta}, \quad i = I, N \tag{3.9}$$

where β is interpreted as the bargaining power of workers.[15] The wage setting function for each type of worker is given by:[16]

$$w_i = \beta f(z_i) + (1-\beta)\frac{b(\rho + \delta_i + s) + p(\theta)\beta f(z_i)}{\rho + \delta_i + s + p(\theta)\beta}, \quad i = I, N. \tag{3.10}$$

Comparing both the wage of natives and immigrants yields the following result:

Corollary 3.2. *Immigrant workers with human capital* $z_I \leq z_N$ *always earn a lower wage* $w_I < w_N$ *compared to a native worker.*

Proof. Taking the total differential of the native wage equation we get:

$$dw_N = -\frac{(1-\beta)\beta p(\theta)\left(f(z_N) - b\right)}{\left(\rho + \delta_N + s + p(\theta)\beta\right)^2} d\delta_N + \frac{(1-\beta)\beta p(\theta) f'(z_N)}{\rho + \delta_N + s + p(\theta)\beta} dz_N < 0$$

Evaluating the total differential at $d\delta_N = r$ and $dz_N \leq 0$ completes the proof. □

This result stems from the fact that immigrants have a higher risk of leaving the host countries' labour market. A higher risk of closing a productive job translates into a lower average job duration which reduces the potential surplus of the job. Therefore the wage rate, a share of the total surplus, has to be smaller to compensate for this lower duration.[17]

[15] By using this formulation we assume that there is no difference in the bargaining power of natives and immigrants. Presumably the bargaining power of immigrants is lower compared to natives at the beginning of their working life in the host country and the same in the long run. However, taking this into account would not alter the results of the model qualitatively.

[16] The derivation of (3.10) can be found in the appendix.

[17] There is a huge empirical literature analysing the evident wage differential between natives and immigrants: cf. Borjas (1999).

For future reference it will be convenient to derive closed form solutions for U_i and J_i, $i = N, I$. Together with the wage setting function we derive the expected present value of unemployment in terms of human capital z_i and labour market tightness θ:

$$U_i = \frac{b(\rho + \delta_i + s) + p(\theta)\beta f(z_i)}{(\rho + \delta_i)\,(\rho + \delta_i + s + p(\theta)\beta)} \quad i = I, N. \tag{3.11}$$

U_i is a weighted average of the value of unemployment b and the share β of the output $f(z_i)$. Note that z_N is endogenous and will be chosen by natives. Using the expression for the wage rate w_i together with the definition of the expected value of a filled job (3.8) of type i yields:

$$J_i = \frac{(1-\beta)(f(z_i) - b)}{\rho + \delta_i + s + \beta p(\theta)} \quad i = I, N. \tag{3.12}$$

This expression can then be used in the free entry condition (3.7) to yield the firms' job creation curve (JCC):

$$\eta_U \frac{q(\theta)(1-\beta)(f(z_I) - b)}{\rho + \delta_I + s + \beta p(\theta)} + (1 - \eta_U)\,\frac{q(\theta)(1-\beta)(f(z_N) - b)}{\rho + \delta_N + s + \beta p(\theta)} = k. \tag{3.13}$$

This job creation curve is equivalent to the standard formulation in search models except that we have two different types of filled jobs.

3.3 Educational decisions and equilibrium

3.3.1 Educational decision

Before entering the labour market natives must decide how much to invest into education. After the investment decision is made, each new entrant will start as an unemployed worker searching for a job. As the expected present value of unemployment U_N already incorporates any future periods of employment and unemployment, it is the expected total lifetime income of a native worker. Consequently, an individual entering the labour market will seek to maximise U_N by choosing the level of human capital z_N appropriately. Therefore native workers' optimisation problem is to maximise the net expected value of unemployment:

$$\max_{z_N} U_N - c z_N.$$

Using the closed form of U_N the first order condition for a native worker is given by:

$$\frac{\beta p(\theta)}{(\rho+\delta_N)\,(\rho+\delta_N+s+\beta p(\theta))} f'(z_N) = c. \tag{3.14}$$

Any native workers chooses investment level z_N as to equalise the marginal return and the marginal cost c. For future reference we will refer to (3.14) as investment decision condition (IDC). Note that both, a higher retirement rate δ_N and higher destruction rate s decrease the level of human capital investment because the time period to recoup the investment will be shorter. Additionally and with the same line of reasoning, increased labour market tightness θ increases the investment level, because unemployment spells are shorter. It is important to note that immigration does not directly influence the individual investment decision. However, immigration influences the equilibrium outcome of the economy in terms of θ and z_N.

3.3.2 *Competitive equilibrium*

A competitive equilibrium consists of a triple $\{z_N^E, \theta^E, u^E\}$ which simultaneously solves the job creation condition (JCC) of firms,

$$G_1^E(z_N,\theta) := q(\theta)\left[\eta_U(\theta) J_I(\theta) + (1-\eta_U(\theta))\, J_N(\theta, z_N)\right] = k, \tag{3.15}$$

the investment decision (IDC) of native workers:

$$G_2^E(z_N,\theta) := \frac{\beta p(\theta)}{(\rho+\delta_N)\,(\rho+\delta_N+s+\beta p(\theta))} f'(z_N) = c, \tag{3.16}$$

and the Beveridge curve:

$$u = \frac{\delta_N + s}{s + p(\theta) + \delta_N} + \frac{\mu}{\delta_I}\frac{\delta_I + s}{s + p(\theta) + \delta_I}. \tag{3.17}$$

Note that the system is block recursive so that equilibrium values of the labour market tightness θ^E and the human capital z_N^E are completely identified by (3.13) and (3.14). Using the resulting θ^E in (3.4) yields the equilibrium number of unemployed workers u^E. As shown in the appendix, both, the JCC and the IDC are positively sloped curves in the (z_N, θ)- space. The IDC starts at the origin and z_N is bounded from above by $\bar{z}$ according to $\{\bar{z}_N : f'(\bar{z}) = (\rho+\delta_N)\, c\}$. In contrast, the JCC starts at a positive θ with no upper bound for z_N and θ. It can be shown, that both curves intersect at least once such that at least one equilibrium exists.[18] Our model exhibits the possibility of multiple equilibria. For reasons to become clear later, we restrict our analysis to stable equilibria only. To define a stable equilibrium we construct simple out-of-steady-state dynamics. Consider a triple $\{z_N^1, \theta^1, u^1\}$ in a sufficiently small neighbourhood of an equilibrium triple $\{z_N^E, \theta^E, u^E\}$. Assuming that labour market tightness θ will respond fastest to eliminate positive profits from open vacancies, we get a new θ according to $\theta^2 = \theta_{G_1^E=k}(z_N^1)$. This new θ^2 will induce workers to revise their investment decision to $z_N^2 = \theta_{G_2^E=c}(\theta^2)$. The sketched dynamics creates a series $\{z_{iN}, \theta_i, u_i\}_{i=1,...}$ which is stable if it converges to $\{z_N^E, \theta^E, u^E\}$. With this kind of out-of-steady-state dynamics it is obvious that any triple in the vicinity of an unstable equilibrium will lead to an ever increasing or decreasing number of unemployed. We restrict our analysis to stable equilibria, because this kind of trend in the number of unemployed is contrary to facts.

With the characterisation of a stable equilibrium we can show that a stable equilibrium is reached if at the intersection of both equilibrium conditions the slope of the IDC is steeper than the slope of the JCC: $\frac{d\theta}{dz_N} |_{G_1^E=k} < \frac{d\theta}{dz_N} |_{G_2^E=c}$.[19]

Figure 3.1 on the next page illustrates the JCC and the IDC in the (z_N, θ)- space in a situation with a stable equilibrium.

3.3.3 *Comparative statics results*

In this section we analyse the impact of immigration on the labour market equilibrium. We discuss two different scenarios: first time immigration into a formerly closed economy without any immigration ($\mu = 0$), and the case of sustained immigration into an economy with existing immigration ($\mu > 0$, $z_I > 0$). Throughout the following sections we assume that we are in a stable equilibrium. Note that immigration only affects the JCC, while the IDC is unaffected: $G_{2,\mu}^E = G_{2,z_I}^E = 0$.[20] Therefore, we can concentrate on the influence of immigration on the JCC only.

[18] For a detailed proof, please consult the appendix.

[19] For the derivation of the slope of the JCC and IDC, please consult the appendix.

[20] To simplify the exposition of our results we use the following notation to denote partial derivatives: $G_{2,k} \equiv \frac{\partial G_2^E}{\partial k}$.

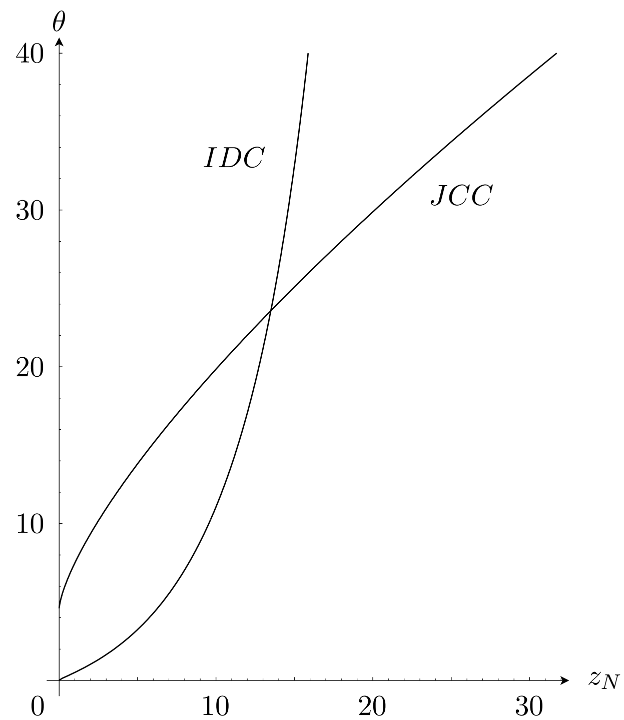

Figure 3.1: The IDC and the JCC determining a stable equilibrium.

In the case of first time migration, the calculation of the partial effect of z_I on the JCC reveals that $G^E_{1,z_I}\big|_{\mu=0} = 0$. However, the influence of the migration rate μ on the JCC is nonzero such that we derive the following results:

$$G^E_{1,\mu}\big|_{\mu=0} = \eta_{U,\mu}\big|_{\mu=0}\, q(\theta)(J_I - J_N) \begin{cases} > 0 & \text{if} \quad (J_I - J_N) > 0 \\ < 0 & \text{if} \quad (J_I - J_N) < 0 \end{cases} \tag{3.18}$$

because $\eta_{U,\mu}|_{\mu=0} > 0$. Together with $G^E_{1,z_N}\big|_{\mu=0} > 0$ and $G^E_{1,\theta}\Big|_{\mu=0} < 0$ we find that first time immigration leads to a clockwise rotation of the JCC at its intersection with the curve $J_I(\theta) = J_N(\theta, z_N)$ (cf. figure 3.1).[21] With first time immigration, the human capital endowment of potential migration (or the minimum requirement in terms of human capital for immigration) only matters for the comparative statics. First time immigration will increase (decrease) the labour market tightness θ^E and native human capital z_N^E if the expected present value of migrant jobs J_I are more (less) valuable than comparative

[21]The curve implicitly defined by $J_I(\theta; z_I) = J_N(\theta, z_N)$ is positively sloped in the (z_N, θ)-space originating from $\tilde{z}_N$ which is the solution to $J_I(0, z_I) = J_N(0, \tilde{z}_N)$. For $\theta \to \infty$ we get $z_N \to z_I$.

native jobs J_N. Due to a higher exit rate δ_I potential immigrants need more human capital than natives to offset this negative effect. Thus, even if potential immigrants are better educated than native workers $z_I > z_N$ the job value of natives can be higher $J_I < J_N$ and both θ^E and z_N^E decrease. To increase the labour market tightness θ^E and native human capital z_N^E immigration policy has to aim at immigrants who are very well educated compared to natives. The native wage rate w_N is positively correlated with θ and z_N such that immigration policy directly influences native labour income. The same is true for native employment which will increase if $J_I > J_N$. The effect on total unemployment $u_I + u_N$ is ambiguous if immigration is high skilled $(J_I > J_N)$ because the decrease of native unemployment is counteracted by an increasing number of unemployed immigrants.

First time immigration is rather unlikely, because today most industrialised countries experience sustained immigration and try to implement a specific immigration policy given a certain history of migration $\{z_I, \mu\}$. A change of the immigration policy can be either a change in the number of immigrants by changing the inflow $d\mu$ or a change of the human capital standards dz_I. We start by assuming that the equilibrium human capital of natives z_N is high enough such that $J_I < J_N$ holds. Either changing the amount of the existing quality of immigration ($d\mu \gtrless 0$) or changing the future quality of immigration ($dz_I \gtrless 0$) leads to the following change of the equilibrium values z_N^E, θ:[22]

$$\frac{d\theta^E}{d\mu}, \frac{dz_N^E}{d\mu} < 0 \quad \frac{d\theta^E}{dz_I}, \frac{dz_N^E}{dz_I} > 0 \quad J_I < J_N. \tag{3.19}$$

Thus, we derive the same result as with first time immigration, that both increased unskilled immigration and decreasing human capital standards will reduce equilibrium labour market tightness and human capital investments. This is because the expected present value of a filled job is reduced with a lower educational attainment of immigrants or an increased number of unskilled immigrants. Therefore, offering a vacancy is less attractive for firms which reduces the number of vacancies and consequently the labour market tightness. Next, we assume that the existing immigration is sufficiently high skilled such that $J_I > J_N$ holds. In this situation, a change of the migration policy will result in the following change of the equilibrium values:

$$\frac{d\theta^E}{d\mu}, \frac{dz_N^E}{d\mu} > 0 \quad \frac{d\theta^E}{dz_I}, \frac{dz_N^E}{dz_I} > 0 \quad J_I > J_N \tag{3.20}$$

[22]For a detailed derivation, please consult the appendix.

We get the result, that an increased number and higher quality of migrants will increase the labour market tightness and the human capital acquisition of natives. For later reference we summarise our findings in:

Proposition 3.1. *In the stable equilibrium, if $J_I < J_N$ an increase in the endowment of human capital of immigrants z_I^E increases θ^E and z_N^E and an increase in the flow of immigrants μ decreases θ^E and z_N^E . If $J_I > J_N$ an increase in the endowment of human capital of immigrants z_I^E and an increased inflow of immigrants μ increases θ^E and z_N^E .*

Our result shows that in the context of search frictions, higher minimum requirement of human capital for immigrants leads to skill upgrading of native workers, because this immigration increases the firms' incentive to supply jobs for workers in the host country. This contrasts with much of the literature which mostly focuses on competitive labour markets. In these models high skilled immigration reduces the incentive to invest into education (cf. Fuest and Thum, 2001). Considering the different labour market institutions shown by search models reveals totally different immigration policy implications.

3.4 Efficiency and labour policies

3.4.1 Social planner

We assume that a social planner seeks to maximise native welfare only. The social welfare function used by the social planner is defined by:[23]

$$\Omega = \int_0^\infty e^{-\rho\tau}(y_N + bu_N - k\theta u_N - \delta_N c z_N)d\tau. \tag{3.21}$$

The first additive term is the total income of natives with y_N denoting the average output per native worker and bu_N denoting the leisure income of natives. The second term summarises total cost: the search cost of firms for native workers $k\theta u_N$ and the cost of

[23]For this formulation see Pissarides (2000).

education borne by natives entering the labour market $\delta_N c z_N$. While taking his choice of u_N and z_N the social planner has to obey the evolution of native unemployment $\dot{u}_N$:

$$\dot{u}_N = \delta_N + s(1 - u_N) - p(\theta)u_N - \delta_N u_N, \tag{3.22}$$

as well as the evolution of average output $\dot{y}_N$:

$$\dot{y}_N = p(\theta)u_N f(z_N) - (s + \delta_N)y_N. \tag{3.23}$$

The first term represents the new jobs which are producing with a native worker and the second term represents the fraction of mature jobs which are destroyed at each instant of time. Maximising (3.21) subject to (3.22) and (3.23) yields the following optimality conditions:[24]

$$G_1^o(z_N, \theta) \equiv \frac{p'(\theta)\,(f(z_N) - b)}{\rho + s + \delta_N + p(\theta) - p'(\theta)\theta} = k, \tag{3.24}$$

$$G_2^o(z_N, \theta) \equiv \frac{(\delta_N + s)\,p(\theta)}{\delta_N\,(s + \delta_N + p(\theta))\,(s + \delta_N + \rho)} f'(z_N) = c. \tag{3.25}$$

The solution of the optimisation problem is given by a triple $\{\theta^o, z_N^o, u_N^o\}$ solving the optimality conditions and the steady state condition for native unemployment, where the superscript o denotes the social optimum. Both optimality conditions are comparable to that of the market outcome. Equation (3.25) corresponds to the IDC and equation (3.24) corresponds to the JCC. Because the social planner is only interested in the welfare of natives these conditions do not reflect the fact that immigrants are active in the economy.

Comparison of the IDC of the market outcome (3.14) with the choice of the social planner (3.25) reveals, that the amount of individual human capital investment z_N in the competitive environment is biased downwards and generates underinvestment:

Lemma 3.1. *The IDC of native workers in the competitive environment generates underinvestment:* $z_N(\theta)|_{G_2^E=c} < z_N(\theta)|_{G_2^o=c}$.

Proof. Please consult the appendix. □

[24] For a detailed derivation of the solution of the optimisation problem, please consult the appendix.

In (z_N, θ)-space, the IDC of the social planner is shifted to the right compared to the IDC of the competitive situation. In our model underinvestment is due to the timing of the investment decision: bargaining after the decision of education leads to hold-ups of native workers. Analysing the loci defined by (3.13) and (3.24) shows, that the bargaining power of workers β is crucial in determining whether the labour market tightness is higher or lower in the competitive environment compared to the choice of a social planner. In equilibrium matching models with free a entry condition, a certain bargaining power β^o will generate an efficient labour market tightness $\theta^E \mid_{z=z^o} = \theta^o \mid_{z=z^o}$ (cf. Hosios, 1990). Any other value of β will result in an inefficient labour market tightness. First, we analyse the efficiency of the market generated θ^E at the optimal investment level $\theta^E \mid_{z=z^o}$ if the expected present value of filled jobs is the same for both natives and immigrants: $J_N = J_I$. In this case, the efficient value β^o coincides with that of an economy without immigration: $\beta^o = \theta q'(\theta)/q(\theta)$, namely if the bargaining power is equivalent to the elasticity of the application rate with respect to the labour market tightness (cf. Pissarides, 2000). With a β larger (smaller) than the efficient value β^o we have too small (large) labour market tightness.

Second, we have to differentiate the cases of immigration resulting in different expected present values of filled jobs of immigrant and natives $J_N \neq J_I$. In this case, the existing immigration in the host country plays a significant role for the threshold value β^o. The efficient value does not only depend now on the elasticity of the application rate $q(\theta)$, but also on the human capital endowment of natives z_N and immigrants z_I. In fact, the educational attainment of immigrants in the host country compared to the natives $(J^e \gtreqless J_N)$ is decisive for the efficient bargaining power β^o. We can not explicitly solve for the new efficient value β_I^o. However, β_I^o is smaller (larger) than β^o if immigration is relatively low skilled (high skilled). Therefore, an economy with mainly low skilled (high skilled) immigrants is characterised by a smaller (larger) efficient bargaining power than in an economy without immigrants. Most importantly, with β larger (smaller) than the efficient value β_I^o we have too small (large) labour market tightness.

Lemma 3.2. *In the case of $J_N \neq J_I$: If the bargaining power of workers β is large enough: $\beta > \beta_I^o$ (small enough: $\beta < \beta_I^o$), the JCC in the competitive environment generates too small market tightness: $\theta(z_N)|_{G_1^E=k} < \theta(z_N)|_{G_1^o=k}$ (too large market tightness: $\theta^E \mid_{z=z^o} > \theta^o$). If $\beta = \beta_I^o$, it generates the optimal market tightness $\theta^E \mid_{z=z^o} = \theta^o$. For the case of $J_N = J_I$, the efficient labour market tightness is given by $\beta^o = \beta_I^o = \theta q'(\theta)/q(\theta)$.*

Proof. Please consult the appendix. □

The lemmata 3.1 and 3.2 reflect the inefficiency of the competitive equilibrium. The underinvestment in human capital always exists irrespective of the actual value of θ^E. However, the labour market tightness is either too small or too high depending on the bargaining power of workers as much as on the educational attainment of immigrants in the host country. We get therefore the same result as Acemoglu and Shimer (1999) and Sato and Sugiura (2003) with the same mechanism at work.

3.4.2 *Education subsidies*

As shown by the first proposition, directed immigration policy - regarding human capital characteristics and/or flows of immigrants - influences directly the JCC. To reach the social optimum, we need a policy tool which allows us to influence the IDC. By introducing education subsidies per invested unit h for native workers the IDC is changed according to:

$$\frac{\beta p(\theta)}{(\rho+\delta_N)(\rho+\delta_N+s+\beta p(\theta))} f'(z_N) = c - h.$$

At a given labour market tightness, the introduction of a subsidy leads to increased investment in human capital. In the (z_N, θ)-space this results in a shift to the right (cf. figure 3.1). However, increased investment in human capital makes it more profitable for a firm to open a vacancy which in turn increases the labour market tightness. The equilibrium outcome of an education subsidy is described in

Proposition 3.2. *In the stable equilibrium, an increase in a subsidy to a unit investment in human capital h increases θ^E and z_N^E and lowers the unemployment rate.*

Proof. Please consult the appendix. □

3.4.3 *Pareto-optimal immigration and labour policy*

We have shown that education subsidies affect the incentives to train and lead to more human capital investments by natives. Immigration policies - either by changing the human-capital composition of immigrants or by changing the inflow of immigrants into the host country - will have direct effect on the job creation of firms. Combining these policies, we can reach the Pareto-optimal human capital investment of natives and labour market tightness thereby removing the hold-up problem.

The starting point of our analysis are the properties of the competitive equilibrium. The investment of native workers always has to be subsidised to remove the underinvestment (see lemma 3.1). Therefore $h^* > 0$ should be the appropriate labour market policy which leads to a shift of the IDC towards the social planner equilibrium (see proposition 3.2).

With a change in the flows of immigrants μ and of the characteristics of immigration z_I on the JCC, we can influence the job creation of firms and therefore we correct for an either too high or too small labour market tightness (lemma 3.2). The effect of an increase of z_I always increases z_N and θ - independently of the human capital endowment of existing immigrants ($J_I \gtrless J_N$). But the effects of an increase in the flow of immigrants μ depends on the existing human capital endowment of immigrants (see proposition 3.1). Thus, the Pareto-optimal immigration policy has to be a combination of policies (h^*, z_I^*, μ^*) which increases z_N^E and either increases or decreases θ^E. For example, in the case of an economy with low skilled immigration and a too high bargaining power, the labour market tightness would be too low and underinvestment in human capital exists. Therefore, we augment education subsidies h to increase z_N^E and θ^E and we could increase the human capital endowment of immigrants z_I or decrease the inflow of low skilled immigrants μ.

Proposition 3.3. *Human capital investments are subsidised with a labour policy $h^* > 0$. If $\beta < \beta_I^o$ we need less skilled immigrants to correct for the too high labour market tightness. If $\beta > \beta_I^o$, we need higher skilled immigrants to correct for the too small labour market tightness: $z_I^* > z_I$. If $\beta \gtrless \beta_I^o$ and $J_I > J_N$, we need more (less) high skilled immigrants to correct for the too low (high) labour market tightness: $\mu^* \gtrless \mu$. If $\beta \gtrless \beta_I^o$ and $J_I < J_N$, we need less (more) low skilled immigrants to correct for the too low (high) labour market tightness. A combination of these policies (h^*, z_I^*, μ^*) induce the Pareto-optimal equilibrium of the social planner.*

Proof. Please consult the appendix □

3.4.4 Numerical exercise

The following numerical exercise serves as an illustration for the theoretical discussion.

Figure 3.1 illustrates the case of the competitive equilibrium for a human capital endowment of immigrants of $z_I = 10$ and an inflow rate $\mu = 0.01$. Table 3.1 summarises the parameter used in the numerical exercise. Rates are chosen on a yearly basis such that they reflect reasonable life time values: e.g. an exit rate of $\delta_N = 0.025$results in an average working life of 40 years. With these parameters we obtain a steady-state stock of immigrants of $I = \mu/\delta_I = 0.2$ meaning that $\sim 18\%$ of the total population are immigrants. The matching function is assumed to be of Cobb-Douglas type $m(u, v) = 5\sqrt{uv}$ which gives an arrival rate of $p(\theta) = 5\sqrt{\theta}$. The production function takes the following form $f(z) = 5z^{0.7} + b$. Using these parameters and solving the social planner's problem results in an efficient labour market tightness $\theta^o = 38.6$ and an efficient level of human capital of natives of $z_N^o = 1895$. The value of unemployment for natives U_N takes the value of 509. The value for a filled native job J_N is equal to 6.12, which is much higher then the assumed search costs. The respective values of unemployment and filled jobs for immigrants are lower than for natives: $U_I = 249$ and $J_I = 3.9$.

Parameter	δ_N	δ_I	s	ρ	b	μ	k	c	β
Value	0.025	0.05	0.2	0.1	15	0.01	25	10	0.5

Table 3.1: Parameters of the numerical example

Because the social planner's problem is independent of immigration, any of the following simulation results can be compared to the outcome of the planner's problem. In this example economy, we get an optimal bargaining power of $\beta_I^o = 0.45$. Therefore the labour market tightness is too low (because the existing bargaining power $\beta = 0.5$) and we would have to admit higher skilled immigrants or more skilled immigrants.

First we discuss the case of an economy with low skilled immigration (compared to the level of native human capital) and a too small labour market tightness. Now, we solely increase the human capital endowment of immigrants, $\theta^E$and z_N^E change as follows:

	$z_I = 10$	$z_I = 20$	$z_I = 30$
θ^E	1.45	1.6	1.67
z_N^E	22	22.3	22.5

Table 3.2: Increasing the human capital requirement for immigrants

With rising human capital of immigrants, the labour market tightness increases as well as the human capital endowment of natives. If we leave the human capital of immigrants constant and change the inflow of immigrants we get the following results:

	$\mu = 0.01$	$\mu = 0.02$	$\mu = 0.03$
θ^E	1.45	1.35	1.28
z_N^E	22	21.7	21.5

Table 3.3: Increasing the inflow of immigrants

In the case of existing low skilled immigration, an increase in the inflows of this kind of immigrants leads to a decreasing labour market tightness and drop of human capital investment of natives. In the case of existing high skilled immigration, increasing the inflow μ leads to an increasing labour market tightness and human capital investment. The case of a too high labour market tightness (remember that the bargaining power has to be lower than the efficient bargaining power) is rather unlikely:

	$\beta = 0.6$	$\beta = 0.5$	$\beta = 0.4$
θ^E	0.96	1.45	2.16
z_N^E	21.8	22	21.8

Table 3.4: Bargaining power

A combination of labour immigration policy (h^*, z_I^*, μ^*) leads to the following optimal values. First we calculate the optimal education subsidy through the IDC which gives $h^* = 7.15$. The optimal human capital endowment of immigrants and the optimal inflow of immigrants lead to the following values: $\mu^* = 0.05$ and $z_I^* = 1899.41$.

3.5 Extension

In the US and the UK, the distribution of educational attainment of immigrants is rather bimodal with both a large number of highly skilled immigrants and a large number of low skilled immigrants. For example Chiswick and Sullivan (2005) report for the US, that immigrants from Asia, Europe and Canada mostly embody at least the same human capital as US natives of the respective group. But immigrants from Mexico and Latin America have significantly lower educational attainment than their native counterparts in the group of unskilled workers. We can discuss this kind of immigration if we consider perfectly segmented labour markets between skill groups in the spirit of Mortensen and Pissarides (1999).

Suppose that an economy consists of two different labour markets, one for high skilled workers and one for low skilled workers. Both labour markets are perfectly separated meaning that a high skilled worker can not switch to the low skilled labour market and vice versa. Assume further that individuals differ with respect to their abilities $a \in [0, \infty)$ distributed according to some general distribution function $g(a)$. High skilled workers acquire the skills needed on their respective labour market at university as discussed in the basic model. If access to universities requires a certain ability $\bar{a}$ individuals with abilities $a \leq \bar{a}$ work as low skilled workers and those with $a > \bar{a}$ work as high skilled workers.[25] Using this simple setup we end up with two segmented labour markets instead of N segmented labour markets as modelled by Mortensen and Pissarides (1999).

Considering the bimodal immigration of e.g. the US or the UK, our analysis of the impact of immigration applies separately for both labour markets. We have immigration of high skilled workers on the labour market of high skilled natives which is comparatively better skilled than their native counterparts. Simultaneously, immigration of low skilled workers takes place on the labour market of low skilled natives. First, entrance of high skilled immigrants (resulting from a higher μ) or higher skilled immigrants (resulting from a higher z_I) lead to increasing job creation of firms and higher wages of high skilled natives. Therefore, native workers have a higher incentive to invest more into education. Second, the same analysis applies for the impact of immigration of low skilled workers. If immigrants in the low skilled sector are comparatively less skilled than native low skilled workers, firms in the low skilled sector will react by opening

[25] The individual with ability $\bar{a}$ is indifferent between going to university or working as low skilled worker.

less vacancies in this sector and the wage rate will decline for low skilled workers. The total effect will be higher investments in education by native high skilled workers due to their wage increases. The labour market prospects of low skilled workers deteriorate due to decreased wages. This summarises a possible impact of the bimodality of US immigration on the existing wage inequality (cf. Borjas et al. (1997)).

3.6 Conclusions

We introduce immigration into a search model of equilibrium unemployment. This allows us to model immigration in terms of flows and its characteristics in terms of human capital. Because of a positive probability of returning to their home countries, immigrants receive lower wages and have a higher unemployment rate compared to natives. We can show that an immigration policy which is concerned about the human capital endowment of immigrants and/or the number of immigrants has a decisive impact on the educational decision of natives. Immigration policy which favours higher skilled immigrants will increase the wage rate for the group of high skilled workers because firms have incentives to increase the number of vacancies. This induces natives to invest more in education. Furthermore, we can show that a combination of education subsidies and directed immigration policy can remove underinvestment in human capital. Education subsidies foster the investment decision of natives and the appropriate immigration policy generates Pareto-improving job creation by firms. The model can be extended to introduce bimodal immigration concerning the educational attainment of immigrants. Applying perfectly segmented labour markets in combination with an immigration of high and low skilled workers results in higher native investment in human capital by high skilled natives and lower wages of low skilled natives.

3.A Appendix

3.A.1 Derivation of the wage setting equation (3.10)

Maximisation of the Nash Product (3.9) yields

$$w_i = \beta f(z_i) + (1-\beta)(\delta_i + \rho)U_i \quad i = I, N. \tag{3.A.1}$$

Substitution of (3.A.1) in(3.6) gives:

$$W_i = \frac{\beta f(z_i) + ((1-\beta)(\rho+\delta_i) + s)\, U_i}{\rho + \delta_i + s} \quad i = I, N. \tag{3.A.2}$$

Substitution of (3.A.2) in (3.5) we end up with reservation wage:

$$(\rho + \delta_i)\, U_i = \frac{b(\rho + \delta_i + s) + p(\theta)\beta f(z_i)}{\rho + \delta_i + s + p(\theta)\beta} \quad i = I, N. \tag{3.A.3}$$

Substitution of the reservation wage in (3.A.1) yields the wage setting equation (3.10).

3.A.2 Existence of the equilibrium

Proof. It is to show that the equilibrium $\{z_N^E, \theta^E, u^E\}$ exists. The functions $G_1^E(\theta, z_N)$ and $G_2^E(\theta, z_N)$ are continuous and $G_{i,z_N}^E \neq 0 \; i = 1, 2$ on the open interval $(0, \infty)$. Therefore, we can apply the implicit function theorem and express z_N as a function of θ denoted by: $z_{1N}(\theta)$, $z_{2N}(\theta)$. Because $\lim_{\theta \to 0} \lim_{z_N \to 0} G_1^E(\theta, z_N) = \infty > k$ the domain of $z_{1N}(\theta)$ is the open interval $(\bar{\theta}_1, \infty)$ with $\bar{\theta}_1 > 0$ and the domain of $z_{2N}(\theta)$ is the open interval $(0, \infty)$. Analysing these functions at their respective domain limits reveals: $\lim_{\theta \to \bar{\theta}_1} z_{1N}(\theta) = 0$ and $\lim_{\theta \to \infty} z_{1N}(\theta) = \infty$. Given that $\lim_{\theta \to \infty} p(\theta) = \infty$, we get $\lim_{\theta \to \infty} z_{2N}(\theta) = \bar{z}_2$ where $\bar{z}_2$ is defined by: $\bar{z}_2 := \{z_2 : f'(z_2) = (\rho + \delta_N)\, c\}$. At the lower boundary we get $\lim_{\theta \to 0} z_{2N}(\theta) = 0$. Next we define the function $\Gamma(\theta) = z_{2N}(\theta) - z_{1N}(\theta)$. Using the previous results we get $\lim_{\theta \to \bar{\theta}_1} \Gamma(\theta) > 0$ because $z_{2N}(\theta)$ is strictly increasing. Furthermore we get $\lim_{\theta \to \infty} \Gamma(\theta) = -\infty$. Thus, the intermediate value theorem guarantees at least one θ' such that $\Gamma(\theta') = 0$. This concludes the proof that at least one equilibrium exists. □

3.A.3 Slope of the IDC and JCC

Differentiation of $G_1^E(\theta, z_N)$ and $G_2^E(\theta, z_N)$ with respect to θ and z_N gives:

$$
\begin{aligned}
G_{1,\theta}^E &= \frac{dq(\theta)\eta_U}{d\theta} J_I + \frac{dq(\theta)\left(1-\eta_U\right)}{d\theta} J_N \\
&\quad + q(\theta)\eta_U J_{I,\theta} + q(\theta)\left(1-\eta_U\right) J_{N,\theta} < 0, && (3.A.4) \\
G_{1,z_N}^E &= q(\theta)\left(1-\eta_U(\theta)\right) J_{N,z_N} > 0, && (3.A.5) \\
G_{2,\theta}^E &= \frac{\beta p'(\theta)\left(\rho+\delta_N+s\right)}{\left(\rho+\delta_N\right)\left(\rho+\delta_N+s+\beta p(\theta)\right)^2} f'(z_N) > 0, && (3.A.6) \\
G_{2,z_N}^E &= \frac{\beta p(\theta)}{\left(\rho+\delta_N\right)\left(\rho+\delta_N+s+\beta p(\theta)\right)} f''(z_N) < 0, && (3.A.7)
\end{aligned}
$$

The slope of the JCC and the IDC can then be calculated as:

$$
\left.\frac{d\theta}{dz_N}\right|_{G_1^E(\cdot)=k} > 0, \quad \left.\frac{d\theta}{dz_N}\right|_{G_2^E(\cdot)=c} > 0.
$$

3.A.4 Comparative statics

The first two derivatives are needed for the further analysis:

$$
\frac{\partial \eta_U}{\partial \mu} = (1-\eta_U)\frac{1}{\delta_I}\frac{\delta_I+s}{\delta_I+s+p(\theta)} > 0,
$$

$$
\frac{\partial \eta_U}{\partial \theta} = p'(\theta)\eta_U(1-\eta_U)\left(\frac{1}{\delta_I+s+p(\theta)} - \frac{1}{\delta_N+s+p(\theta)}\right) > 0.
$$

The derivatives of the JCC and the IDC in the competitive equilibrium look as follows:

$$
G_{1\mu}^E = \frac{d\eta_U}{d\mu}(J_I - J_N)\begin{cases} > 0 & (J_I - J_N) > 0 \\ < 0 & (J_I - J_N) < 0 \end{cases},
$$

$$
G_{1z_I}^E = \eta_U(\theta)\frac{q(\theta)(1-\beta)f'(z_I)}{\rho+\delta_I+s+\beta p(\theta)} > 0.
$$

3.A.5 Optimality conditions

Given the following Hamiltonian:

$$H = e^{-\rho\tau}[y_N + bu_N - k\theta u_N - \delta_N c z_N] + \lambda_1\{\delta_N + s(1-u_N) - [p(\theta)+\delta_N]u_N\}$$
$$+\lambda_2\{p(\theta)u_N f(z_N) - (s+\delta_N)y_N\},$$

we get the following first order conditions:

$$\frac{\partial H}{\partial u_N} = e^{-\rho\tau}(b-k\theta) - \lambda_1[s+p(\theta)+\delta_N] + \lambda_2 p(\theta) f(z_N) + \dot{\lambda}_1 = 0, \quad (3.A.8)$$
$$\frac{\partial H}{\partial y_N} = e^{-\rho\tau} - \lambda_2(s+\delta_N) + \dot{\lambda}_2 = 0, \quad (3.A.9)$$
$$\frac{\partial H}{\partial \theta} = -e^{-\rho\tau} k u_N - \lambda_1 p'(\theta) u_N + \lambda_2 p'(\theta) u_N f(z_N) = 0, \quad (3.A.10)$$
$$\frac{\partial H}{\partial z_N} = -e^{-\rho\tau}\delta_N c + \lambda_2 p(\theta) u_N f'(z_N) = 0. \quad (3.A.11)$$

Solving the differential equation (3.A.9) and equating the solution at the steady state $\dot{\lambda}_2/\lambda_2 = -\rho$ we yield the steady state value of λ_2:

$$\lambda_2 = \frac{e^{-\rho\tau}}{s+\delta_N+\rho}.$$

Replacing λ_2 in (3.A.8), solving the differential equation and equating the solution at the steady state $\dot{\lambda}_1/\lambda_1 = -\rho$ gives:

$$\lambda_1 = \frac{e^{-\rho\tau}}{\rho+s+p(\theta)+\delta_N}\left((b-k\theta) + \frac{p(\theta)f(z_N)}{s+\delta_N+\rho}\right).$$

Using λ_2 in (3.A.11) and solving for c yields (3.25):

$$\frac{p(\theta)u_N}{\delta_N(s+\delta_N+\rho)} f'(z_N) = c.$$

Replacing $u_N$with the steady state value yields (3.24):

$$\frac{(\delta_N+s)\,p(\theta)}{\delta_N\,(s+\delta_N+p(\theta))\,(s+\delta_N+\rho)} f'(z_N) = c.$$

Using λ_1 and λ_2 in (3.A.10) and solving for k gives:

$$\frac{p'(\theta)\left(f(z_N)-b\right)}{\rho+s+\delta_N+p(\theta)-p'(\theta)\theta}=k.$$

3.A.6 *Proof of Lemma 3.1*

Proof. We need to compare the loci defined by (3.14) and (3.25). Assume that $z_N(\theta)|_{G_2^E=c} < z_N(\theta)|_{G_2^o=c}$ holds for any $\theta=\bar{\theta}$. This implies the following inequality:

$$\frac{\beta p(\bar{\theta})}{(\rho+\delta_N)\left(\rho+A+\beta p(\bar{\theta})\right)} < \frac{Ap(\bar{\theta})}{\delta_N\left(p(\bar{\theta})+A\right)(A+\rho)},$$

with $A \equiv \delta_N + s$. First note that if the inequality holds for $\beta = 1$ it will also hold for $\beta < 1$ because the LHS increases in β. Therefore we set $\beta = 1$ and check whether this is true or not. Reorganising terms yields:

$$\begin{aligned}
\delta_N\left(p(\bar{\theta})+A\right)(A+\rho) &< A(\rho+\delta_N)\left(\rho+A+p(\bar{\theta})\right),\\
\delta_N p(\bar{\theta}) &< A\rho+A^2+Ap(\bar{\theta}).
\end{aligned}$$

which by using the definition of A is true for any value of $\bar{\theta}$ and completes the proof. □

3.A.7 *Proof Lemma 3.2*

Proof. Assume that $z_N^E = z_N^o$. First we consider an economy without immigration $\mu = 0$. Evaluating (3.13) and (3.24) at $z_N^E = z_N^o$ and comparing both terms yields:

$$\frac{(1-\beta)p(\theta^E)/\theta^E}{\rho+\delta_N+s+\beta p(\theta^E)}=\frac{p'(\theta^o)}{s+\delta_N+\rho+p(\theta^o)-\theta^o p'(\theta^o)}$$

$\theta^E = \theta^o$ holds if $\beta = \frac{p(\theta^E)-\theta^E p'(\theta^E)}{p(\theta^E)} = \theta^E \frac{q'(\theta^E)}{q(\theta^E)} \equiv \tilde{\beta}$. This is the well known Hosios-condition for an efficient bargaining power of workers (Hosios, 1990). Note that, because $G_{1,\theta}^E < 0$ and $G_{1,\beta}^E < 0$ we can conclude that for any $\beta \gtreqless \tilde{\beta}\ \theta^E \lesseqgtr \theta^o$.

Next we are considering an economy with immigration. With immigration we can not analytically find an efficient $\tilde{\beta}$. However, an efficient $\tilde{\beta}$ solves the following equation:

$$\tilde{\beta} := \{\beta : q(\theta^o) J^e(\theta^o, z_N^o; \beta) = G_1^o(z_N^o, \theta^o)\}$$

Note, that we have to differentiate the two possible cases $J_I > J^e > J_N$ and $J_N > J^e > J_I$. Furthermore, because $G^E_{1,\beta} < 0$ and $G^E_{1,\theta} < 0$ with same line of reasoning as before we can conclude that for any $\beta \gtreqless \tilde{\beta}_I$ $\theta^E \lesseqgtr \theta^o$. □

3.A.8 Proof Proposition 3.1

Proof. We are in a stable equilibrium: $G^E_{1\theta} G^E_{2z_N} - G^E_{2\theta} G^E_{1z_N} > 0$:

$$\frac{d\theta^E}{d\mu} = -\frac{G^E_{1\mu} G^E_{2z_N}}{G^E_{1\theta} G^E_{2z_N} - G^E_{2\theta} G^E_{1z_N}} \begin{cases} > 0 & iff \ \ (J_I - J_N) > 0 \\ < 0 & iff \ \ (J_I - J_N) < 0 \end{cases},$$

$$\frac{dz^E_N}{d\mu} = -\frac{-G^E_{2\theta} G^E_{1\mu}}{G^E_{1\theta} G^E_{2z_N} - G^E_{2\theta} G^E_{1z_N}} \begin{cases} > 0 & iff \ \ (J_I - J_N) > 0 \\ < 0 & iff \ \ (J_I - J_N) < 0 \end{cases}.$$

$$\frac{d\theta^E}{dz_I} = -\frac{G^E_{1z_I} G^E_{2z_N}}{G^E_{1\theta} G^E_{2z_N} - G^E_{2\theta} G^E_{1z_N}} > 0,$$

$$\frac{dz^E_N}{dz_I} = -\frac{-G^E_{2\theta} G^E_{1z_I}}{G^E_{1\theta} G^E_{2z_N} - G^E_{2\theta} G^E_{1z_N}} > 0.$$

The number of unemployed workers changes as follows:

$$du = \left.\frac{\partial u}{\partial \theta}\right|_{\mu=0} d\theta + \left.\frac{\partial u}{\partial \mu}\right|_{\mu=0} d\mu,$$

$$du = -\frac{(s + \delta_N)\, p'(\theta)}{(s + \delta_N + p(\theta))^2} d\theta + \frac{1}{\delta_I} \frac{(s + \delta_I)}{(s + \delta_I + p(\theta))} d\mu.$$

□

3.A.9 Proof Proposition 3.2

Proof. For the stable equilibrium $G_{1\theta}^E < 0$ and $G_{1\theta}^E G_{2z_N}^E - G_{2\theta}^E G_{1z_N}^E > 0$ hold:

$$\frac{d\theta^E}{dh} = \frac{G_{1z_N}^E}{G_{1\theta}^E G_{2z_N}^E - G_{2\theta}^E G_{1z_N}^E} > 0,$$

$$\frac{dz_N^E}{dh} = -\frac{G_{1\theta}^E}{G_{1\theta}^E G_{2z_N}^E - G_{2\theta}^E G_{1z_N}^E} > 0.$$

□

3.A.10 Proof Proposition 3.3

Proof. We will compare the JCC and the IDC in the competitive equilibrium with their counterparts of the social planner. Education subsidies shall be positive: $h^* > 0$ which can be shown by the following expression:

$$h^* = f'(z_N)\left[\frac{(\delta_N + s)\,p(\theta)}{\delta_N\,(\delta_N + s + \delta_N)\,(s + p(\theta) + \rho)} - \frac{\beta p(\theta)}{(\rho + \delta_N)\,(\rho + \delta_N + s + \beta p(\theta))}\right] > 0,$$

where the first expression is the IDC of the social planner (3.25) and the second expression is the IDC of the competitive equilibrium (3.14).

The comparison of the JCC cannot not be made in the same way. We have to rely on the comparative static results for changes in $z_I$and μ. First, we consider a change in z_I: $\frac{d\theta^E}{dz_I}, \frac{dz_N^E}{dz_I} > 0$ irrespective of the expected present value of a filled job. If $\beta < \beta_I^o$, we have too high labour market tightness and therefore we need lower educational attainment of immigrants $z_I^* < z_I$. For a $\beta > \beta_I^o$, the educational attainment has to be higher: $z_I^* > z_I$.

Second we consider a change in the inflow of immigrants μ: if $J_I < J_N$, we have less skilled immigrants compared to natives coming into the host country. The following comparative static will then apply $\frac{d\theta^E}{d\mu}, \frac{dz_N^E}{d\mu} < 0$. With this kind of immigration and a $\beta > \beta_I^o$, we have too small labour market tightness and we have to decrease the inflow of immigrants $\mu^* < \mu$. For a $\beta < \beta_I^o$, we need $\mu^* < \mu$. If $J_I > J_N$ then $\frac{d\theta^E}{d\mu}, \frac{dz_N^E}{d\mu} > 0$. With a $\beta > \beta_I^o$, we have too small labour market tightness and we have to increase the inflow of immigrants $\mu^* > \mu$. For a $\beta < \beta_I^o$, we need $\mu^* < \mu$. $\square$

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Chapter 4

Educational Systems and Globalisation

4.1 Introduction

The influence of a country's institutional framework on trade has been a central question in the theory of international trade during the last 15 years. In course of that time a huge body of literature emerged focusing on different aspects of institutional arrangements – e.g., financial institutions (cf. Kletzer and Bardhan, 1987) and industrial organisation (cf. Grossman and Helpman, 2002, 2003) – as a way to explain the actual comparative advantage of countries. A recent contribution by Belloc (2006) surveys and categorises this literature. She concludes that "institutions matter", but unfortunately many important questions like "How do institutions affect competitiveness and comparative advantage" are unanswered yet (Belloc, 2006, p. 21). To that end, our paper brings together the discussion about educational institutions and the determination of comparative advantage. The major questions to be discusses are: (1) To what degree do different institutional arrangements in the educational sector matter for the determination of a country's comparative advantage, and (2) can globalisation trigger institutional changes in the educational sector.

The ever increasing volume of trade after World War II attracted a lot of attention and gave rise to both intense public and academic discussion. A major focus has been on the presumed negative distributional consequences of international trade. In industrialised countries, these consequences became evident in the deteriorating labour market position of low-skilled workers reflected by increased wage inequality between skill groups and deteriorating employment opportunities (Wood, 2002; Wood and Ridao-Cano, 1999; Wood, 1998; Slaughter, 1998). At the same time another heatedly debated topic has been the design of the educational policy. Most of the interest stems from the fact that in the presence of credit market imperfections the income distribution is an important determinant of economic growth (Benabou, 1997; Galor and Zeira, 1993). Consequently, a well designed educational system can mitigate the impact of credit market imperfections and promote economic growth (Tanaka, 2004; Epple and Romano, 1998, 1996b,a). Governments implementing an educational system, however, face a trade-off between its efficiency and its equity.

During the last decade the (public) discussion about educational policy merged more and more with the discussion about globalisation. Their main line of reasoning is that promoting higher education might serve as a policy instrument to maintain the actual comparative advantage of the industrialised countries in human capital intensive goods and to dampen the aforementioned unintended distributional consequences of globalisation.

Formation of human capital has been introduced into the theory of international trade by Findlay and Kierzkowski (1983), but without considering the institutional framework in detail. They show that with endogenous acquisition of human capital, a country's endowment of its specific inputs in the educational sector determines the comparative advantage. Their model has been used extensively in the literature to analyse, e.g., the impact of increased international integration with differing labour market institutions (Kreickemeier and Nelson, 2006; Davis and Reeve, 1998), or to analyse the welfare implications of globalisation for various skill groups (Falvey et al., 2005). However, despite the intense public discussion about educational policy as a countermeasure to globalisation, there are surprisingly few papers in the theoretical literature on international trade emphasising the specific role of the institutional framework of the educational system. Among these few are papers combining models of human capital acquisition under incomplete credit markets with the classical Heckscher-Ohlin model (Cartiglia, 1997; Ranjan, 2001, 2003). These models give an answer to the important question of how the long-term income distribution interacts with increased openness to trade. Nevertheless, all these models lack a detailed description of the educational system itself.

We try to fill this gap by presenting a model that accounts for the different institutional arrangements in the educational sector. Concerning the institutional differences we will concentrate on three different cases: Both the polar cases of an exclusively privately funded system of higher education and of a system of publicly funded higher education are analysed. In contrast to the public system where only one type of university with an average quality is offered, the private system offers each individual a range of universities with a specific teacher-student ratio. As a third case we discuss a mixed system with both private and public universities. In our subsequent analysis we will focus on two different aspects: First, we analyse the influence of institutional differences in the educational sector on international trade patterns. Second, we compare how these institutions react to globalisation shocks.

We develop an overlapping-generations model of international trade in the spirit of Findlay and Kierzkowski (1983). In contrast to their analysis, our economy is populated by heterogeneous agents differing in their inate abilities. Irrespective of the institutional framework, each individual has to decide whether to invest into (further) education or not. In case of a mixed educational system, individuals opting for education additionally have to decide about entering a public or a private university. The aggregate supply of human capital will typically depend on the educational institutions and the wage differential between high-skilled and low-skilled workers. Compared to Findlay and Kierzkowski (1983) our model is more general in the sense that we can show that their results correspond to the case of a publicly funded university system with fixed endowments in the educational sector.

Our paper is structured as follows: Section 4.2 develops the basic model. The educational decision problem of households as well as the description of the production sector are outlined. The details of the different institutional frameworks of the educational sector and its consequences will be discussed in section 4.3. Section 4.4 analyses the general equilibrium of the closed economy. Furthermore, the influence of the educational system on the relative supply of goods is discussed. Section 4.5 answers the question of how the institutional framework affects the comparative advantage of a country. Endogenous institutional change as a consequence of increased international integration will be analysed and some evidence for our results is presented. Section 4.6 concludes.

4.2 The basic model

4.2.1 Households

Individuals live for two periods of time and consume two different tradable goods: X, Y. For simplicity we assume that all individuals, high skilled and low skilled, consume their total income in the second period of their life.[1] Preferences are homothetic and identical for all individuals. For the ease of exposition we assume Cobb-Douglas preferences giving the following relative aggregate demand:

$$D_Y/D_X = \frac{(1-\lambda)}{\lambda p}, \quad \lambda \in (0,1) \tag{4.1}$$

with $1-\lambda$ representing the share of income devoted to the consumption of good Y and $p \equiv p_Y/p_X$ denoting its relative price.

The economy is populated by individuals who are heterogeneous with respect to their abilities. We assume that individuals entering the economy in period 1 have already

[1] This assumption has been employed in many models to concentrate only on the educational decision and to simplify the analysis (cf. Galor and Zeira, 1993).

attended compulsory schooling at the beginning of their "life". In our model, abilities are considered to be an amalgam of general knowledge, innate abilities and the like. Each individual is indexed by its ability $\theta \in [0,1]$ which is drawn from a uniform distribution function $f(\theta) = 1$ with mean 0.5. At the beginning of its life, an individual θ has to decide whether to enter the labour market immediately, or whether to invest into higher education. Without any further education, an individual enters the labour market as a low-skilled worker in the first period. We assume that a low-skilled worker supplies one efficiency unit of low-skilled labour in both periods. Abstracting from discounting, the gross lifetime income of a low-skilled worker can be written as

$$I_L = 2w_L, \tag{4.2}$$

where w_L denotes the wage rate of low-skilled workers per efficiency unit. Note that the labour income of low-skilled workers is independent of θ.[2]

An individual θ who opts for higher education has to spend the complete first period at university and enters the labour market after graduation at the beginning of the second period. Higher education transforms the qualitative nature of labour from low-skilled productivity units to productivity units of high-skilled labour depending on the individual ability θ. By enrolling in university an individual transforms his abilities θ into efficiency units of high-skilled labour $H(\theta, e)$ according to

$$H(\theta, e) = \theta h(e) \qquad h'(\bullet) > 0, h''(\bullet) < 0\,, \tag{4.3}$$

where $h(e)$ describes the human-capital-production function of the educational system.[3] That function is determined by the educational input of e efficiency units of high-skilled "teachers" per enrolled student the teacher-student ratio. Depending on the educational system, a potential student with ability θ can either choose among private universities (that one which suits his ability best) or she has to enter a public university with a given

[2]Relaxing this assumption does not change our results qualitatively but this assumption helps to simplify the exposition of the model and derivation of the main results.

[3]This multiplicative form has been used extensively in the literature. E.g., Stiglitz (1974) used this form to analyse the demand for education. Using this functional form helps to simplify the analytic presentation. Note that the qualitative results do not change if we allow for any other linear homogeneous transformation function $F(\theta, e)$.

teacher–student ratio e. The gross lifetime income of high-skilled workers consists of the second period income only:

$$I(w_H, \theta) = w_H \theta h(e), \tag{4.4}$$

where w_H denotes the wage rate per efficiency unit of high-skilled labour. Whichever educational system is in place, a student θ has to bear decision related tuition fees such that gross and net income differ. This will be explained in more detail in the section 4.3 which covers the different educational institutions.

The individual decision to invest into further education determines both the aggregate supply of high- and low-skilled workers. Obviously, relative labour supply depends on the relative wage w_H/w_L.

4.2.2 *Firms and production technology*

We consider an economy with two different sectors producing two tradeable goods, X and Y, by utilising two distinct factors of production. The production technologies of both industrial sectors exhibit constant returns to scale. The two different factors of production are high-skilled labour H and low-skilled labour L, both are measured in efficiency units. Specifically, we assume that the production technologies are given by[4]

$$X = L, \quad Y = H_Y. \tag{4.5}$$

Assuming perfectly competitive markets for goods and factors and incomplete specialisation, the equilibrium conditions are given by:

$$p_X = w_L, \quad p_Y = w_H, \tag{4.6}$$

with w_H and w_L denoting the wage rate per efficiency unit of high-skilled and low-skilled labour, respectively. Thus, the relative wage in equilibrium can be written as: $\omega \equiv w_H/w_L = p$. To simplify the notation we normalise the price of good X to unity such that p represents the price of good X and the wage rate of high-skilled labour as well as the relative price and wage.

[4]Because the aggregate supplies of the different types of labour are determined endogenously in the educational sector, we can use this rather simple setup of the production sector. Assuming a Heckscher-Ohlin type structure of the production sector does not alter the qualitative results of the model.

Besides these two sectors producing tradable goods, an educational sector "produces" high-skilled labour by utilising already trained high-skilled workers as the only input. The total employment in the educational sector is denoted by H_E. These teaching units are also measured in efficiency units. The total number of efficiency units of high-skilled labour available for sector Y is given by the difference of total high-skilled labour and high-skilled labour used for teaching: $H - H_E$. Since $H - H_E$ depends on individuals' decision to train, it will generally depend on the actual educational system in place and the relative price p.

Next we derive the market clearing condition for the factor markets. The total demand for high-skilled labour H is the sum of demand arising from production sector Y and demand from the educational sector H_E:

$$H = Y + H_E \tag{4.7}$$

$$L = X \tag{4.8}$$

To derive the relative supply of goods (X/Y), we use (4.7) and (4.8) which yields:

$$Y/X = \frac{H - H_E}{L}. \tag{4.9}$$

4.3 Educational institutions

Within this section we will describe the educational decision made by individuals taking as given the different institutional settings of the educational system. We distinguish the following three alternative specifications of the educational sector: (i) a system which is exclusively privately funded with privately managed universities only; (ii) a tax-funded system with publicly funded and managed universities; (iii) a mixture of both with active private and public universities.

To concentrate on the institutional differences between public and private universities we assume that the education-production function $H(\theta, e)$ is identical for the various educational systems. For simplicity, we further assume the following human capital production function: $h(e) = e^{\delta}, \quad \delta \in (0, 1)$.

4.3.1 *Privately funded education*

With a purely private system the educational sector consists of a continuum of universities supplying education with different teacher-student ratios e. Each university is indexed by the teacher-student ratio e it offers. We assume that private universities demand a constant markup $\mu \geq 1$ on their marginal cost p: $p_e = \mu p$. In our context, the parameter μ represents any kind of inefficiencies of the economy leading to a distortion of private decisions to educate.[5]

The individual demand for education, e_d, is derived by maximising the net individual income $I_H(\theta) - p_e e$ with respect to the teacher-student ratio e. Using the given human capital production function and imposing the universities pricing rule, $p_e = \mu p$, with p_e being the price per teacher efficiency unit, the decision problem of individual θ can be written as:

$$\max_e \{p\theta e^\delta - p_e e\}, \tag{4.10}$$

where $p_e e$ represents the total tuition fee to be paid to the privately owned university.

Maximisation of (4.10) yields the following optimal choice of e_d as a function of θ:

$$e_d(\theta) = \left(\frac{\theta}{\mu}\delta\right)^{\frac{1}{1-\delta}}. \tag{4.11}$$

Due to our normalisation of abilities the highest demand for education is $e_d(1) = (\delta/\mu)^{1/(1-\delta)} < 1$, with $0 < \delta < 1 \leq \mu$. Note also that a higher degree of market failure μ results in a lower (aggregated) volume of private investment into education: $de_d/d\mu < 0$.

Substitution of (4.11) into the net income function (4.10) and applying the pricing rule of private universities yields the maximised net lifetime income of individual θ:

$$I_H^*(p, \theta) - p_e e_d = p(1-\delta)\theta^{\frac{1}{1-\delta}} \left(\frac{\delta}{\mu}\right)^{\frac{\delta}{1-\delta}}. \tag{4.12}$$

The net lifetime income function is a monotone increasing and convex function of individual ability θ. Larger inefficiencies μ reduce the net income for each individual θ.

[5] Appendix 4.A.3 gives a microeconomic foundation for this assumption. Furthermore, there exists a huge literature, providing alternative theoretical explanations for the assumption made in this paper. For a concise overview in the context of economic growth, see Benabou (1997) and the literature cited therein.

The decision problem for individual θ is to choose higher education whenever the net income with higher education exceeds that without higher education. With an exclusively private university system the net income $I_P(\theta)$ for individual θ can generally be written as:[6]

$$I_P(p,\theta) := \max\{I_H^*(p,\theta) - p_e e_d,\ I_L\}. \tag{4.13}$$

Because $I_H^*(p,0) - p_e e_d(0) = 0$ holds, and $d\left(I_H^*(p,0) - p_e e_d(0)\right)/d\theta > 0$, there exists at most one threshold value $\tilde{\theta}_P$ such that $I_H^*(p,\tilde{\theta}_P) = I_L$. By substituting $I_H^*(p,\theta) - p_e e_d$ and I_L from (4.12) and (4.2) and bearing in mind that $w_L = 1$, the educational cut-off value can be calculated as:

Corollary 4.1. *With a privately funded system, the educational cut-off value $\tilde{\theta}_P$ is given by:*

$$\tilde{\theta}_P(p) = \left(\frac{\mu}{\delta}\right)^{\delta} \left(\frac{2}{(1-\delta)\,p}\right)^{1-\delta}, \qquad \tilde{\theta}'_P(p) < 0. \tag{4.14}$$

A positive amount of education is guaranteed if and only if $p > \frac{2}{1-\delta}\left(\frac{\mu}{\delta}\right)^{\frac{\delta}{1-\delta}} \equiv \tilde{p}_P$.

Figure 4.1 depicts the derivation of $\tilde{\theta}_P$:[7] the horizontal line is the value of the outside option of working as a low-skilled worker (4.2). The convex function starting from the origin is the net income function (4.12). At the intersection of both curves individual $\tilde{\theta}_P$ is indifferent between investing into further education and working as unskilled.

The educational cut-off value is negatively related to the relative wage p: $\tilde{\theta}'_P(p) < 0$ i.e. a higher relative wage renders the investment into education more profitable. It is important to note that a higher degree of market failure μ results not only in a lower amount of individual investments (i.e. $de_d(\theta)/d\mu < 0$), but also in a lower aggregate amount of schooling via a higher cut-off value: $d\tilde{\theta}_P/d\mu > 0$. A lower individual investment level e is chosen because education gets comparably more expensive than the alternative of not investing into education. The consequence of a reduced individual investment level for every student is that the marginal student $\tilde{\theta}_P$ decides not to enter university. Thus, the ability of the marginal student who enters university increases. Additionally, the lower bound of the relative wage $\tilde{p}_P$ increases, meaning that a higher relative wage p is needed to create an incentive high enough such that individuals with the highest ability start investing into further education.

[6]Throughout the paper subscript P denotes the private educational system.

[7]Subsequently, we drop the functional argument(s) of the respective cut-off value if this causes no confusion.

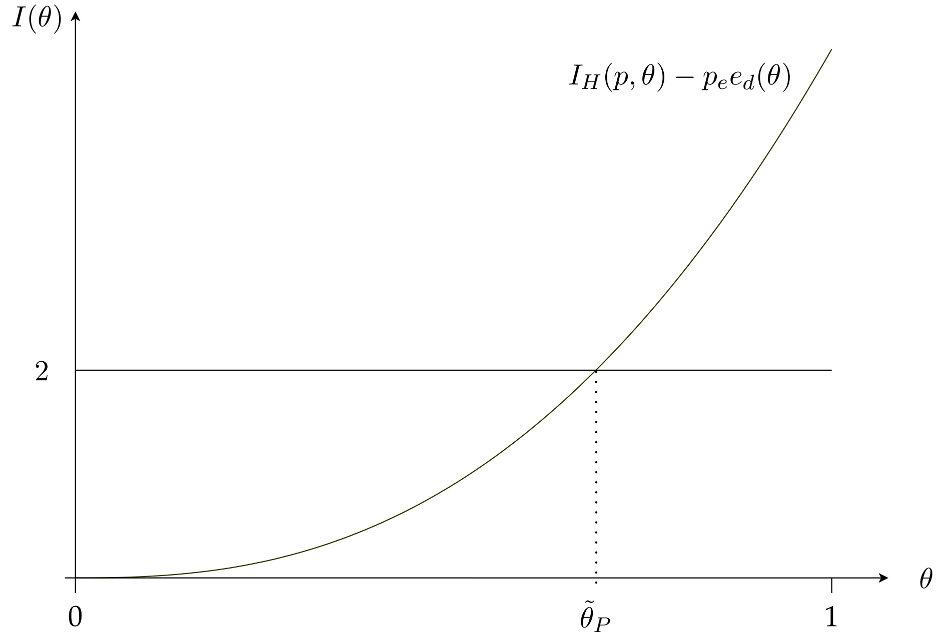

Figure 4.1: Derivation of the cut-off value in the private system $\tilde{\theta}_P(p)$.

Given these results, the net supply of high-skilled labour available for production of goods $\eta_P(p) = H - H_E$ can be written as a function of $\tilde{\theta}_P(p)$ which in turn depends on p:

$$\begin{aligned}\eta_P(p) &= \underbrace{\int_{\tilde{\theta}_P(p)}^{1} \theta e_d(\theta)^{\delta} d\theta}_{=H} - \underbrace{\int_{\tilde{\theta}_P(p)}^{1} e_d(\theta) d\theta}_{=H_E}; \quad p \geq \tilde{p}_P \\ &= \frac{\mu - \delta}{\delta} \left(\frac{\delta}{\mu}\right)^{\frac{1}{1-\delta}} \int_{\tilde{\theta}_P(p)}^{1} \theta^{\frac{1}{1-\delta}} d\theta, \end{aligned} \tag{4.15}$$

with $\eta'_P(p) > 0$.

It is important to note that the calculated change of the labour supply $\eta_P(p)$ is a steady-state change. As each individual lives for two periods, the aggregate human capital H results from individuals' decisions made at the beginning of the previous period. Since these decisions cannot be revised, the aggregate supply of high-skilled labour H is perfectly inelastic in the short run. A change in the relative wage p today only increases the aggregate demand for education today H_E. Consequently, this leads to a reduction of the total amount of high-skilled labour which can be used in production today.

Labour supply of low-skilled efficiency units is formed by young and old workers:

$$L_P(p) = 2 \int_0^{\tilde{\theta}_P(p)} d\theta = 2\tilde{\theta}_P; \quad p \geq \tilde{p}_P \tag{4.16}$$

with $L'_P(p) < 0$. As long as $p \geq \tilde{p}_P$ holds a positive amount of efficiency units of both types of labour will be supplied. With $p \geq \tilde{p}_P$, only low-skilled labour is supplied which leads to specialisation in good X.

4.3.2 *Public provision of education*

In contrast to a private university system, a public system is characterised by a teacher-student ratio which is the same for all students: $e = E_B \; \forall \, \theta$.[8] We assume that the public system of education is endowed with a given total amount of efficiency units of teachers T.[9] Entry to higher education is free to all individuals and depends only on their individual choice to enter further education. Consequently, the number of students S will be the result of these individual decisions and the efficiency units of teachers per student $E_B = \frac{T}{S}$ will be determined endogenously. The teacher-student ratio E_B – and with it the quality of education for each individual – decreases with the number of students S in the educational system. This means that public education is a public resource, and an increasing number of students using this resource leads to a congestion effect.[10]

First, we will analyse the individual decision to educate for an exogenously given student-teacher ratio E_B. Then we will determine the equilibrium in the public education sector which determines the number of students S and with it the teacher-student ratio $E_B = T/S$.

[8] Throughout the paper, subscript B denotes the exclusively public system of higher education

[9] We ignore any political process which leads to a certain amount of resources T in the public system. In our model, countries do not only differ with respect to institutions, but also with respect to the resources allocated to publicly supplied education.

[10] As we will see in the following, this kind of educational system corresponds to the model of Findlay and Kierzkowski (1983). They assume homogeneous individuals and postulate an aggregate human capital production function $H = F(T, S)$ with constant returns to scale, where T denotes the specific resource in the educational sector and S denotes the number of students. An increase in S leads to the aforementioned congestion effect resulting from decreasing returns in S.

We require the governments budget to be balanced such that the total spending for teachers pT equals the total tax revenues. To simplify the analysis we assume that total tax revenue is collected via a lump sum tax τ.

When deciding about education, each individual θ takes both the tax rate τ and the teacher-student ratio E_B as given. The pre-tax income of a high-skilled worker θ can be written as:

$$I_H(E_B, p, \theta) = p\theta E_B^{\delta}. \tag{4.17}$$

An individual θ decides to enter higher education whenever the income as a high-skilled worker is higher than the total income as an low-skilled worker: $I_H(E_B, p, \theta) \geq I_L$. With an exclusively public university system, the pre-tax income for individual θ can generally be written as:

$$I_B(\theta) := \max\{I_H(E_B,\ p, \theta), I_L\}. \tag{4.18}$$

Because $I_H(E_B, p, 0) = 0$ holds, and $\partial\left(I_H(E_B, p, \theta)\right)/\partial\theta > 0$, there exists at most one threshold value θ_B such that $I_H(E_B, p, \theta_B) = I_L$. The *conditional* educational cut-off value can be calculated as:[11]

Corollary 4.2. *With a publicly supplied system of education the conditional educational cut-off value θ_B is given by:*

$$\theta_B(p) = \frac{2}{pE_B^{\delta}}, \qquad \theta'_B(p) < 0. \tag{4.19}$$

A positive amount of education is guaranteed if and only if $p > \frac{2}{E_B^{\delta}} \equiv \tilde{p}_B$.

The income function is depicted in figure 4.2. While the value of the outside option of working as low-skilled is still represented by the horizontal line, the income of a high-skilled worker θ is the linear function starting from the origin. The intersection of both income functions gives the educational cut-off value θ_B. As in the private system, a higher relative wage p increases the incentive to educate resulting in a lower educational cut-off θ_B. Beside that, increased per capita spending of resources in the educational sector (a higher E_B) increases *ceteris paribus* the number of students (a lower θ_B).

[11] Throughout the paper, cut-off values with tilde ($\tilde{\theta}_i$) denote cut-off values of education compatible with an equilibrium in the educational sector for alternative educational systems.

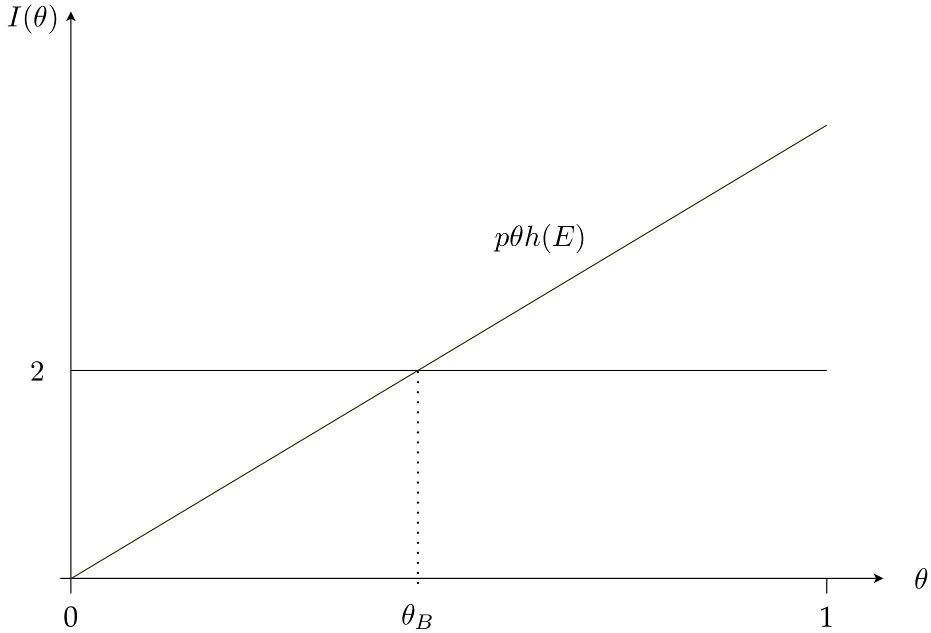

Figure 4.2: Derivation of the conditional cut-off value in the public system $\theta_B(p)$.

The overall effect on human capital available for production depends on total resources devoted to education and on the actual number of students S. Because the number of students in the public system $S_B = 1 - \tilde{\theta}_B$ is endogenous and depends on the educational cut-off value as well as on the total resources T, the resulting teacher-student ratio E is also endogenous. This means that the total effect of an increase of p is partly offset by a decrease in E. By substituting for E in (4.19) by $T/(1 - \tilde{\theta}_B)$, the equilibrium cut-off value $\tilde{\theta}_B$ for given resources in the public sector, T, is the solution of:

$$\frac{\theta_B}{(1-\theta_B)^{\delta}} = \frac{2}{\omega T^{\delta}}. \tag{4.20}$$

The LHS of (4.20) is a mapping of $[0, 1] \rightarrow [0, \infty)$ that is increasing in θ_B. Therefore, each value of $p \geq 0$ is mapped to a single θ_B. We describe the cut-off value $\tilde{\theta}_B(p, T)$ as a function of the relative wage p and total teaching resources T. The educational cut-off value $\tilde{\theta}_B$ depends negatively on p:[12]

$$\frac{\partial \tilde{\theta}_B}{\partial p} = -\frac{\tilde{\theta}_B}{p} \frac{(1-\tilde{\theta}_B)}{(1-\tilde{\theta}_B) + \delta \tilde{\theta}_B}. \tag{4.21}$$

The first term $(\tilde{\theta}_B/p)$ measures the direct impact of an increase of the relative wage p at a constant teacher-student ratio[13] while the second term $([1-\tilde{\theta}_B]/([1-\tilde{\theta}_B] + \delta\tilde{\theta}_B) < 1)$ is a measure of the congestion effect of increased number of students opting for further education. The negative effect on education incentives from congestion, however, cannot dominate the the positive effect from higher wage income.

The net supply of skilled labour available for production $\eta_B(p,T)$ can be written as a function of $\tilde{\theta}_B(p,T)$ which in turn depends on p and T:

$$\begin{aligned} \eta_B(p,T) &= \int_{\tilde{\theta}_B(p)}^{1} \theta \left(\frac{T}{S}\right)^{\delta} - \frac{T}{S} d\theta \\ &= [1-\tilde{\theta}_B(p)] \left(\frac{T}{1-\tilde{\theta}_B(p)}\right)^{\delta} \frac{1}{2}[1+\tilde{\theta}_B(p)] - T. \end{aligned} \tag{4.22}$$

The first term of (4.22) is the total amount of skilled labour which is given by the number of students $[1-\tilde{\theta}_B]$ times the net human capital of the representative student $\frac{1}{2}[1+\tilde{\theta}_B]E^{\delta}$. Subtracting the total number of teacher T gives us the net supply of skilled labour which can be used in the production sector. Clearly, the amount of net human capital can be negative if the public per capita investment E is too high: $\frac{1}{2}[1+\tilde{\theta}_B] < E^{1-\delta}$. Because a negative amount of human capital is impossible and for that reason cannot represent an equilibrium, we will rule out this case.

The net supply of human capital $\eta_B(p,T)$ is increasing in p as long as $\tilde{\theta}_B > \delta/(2-\delta)$. This is because public education provides an average teaching level E for each student. That level, however, is optimal for only one specific ability level $\hat{\theta}$. Each individual with ability below or above that certain ability level $\theta \neq \hat{\theta}$ is supplied with an E that is either too high or too low compared to their optimal investment level $e_d(\theta)$. Therefore, the investment of E for every individual with $\theta < \delta/(2-\delta)$ results in a net loss of human capital. One possible solution for public systems to overcome the problem is

[12] We drop the functional arguments when this causes no confusion.

[13] Note, that the first term $\tilde{\theta}_B/p$ is the derivative of (4.19) with respect to p.

that some minimum ability standards are introduced at the ability level $\delta/(2-\delta)$. So every individual with abilities lower than $\delta/(2-\delta)$ is not allowed to enter universities. Many countries have in one or the other way such minimum standards. To simplify the exposition we will assume that once the minimum admission standard is binding ($\tilde{\theta}_B < \delta/(2-\delta)$ no additional students will enter universities.[14] Consequently, $\partial\eta_B/\partial p > 0$ for $\tilde{\theta}_B \geq \delta/(2-\delta)$.

Eventually, the supply of low-skilled labour is given by:

$$L_B(p,T) = 2 \int_0^{\tilde{\theta}_B(p)} d\theta = 2\tilde{\theta}_B(p),$$

with $\partial L_B/\partial p < 0$ because $\partial\tilde{\theta}_B/\partial p < 0$ holds.

4.3.3 Mixed educational regime

Having considered the two polar institutional cases, we will now develop a mixed educational regime. This system is characterised by both an active public and an active private educational sector. A necessary condition for coexistence of both public and private education is, that the public threshold $\tilde{\theta}_B$ is strictly smaller that the private threshold $\tilde{\theta}_P$ (cf. figure 4.2 and 4.1). Otherwise no individual would prefer to enter the public system leading ex-post to a private system.

In this section we proceed as we did in the case of the public system by assuming that the teacher-student ratio is fixed at E. This has the advantage to work out the basic mechanism behind such a mixed educational system without considering the equilibrium effects. Then we will derive the equilibrium outcome in the mixed educational system with given resources T.

An individual θ has to decide whether to opt out of the public system by entering the privately funded university or work as an low-skilled worker. The pre-tax income function is then given by:

$$I_M(\theta) := \max\{I_H(E_M, p, \theta),\ I_H^*(p,\theta) - p_e e_d,\ I_L\}, \tag{4.23}$$

[14]For example, in Germany the "Abitur" is a de facto minimum admission standard for universities because without this degree studying is not possible.

where all elements are defined as before.[15] With a mixed educational system we will get two different equilibrium cut-off values: the lower cut-off value $\tilde{\theta}_{BM}$ dividing publicly educated and low-skilled workers, and another cut-off value $\tilde{\theta}_M$ dividing publicly and privately educated workers.[16]

Because the *conditional* cut-off value θ_{BM}[17] is defined as in corollary 4.2, we only need to describe the conditional cut-off value θ_M:

Corollary 4.3. *With a mixed educational system where $\tilde{\theta}_B \leq \tilde{\theta}_P \leq 1$ holds, the conditional educational cut-off value θ_M dividing public and private education is given by:*

$$\theta_M = \frac{\mu}{\delta} E_M^{1-\delta} \left(\frac{1}{1-\delta} \right)^{\frac{1-\delta}{\delta}} \quad . \tag{4.24}$$

The derivation of the two different cut-off values in the mixed educational system is depicted in figure 4.3. Both income curves are relevant in this case. The intersection of the income curve resulting from entering the public system and the income function generated from the private system defines the cut off-value θ_M. Obviously a higher teacher-student ratio E is associated with a higher educational cut-off value θ_M, because a public system offering a rather high educational quality increases life time income of any potential student. A better income generated by the public system means that a higher ability is needed such that opting out of the public system is profitable.

However, as in the exclusive public system, the number of students $S = \tilde{\theta}_M - \tilde{\theta}_{BM}$, and with it the teacher-student ratio $E_M = T/S$, is determined endogenously. Together with (4.24), (4.19) the equilibrium cut-off values $\tilde{\theta}_M$, $\tilde{\theta}_{BM}$ are the solution to the following system of equations:

$$\theta_M = \frac{\mu}{\delta} \left(\frac{T}{\theta_M - \theta_{BM}} \right)^{1-\delta} \left(\frac{1}{1-\delta} \right)^{\frac{(1-\delta)}{\delta}} \tag{4.25}$$

$$\theta_{BM} = \frac{2}{p} \left(\frac{\theta_M - \theta_{BM}}{T} \right)^{\delta} \tag{4.26}$$

[15] Subscript M denotes the mixed system.

[16] To distinguish the educational cut-off value of the exclusively public system θ_B from the public part in the mixed educational system we use the subscript BM.

[17] The subscript BM denotes the lower cut-off value of the publicly supplied part of the educational system.

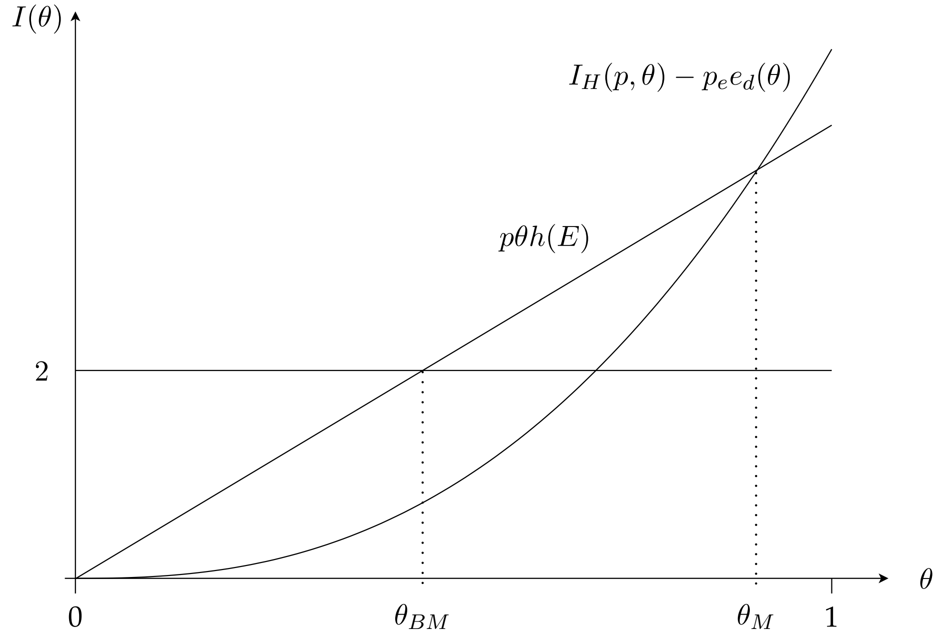

Figure 4.3: Derivation of the conditional cut-off values in the mixed system $\theta_{BM}(p)$, $\theta_M(p)$.

As shown in appendix 4.A.1, the locus defined by (4.25) is increasing in θ_{BM} with a slope less than unity while the locus defined (4.26) is increasing in θ_{BM} with slope exceeding unity. An interior solution, $\tilde{\theta}_{BM} < \tilde{\theta}_M < 1$, is guaranteed as long as the requirements for a coexistence of public and private education are met.

A change of the relative price p changes the equilibrium in the educational sector $\tilde{\theta}_M$, $\tilde{\theta}_{BM}$ as follows:

$$\frac{d\tilde{\theta}_M}{dp} = -\frac{\tilde{\theta}_{BM}}{p}\frac{\tilde{\theta}_M(1-\delta)}{(1-\delta)(\tilde{\theta}_M-\tilde{\theta}_{BM})+\tilde{\theta}_M} < 0 \tag{4.27}$$

$$\frac{d\tilde{\theta}_{BM}}{dp} = -\frac{\tilde{\theta}_{BM}}{p}\frac{[(\tilde{\theta}_M-\tilde{\theta}_{BM})+\tilde{\theta}_M(1-\delta)]}{(1-\delta)(\tilde{\theta}_M-\tilde{\theta}_{BM})+\tilde{\theta}_M} < 0 \tag{4.28}$$

It it important to note that the change in $\tilde{\theta}_{BM}$ exceeds the change in $\tilde{\theta}_M$. The basic mechanism of an increase in the relative price p can be described as follows: A higher relative price p increases the relative wage ω of high skilled which renders it profitable for formerly low-skilled workers to enter public universities. Together with an increasing number of students the teacher-student ratio deteriorates. As corollary 4.3 indicates, the most able students of the public system decide to opt out and enter the private system as E decreases. This will reduce the number of students in the public system and partially compensate for the congestion effect:

Proposition 4.1. *The transition from an exclusively public system of education to a mixed system of education reduces the congestion in the public part of the educational system:* $\frac{d\tilde{\theta}_{BM}}{dp} < \frac{d\tilde{\theta}_{B}}{dp}$.

Proof. Compare two otherwise identical economies: one with an exclusively public system and the other with a mixed system where in the latter case at the prevailing relative price p individuals with $\theta = 1$ are indifferent between entering private universities or not ($\tilde{\theta}_{BM} = \tilde{\theta}_B$ and $\tilde{\theta}_M = 1$). Transition means that and we evaluate (4.28) at $\tilde{\theta}_M = 1$ and $\tilde{\theta}_{BM} = \tilde{\theta}_B$. Comparing the resulting expression with (4.21) evaluated at $\tilde{\theta}_B$ yields the desired result and completes the proof □

The existence of a private alternative which is chosen by some of the students yields a positive externality for those students who enter the public system. This is, because the congestion effect is reduced, leading to a higher teacher-student ratio E compared to the case of an exclusively public system with the same number of teacher unit T in the public universities. Figure 4.4 illustrates this result. The dashed straight line represents the income function in the exclusively public system at the equilibrium value $\tilde{\theta}_B$ while the solid straight line represents the income function of the public part of the mixed system at the equilibrium values $\tilde{\theta}_{BM}(p)$, $\tilde{\theta}_M(p)$. Although the number of teachers in the public system is the same, the returns to schooling (the slope of the income function) in the public part of the mixed systems are higher than in the exclusively public system because the equilibrium teacher-student ratio is higher.

The net supply of high-skilled efficiency units is given by the sum of efficiency units of those students graduating from the public universities ($\tilde{\theta}_M - \tilde{\theta}_{BM}$) and those from the private universities ($1 - \tilde{\theta}_M$):

$$\eta_M(p,T) = \left(\tilde{\theta}_M(p) - \tilde{\theta}_{BM}(p)\right)\left(\frac{T}{\tilde{\theta}_M(p) - \tilde{\theta}_{BM}(p)}\right)^{\delta}[\tilde{\theta}_M(p) + \tilde{\theta}_{BM}(p)] - T + \int_{\tilde{\theta}_M(p)}^{1} e(\cdot)^{\delta}\theta - e(\cdot)d\theta. \quad (4.29)$$

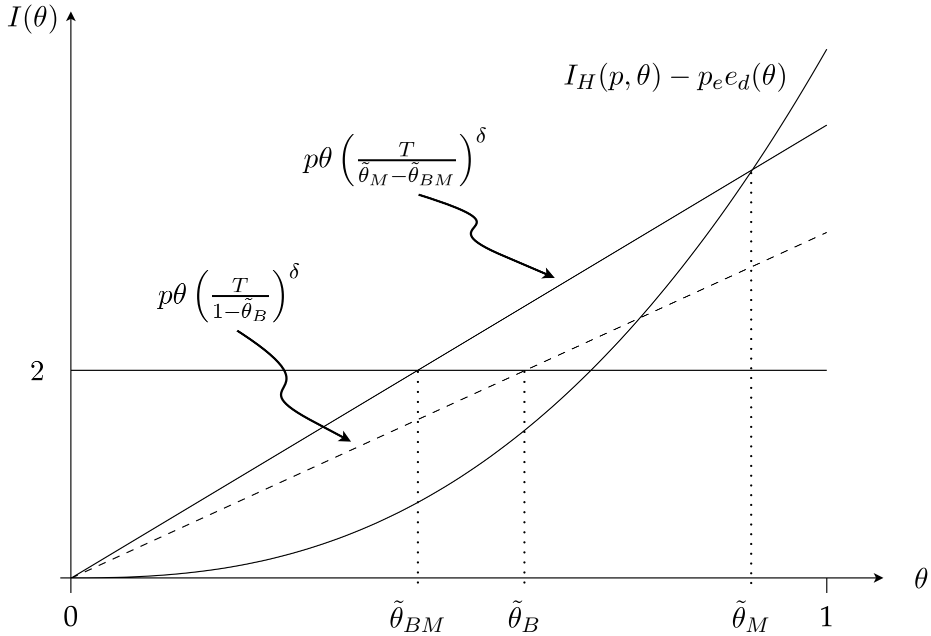

Figure 4.4: Comparison between the equilibrium outcome in the exclusively public system $\tilde{\theta}_B(p)$ and the mixed system $\tilde{\theta}_{BM}(p)$, $\tilde{\theta}_M(p)$ with the same number of teacher in the public system T.

Generally $\partial\eta_M/\partial p$ will be positive. As long as the endowment of the public system T is high enough, no individual will decide to attend private universities and we will have a corner solution of an exclusively public system: $\tilde{\theta}_{BM} = \tilde{\theta}_B < 1,\ \ \tilde{\theta}_M = 1$. Consequently, the supply of efficiency units of high-skilled labour will be the same as in the case of exclusively public universities.

Comparing for two otherwise identical countries the change in the supply of high-skilled efficiency units at the verge of transition yields the following proposition:

Proposition 4.2. *At the verge of transition the supply curve of the mixed system is steeper than the supply curve of the public system:*

$$\frac{\partial\eta_M}{\partial p} > \frac{\partial\eta_B}{\partial p}.$$

Proof. See appendix 4.A.2 □

The supply of efficiency units of low-skilled workers is given by:

$$L_M(p,T) = \int_0^{\tilde{\theta}_{BM}(p)} 2d\theta = 2\tilde{\theta}_{BM}. \tag{4.30}$$

Our model answers the question under which circumstances a mixed system is able to exist. But whether a mixed system is allowed to exist or not has to be regarded mainly as a political decision. If, for whatever reason, a society decides not to allow private universities in the educational sector, a transition from a exclusively public system to a mixed system will be prevented.

4.3.4 *Analysis of the different educational regimes*

Equipped with the formulation of the three different educational systems and its relevant cut-off values, we can now analyse how these different systems are related to each other. Depending on the actual system, the requirement that $\tilde{\theta}_i \in (0,1)$, $i = P, B, M$, restricts the admissible space of p and E. By fixing the teacher-student ratio, we take a different perspective as in the previous sections where fixed the total endowment. We do this because the basic mechanism of the different institution is easier to grasp with a given teacher-student ratio, and because we want to show that the mixed system supplies more human capital than the exclusively public system even in the case of identical teacher-student ratios.

For the public system this requirement leads to the necessary condition $p \geq 2/E^{\delta}$ as stated in corollary 4.2. This boundary condition holding with equality is depicted in (p, E)-space in figure 4.5. In the case of a private system corollary 4.1 stated the necessary condition to be $p \geq \frac{2}{1-\delta}\left(\frac{\mu}{\delta}\right)^{1/(1-\delta)}$ which is independent of E. This condition is illustrated by the horizontal line in figure 4.5. The mixed system places an additional restriction on the public part of the educational system: $E \leq (1-\delta)^{1/\delta}\left(\frac{\delta}{\mu}\right)^{1/(1-\delta)}$. This states that the public part should not be equipped to well. Otherwise the public system attracts all potential students, leaving no students for the private alternative. Furthermore, for both the public and private universities to exist in equilibrium we require $\tilde{\theta}_B < \tilde{\theta}_P < 1$. This implies the following condition: $p \geq \frac{2\delta}{\mu E}(1-\delta)^{\frac{1-\delta}{\delta}}$. Both conditions are illustrated in figure 4.5. The mixed educational system is only possible at the intersection of both conditions: $\tilde{\theta}_P, \tilde{\theta}_M \leq 1$, $\tilde{\theta}_B < \tilde{\theta}_P$. The hatched area in figure 4.5 illustrates the admissible combinations of E and p compatible with a mixed educational system.

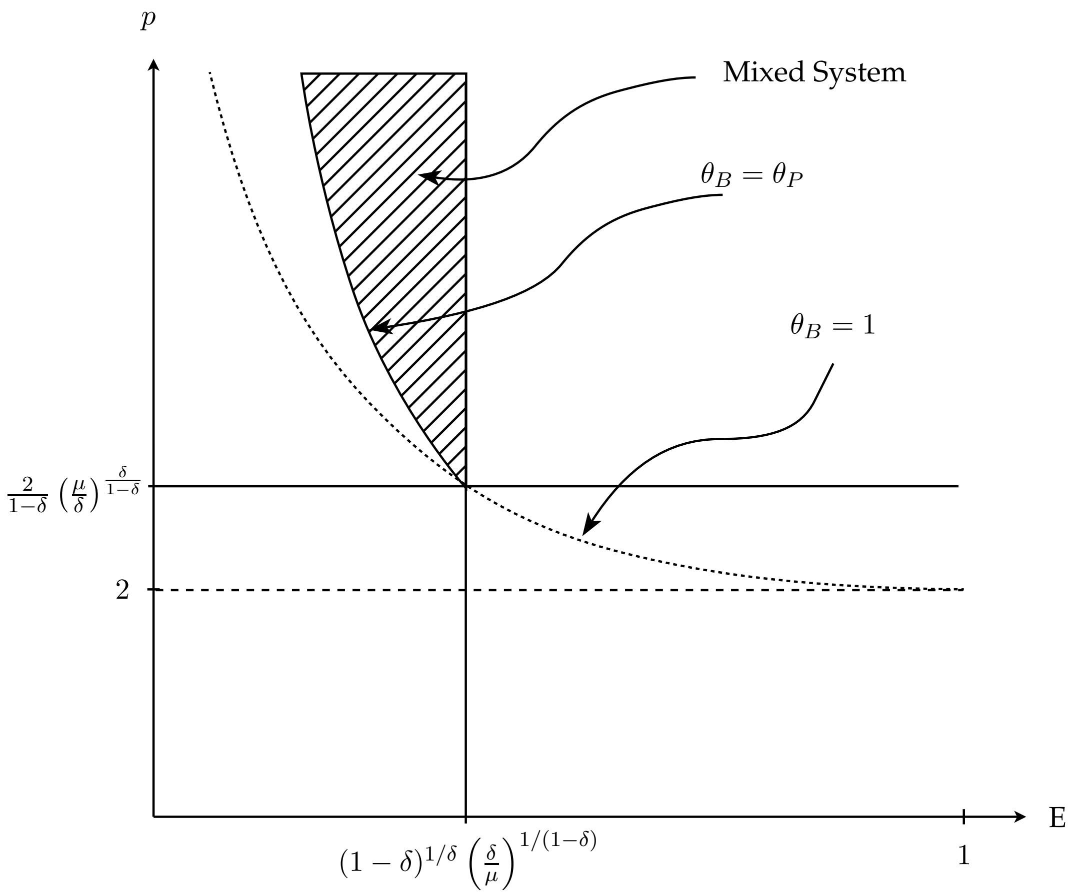

Figure 4.5: Admissible values for the different educational regimes

Next we compare the relative labour supply of the mixed and the public system where both share the same teacher-student ratio E.[18] As the public system and the mixed system share the same educational cut-off value $\tilde{\theta}_B(p, E)$ we arrive at the following proposition:

Proposition 4.3. *Even with identical teacher-student ratios E, the net relative labour supply of the mixed system $\frac{\eta_M(p,E)}{L_M(p,E)}$ is strictly greater than the net relative labour supply of the public system $\frac{\eta_B(p,E)}{L_B(p,E)}$.*

[18]By doing this, we seek to answer the question what the outcome for the public system would be if it transforms to a mixed system. That is, we look only at combinations of E and p which are admissible combinations (cf. figure (4.5)).

Proof. The cut-off value $\theta_B(p, E)$ is the same in both regimes, leading to the same supply of low-skilled workers $L_B(p, E) = L_M(p, E)$. For $\frac{\eta_M(p,E)}{L_M(p,E)} > \frac{\eta_B(p,E)}{L_B(p,E)}$ to hold, we have to show that $\eta_M(p, E) > \eta_B(p, E)$:

$$\int_{\theta_{BM}(p)}^{\theta_M} (\theta E^\delta - E)dF(\theta) + \int_{\theta_M}^{1} \theta e_d(\theta)^\delta - e_d(\theta)dF(\theta) > \int_{\theta_B(p)}^{1} (\theta E^\delta - E)dF(\theta).$$

Because $\theta_B(p, E) = \theta_{BM}(p, E)$ holds and both systems are identical up to θ_M, we only need to compare the remaining part $\theta \geq \theta_M$ of the mixed system with the public system:

$$\int_{\theta_M}^{1} \theta e_d(\theta)^\delta - e_d(\theta)dF(\theta) > \int_{\theta_M}^{1} (\theta E^\delta - E)dF(\theta).$$

This inequality holds if $\theta e_d(\theta)^\delta - e_d(\theta) > \theta E^\delta - E$ for $\theta \geq \theta_M$. From corollary 4.3 we know that the following condition holds:

$$p\theta e_d(\theta)^\delta - \mu p e_d(\theta) \geq p\theta E^\delta; \quad \theta \geq \theta_M \tag{4.31}$$

With $p\theta E^\delta > p\theta E^\delta - pE$ and $\mu \geq 1$, it follows that $\theta e_d(\theta)^\delta - e_d(\theta) > \theta E^\delta - E$ for $\theta \geq \theta_M$. □

Proposition 4.3 states that as long as a public system leaves room for a mixed system, this mixed system will outperform the public system in terms of total net human capital $\eta_M(\cdot)$ and consequently in terms of relative supply of skills η_M/L_M. This strengthens the result of proposition 4.2, because an identical teacher-student ratio for both system translates into a lower total amount of resources T in the mixed system compared to the exclusively public system. This means that less public resources are needed to ensure at least the same number of students in higher education but supplying more aggregate human capital.

In a world with two countries with the same per capita investment in public education E the country with the mixed system will be relatively skill abundant compared to the country with exclusive public education. Unfortunately, no clear-cut result with respect to is possible between the exclusively private and public system.

4.4 General equilibrium

4.4.1 *Closed economy*

The equilibrium of the closed economy can now exclusively be described in terms of the endogenous variable p. Relative supply and demand is given by:

$$\frac{Y}{X} = \frac{\eta_i(p)}{L_i(p)}, \qquad \frac{D_Y}{D_X} = \frac{(1-\lambda)}{\lambda p}; \qquad i = B, P, M.$$

As the relative demand curve is negatively sloped in the $(p, Y/X)$-space and the relative supply curve is positively sloped the system describes a unique equilibrium p^*. The respective equilibrium values of all other endogenous variables $L_i^*, \eta_i^*, X^*, Y^*$can then be calculated using the equilibrium value p^*.

4.4.2 *Educational system and relative supply*

In the subsequent analysis we assume that preferences are the same for each country. In order to illustrate how the educational system determines the relative supply curve, we begin with the public system of education. Assume two countries differing only in their endowment of the public system: $T_2 > T_1$. A higher endowment T leads to increased education in terms of the number of students as well as more efficiency units of high-skilled labour. This results in a higher relative supply of high-skilled labour at each relative wage ω and with it a higher relative supply of goods Y/X at each relative price p. This situation is depicted in figure 4.6: The better the educational sector is endowed the higher is *ceteris paribus* the relative supply and the lower is the relative price prevailing in equilibrium.

The mixed system of education is equivalent to the public system up to that specific relative price p where opting out of the public system is profitable for individuals with the highest ability ($\theta = 1$). The relative supply curve for $T = T_2$ is depicted in figure 4.6: Up to point A the solid segment represents the relative supply curve. Because no individual chooses the private university, the educational system must be regarded as an exclusively public system (solid segment). At point A the congestion effect leads to a deteriorating teacher-student ratio such that individuals with the highest ability

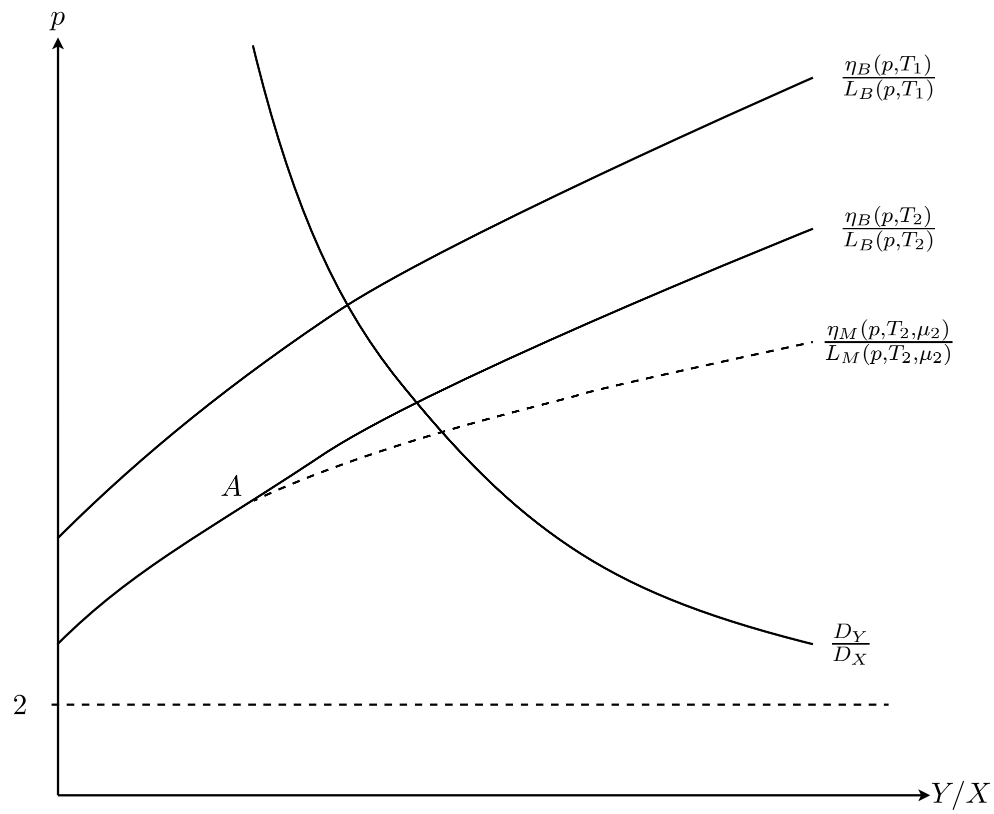

Figure 4.6: Relative demand and supply: Exclusively public system of education (solid), Mixed system of education (dashed segment)

will opt out of the public system. As a result, a new relative supply curve originates at point A (the dashed segment). Compared to an exclusively public system with the same endowment $T = T_2$, the relative supply increases and the equilibrium relative price decreases.

In contrast, the parameter which differentiates countries with an exclusively private system of education is the degree of distortion μ. A higher degree of distortion decreases the relative supply Y/X at each relative price p. However, as described in the previous section a comparison of the equilibrium outcome of an exclusively private system with either a public or a mixed system of education is not directly possible.

4.5 Trade and educational policy

4.5.1 *Comparative advantage*

We consider a two-country world where differences in the educational sector are the only source for trade in goods between countries. Consumer preferences and production technologies are assumed to be identical in both countries. As described in the previous sections, differences arise either from different institutional arrangements, differences in the degree of distortions μ and/or the volume of public investment in education T.

First, we concentrate on the case where the "world" consists of countries with only one kind of educational institution. If all countries have a private system of education, then those countries with a low degree of distortion μ have a comparative advantage in the production of the high-tech good Y. In that case, our model yields the same result as, e.g., Falvey et al. (2005).[19] The better the private supply of education, the more likely is a comparative advantage in these goods using educated workers more intensively.

In a world consisting of countries with an exclusively public system of education, the volume of public investment in education is the determinant of comparative advantage. As depicted in figure 4.6 the country with investment level T_2 has a higher relative supply Y/X at each relative price p compared to a country with lower investment level $T_1 < T_2$. A country with a higher investment level T will have comparative advantage in the high-tech good Y. This educational regime gives exactly the result of Findlay and Kierzkowski (1983). As in our model, the sector-specific capital is the driving force behind comparative advantage.

Things are different in a world consisting of countries that both have a mixed system of education. The mixed system relies on the investment level T as well as on the degree of distortions μ. The lower the degree of distortions μ, the more likely is the coexistence of a public and a private university. This means that even though two countries have the same public investment level T, their relative supply Y/X will differ. The case with two countries $\mu_1 > \mu_2$ is depicted in figure 4.7: The economy with a higher degree of distortion μ_1 is represented by the relative supply curve going trough point B while the country with μ_2 is represented by the relative supply curve going trough point A. A

[19] Falvey et al. (2005) assume that education is private and the efficiency of the educational sector is reflected by the number of efficiency units an individual has to rent. The higher the efficiency the less efficiency units an individual has to rent.

higher degree of market failure decreases the teacher-student ratio necessary to induce individuals to opt out of the public system. The country with a lower degree of distortion will be skill abundant and has a comparative advantage in good Y compared to the the country with a higher degree of market failure.

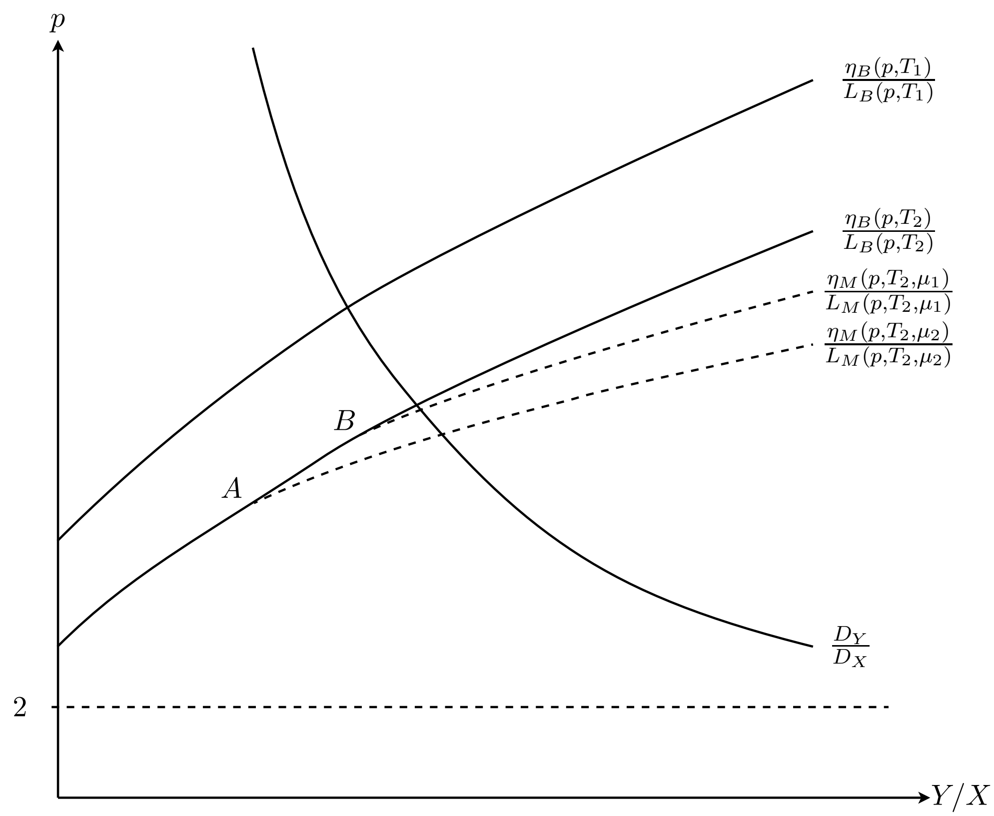

Figure 4.7: Relative demand and supply: Exclusively public system of education (solid), Mixed system of education (dashed segments) with a different amount of distortions $\mu_1 > \mu_2$

4.5.2 *Globalisation shock in an asymmetric world*

In this section we consider the case of the entry of unskilled abundant countries like China into an already integrated world market. We assume that two trade blocks are already integrated, namely the United States and Europe, such that the US is being characterised by a mixed educational system and Europe being characterised by an exclusively public system of education. This means, that the amount of public resources in the educational system is assumed to be higher than in the US: $T_{EU} > T_{US}$.[20]

A globalisation shock is modelled as the entry of previously closed developing or newly industrialising countries such as China. It is further assumed that, at the pre-globalisation price ratio p_0, these new entrants are net supplier of low-skilled labour intensive goods. Integration then generates a change in the equilibrium price from p_0 to $p_1 > p_0$. As a result, in both the US and Europe education is getting more profitable such that the number of students increases. In Europe, we may additionally have a change in the educational system from an exclusively public to a mixed educational system. This may happen, if the teacher-student ratio falls below the critical value such that students opt out of the public system.[21]

In figure 4.8 we provide some evidence that such a change has been taken place in Germany during the last 25 years: between the 1980 and 2005 a total of 46 universities and universities of applied science had been founded. Together with the 10 universities which were established during the decades before 1980 the number of private universities (and universities of applied science) in Germany rose to 56.[22] Most of the foundations took place between 1990 and 2000 with an average of approximately 3 foundations per year.

4.6 Conclusions

We have developed a model of international trade that accounts for the different institutional arrangements in the educational sector with endogenous regime choice. In our model the institutions of the educational sector constitute the comparative advantage of a country. Countries lacking a well developed public system of higher education and imperfect credit markets, a situation which applies to many less developed countries, will have a comparative advantage in low-skilled intensive production. For this group of

[20]Even with a $T_{EU} < T_{US}$ an exclusively public system will be in place in Europe if for whatever reason a private system is not allowed to exist. Indeed, there is evidence that in many countries regulations in the educational sector are rather strict.

[21]As mentioned above, in case of a strict regulation this endogenous change might be hindered.

[22]Source: Hochschulrektorenkonferenz, own data collection. These data include private universities which are state-approved. Not included are any ecclediastical universities.

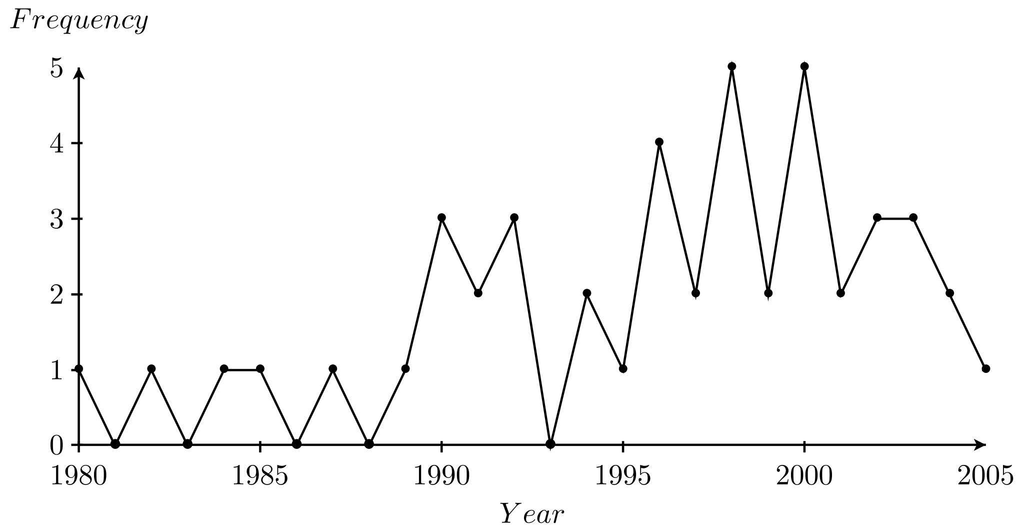

Figure 4.8: Number of newly founded private universities (of applied science) in Germany between 1980 and 2005

countries, trade liberalisation can have a strong negative effect on the educational sector, because increased world-market integration reduces the relative wage of high-skilled labour and with it the incentives to educate.

As a second result, our model can explain an endogenous change of the educational system as consequence of trade liberalisation. Globalisation may evoke the foundation of private universities in a country with a public system of education and a comparative advantage in high-skilled labour intensive goods. This is because an increased relative wage induces more individuals to choose higher education while at the same time decreasing the quality of public education by congestion. As a result, formerly unattractive private universities become attractive thereby reducing congestion of public universities. The total effect is a higher incentive for the most able individuals to enter a private university. Educational policy can make use of this incentive effect to increase the efficiency of the public system while increasing human capital accumulation of the most able individuals. The policy implication here is that policy makers should not oppose the foundation of a private sector of higher education, because it fosters human capital acquisition and lowers the congestion effects of increasing numbers of students in the public system. However, drastic privatisation in terms of transforming the public system of higher education to a system consisting of private universities only can lead to a loss of the comparative advantage in high-skilled intensive goods.

Within our framework we are also able to show how different contributions of the literature which explicitly model human capital acquisition in trade models relate to certain educational systems. In particular, we can show that the model of Findlay and Kierzkowski (1983) and results relate to a public system of education. This is of immportance, because their model is a workhorse in the relevant literature.

Our approach provides promising scope of extensions that will be addressed in future research. First of all, it can be used to analyse whether educational institutions play a decisive role or not in the determination of the distributional consequences of trade liberalisation. This problem has been emphasised in, e.g., Meckl and Weigert (2003), but without a detailed description of the educational system. Furthermore, educational institutions are not considered in models of knowledge based intra-industrial trade as discussed by, e.g., Dinopoulos and Segerstrom (1999). As policy makers consider educational policy as tool to increase international "competitiveness" of a country, it is important to know which educational institutions are best-suited to reach this goal. Other extensions should introduce the political process, because our model is used to analyse the *consequences* of different institutions, but it gives no answer to the question why a certain institution has been chosen. Additionally, capital market imperfections as a justification of a public system of higher education should be introduced to discuss the optimal path of educational policy over time and its feedback effect on international trade.

4.A Appendix

4.A.1 Equilibrium in the educational sector of the mixed system

In the mixed system an equilibrium in the educational sector is described by the following set of equations:

$$\phi_1 \equiv \theta_M \quad - \quad \frac{\mu}{\delta}\left(\frac{T}{\theta_M - \theta_{BM}}\right)^{1-\delta}\left(\frac{1}{1-\delta}\right)^{\frac{(1-\delta)}{\delta}} = 0, \tag{4.A.1}$$

$$\phi_2 \equiv \theta_{BM} \quad - \quad \frac{2}{p}\left(\frac{\theta_M - \theta_{BM}}{T}\right)^{\delta} = 0. \tag{4.A.2}$$

The slope of the loci described by (4.A.1) and (4.A.2) is given by:

$$\left.\frac{d\theta_M}{d\theta_{BM}}\right|_{\phi_1=0} = \frac{\theta_M(1-\delta)}{(\theta_M - \theta_B) + \theta_M(1-\delta)} < 1,$$

$$\left.\frac{d\theta_M}{d\theta_{BM}}\right|_{\phi_2=0} = \frac{(\theta_M - \theta_{BM}) + \theta_{BM}\delta}{\theta_{BM}\delta} > 1.$$

A variation of the relative price p only affects the (4.A.2) without changing (4.A.1). An increase of p shifts the locus of (4.A.2) inwards thereby reducing both $\tilde{\theta}_M$ and $\tilde{\theta}_{BM}$. The equilibrium change of $\tilde{\theta}_M$ and $\tilde{\theta}_{BM}$ is given by:

$$\frac{d\tilde{\theta}_M}{dp} = -\frac{\tilde{\theta}_{BM}}{p}\frac{\tilde{\theta}_M(1-\delta)}{(1-\delta)(\tilde{\theta}_M - \tilde{\theta}_{BM}) + \tilde{\theta}_M} < 0, \tag{4.A.3}$$

$$\frac{d\tilde{\theta}_{BM}}{dp} = -\frac{\tilde{\theta}_{BM}}{p}\frac{[(\tilde{\theta}_M - \tilde{\theta}_{BM}) + \tilde{\theta}_M(1-\delta)]}{(1-\delta)(\tilde{\theta}_M - \tilde{\theta}_{BM}) + \tilde{\theta}_M} < 0, \tag{4.A.4}$$

with $\frac{d\tilde{\theta}_{BM}}{dp} < \frac{d\tilde{\theta}_M}{dp}$ because $\tilde{\theta}_M > \tilde{\theta}_{BM}$.

4.A.2 Proof of proposition 4.2

Proof. We compare two countries differing in their educational system (public system vs. mixed system) but with the same public endowment T. We compare (4.22) and (4.29) at the verge of transition which means that $\tilde{\theta}_{BM} = \tilde{\theta}_B < 1,\ \tilde{\theta}_M = 1$ is an interior solution to the system described by (4.25) and (4.26). Differentiation of (4.22) and (4.29) with respect to p yields and evaluating $\partial\eta_M/\partial p$ at $\tilde{\theta}_M = 1$:

$$\frac{d\eta_B}{dp} = \left(\frac{T}{1-\tilde{\theta}_B}\right)^{\delta}\left(\frac{\delta}{2}[1+\tilde{\theta}_B]-\tilde{\theta}_B\right)\frac{d\tilde{\theta}_B}{dp}, \tag{4.A.5}$$

$$\begin{aligned}\frac{d\eta_M}{dp} &= -\left(\frac{T}{\tilde{\theta}_M-\tilde{\theta}_{BM}}\right)^{\delta}\frac{\delta}{2}[\tilde{\theta}_M+\tilde{\theta}_{BM}]\left(\frac{d\tilde{\theta}_M}{dp}-\frac{d\tilde{\theta}_{BM}}{dp}\right)-\left(e(\tilde{\theta}_M)^{\delta}\tilde{\theta}_M-e(\tilde{\theta}_M)\right)\frac{d\tilde{\theta}_M}{dp}\\ &+ \left(\frac{T}{\tilde{\theta}_M-\tilde{\theta}_{BM}}\right)^{\delta}[\tilde{\theta}_M\frac{d\tilde{\theta}_M}{dp}-\tilde{\theta}_{BM}\frac{d\tilde{\theta}_{BM}}{dp}].\end{aligned} \tag{4.A.6}$$

We know from (4.24) that for $\mu > 1$, $\tilde{\theta}_M e(\tilde{\theta}_M)^{\delta} - e(\tilde{\theta}_M) > \tilde{\theta}_M e(\tilde{\theta}_M)^{\delta} - \mu e(\tilde{\theta}_M) = \left(T/\left(\tilde{\theta}_M-\tilde{\theta}_{BM}\right)\right)^{\delta}\tilde{\theta}_M$ holds. Therefore, it is sufficient to show that for $e(\tilde{\theta}_M)^{\delta}\tilde{\theta}_M - \mu e(\tilde{\theta}_M)$ the slope of the supply function of the mixed system is larger than the slope of the public system: $\left.\frac{d\eta_M}{dp}\right|_{\tilde{\theta}_M=1} > \frac{d\eta_B}{dp}$. Evaluating (4.A.6) at $\tilde{\theta}_M = 1$ and using $e(\tilde{\theta}_M)^{\delta}\tilde{\theta}_M - \mu e(\tilde{\theta}_M)$ instead of $e(\tilde{\theta}_M)^{\delta}\tilde{\theta}_M - e(\tilde{\theta}_M)$ yields:

$$\frac{d\eta_M}{d\omega} = \frac{\delta}{2}[1+\tilde{\theta}_{BM}]\left(\frac{d\tilde{\theta}_M}{dp}-\frac{d\tilde{\theta}_{BM}}{dp}\right)+\left(\frac{T}{1-\tilde{\theta}_{BM}}\right)^{\delta}\tilde{\theta}_{BM}\frac{d\tilde{\theta}_{BM}}{dp}. \tag{4.A.7}$$

Using (4.A.5) and (4.A.7) in the inequality $\left.\frac{d\eta_M}{dp}\right|_{\tilde{\theta}_M=1} > \frac{d\eta_B}{dp}$ and bearing in mind that $\tilde{\theta}_{BM} = \tilde{\theta}_B$, yields:

$$\begin{aligned}-\frac{\delta}{2}[1+\tilde{\theta}_{BM}]\left(\frac{d\tilde{\theta}_M}{dp}-\frac{d\tilde{\theta}_{BM}}{dp}\right)-\tilde{\theta}_{BM}\frac{d\tilde{\theta}_{BM}}{dp} &> \frac{\delta}{2}[1+\tilde{\theta}_B]\frac{d\tilde{\theta}_B}{dp}-\tilde{\theta}_B\frac{d\tilde{\theta}_B}{dp}\\ -\frac{\delta}{2}[1+\tilde{\theta}_{BM}]\left(\frac{d\tilde{\theta}_M}{dp}-\frac{d\tilde{\theta}_{BM}}{dp}+\frac{d\tilde{\theta}_B}{dp}\right)-\tilde{\theta}_B\left(\frac{d\tilde{\theta}_{BM}}{dp}-\frac{d\tilde{\theta}_B}{dp}\right) &> 0.\end{aligned}$$

Evaluating the first a term in brackets results in:

$$\frac{d\tilde{\theta}_M}{dp}-\frac{d\tilde{\theta}_{BM}}{dp}+\frac{d\tilde{\theta}_B}{dp}=\frac{\tilde{\theta}_B}{p}\left(\frac{(1-\tilde{\theta}_B)}{(1-\tilde{\theta}_B)+\delta\tilde{\theta}_B+(1-\delta)}-\frac{(1-\tilde{\theta}_B)}{(1-\tilde{\theta}_B)+\delta\tilde{\theta}_B}\right)<0.$$

Together with result from proposition 4.1 that $\frac{d\tilde{\theta}_{BM}}{dp} < \frac{d\tilde{\theta}_B}{dp}$ we get the stated result that $\left.\frac{d\eta_M}{dp}\right|_{\tilde{\theta}_M=1} > \frac{d\eta_B}{dp}$. □

4.A.3 *Educational decision with credit constraints*

We will show that the assumption of monopolistic competition between private universities leads to the same qualitative results as modelling the educational decision with credit constraints and perfect competition between universities.

As stated in the text, using an exogenous parameter μ to capture inefficiencies of the private schooling system leads to (a) lower individual demand for education and (b) to lower aggregated educational attainment.

Assume that abilities are still distributed uniformly on the closed interval $[0, 1]$ and that the educational decision is the same as stated in section 4.2.1 except that each student has to pay its fees during the first period of life. To simplify the exposition we further assume that individual endowment W at the beginning of the first period is uniformly distributed on the closed interval $[W_0, W_1]$. Additionally we assume that the individual endowment is independent of individual ability θ: $f(W, \theta) = f(W)f(\theta) = \frac{1}{(W_1 - W_0)}$. The optimal demand for education given individual ability θ is still given by (4.11) evaluated at $\mu = 1$. However, because credit markets are absent the individual endowment needed to invest optimally in human capital is given by $W \geq w_H e_d(\theta)$ which is increasing in θ. With $W < w_H e_d(\theta)$ an individual is constrained by its endowment and will only invest into further education if the investment of his total endowment $e = W/w_H$ yields a higher total income than working as low-skilled worker. This yields a necessary endowment $\bar{W}(\theta)$ defined by:

$$w_H \theta \left(\bar{W}/w_H\right)^{\delta} = 2w_L + \bar{W}. \tag{4.A.8}$$

The $\theta - \bar{W}$ locus originates at the point $(\tilde{\theta}_P, w_H e_d(\tilde{\theta}_P)$ and has slope

$$\frac{d\bar{W}}{d\theta} = -\frac{w_H \left(\bar{W}/w_H\right)^{\delta}}{\theta\delta \left(\bar{W}/w_H\right)^{\delta-1} - 1} < 0. \tag{4.A.9}$$

Note that the denominator of (4.A.9) is positive, because being constrained means that $\frac{W}{w_H} < e_d(\theta)$ such that $w_H \theta h'(W/w_H) > w_H$. Because the necessary endowment $\bar{W}$ to invest is decreasing with the individual ability θ it renders endowment and abilities imperfect substitutes. Any individual with abilities $\theta \geq \tilde{\theta}_P$ should invest into higher education but only those individuals θ with $W \geq \bar{W}(\theta)$ can afford investment. Therefore the group of students is divided in two subgroups: those with $W \geq w_H e_d(\theta)$ who invest optimally and those with $W \in [\bar{W}(\theta_H e_d(\theta))$ who invest suboptimally. The different cases are depicted in figure 4.9. Compared to the case without any credit market constraints the average investment level per ability θ in terms of e is smaller:

$$\overline{e}(\theta) = \frac{1}{(W_1 - W_0)} \left(e_d(\theta)\left(W_1 - w_H e_d(\theta)\right) + \int\limits_{\bar{W}(\theta)}^{w_H e_d(\theta)} W/w_H dW \right) < e_d(\theta).$$

Those who cannot afford to invest into higher education work as low-skilled worker, thereby reducing the total number of students. Note that lower wealth in the economy W_1 and W_0 intensifies the impact of imperfect credit markets. Thus the introduction of monopolistic competition yields the same qualitative results as explicitly considering credit market imperfections. It is important to keep in mind that the example given here is the polar case of a non-existent credit market for educational loans. With a loan market the result is qualitatively the same as long as there is a positive yield spread between educational loans and other investments which results e.g. from asymmetric information between lenders and borrowers. However, a third subgroup of students will exist in this case: those who have insufficient funds to finance their investment and take a loan to enter the university.

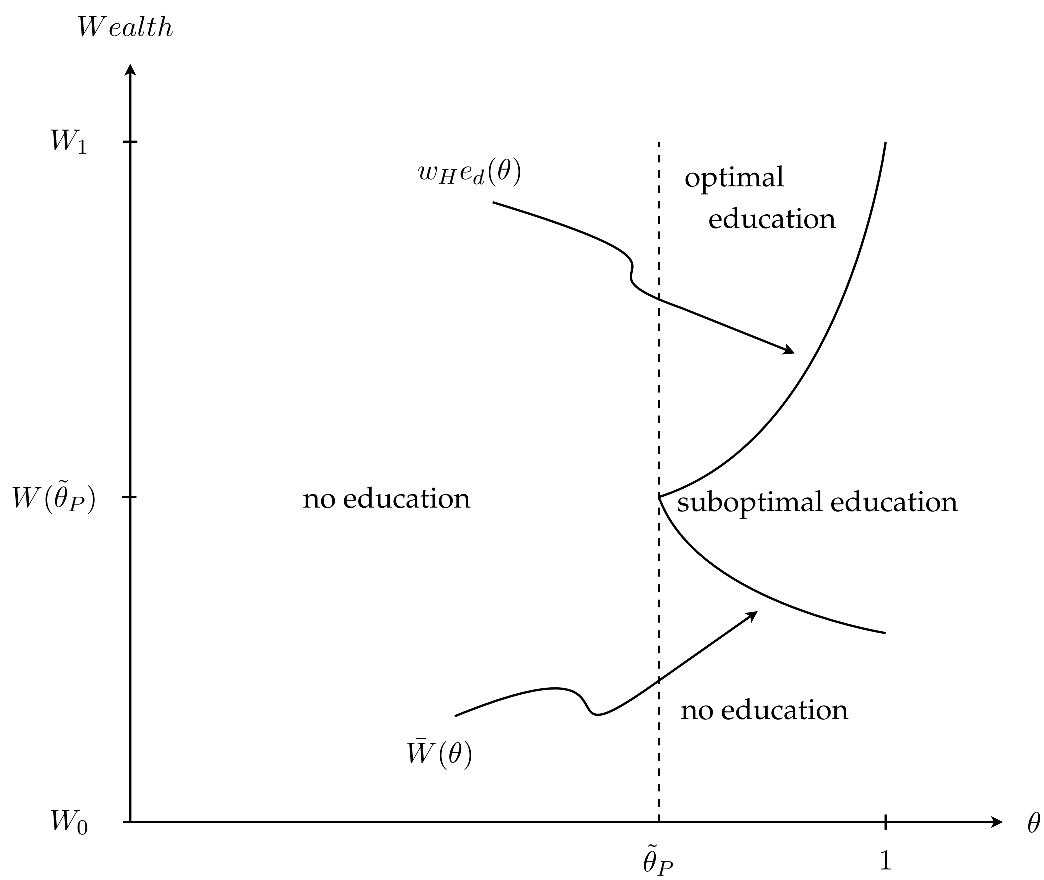

Figure 4.9: Credit constrained private education

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Erklärung

Ich erkläre hiermit, dass ich die vorliegende Arbeit mit dem Thema

Four Essays on International Trade and Labour Markets

ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Die aus anderen Quellen direkt oder indirekt übernommenen Daten und Konzepte sind unter Angabe der Quelle gekennzeichnet. Weitere Personen, insbesondere Promotionsberater, waren an der inhaltlich materiellen Erstellung dieser Arbeit nicht beteiligt. Die Arbeit wurde bisher weder im In- noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

Gießen, 6. February, 2007

(Benjamin Weigert)

Abgrenzung

Kapitel 1 entstammt einer gemeinsamen Arbeit mit Herrn Prof. Dr. Jürgen Meckl (Universität Gießen). Die individuelle Leistung im Rahmen dieser Arbeit gliedert sich wie folgt:

i. Introduction:
50% Meckl / 50% Weigert
ii. The model:
50% Meckl / 50% Weigert
iii. Price changes and the skill premium:
50% Meckl / 50% Weigert
iv. Conclusions:
50% Meckl / 50% Weigert

Kapitel 2 entstammt einer gemeinsamen Arbeit mit Herrn Christian Lumpe (Universität Gießen). Die individuelle Leistung im Rahmen dieser Arbeit gliedert sich wie folgt:

i. Introduction:
50% Lumpe / 50% Weigert
ii. The model:
50% Lumpe / 50% Weigert
iii. Price changes and the skill premium:
50% Lumpe / 50% Weigert
iv. Immigration and the labour market:
50% Lumpe / 50% Weigert
v. Conclusions:
50% Lumpe / 50% Weigert

Kapitel 3 entstammt einer gemeinsamen Arbeit mit Herrn Christian Lumpe (Universität Gießen). Die individuelle Leistung im Rahmen dieser Arbeit gliedert sich wie folgt:

i. Introduction:
50% Lumpe / 50% Weigert
ii. Basic model:
50% Lumpe / 50% Weigert
iii. Efficiency and labour policies:
50% Lumpe / 50% Weigert
iv. Extension:
50% Lumpe / 50% Weigert
v. Conclusions:
50% Lumpe / 50% Weigert

Ich versichere hiermit, dass ich Kapitel 4 der vorliegenden Arbeit ohne Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe.

Gießen, 6. Februar, 2007

(Benjamin Weigert)