FDI decision-making and multinationalization

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Tiivistelmä – Referat – Abstract

Foreign direct investment (FDI) flows have increased tremendously in the past twenty years, and these investments have grown especially in developing economies. FDI has become an efficient mechanism to increase economic development in poor countries. This thesis opens up the decision-making process of developed countries related to FDI decisions. The main focus is to concentrate on FDI in developing countries, and how they try to find relevant policies in order to attract more FDI flows. Some relevant empirical findings between China and Sub-Saharan Africa are shown to support the benchmark model. The model does not go through every possible aspect of FDI but shows how different southern technology frontiers and risks in production might affect the final FDI flows in developing countries.

The benchmark model is a North-South model where the North and South are the developed and developing country, respectively. The main feature of this model is that a northern firm might opt out of doing FDI, if the technology frontier in a southern industry is too low for a northern firm with a relatively high technology. This situation might cause a risk of FDI quality failure, where the production chain in the South fails to complete successfully. This kind of failure is possible, if the skills or knowledge of the southern workers is not high enough. The benchmark model is later extended with the innovative and imitative South in this thesis, and lastly technology-neutral risks are introduced and added to the benchmark model.

The benchmark model shows that only firms with intermediate technology levels in the North move production to the South or become multinationals. Additionally, more multinational production increases the technology frontier in the South and eventually decreases the risk of FDI quality failure. This development leads to more FDI flows and widens the technology spectrum of the multinational firms. The aim of governments in developing countries is to increase their technology frontiers in different industries. This thesis goes through many important policy parameters which can improve the technology frontier in the South and eventually lead to more multinational production.

Avainsanat – Nyckelord – Keywords

Foreign Direct Investment, Multinational Enterprises, Technology Frontier, Risk, Imitation, Developing Countries

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List of symbols

$\frac{1}{1-\alpha}$	Price elasticity of demand for each variety of an industry
$\Gamma(\cdot)$	Learning function
δ_D	Depreciation rate of the South's learning experiences
δ_L	Learning speed in the South
Θ^S	Technology content of inward FDI
θ	Technology level of a northern firm
$\lambda(s)$	The intensity of effort used to carry out step s
π^S, π^N	Profits in the South and North
$\frac{1}{1-\rho}$	Elasticity of substitution between any two steps s
$c^l(\theta)$	Cost function
f^S, f^N	Fixed costs in the South and North
$G(\theta)$	Cumulative distribution function
i	Imitation in the South
K	Infrastructure in the South
$p_j(i)$	Price of variety i of industry j
Q_t^S	Discounted multinational production at time t
r	Technology-neutral risk
s	Number of steps in production
T_t^S	Technology frontier in the South at time t
T_0^S	Initial technology frontier in the South
w^S, w^N	Wage rates in the South and North

X^S	Multinational production
$x_j(i)$	Demand for variety i of industry j
z	Risk parameter of FDI

1 Introduction

Foreign direct investment (FDI) is an investment in a business by an investor from another country, and the foreign investor also has control over the company purchased. The Organization of Economic Cooperation and Development (OECD) defines control as owning 10% or more of the business. Businesses that make foreign direct investments are often called multinational corporations (MNCs) or multinational enterprises (MNEs). MNEs can make a direct investment by creating a new foreign enterprise which is called a green field investment. For example a subsidiary in a foreign country is an investment of this type. Another type of FDI is a brown field investment which can for example be an acquisition of a foreign firm. A firm can be merged with another firm in a receiving country of FDI. The other important concept is multinationalization which is not that easy to define. My own definition of multinationalization is that a firm decides to start doing FDI in a different country/countries where its headquarters is located. A MNE is thus operating or at least partly controlling the business abroad in one or more countries simultaneously.

One of my main interests in this thesis is to analyze the decision-making process of firms doing FDI from the perspective of developing countries. Governments in developing countries have to understand how the developed countries decide their foreign investment location in order to attract FDI. The next chapter is going to support the fact, that FDI can be beneficial for developing countries. The connection between FDI, economic growth, poverty, and inequality is analyzed there. This thesis deals with the following issues related to the decision-making process of firms doing FDI:

1) Differences in technology (frontier) levels between the FDI host countries and the firms doing FDI
2) Risk of FDI quality failures because of technology gaps
3) Intellectual property rights (IPR), innovation and imitation in the host countries of FDI
4) Technology-neutral risks for all industries in the receiving countries of FDI

FDIs between developed and developing world have increased very rapidly in the last ten to twenty years. As expected, Asia is the biggest receiver of FDI (measured in year 2014) when talking about developing economies. Asia had FDI inflows of roughly $US 465 000 millions compared to Africa's $US 54 000 millions in year 2014 (UNCTAD 2016). Figure 1 below shows how Africa has quickly increased its part of the world's FDI flows. In 1990, Africa was receiving practically zero FDI, but today it is not any more an insignificant factor in the field of FDI.

Traditionally FDI flows have gone to the industrialized countries, but developing countries have become increasingly attractive FDI destinations in recent years. One of the main fears for Western countries is a risk of losing competitiveness because of low production costs in the emerging countries (Hajzler 2014). For example China has received a lot of FDI flows in recent years, and China's economic growth has definitely benefited from this. In the future Africa might be a huge possibility for FDI firms, and this could help Africa to speed up its economic development. It is possibly a win-win situation, so one would expect increasing FDI flows to Africa in the following ten or twenty years. To sum it up, FDI can be very beneficial for poor economies which acutely need foreign capital and investments in order to improve their economic development.

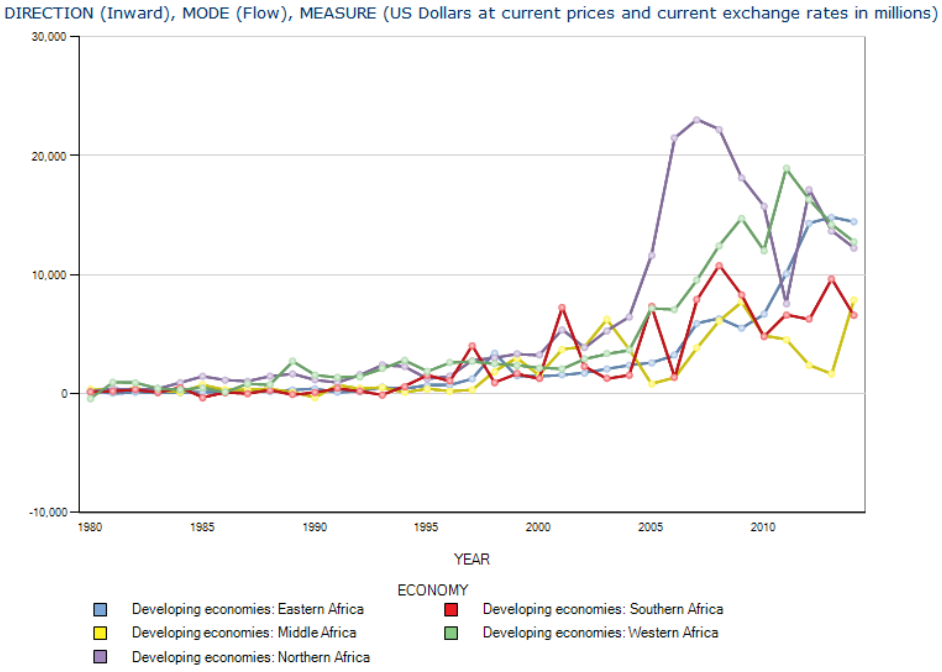

Figure 1: Inward FDI flows in Africa (millions of $US), 1980-2014 (Source: UNCTAD 2016)

1.1 FDI, economic growth and inequality

I want to include this subchapter into my introductory part of this thesis, because it is really important to understand why FDI might be desirable for an emerging country. Economic growth and inequality together are a good combination of measures for the economic development of emerging countries. There are many studies which have tackled the connection between FDI, economic growth and inequality/poverty. Few of these studies are opened up a little more in the following sections.

The connection between FDI and economic growth is not as straightforward as many people might think. There has been a lot of researches on this connection, and the results are mixed. Borensztein et al. (1998) find that FDI is an important vehicle for the transfer of technology benefiting the growth of a receiving country more than domestic investments. They also find that FDI can have positive effects on economic growth only if the host country has a minimum threshold stock of human capital. In other words, there has to be enough skilled labor in order to learn from new advanced technologies and to get economic growth. This is one of the main reasons why FDI flows usually go to the more advanced and matured economies.

Azman-Saini et al. (2010) make a finding which suggest that FDI might have positive effects on economic growth only if a certain level of economic freedom is achieved. They find that freedom of economic activities in the host country makes a difference when talking about FDI effects on the long-run economic growth. They define economic freedom by using four different aspects of it, and they are

1) Free and competitive markets
2) Labor laws
3) The protection of property rights
4) Freedom of exchange across borders

Firstly, they point out that less regulation is good for economic development. Firms are more willing to invest in foreign countries where the markets function well. One example is financial markets where regulation is bad for possible MNEs. *Secondly*, elastic labor markets make knowledge spillovers from MNEs to local firms possible. Workers

who have been in MNEs might have difficulties to join local companies, if the labor laws are very restricted. *Thirdly*, countries with strong property rights are able to attract FDI of higher technology firms (Javorcik 2004). Many of these firms rely their production on strong property rights. *Lastly*, free export markets for the local firms might help them to enter the international markets. The main lesson from all of this is that certain minimum level of economic freedom might be needed in order to have full impact from FDI. It is thus very important for developing countries to firstly increase their economic freedom, and only after that start aiming to attract FDI inflows.

There is one common determinant of the two previous studies alongside many others, and that is the absorptive capacity of a host country of FDI. Absorptive capacity basically determines the efficiency of FDI for a host country. The previously mentioned economic freedom is one element of absorptive capacity, as is the minimum level of human capital by Borensztein et al. (1998). Absorptive capacity thus includes a large set of different features, and it basically tells the capacity of a country or a firm to absorb technological information.

Next I want to introduce the relationship between FDI, inequality, and poverty. Gohou and Soumaré (2012) did research in some African countries and found that FDI net inflows reduce poverty in the host economies there. They used human development index (HDI) and the real per capita GDP as measures of welfare. The first important observation they made was that FDI had different welfare effects among different regions. Secondly, they found that FDI's impact on welfare is more effective in poorer than richer countries. This finding should make low income economies very encouraged to fight against poverty.

Basu and Guariglia (2007) found a positive relationship between FDI and inequality. This finding is especially strong in an environment, where poor people are unable to access new technologies because of low initial human capital. This fact can widen the gap between the rich and the poor and thus increase inequality. As noted earlier in Borensztein et al. (1998), some threshold amount of human capital is needed to get positive effects from FDI to economic growth. Same is true with inequality; in this case certain amount of human capital is needed, so that poor people are able to become

entrepreneurs and catch-up with the rich, as Basu and Guariglia (2007) describe in their article.

Wu and Hsu (2012) make similar findings as Basu and Guariglia (2007). They found a positive relationship between FDI and inequality which strengthens the idea of FDI's harmful effects. Absorptive capacity is also a crucial factor in their research, and they use infrastructure and initial GDP as a proxy of it. Good infrastructure is important in the sense that the poor can have an access to new technologies. They find that FDI is associated with more inequality in the countries with less absorptive capacity and vice versa. A famous work of Kuznets (1955) claims that economic growth first increases inequality, and at some point inequality starts to decline. One would expect that economic growth increases the share of urban population where new technologies are used. Poorer rural areas might see no economic development at this stage, and thus it would also be important to introduce new technologies in rural areas to decrease inequality in the short-term.

1.2 Research questions

This thesis tries to tackle many different questions related to FDI, but there are few questions that rise above the others. Basically there are two questions which are tightly connected to each other, and they are

1) How can developing countries attract more FDI?
2) What is behind the decision of FDI firms to move production to developing countries?

These two questions can be answered from the perspective of different parties. My goal is to answer these questions from the perspective of developing countries. The governments in developing countries try to understand what the firms doing FDI are actually thinking. There are many reasons for a choice of moving production to developing countries, but FDI firms with different technology levels are a special interest of a research in this thesis. Different risk factors of multinational production are also discussed in more detail.

1.3 The structure of the thesis

This thesis continues so that chapter two goes through some literature of previous FDI models related to the main model used in this thesis. Chapter two also includes a closer look at the O-ring theory by Kremer (1993) which is closely related to the main model introduced later in the thesis. After going through some earlier models of FDI, chapter three introduces a special case of FDI flows from China to Sub-Saharan Africa (SSA). That chapter is trying to arouse interest and support the main theoretical model in the following chapter. The relationship between China and SSA is a very current topic which is opened up by taking many different perspectives.

A logical continuum for chapter three is an introduction of the main theoretical model of risk and technology content of FDI (Chang and Lu 2012) in chapter four. This chapter goes through the model in the context of "North-South" FDI. For example dynamics of FDI and comparative statics are done with the model in chapter four. Turning into chapter five, southern imitation and innovation by the model of He and Maskus (2012) are discussed and combined with the main model introduced in chapter four. Chapter five also discusses both technology-related risks and technology-neutral risks. This chapter tries to raise questions and give a new point of view related to FDI and multinationalization decisions. Lastly, chapter six concludes and summarizes all the most important and relevant issues discussed in the thesis.

2 Literature review

2.1 Previous models

There has been a lot of different models in the history of FDI framework. First models come from the 1960s and since then lots of various paths have been taken related to this topic. My interest is to talk more about models which are close to the model I use in chapter four. I will not go through all of the models but choose the most relevant ones in this context. Usually the standard FDI literature assumes away the risk of FDI quality

failure. One example of this kind of article is written by Antrás and Helpman (2004). They assume that moving production to the South includes same risks in production as producing a good in the North. This kind of model suggest that most technologically advanced firms do FDI, but this is not supported by empirical findings. The model used in this thesis (Chang and Lu (2012)) specifically tackles this problem and takes FDI risk of quality into account.

Next I want to go through the model of Costinot (2009). This model is a simple theory of international trade with endogenous technology differences across countries. An economy in this model consists of two large countries with a continuum of goods and one factor of production which is labor. The core of this model lies in the production of the goods, where each good has to be completed with a team. Under free trade larger teams specialize in producing the more complex goods. Team size increases with institutional quality and the complexity of a good but decreases with human capital per worker. There are increasing returns to scale in the performance of each task, but also uncertainty in the enforcement of each contract. These two effects have a trade-off, which makes northern firms to think about their FDI decisions.

Glass and Saggi (1998) build a quality ladders product cycle model which introduces a similar property as the main model used in this thesis. They find that northern firms move production to the South because of low costs, but only for quality levels slightly above the southern technological frontier. The model of Antrás (2005) has similar kind of features as the model of Glass and Saggi. There exists a trade-off between lower costs of southern manufacturing and higher incomplete-contracting distortions associated with it. Thus, a possible incomplete nature of contracts can change the decision-making of a northern firm related to FDI, so that production is not moved to the South.

All these models have more or less similar features as the model used in this thesis. Most of the models in the FDI literature only analyzes the benefits of moving production to the South, but only some of them can include risk in some form. The model of Chang and Lu (2012) introduces an exogenous risk parameter, which introduces the risk of inadequate skills and knowledge in the South compared to the technology of MNEs. This new feature makes the analysis of FDI decision-making process much more interesting and relevant in many ways.

2.2 O-ring theory by Kremer

In chapter four I use a model where the idea of O-ring theory by Kremer (1993) is extended when talking about a risk of FDI quality failure. I find it very important to open up this model of Kremer more here, because it will be easier to understand the main model I use later. This particular theory is based on the idea that production processes have a continuum of tasks which have to be completed. If there exist mistakes or errors in one of these tasks, then the value of the product can be seriously decreased. This of course means that the more tasks a firm have in a production chain, the more it increases the probability of failing in production. Kremer also assumes that the probability of a mistake by one worker does not depend on mistakes by other workers.

Kremer assumes that it is not possible to substitute many low-skilled workers for one high-skilled worker in a production chain of several tasks. He defines skill as a probability to complete a task successfully. For example a low-skilled worker could have a probability of 0.85 to complete a task. The probability for a high-skilled worker could be 0.95 for example. The probability for successfully completing the production chain with three high or low skilled workers would now be

- $0.85 * 0.85 * 0.85 \approx \mathbf{0.61}$ with three low-skilled workers
- $0.95 * 0.95 * 0.95 \approx \mathbf{0.86}$ with three high-skilled workers

To clarify things, I will present the basic O-ring production function which is

$$E(y) = k^{\alpha}(\prod_{i=1}^{n} q_i)\, nB$$

where $E(y)$ is expected production, k is capital, q_i is the probability of ith worker to successfully complete a task, n is the number of tasks and B is output per worker with a single unit of capital, if all tasks are performed perfectly. This functional form is a basic Cobb-Douglas function. Firms are assumed to be risk-neutral, so expected production equals production in this case. Capital is so that there is a fixed supply of capital k^*, and a continuum of workers with an exogenous distribution of quality $\phi(q)$. Supply of labor is inelastic, and workers do not make a labor-leisure choice here.

One interesting feature in this O-ring production function is that quantity cannot be substituted with quality within a single production chain. It is thus impossible to replace two or more low productive workers to one high productive worker. Increasing returns to skill are also assumed to be true at this stage. Kremer solves a competitive equilibrium in his article, but I only am going to present the most important results from the perspective of my thesis. In the analysis of Kremer firms maximize profits, and the market clears for capital, and for workers of all skill levels.

The first and one of the most important findings is that in equilibrium workers with same skill levels work together within a single production chain. At this stage workers are assumed to have perfect matching, which means that the workers with similar skill levels work together. In the further analysis Kremer shows that firms are indifferent between the skill levels of their workers as long as the workers have same skill levels between them.

2.2.1 Stylized facts and the O-ring theory

Kremer presents some stylized facts of development and labor economics and compares them with his O-ring theory in his article. This chapter of his work connects theory and empirics nicely together. I am going to analyze the most important stylized facts when talking about production (chains) in developing countries.

The first stylized fact says that "wage and productivity differentials between rich and poor countries are enormous". The O-Ring theory explains this fact so that small differences in worker skill should make differences in productivity and wages even larger. More physical capital is also used with high-skilled workers than low-skilled workers in equilibrium. It is thus important for developing economies to raise their human capital level in order to attract physical capital flows into those countries.

All this earlier analysis has assumed that the n tasks are performed simultaneously, but now it is time to move on to sequential production analysis. Sequential production means that all the n tasks are done one after another, not at the same time. This feature sounds more realistic with the real world. Kremer shows that it is optimal to allocate

workers with the highest q in the later stages of production. This is intuitively quite reasonable, because low-skilled workers could destroy more of a production chain if allocated to later stages of production. For example with $n = 8$, step seven is much more valuable than step two. The value of the product is obviously much higher at the later stage of a production chain. Kremer's theory can also be discussed with another two stylized facts which are important for developing countries. They are in line with the O-ring theory, and those are "Poor countries have higher shares of primary production in GNP" and "Workers are paid more in industries with high value inputs".

Next stylized fact is "Rich countries specialize in complicated products". It can also be interpreted to say that poor countries specialize in simpler technologies. Kremer assumes that if all tasks are completed perfectly, there are benefits to use these more complicated technologies. $B(n)$ is defined as the value of output per task if all n tasks are performed perfectly with two properties: $B'(0) > 0$ and $B''(n) < 0$. The first property imply increasing benefits if more complex technology is used, and the second property says that the marginal benefit is decreasing with more complex technologies. For example in developing economies there is a serious risk of production failures in different tasks with more complex technologies because of low initial human capital and knowledge.

2.2.2 Imperfect matching

The assumption of perfect matching of workers is quite strict and unrealistic, because limited availability of certain level of workers might cause problems in matching. Kremer points out that higher level of population increases the marginal product of skill $dw/dq_i = E(\prod_{j \neq i} q_j)$ under imperfect matching. This is quite reasonable, because the probability of finding coworkers with similar skills is higher with higher level of population. Workers with same level of skills are also expected to have greater production in this case.

People is thus expected to move from rural areas to cities (higher population) based on this theory. For example city clusters or training centers aim to have workers with similar

(usually high) skills in order to match workers better. In developing countries it is important to connect the largest cities with infrastructure in order to get more people with similar skills together. High skill level of coworkers increases also your marginal product. Training centers increase the level of skills of other workers and when this is known, it is useful to invest in skill even more.

In this earlier analysis q is assumed to be exogenous, but it also is possible to endogenize q. Kremer describes skill q as a product of investment in education or effort e. The main finding I make out of Kremer's is that small differences between countries in exogenous multiplier variables can have large effects in q between different countries. One of these variables might be the quality of an education system for example. Kremer shows also that the parameter e might increase a lot with an education subsidies because of multiplier effect. These kind of subsidies increase e directly, and the subsidies also increase e indirectly.

3 FDI flows from China to Sub-Saharan Africa

I want to start with an exceptionally good words by the former US Secretary of State Hillary Clinton (2011), which basically is a great summary of the situation in Africa:

"*Well, our view is that over the long run, investments in Africa should be sustainable and for the benefit of the African people. It is easy – and we saw that during colonial times – it is easy to come in, take out natural resources, pay off leaders, and leave. And when you leave, you don't leave much behind for the people who are there. You don't improve the standard of living. You don't create a ladder of opportunity. We don't want to see a new colonialism in Africa. We want, when people come to Africa and make investments, we want them to do well, but we also want them to do good. We don't want them to undermine good governance. We don't want them to basically deal with just the top elites and, frankly, too often pay for their concessions or their opportunities to invest*."

China and Sub-Saharan Africa (SSA) have rapidly increased their cooperation related to FDI. Especially economic cooperation between those two has increased compared to more political connections in the 20th century. China's "Going Global" policy was introduced in year 2002, and its aim was to promote China's overseas investment activity. Between 2003 and 2009 China's outward direct investments (ODI) rose from $33 billion to $230 billion (Cheung et al. 2012). More and more of those investments are going to the emerging economies in Africa.

SSA has a huge economic growth potential, and that's why it is a very interesting topic to make research on. A usual misunderstanding is that the economic potential of SSA is only based on the vast natural resources. China's own economic development has increased the demand for energy there, and that's why the interest in natural resources is quite logical in Africa. Of course this one-sided interest has been even more an issue at the beginning of the SSA economic development story, but in recent years Chinese investments have gone to various different industries. In fact, finance, construction, and manufacturing now make up half of total FDI in SSA (World Bank 2015). This number is very promising for the economies in SSA as a whole.

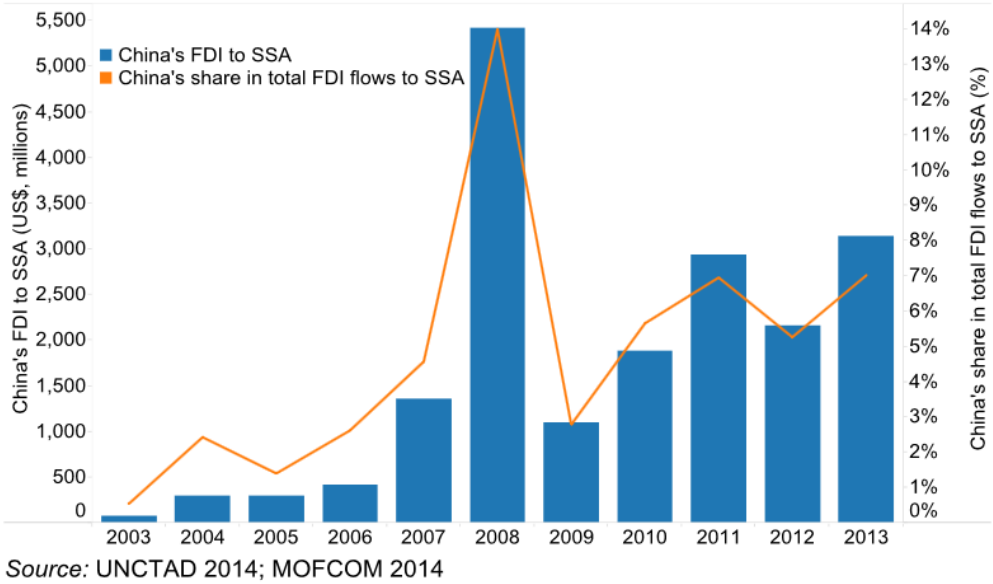

Figure 2: Chinese FDI flows to SSA, 2003–13 (US$,millions)

Chinese FDI outflows to SSA have dramatically increased since early 2000s, which is easy to see by looking at Figure 2. Actually China was almost a nonexistent player in SSA back

then when talking about FDI. The world sees and has seen foreign investments to China and U.S. for example, but the investments are surely going to accelerate in SSA with increasing amounts in the future.

It is very important that the governments in SSA make right political decisions in order to get the development properly started from the perspective of economic development in the countries of SSA. Many African countries still have authoritarian regimes, which hinder the possibly better times for the people there. Proper government policies might get a poor country out of a development trap as we will see in later analysis. It can be concluded that now it is the time for African countries to attract strategic, job-creating investments from foreign investors, for example China. These following four improvements are a good way to start getting more FDI from China and other countries (World Bank 2015):

(i) Lower transport costs
(ii) Eliminate formal and informal barriers that undermine investments in regional processing activity
(iii) Increase the effectivity of labor markets
(iv) More effective competition policies

3.1 Risks and possibilities in China-SSA FDI

Africa is seen to be a risky place to make investments from the perspective of the rest of the world. China is different in the sense that it also makes lots of investments in countries with politically fragile environments. One crucial exogenous risk is a political risk, which many studies have found to be negatively correlated with FDI inflows, see for example Guerin and Manzocchi (2009). They find that democracy increases the amount and probability of FDI flows into emerging countries when compared to other regimes. It is commonly known that few countries in SSA have democracy as a regime.

When talking about technologies, it is noticeable that Chinese firms use technologies that may suit very well for the countries in SSA. China itself has been a poor country only a few years ago, and it probably has many suitable intermediate or low-skill technologies

for SSA. Chinese production is going to concentrate more on higher skilled production (Song 2011) which most likely releases lots of low-skill production capacity from China to Africa in the following years. These investments could increase the technology frontier of Africa and SSA in different industries which again would attract more FDI from China. Too high-skilled technologies would not be suitable for a continent like Africa, because the overall human capital level is too low. This particular pattern is one key advantage for China to invest in SSA compared to other countries (Busse et al. 2014.)

As noted earlier, natural resources has been one of the most important reasons for China to invest in SSA. Figure 3 shows a clear connection between investments in resource-rich countries and crude oil price. It is important that the resource-rich SSA countries do not rely their future economic development solely on FDI in natural resources but diversify their economic structures. Volatile prices of oil and natural gas for example make these countries more vulnerable compared to more diverse economies.

Figure 3 also shows that the less resource-rich countries are increasing their share of all investments. This trend is also going on with the investments from China to SSA. Cheung et al. (2012) mention that the extent of natural resources in African countries rather determines the size of Chinese firms' investment decision than the investment decision altogether. They also point out that a common phenomenon in Africa is that Chinese firms build infrastructure there by using the revenues coming from natural resources. Natural resources can thus be an important part of the whole pie of economic development, but other industries need to be developed to keep economic development more stable in the future.

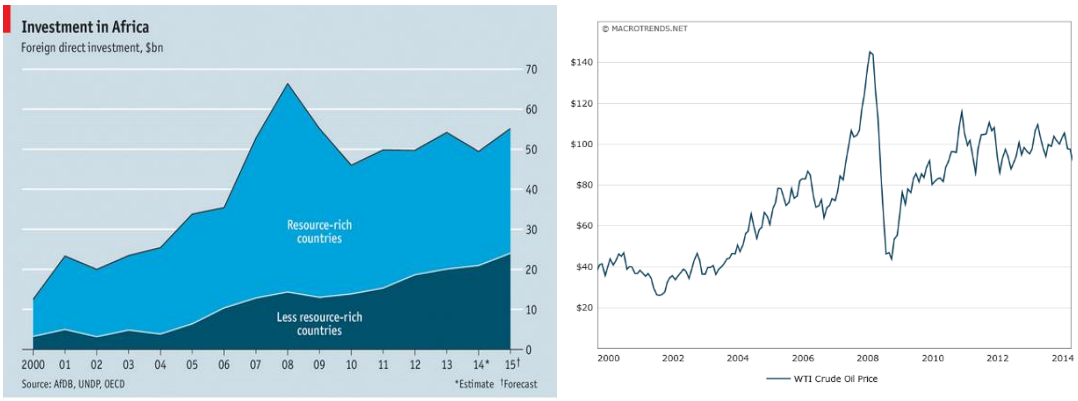

Figure 3: Investment in African countries (Source: The Economist 2015) and Crude Oil Price (Source: Macrotrends)

It is also important to notice that labor costs have increased a lot in recent years in China, and that's why African low wage countries have become increasingly attractive for Chinese firms. The wages of Chinese workers have outpaced productivity growth, which has reduced the competitive advantage especially in manufacturing compared to SSA countries (Ceglowski et al. 2015). It is important to keep in mind though, that there are other important factors (institutions, infrastructure etc.) which affect the location of final production.

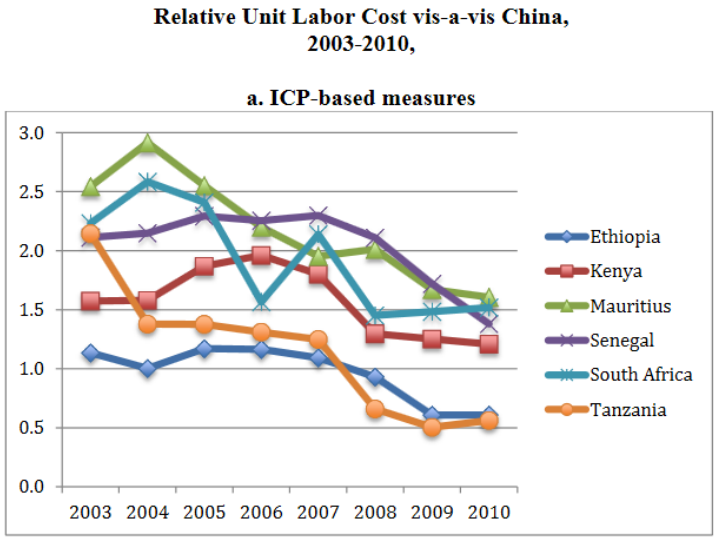

Figure 4: Relative Unit Labor Costs relative to China (Source: Ceglowski et al. 2015)

Figure 4 shows that Ethiopia and Tanzania are competitive with China when talking about relative unit labor costs. The relative unit labor costs in SSA countries related to China have decreased at a constant rate in the 2000s. Still, most of the SSA countries are

not competitive enough when compared to China. The future might of course change this relationship even more in favor of SSA, if the ongoing trend continues.

Chinese networks in SSA are extremely important when talking about risk factors of investing abroad. Chinese private FDI firms have got really important help from the business networks of overseas Chinese (Song 2011). There has been three different generations of Chinese firms, which are presented in Figure 5. Now the newest generation of private Chinese firms can utilize these former networks. Chinese FDI private firms are relatively small, so for them it is beneficial to use these networks to survive against the local competition. Hayakawa et al. (2013) point out that the sunk costs of FDI include acquiring information of the host country in order to know how everything works there. One would assume that for example learning a local language is very important factor related to the sunk costs. These kind of special networks decrease the sunk costs, and without these networks Chinese firms might invest in other regions of the world.

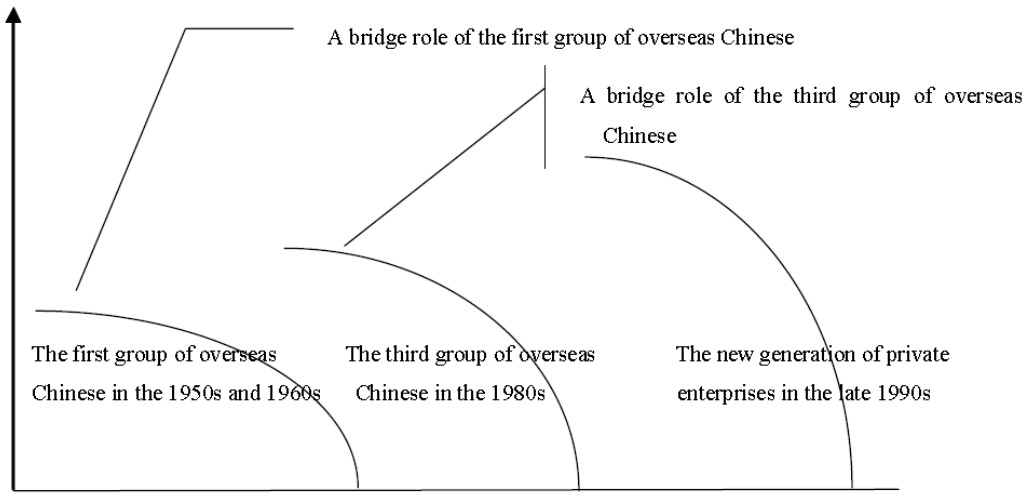

Figure 5: Networks of Overseas Chinese and Private Enterprises in Africa (Source: Song (2011))

3.2 Local labor and contracts with China

One of the most important issues for SSA is that local labor is used in Chinese FDI projects. Additional jobs give the host country a boost for their economic development

in the future if local labor is used. It is thus expected that employment levels and technology transfers are going to increase, if these kind of policies are implemented. It is understandable that there might not be enough local knowledge to utilize the labor of the host country in the industries with complex technologies. Of course Chinese FDI firms might want to keep their technologies in secrecy to some extent. These spillover effects are discussed more in this chapter later.

There are many examples where Chinese companies bring their own workers to the host country. For example Adisu et al. (2010) find this kind of pattern existing in Africa. On the other hand, Kamwanga and Koyi (2009) firstly mention that the hiring of local workers depends on how long a Chinese FDI firm has been in Africa. Secondly, they note that finding relevant and right type of labor might be a problem. This second point of course requires flexible and efficient labor markets in the host country. Relatively backward countries unfortunately do not have these kind of labor markets. This can lead to a bad situation where only Chinese labor is used instead of some local African labor. African governments can correct this issue by making laws or requirements where a proportion of labor in FDI projects has to be local (Asongu and Aminkeng 2013). Technology transfer from Chinese MNEs to African local firms is not of course guaranteed with the use of local labor, because technologies might not efficiently transfer from one party to another in the MNEs.

In some ways it is quite understandable that Chinese FDI firms do not want to employ local labor. Gadzala's (2010) article deals with the labor practices of Chinese FDI firms in Zambia. These labor practices also apply more generally in other African and SSA countries. She mentions few possible worrying issues related to local labor including the lack of appropriate skills and trust to local workers. The following quotation of an employee of the China National Oil and Gas Exploration and Development Corporation nicely summarizes this whole story:

"*If my supervisor gives me a task to finish in two hours, I work hard to finish it in one. If I give an African a task to finish in a day and at the end of the day ask him if it is finished, the response often is ´Insha'Allah´ and the task remains unfinished*". (Personal communication, Beijing, September 2007).

Chinese FDI firms in Zambia violate many acts for example by paying salaries below minimum wages and laying off local workers before the end of their contracts (Gadzala 2010). These practices are not uncommon in other developing countries in SSA, and that's why they should be corrected. It is absolutely crucial that the governments in SSA make specific and strict policies related to Chinese FDI. Things like local content requirement and technology transfers are two important issues along many others. Of course there are differences between countries in SSA related to the development of these kind of policies. SSA countries differ in many ways, but the overall implementation level of these requirements and laws are still way too low in SSA.

Technology transfer or spillovers from Chinese MNEs to local firms are important when talking about technological and economic development in SSA. The problem here is that Chinese and other FDI firms do not want to reveal their technologies easily because of valuable information. Blomström and Sjöholm (1999) mention that FDI firms might bring less advanced technologies with them or even refuse to invest because of this particular fact. They point out that many governments in developing countries have imposed restrictions that force MNEs to make joint venture agreements. Joint ventures are good for the developing economies from the perspective of technology diffusion, because the local partners probably learn better working in joint ventures than from the products of subsidiaries. A joint venture has also some benefits for MNEs; local partners probably have better knowledge of local markets and employees along with many other specific information.

3.3 A case study of China-Nigeria FDI

Countries in SSA are quite different when talking about their structure of economies but most of them have vast natural resources. One of them is Nigeria which is the biggest economy in Africa. This is one of the reasons I chose to take a closer look to Nigeria, but another reason is that there does not yet exist a lot of research material about other countries. This case of China-Nigeria FDI should still give a lot of important experiences and examples how to utilize a massive possibility of Chinese investments in the future. I am going to use three different main sources of articles to open up this case a little more.

Nigeria is a large country by a population over 180 million and with potentially large consumer markets in the future. China is investing in almost every country in SSA, but Nigeria is getting the biggest part of Chinese FDI (UNCTAD, 2009). China's FDI in Nigeria is going to the oil and gas sector with the share of roughly 75% (Oyeranti et al. 2011), but China has increasingly expanded its presence in other sectors at the same time. One of the fastest growing sectors (related to foreign investments) outside the extractive industries is manufacturing (Nnanna 2015). This is a risk for Nigerian manufacturing firms, because they face stern competition from Chinese manufacturing MNEs. He also discusses the problem of worsening unemployment in Nigerian manufacturing sector. Chinese MNEs have for example better skills and infrastructure, so they are much more competitive than corresponding Nigerian firms. It is thus very important to make policies which ensure that FDI inflows are not by any means harmful for manufacturing or other industries.

Let's now turn the discussion to the attractiveness of Nigeria as a receiving country of FDI. How has Nigeria been able to increase its attractiveness when talking about FDI? First step was when Nigeria became a democracy in year 1999. This event made economic renewal possible. Before this event Nigeria was having decades of political instability, corruption and economic mismanagement which did not help the attractiveness of Nigeria related to possible FDI inflows. According to WTO (2005) there are three reasons why Chinese FDI flows have started to increase into Nigeria and they are

1) Changes in FDI regime
2) Privatization programme of the government
3) Aggressive drive of the government in attracting FDI into the country

These three points are common for every African country who wants to increase FDI inflows from other countries. Nnanna (2015) still points out that investing in Nigeria is very risky, although Nigerian government has implemented many important laws in terms of FDI inflows.

There is a clear pattern of Chinese investments when talking about private firms vs. state-owned firms (SOFs). Majority of the investments in Nigeria are made by Chinese

SOFs, actually 84.25 per cent in year 2006 (Oyeranti et al. (2011)). Another usual way of Chinese firms doing FDI is by joint ventures. Joint venture is the best way to do FDI according to Oyeranti et al., because it potentially benefits the receiving country of FDI most. Technology and skills might be transferred easier to the host country from joint ventures compared to subsidiaries. Employment of Nigerian workers should theoretically be better in joint ventures especially if labor practices are not efficiently implemented in Chinese MNEs.

What is common for many researches about Nigeria and Africa is that infrastructure is a big problem in many countries. Oyeranti et al. (2011) point out that China and Nigeria have economic complementarities: Nigeria needs a vast amount of infrastructure investments to build its investment climate, and China has really large construction industries with financial assistance to support this urgent need. For example China's rapidly increasing manufacturing sector needs lots of raw materials which can be found in Nigeria. It is also important to notice that Chinese firms have to face a lot of different problems when operating in Nigeria. One good example is the case of Chinese National Petroleum Corporation (CNPC) which made a deal in oil industry with a goal to refine 110,000 barrels of oil per day. In the end CNPC was able to refine only 70% of this target due to the lack of maintenance (Oyeranti et al. 2011). This event just shows that there are lots of uncertainties and risks to invest in Nigeria.

Free Trade Zones (FTZ) are a way to promote economic development in many different ways. China has been interested to develop these kind of zones in Nigeria. Nnanna (2015) mentions that China's public and private firms want to connect the major cities with new roads, airports etc. Oyeranti et al. (2011) discuss many incentives these FTZs have for foreign investors including for example tax holidays and duty-free importation of raw materials. One of these zones is Lekki-FTZ (LFTZ) in Lagos, Nigeria which has many important missions related to improving the investment climate for Chinese investors. I think that out of the six missions mentioned in the article of (Oyeranti et al. (2011)) the two most important are

- Attracting foreign investments and
- Creating job opportunities

It is crucial to get Nigerian workers to work in Chinese MNEs. There has been a serious concern that Chinese firms would bring not only their own workers but complete products and technologies with them. This kind of inefficiency might have harmful effects for the economy of Nigeria. The basic idea for Nigeria is to transfer technologies and skills from China. Nigeria has to ensure that labor law, social responsibility law and local content requirement (human and physical) are in good shape in order to get the benefits out of the FDI cooperation with China. An encouraging example though is Huawei's action to establish a training center in Nigeria. It is possible for 2,000 Nigerian telecoms engineers (per annum) to increase their skills and knowledge in this place. This should lead to a higher level of human capital and technology frontier and eventually make Nigeria more attractive FDI destination at least in the industry of telecommunication. (Oyeranti et al. 2011.)

4 The model of risk and technology content of FDI

Many firms with a high-tech product line have moved their production to developing countries but brought back the production to their home country. Why does this kind of development spring up? The model of Chang and Lu (2012) tries to open up this interesting feature by introducing a risk of FDI quality failure because of a technology gap between the North and South. They bring up an example of a Japanese firm Canon, where it decided to keep a large part of its production in Japan instead of producing in China. Canon is accustomed to make high quality products for example digital cameras and photocopiers. The model explains this so that the cheaper labor in China was not enough to compensate the loss coming from the risk of FDI quality failure in production, and the higher fixed costs in the South than North.

4.1 Production technology and the risk of FDI quality failure

Chang and Lu (2012) build a North-South model where they introduce the risk of FDI quality failure, and technology frontiers in the South. The lower the technology gap between the North and South, the more FDI the South attracts. There are two countries

in the model: the more advanced North and the developing South. Consumers in both countries have identical preferences, and the demand for good i of industry j is

$$x_j(i) = p_j(i)^{-\frac{1}{1-\alpha}}, 0 < \alpha < 1 \quad (1)$$

where $p_j(i)$ is the price of variety i of industry j, and $\frac{1}{1-\alpha}$ is the price elasticity of demand for each variety of an industry. In the upcoming analysis $x_j(i)$ is denoted as x, because this simplifies presentation. The production follows the O-ring theory of Kremer (1993), so that a certain amount of steps $s \in [0, \theta]$ are needed to complete the production chain. This theory is discussed more in detail in subchapter 2.2. The amount of steps is a very important number, because it measures the complexity of the production technology. Higher θ implies more advanced technology and all the steps have to be completed successfully in order to sell the product in the markets:

$$x = \begin{cases} [\int_0^\theta \lambda(s)^\rho ds]^{1/\rho}, & \text{in case of success;} \\ 0, & \text{in case of failure,} \end{cases} \quad 0 < \rho < 1, \quad (2)$$

where $\lambda(s)$ is the intensity to complete step s, and $\frac{1}{1-\rho}$ is the elasticity of substitution between any two steps s.

It is important to notice that labor is the only factor of production in the model and the wage rates are so that $w_n > w_s$ (wages are higher in the North than in the South). The production cost is $\int_0^\theta w^l \lambda(s) ds$ and it is tried to be minimized with a production technology θ. The steps are symmetric so that $\lambda(s) = \lambda = x\theta^{-1/\rho}, \forall s \in [0, \theta]$. Substituting $\lambda(s)$ into the cost function we get the minimized unit production cost:

$$c^l(\theta) = w^l \theta^{\frac{\rho-1}{\rho}}, \quad (3)$$

where $\frac{\partial c^l(\theta)}{\partial w^l} > 0$ and $\frac{\partial c^l(\theta)}{\partial \theta} < 0$. The conduct of equation (3) is presented in Appendix B.

→ Firms who relocate their production in the South, or who have a more advanced technology get a cost advantage compared to others

→ The unit cost is paid even in the case of failure in production (all steps are not successfully completed)

The next two equations are very important, because they show the probability $\gamma^l(\theta)$ to successfully complete all the steps in location l, when a firm has a technology θ:

$$\gamma^N(\theta) \triangleq 1, \qquad \forall\theta, \text{ where } 1 \leq \theta \tag{4}$$

$$\gamma^S(\theta) = \begin{cases} 1, & \text{if } 1 \leq \theta \leq T^S \\ \left(\frac{T^S}{\theta}\right)^z, & \text{if } T^S < \theta \end{cases} \tag{5}$$

where $T^S > 1$ is the technology frontier or level of the South and z is the degree of risk sensitivity, as Chang and Lu (2012) denote. They define z as follows: "The risk sensitivity z reflects the elasticity of the success probability to the technology gap". This risk parameter is opened up more in subchapter 5.2, where different risks of FDI are discussed more.

We can make two basic conclusions from equations (4) and (5): Firstly, there exists no risk of FDI quality failure in the North and secondly, there exists a risk of FDI quality failure in the South, if there is a technology gap between the North and South so that $\theta > T^S$. The lack of proper skills and knowledge of southern workers increase the probability of FDI quality failure in southern production. They should be able to use technologies that the FDI firms bring with them either in advance or through some training of skills. The risk parameter z finally defines how sensitively the changes in technology frontier in the South affect the final success probability $\gamma^S(\theta)$.

Firms also have to pay a fixed setup cost, and it is assumed to be higher in the South than in the North ($f^S > f^N$). The profit in country l is then:

$$\max_x \pi^l(\theta) = \gamma^l(\theta)x^\alpha - c^l(\theta)x - w^N f^l, \tag{6}$$

$$\text{and} \qquad x^l(\theta) = \left(\frac{\alpha\gamma^l(\theta)}{c^l(\theta)}\right)^{\frac{1}{1-\alpha}} \tag{7}$$

where the fixed costs f^l are denominated in terms of northern labor. Equation (7) gives the optimal output level in country l. The conduct of equation (7) is presented in Appendix B. It is easy to see that a firm has higher output levels, if its unit cost of production decreases or the probability of succeeding in production increases. This is intuitively quite clear, what Chang and Lu (2012) present here. The optimal output levels

(8) and (9) for the North and South respectively are obtained by substituting Eq. (3), (4), and (5) into Eq. (7):

$$x^N(\theta) = \Omega^N \theta^v, \qquad \forall\theta, \text{ where } 1 \leq \theta \tag{8}$$

$$x^S(\theta) = \begin{cases} \Omega^S \theta^v, & \text{if } 1 \leq \theta \leq T^S \\ \Omega^S \left(\frac{T^S}{\theta}\right)^{\frac{z}{1-\alpha}} \theta^v, & \text{if } T^S < \theta \end{cases} \tag{9}$$

where $v \equiv \left(\frac{1-\rho}{\rho}\right)\left(\frac{1}{1-\alpha}\right) > 0$, and $\Omega^l \equiv \left(\frac{\alpha}{w^l}\right)^{\frac{1}{1-\alpha}}$ where $\Omega^N < \Omega^S$. The conduct of equations (8) and (9) are presented in Appendix B. It is easy to see that better technology increases output of the firms if there exists no FDI risk. In the existence of FDI risk, firms do less FDI in the South and even more so if the technology gap is large.

The expected profits in the North and South can simply be calculated by using Eq.(6) where the profit of a country l is defined. With some basic substitutions the following profit functions for both countries are obtained:

$$\pi^N(\theta) = \psi^N \theta^{v\alpha} - w^N f^N, \qquad \forall\theta, \text{where } 1 \leq \theta \tag{10}$$

$$\pi^S(\theta; T^S, z) = \begin{cases} \psi^S \theta^{v\alpha} - w^N f^S, & \text{if } 1 \leq \theta \leq T^S \\ \psi^S \left(\frac{T^S}{\theta}\right)^{\frac{z}{1-\alpha}} \theta^{v\alpha} - w^N f^S, & \text{if } T^S < \theta \end{cases} \tag{11}$$

where $\psi^l = (1-\alpha)(\Omega^l)^\alpha$ with $\psi^N < \psi^S$. Figure 6 in next subchapter 4.2 includes transformations of $\tilde{\theta} = \theta^{v\alpha}$ and $\tilde{T}^S \equiv (T^S)^{v\alpha}$ because of illustrative reasons.

The trade-off in the South is between lower wages w^S and higher risk of FDI quality failure z, or formally $\frac{\partial(\pi^S - \pi^N)}{\partial w^S} < 0$ and $\frac{\partial(\pi^S - \pi^N)}{\partial z} < 0$. This trade-off can be interpreted as a relative unit labor cost $w^S/(1/z)$ in the South. Here I of course assume that $1/z$ measures productivity so that higher z implies lower productivity and vice versa. Higher z could for example imply longer time of doing one step of a production by a worker. This would decrease productivity and the value of a product.

Next chapter introduces the most important part of this analysis up to this point, and it is the FDI decision-making process of the northern firms. Four different combinations of z and T^S are used to illustrate how the FDI flows might differ depending on these two parameters. The basic idea is to compare the expected profits in the North and South

and then decide whether a firm's technology is suitable and profitable enough to move production to the South.

4.2 FDI decision-making of the northern firms

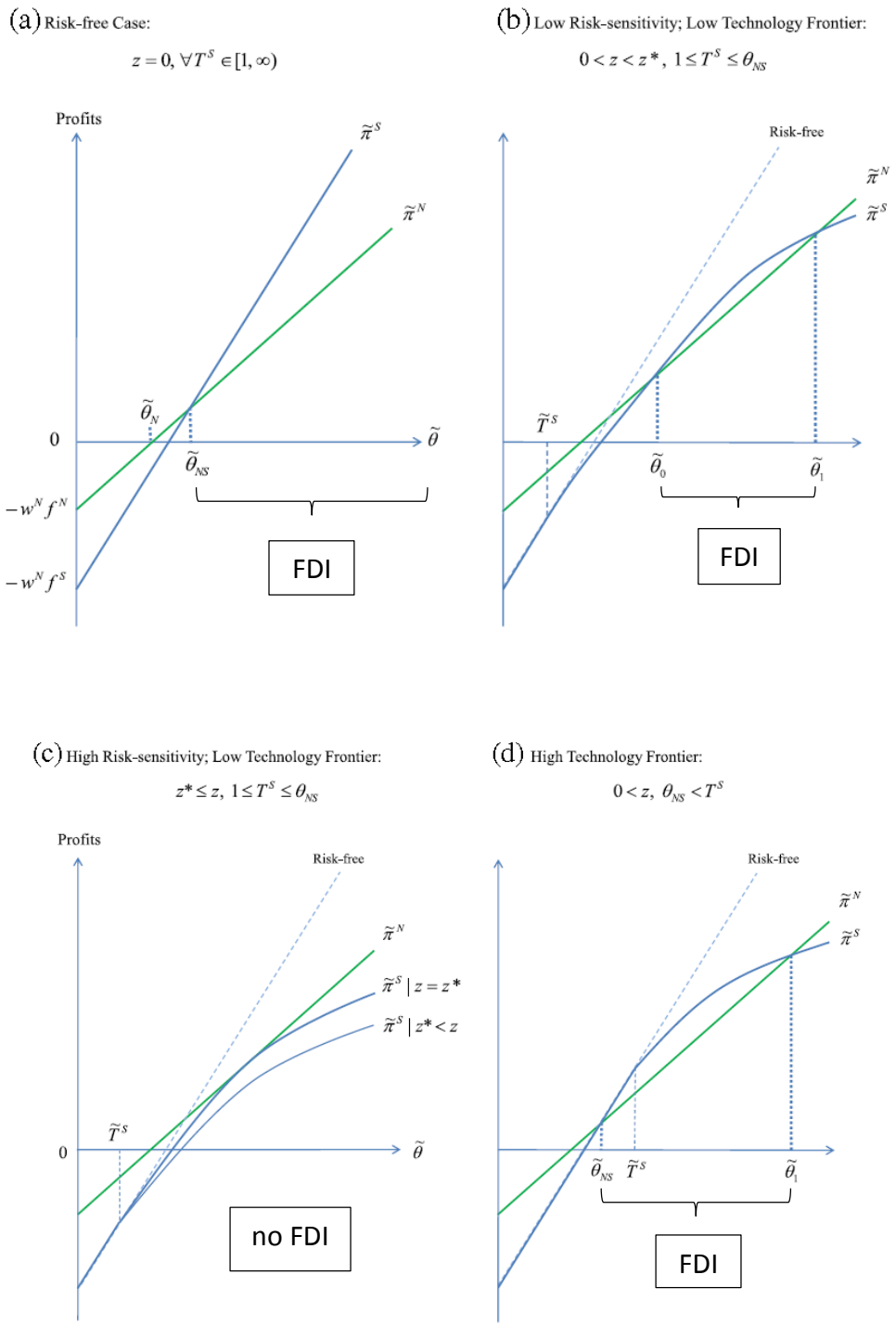

Figure 6: Expected profits of FDI and production in the North (Source: Chang and Lu (2012))

There are two profit-curves in Figure 6: the blue one $\tilde{\pi}^S$ reflects the profits in the South, and the green one $\tilde{\pi}^N$ reflects the profits in the North. A firm always wants to make FDI (or move production to the South), when the profit-curve of the South is above the North one. There exists no FDI risk in the North, so the profit-curve of the North is increasing to the technology level $\tilde{\theta}$ in every case from (a) to (d). On the other hand, the profit-curve of the South is concave when there exists a risk of a FDI quality failure ($z > 0$). Depending on z and the technology frontier in the South T^S, the profit-curve in the South changes its position in Figure 6.

The risk-free case in Figure 6(a) is only a theoretical base for the analysis, because it is not possible to start a risk-free production in a developing country for a relatively high-tech firm. The technology frontier cannot be that high in any case here. Figure 6 also reveals the following assumption which gives the relationship between θ_N and θ_{NS}:

Assumption 1.

$\theta_N < \theta_{NS}$, where $\theta_N \equiv \left(\frac{w^N f^N}{\psi^N}\right)^{\frac{1}{\nu\alpha}}$, and $\theta_{NS} \equiv \left(\frac{w^N (f^S - f^N)}{\psi^S - \psi^N}\right)^{\frac{1}{\nu\alpha}}$

This Assumption 1 is usually assumed in the standard literature, and it ensures that some northern firms with relatively low technology stay and produce in the North because of too high fixed costs in the South. The worst-case scenario is of course seen in the case of (c), because the host country is able to attract no FDI. This result is based on the fact that the technology level is very low in the South, and at the same time the risk of FDI quality failure is high enough to prevent any FDI flows from the North. In the range of $1 \leq T^S \leq \theta_{NS}$, z^* depicts the threshold, so that all $z < z^*$ would invite at least some firms in the North to do FDI.

The two remaining figures [6(b) and 6(d)] represent the only realistic possibilities for FDI to flow from the North to South. In both of the cases there exists three different firms in the North: *Firstly*, some of the firms exit the markets. These firms have very low technology levels ($\theta \in [1, \theta_N]$), and they make negative profits. *Secondly*, another group of firms stay in the North and thus do not practice FDI ($\theta \in [\theta_N, \theta_0]$) or $\theta \in [\theta_1, \infty)$). This result is based on two facts:

1) Firms with very high technologies would have a large market share in the South, but the (very high) risk z is too large, so the firms find it unprofitable to do FDI.
2) On the other hand, firms with technologies $\theta \in [\theta_N, \theta_0]$ understand that they would not have large enough market share in the South, even though their risk for FDI failure would be relatively small. Thus, they find it unprofitable to produce in the South.

Thirdly, the rest of the firms $\theta \in [\theta_0, \theta_1]$) move their production to the South or in other words do FDI. This group of firms is the key for a host country to accelerate its economic development. This model thus finds that only firms with intermediate technology levels find it profitable to rather produce in the South than North.

If it is expected that FDI flows improve the technological capacity of the South, as for example Matsuyama (2002) suggests, then the technology gap decreases between the South and North. This of course decreases the risk z, and more firms are willing to do FDI after this event. The following Proposition 1 and Figure 7 nicely summarize the whole analysis between z and T^S in a more precise way:

Proposition 1.

(i) *For relatively low levels of technology frontiers $T^S \in [1,\ \theta_{NS}]$ in the South, there exists a unique risk sensitivity ceiling $z^*(T^S)$, such that positive amounts of FDI take place if and only if $z < z^*(T^S)$; for relatively high levels of technology frontiers $T^S \in (\theta_{NS}, \infty)$ in the South, FDI occurs regardless of risk sensitivity z.*

(ii) *Alternatively, for any given degree of risk sensitivity z, there exists a unique threshold $T^{S^*}(z)$ for the technology frontier in the South, such that $T^{S^*}(z)$ weakly increases in z and that positive amounts of FDI take place if and only if $T^S > T^{S^*}(z)$.*

The proof of Proposition 1 is presented in Appendix A.

The following figure tries to demonstrate Proposition 1 in an intuitive fashion:

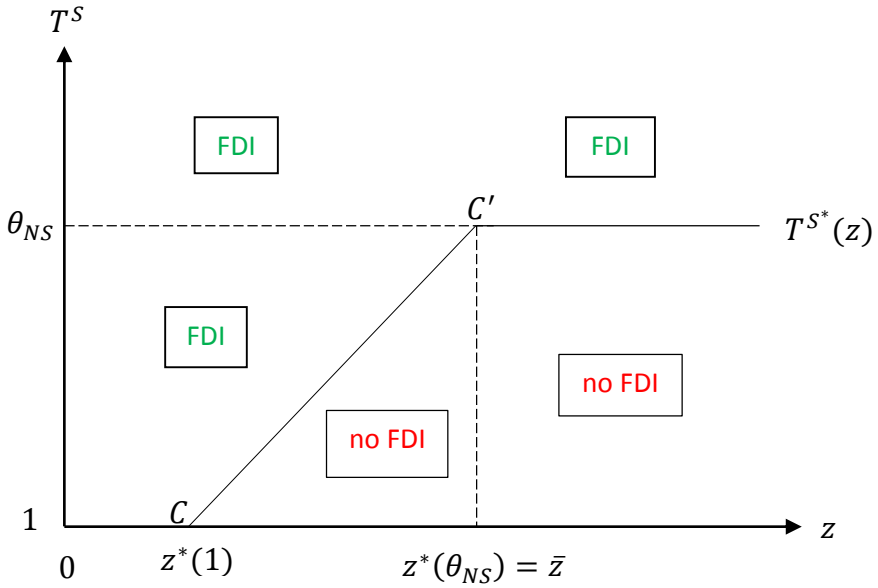

Figure 7: Threshold technology frontier for inward FDI (Author's own version of Chang and Lu (2012))

Figure 7 shows that FDI is more likely to occur in situations where z is low and T^S is high. There exist a certain threshold level of technology θ_{NS} in the South, and this ensures that FDI always takes place. The curve CC' demonstrates a situation, where the expected profits in the South and North are equal. It thus determines the decision of move or not to move production to the South.

4.2.1 Machines in the North as substitutes for southern labor

Machines and robots have started to become much cheaper in recent years. Machines in developed countries are starting to substitute cheap labor in particular industries of developing countries. The Economist (2016) evaluates that especially jobs in poorer countries are in danger of automatization. It is estimated that 69% of jobs in India, 77% in China and 85% in Ethiopia are threatened. Two main reasons for these estimates stand up from that article: Firstly, there are not plenty of jobs that are hard to automate. In other words, jobs in those countries usually require less skills and knowledge than in

more developed countries. Secondly, the jobs in those countries are usually very labor intensive and not much capital is tied up in production.

The risk for developing countries lies in the fact that developed countries might pull back their production due to this development. On the other hand, it is possible that they do not even start the production in developing countries. This was the case, when a Chinese firm PPC (which makes connectors to televisions) chose not to move production to Vietnam because of continually cheaper machines (one of the reasons). Especially industries with high elasticity of substitution between labor and capital $\sigma = \left\{\left[\frac{\Delta(K/L)}{K/L}\right] / \left[\frac{\Delta(w/r)}{w/r}\right]\right\}$ are in danger in the South related to FDI. The notations are so that K is capital, L is labor, w is the wage rate, and r is the real interest rate.

Even though the benchmark model has labor as its only factor of production, I think it would be very demonstrative to show how this recent pattern of cheaper machines would change the profit curves in the South and North. Thus I assume that machines are used instead of labor in the North, and w^N is substituted with r so that $r < w^N$. Obviously it is important to remember that these machines need some labor to use them. To not make this too complicated, I assume that r includes the cost of the workforce using machines in the North.

These assumptions would imply increase in $\psi^N \theta^{v\alpha}$ in the profit function of the North. This part of the profit function defines the slope of the northern profit curve. Another assumption I make is that machines are making no mistakes so that $z = 0$. Thus, the change in the profit curve of the North is the following one:

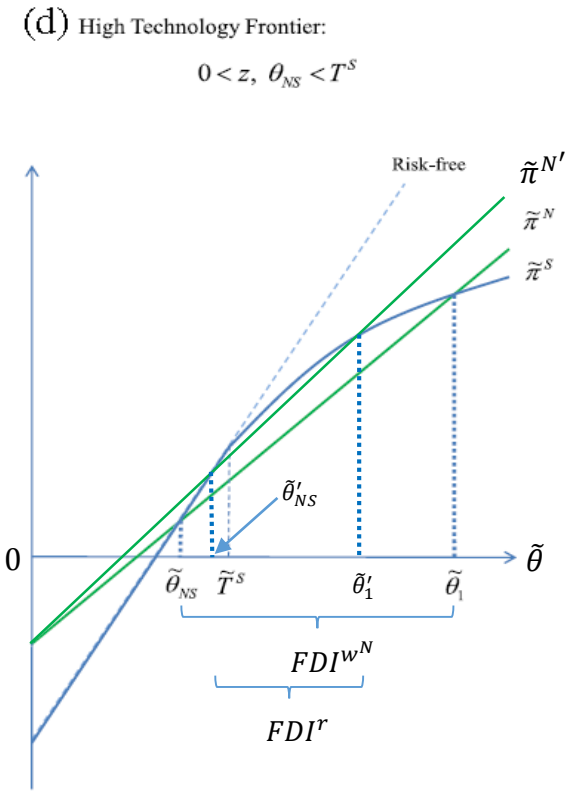

Figure 8: The effect of cheaper machines in the North (Author's own variation of Chang and Lu (2012))

where $\tilde{\pi}^{N'}$ is the new profit curve of the North, $\tilde{\theta}'_{NS}$ denotes the new cutoff level, $\tilde{\theta}'_1$ denotes the new upper bound of FDI, FDI^{w^N} shows the amount of FDI with only labor used in the North, and FDI^r shows the amount of FDI with machines in the North substituting southern labor. The example in Figure 8 is the case of high technology frontier in the South, but it could be any combination of z and T^S. The most important conclusion here is that cheaper machines in the North decrease the amount of FDI in both lower and upper bounds ($FDI^r < FDI^{w^N}$). It could also be the case that some industries might lose all the FDI flows, if machines are relatively much cheaper than southern labor. Especially northern firms with high technology might decrease their FDI flows quite a lot, and the existing high-tech FDI firms might pull back their production.

4.3 Extensive and intensive margins of FDI

Analysis in this subchapter is concentrating only on the case where the South meets the minimum threshold of technology level, and FDI is implemented. Let technology content of inward FDI be denoted by $\Theta^S \equiv [\theta_0, \theta_1]$. The lower and upper bounds are defined as follows:

$$\pi^N(\theta_1) = \pi^S(\theta_1; T^S, z), \qquad \text{with } \pi^N_\theta(\theta_1) > \pi^S_\theta(\theta_1) \tag{12}$$

$$\pi^N(\theta_0) = \pi^S(\theta_0; T^S, z), \qquad \text{with } \pi^N_\theta(\theta_0) < \pi^S_\theta(\theta_0) \tag{13}$$

where $\pi^l_\theta \equiv \partial\pi^l/\partial\theta$ for $l \in \{N, S\}$

An interesting question is how the lower and upper bounds (where $\tilde{\pi}_N = \tilde{\pi}_S$) change when the technology frontier of the South T^S changes. This is shown in the following Lemma 2:

Lemma 2.

The upper bound θ_1 of the technology content Θ^S of inward FDI increases, while the lower bound θ_0 of the technology content Θ^S of inward FDI decreases weakly, with the South's technology frontier T^S:

$$\frac{\partial\theta_1}{\partial T^S} = [\pi^N_\theta(\theta_1) - \pi^S_\theta(\theta_1)]^{-1}\, \pi^S_{T^S}(\theta_1) > 0, \tag{14}$$

$$\frac{\partial\theta_0}{\partial T^S} = \begin{cases} [\pi^N_\theta(\theta_0) - \pi^S_\theta(\theta_0)]^{-1}\, \pi^S_{T^S}(\theta_0) < 0 & \text{if } 1 \le T^S < \theta_{NS} \\ 0, & \text{if } \theta_{NS} \le T^S \end{cases} \tag{15}$$

where $\pi^S_{T^S} \equiv \partial\pi^S/\partial T^S$. The proof of Lemma 2 is presented in Appendix A.

Aggregate production function of the MNEs in the South is assumed to be $X^S \equiv \chi(\theta_0, \theta_1, T^S) = \int_{\theta_0}^{\theta_1} x^S(\theta)\, dG(\theta)$ in a given industry. $G(\theta)$ is a cumulative distributive function, which is assumed to have a Pareto distribution with shape k: $G(\theta) = 1 - (1/\theta)^k$ for $\theta \ge 1$ with $k > \nu$. The parameter k tells the dispersion of firm productivity, where higher (lower) k implies lower (higher) dispersion of firms related to productivity. Using equation (9), the aggregate production of the MNEs in a given industry in the South becomes

$$\chi(\theta_0, \theta_1, T^S) = \begin{cases} \frac{\Omega^S k}{a}(T^S)^{\frac{z}{1-\alpha}}\left[(\theta_0)^{-a} - (\theta_1)^{-a}\right], & \text{if } 1 \le T^S < \theta_{NS}, \\ \frac{\Omega^S k}{(k-\nu)}\left[(\theta_0)^{-(k-\nu)} - (T^S)^{-(k-\nu)}\right] + & \\ \frac{\Omega^S k}{a}(T^S)^{\frac{z}{1-\alpha}}\left[(T^S)^{-a} - (\theta_1)^{-a}\right], & \text{if } \theta_{NS} \le T^S \end{cases} \quad (16)$$

where $a \equiv \frac{z}{1-\alpha} + k - \nu > 0$ holds under the parameter restriction $k > \nu$, and this leads to the fact that the aggregate output is well defined in all scenarios. The conduct of equation (16) is presented in Appendix B. Next, the effect of change in the technology frontier to the production of the MNEs in the South is defined by Proposition 3:

Proposition 3.

The aggregate production X^S of the multinationals in a given industry increases with the South's technology frontier T^S:

$$\frac{dX^S}{dT^S} = \left(\frac{\partial \chi}{\partial \theta_0}\frac{\partial \theta_0}{\partial T^S} + \frac{\partial \chi}{\partial \theta_1}\frac{\partial \theta_1}{\partial T^S} + \frac{\partial \chi}{\partial T^S}\right) \equiv \Lambda > 0 \quad (17)$$

The proof of Proposition 3 is presented in Appendix A.

4.4 Technology frontier evolution and the dynamics of FDI

The evolution of the technology frontier in the South is constructed in this subchapter, and it is made endogenous in the article of Chang and Lu (2012). Some of the equations in the remaining subchapters are only presented in the working papers of Chang and Lu (2011 and 2010). They model this technology process by introducing a learning function of Matsuyama (2002). The South increases its technology frontier by accumulating production learned from MNEs. As mentioned earlier, the focus of this thesis is to look things from the perspective of the South and same is done with this model. The aggregate discounted production activities of the MNEs in the South at time t is

$$Q_t^S \equiv \sum_{\tau=0}^{t}\left(\frac{1}{1+\delta_D}\right)^{t-\tau}\delta_L X_\tau^S \quad (18)$$

where $\delta_D > 0$ is the depreciation rate of the base of technology spillover, and $\delta_L > 0$ is the learning speed of the South related to the absorbing capacity of products of MNEs.

In real life higher δ_D would mean a loss of knowledge because of retirement of workers for example. The second parameter δ_L can become larger if human capital of the South increases or IPR protection is weakened. A weaker IPR protection should imply a faster rate of technological spillover from the MNEs to the South. The weaker IPR would also imply higher imitation risk, which could decrease the rate of multinationalization of northern firms. Thus there would be a lot less technologies to imitate after these events. It is not thus straightforward how tight the IPR policies should be made. Imitation and its effects on multinationalization is discussed more in subchapter 5.1 later on in this thesis. Now that Q_t^S is known, the basic function of the evolution of the technology frontier in the South can be presented, and it is assumed to be

$$T_t^S \equiv T_0^S + \Gamma(Q_t^S),\ t = 1, 2, \ldots \tag{19}$$

where $\Gamma(\cdot)$ is the mapping from Q_t^S to the improvement in T_t^S with three important properties: $\Gamma(0) = 0, \Gamma_Q \equiv \frac{d\Gamma}{dQ^S} > 0$ and $lim_{Q^S \to \infty} \Gamma(Q^S) \to \infty$. Two important conclusions can be made from these properties:

1) More activities by MNEs in the South increase technology frontier there
2) More recent production activities by MNEs are more valuable for the South

As earlier, I want to first show a figure which illustrates the dynamics of FDI:

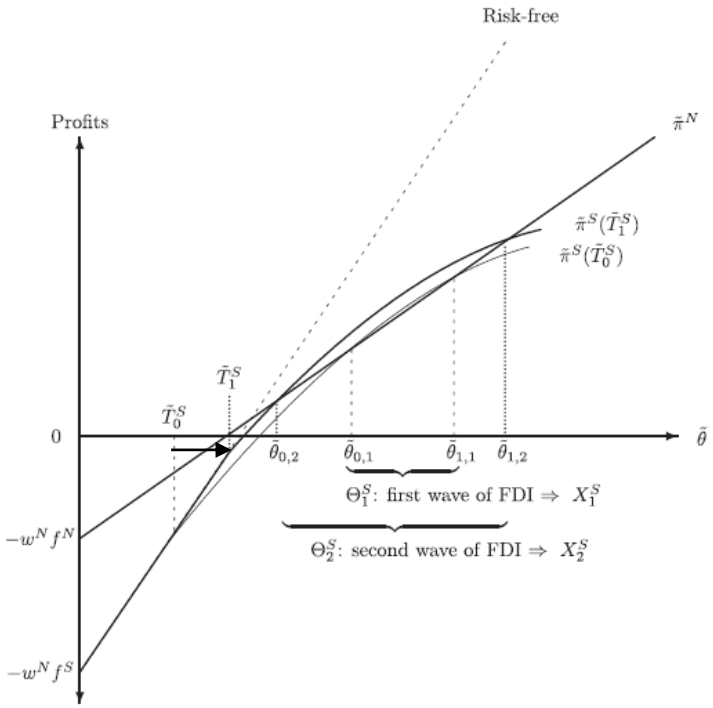

Figure 9: Dynamics of FDI (Source: Chang and Lu 2010)

It is assumed that there is no FDI at the beginning ($Q_0^S = 0$). Initial technology frontier in the South is here $T_0^S \in [1, \theta_{NS}]$, and $T^S = T_{t-1}^S$. In this case the risk parameter z has to be low enough [$z < z^*(T_0^S)$] in order to the first wave of FDI to take place. This allows the South to start a technology catch-up process. Thus in period $t = 2$, the technology frontier is higher ($T_1^S > T_0^S$), because the risk of FDI quality failure z is now lower. Lower z strictly implies higher profits for all firms with $\theta > T_0^S$. That leads to a second wave of FDI with wider range of northern firms at both the extensive and intensive margins.

4.5 Steady state

That kind of a mechanism in the previous subchapter is called a self-reinforcing agglomeration process, which makes this technology transfer very useful for the South. In the steady state we have $Q^S = \delta X^S$, where δ ($\equiv 1 + 1/\delta_D)\delta_L$ is the depreciation rate of the base of technology spillover. When $Q^S = \delta X^S$ is substituted into Eq. (19), and Eq.

(12) and (13) into Eq. (16), the steady state of the dynamic system is obtained (two simultaneous equations):

$$T^S = T_0^S + \Gamma(\delta X^S) \tag{20}$$

$$X^S = \chi(\theta_0(T^S), \theta_1(T^S), T^S) \tag{21}$$

Figure 10(a) and the curves LL (learning) and PP (production) below show the relationship between X^S and T^S, where LL illustrates Eq. (20) and PP illustrates Eq. (21). The following equations (22) and (23) are the aggregate production levels of the MNEs at $T^S = T_0^S$ and at $T^S \to \infty$, respectively:

$$\underline{X}^S \equiv \chi(\theta_0(T_0^S), \theta_1(T_0^S), T_0^S) > 0 \tag{22}$$

$$\bar{X}^S \equiv \int_{\theta_{NS}}^{\infty} \Omega^S \theta^\nu dG(\theta) = \frac{\Omega^S k}{(k-\nu)} (\theta_{NS})^{-(k-\nu)} \tag{23}$$

$\underline{X}^S > 0$, because the assumption is that a positive amount of FDI is done at the beginning. When talking about $\bar{X}^S$, it is only possible in the case of risk-free FDI ($T^S \to \infty$). From Proposition 3 it is known that X^S increases in T^S at a rate $\Lambda > 0$.

LL curve has a characteristic that the level of technology frontier in the South would stay at its initial level if no FDI took place. The two other properties of the LL curve can be deduced straightforwardly and are presented below. All these properties of PP and LL curves are summarized below:

PP (production) curve has the following properties:

i. PP reaches the lower bound $\underline{X}^S > 0$ at $T^S = T_0^S$
ii. PP increases in T^S at rate $\Lambda > 0$
iii. PP approaches the maximum level of FDI $\bar{X}^S$ as T^S goes to infinity

LL (learning) curve has the following properties:

i. LL goes through the point where the $X^S = 0$ (no FDI) and $T^S = T_0^S$
ii. LL increases in X^S at rate $\delta\Gamma_Q$
iii. LL reaches the upper bound $\bar{T}^S \equiv T_0^S + \Gamma(\delta \bar{X}^S)$ if all firms above the cutoff level θ_{NS} were to undertake FDI as in the risk-free case

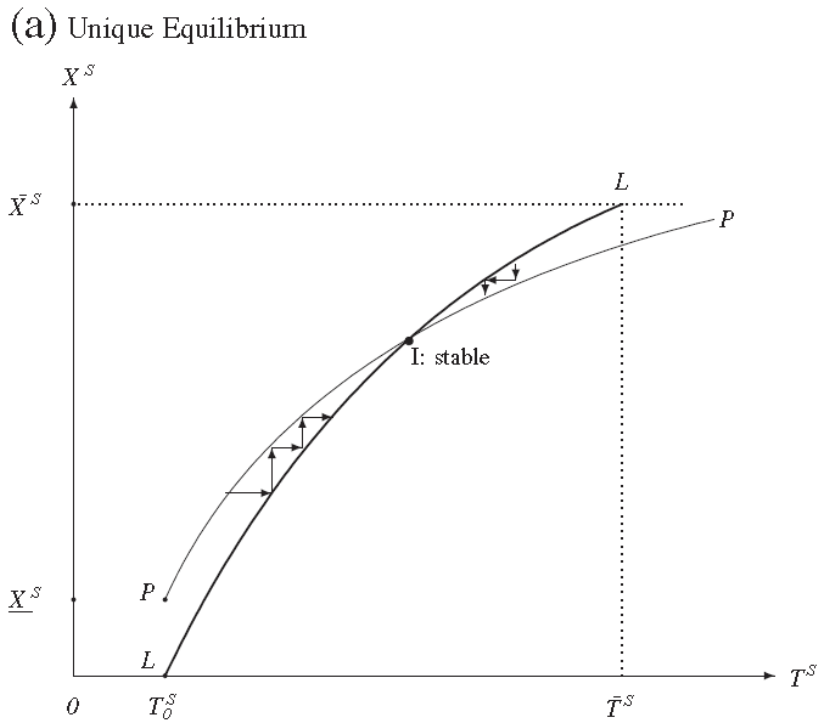

Figure 10(a): Existence of steady state (Source: Chang and Lu (2010))

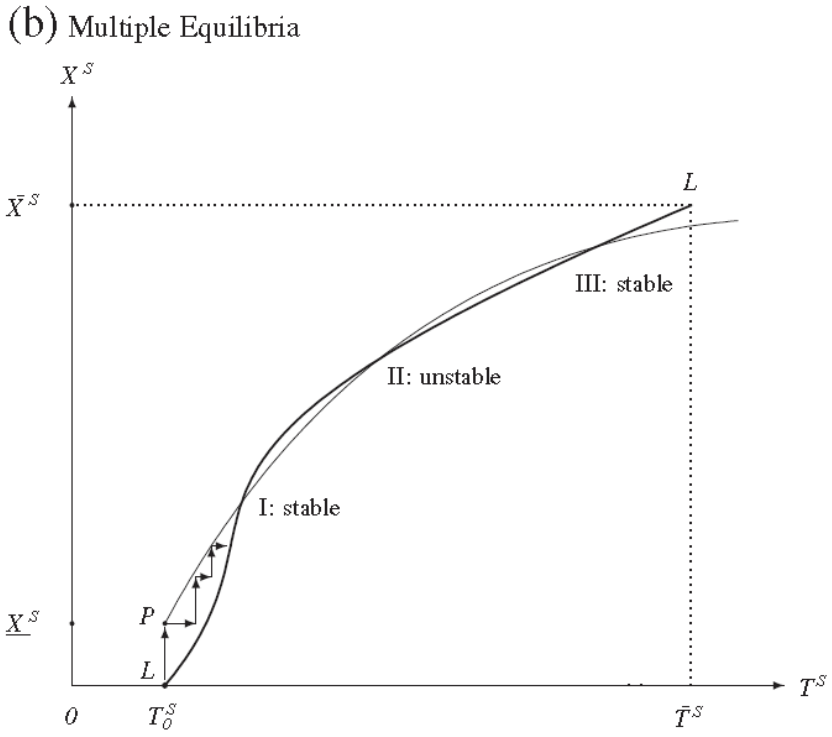

Figure 10(b): Stability of steady state (Source: Chang and Lu (2010))

These properties ensure the fact that the two curves have to cross each other at least once. Thus, there has to exist at least one steady state. Figure 10(a) illustrates the case of only one steady state, and Figure 10(b) tries to demonstrate the case of multiple steady states. In Figure 10(a) the curves cross only once, and it can be seen that the steady state is stable there. On the other hand, there can be stable and unstable steady states in the case of multiple equilibria [Figure 10(b)]. The lowest stable steady state is usually called a development trap, which is the steady state if starting with the initial technology frontier T_0^S. FDI inflows are on relatively low levels (as is the technology frontier T^S) in the development trap. A government of a developing country can have a huge effect in this kind of bad steady state situation towards the higher steady state. Different government policies are discussed intuitively and analytically in greater detail in the next subchapter. It is now important to analyze the stable steady states, and the following stability property comes from the following Lemma 4:

Lemma 4.

At a stable steady state, the following property holds,

$$\delta\Gamma_Q\Lambda < 1 \tag{24}$$

The proof of Lemma 4 is presented in Appendix A. An increase to the technology frontier in the South T^S leads to an increase in the multinational production X^S by a rate Λ. This higher X^S again increases T^S by a rate $\delta\Gamma_Q$. Thus, these two sequential effects lead to a total effect of $\delta\Gamma_Q\Lambda$. This total effect has to be below one in order an economy to be in a stable steady state. Otherwise the economy would not be in a stable steady state, and this is not what the interest here is. Now it is time to turn the focus on analyzing these stable steady states by using comparative statics with various policy parameters. The main motivation in the next subchapter is to try to find a way to get a developing country out of the development trap to the higher stable steady state.

4.6 Comparative static analysis and government policies

This subchapter utilizes the analysis made in Chang and Lu (2010). In this subchapter q denotes one of the exogenous parameters which are discussed in the earlier part of the thesis $(T_0^S, \delta_D, \delta_L, w^S, f^S, z, \rho)$. If we now take the total differentiation of (21) with respect to X^S, T^S and q; we have

$$\frac{dX^S}{dq} = \Xi + \Lambda \frac{dT^S}{dq} \tag{25}$$

where $\Xi \equiv (\frac{\partial \chi}{\partial \theta_0}\frac{\partial \theta_0}{\partial q} + \frac{\partial \chi}{\partial \theta_1}\frac{\partial \theta_1}{\partial q} + \frac{\partial \chi}{\partial q})$. The conduct of equation (25) is presented in Appendix B. The first two terms of Ξ are the extensive-margin effect, and the third term is the intensive-margin effect of q on the aggregate production X^S. From earlier it is known that $\Lambda = \frac{dX^S}{dT^S} > 0$. It is also important to notice that the parameter q also affects X^S indirectly: Changes in q affect T^S, and changes in T^S again affect X^S. Next we take the total differentiation of (20) with respect to X^S, T^S and q. After substituting $\frac{dX^S}{dq}$ in equation (25) into that expression; we obtain

$$\frac{dT^S}{dq} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial \delta}{\partial q} + \Sigma^{-1}\frac{\partial T_0^S}{\partial q} \tag{26}$$

where $\Sigma \equiv 1 - \delta\Gamma_Q\Lambda$. The conduct of equation (26) is presented in Appendix B. There are thus three different ways how a change in q can affect the technological frontier in the South:

1) The first term $(\Sigma^{-1}\delta\Gamma_Q\Xi)$: When $q = \{w^S, f^S, z, \rho\}$, a change in one of those parameters has a direct effect Ξ on X^S, which again affects T^S by a rate $\delta\Gamma_Q$. Positive reinforcing feature also generates a multiple Σ^{-1} of the initial effect on T^S.
2) The second term $\left(\Sigma^{-1}X^S\Gamma_Q\frac{\partial \delta}{\partial q}\right)$: When $q = \{\delta_D, \delta_L\}$, these parameters have a direct effect on the base of spillover Q^S through δ. The technology frontier

is then affected by a rate $X^S\Gamma_Q$. Another multiplier effect Σ^{-1} on the technology frontier is also generated.

3) The third term $\left(\Sigma^{-1}\frac{\partial T_0^S}{\partial q}\right)$: When $q = T_0^S$, it affects the steady-state T^S directly through $T^S = T_0^S + \Gamma(\delta X^S)$.

Those different parameters of q affect T^S only through one specific channel mentioned above. For example w^S affects only through channel 1) and δ_D only through channel 2) etc. Changes in the steady-state technology content of inward FDI can also be characterized with changes in lower and upper bounds. Let's take the total differentiation of (12) and (13):

$$\frac{d\theta_1}{dq} = \frac{\partial\theta_1}{\partial q} + \frac{\partial\theta_1}{\partial T^S}\frac{dT^S}{dq}, \tag{27}$$

$$\frac{d\theta_0}{dq} = \begin{cases} \frac{\partial\theta_0}{\partial q} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{dq}, & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{\partial\theta_0}{\partial q}, & \text{if } \theta_{NS} \leq T^S \end{cases} \tag{28}$$

The equations (27) and (28) show that an exogenous parameter q can directly affect upper and lower bounds of FDI inflows, if q appears in the profit functions. Upper and lower bounds can also be affected indirectly through the change in the equilibrium technology frontier following a change in q.

Many developing countries are trapped in a bad steady state as mentioned earlier, and there is a place for government intervention. This kind of intervention could shift the LL or PP curves so that a country jumps toward a higher stable steady state. The following proposition shows analytically how changes in crucial parameters could help countries to jump toward a higher steady state FDI flows:

Proposition 5.

The effects of general FDI promoting policies:

(i) $\frac{dT^S}{dT_0^S} > 0,\ \frac{dX^S}{dT_0^S} > 0,\ \frac{d\theta_1}{dT_0^S} > 0,\ \frac{d\theta_0}{dT_0^S} \leq 0$ with equality when $\theta_{NS} \leq T^S$;

(ii) $\frac{dT^S}{d\delta_D} < 0,\ \frac{dX^S}{d\delta_D} < 0,\ \frac{d\theta_1}{d\delta_D} < 0,\ \frac{d\theta_0}{d\delta_D} \geq 0$ with equality when $\theta_{NS} \leq T^S$;

(iii) $\frac{dT^S}{d\delta_L} > 0,\ \frac{dX^S}{d\delta_L} > 0,\ \frac{d\theta_1}{d\delta_L} > 0,\ \frac{d\theta_0}{d\delta_L} \leq 0$ with equality when $\theta_{NS} \leq T^S$;

(iv) $\frac{dT^S}{dw^S} < 0,\ \frac{dX^S}{dw^S} < 0,\ \frac{d\theta_1}{dw^S} < 0,\ \frac{d\theta_0}{dw^S} > 0$;

(v) $\frac{dT^S}{df^S} < 0,\ \frac{dX^S}{df^S} < 0,\ \frac{d\theta_1}{df^S} < 0,\ \frac{d\theta_0}{df^S} > 0$.

The proof of Proposition 5 is presented in Appendix A. Let's first start the discussion with the initial technology frontier T_0^S. Proposition 5 shows that higher T_0^S increases the mass of multinational production at both the extensive and intensive margins. Chang and Lu (2010) point out that a country's advantage in T_0^S compared to others is persistent and thus a very important parameter here. One example of a raise to T_0^S could be a policy directing resources in infrastructure investment. Better infrastructure attracts more direct investments by MNEs and thus leads to higher T_0^S. This decreases the risk of FDI quality failure and leads to even more production by MNEs. The following figure 11(a) below shows the movement away from the old steady state I to the new higher steady state I' in the case of a unique equilibrium:

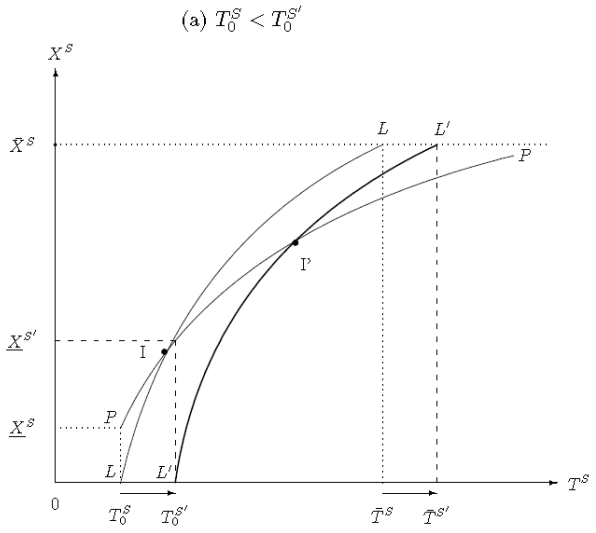

Figure 11(a): Comparative statics with T_0^S and $T_0^{S'}$ (Source: Chang and Lu (2010))

From earlier it is known that Q_t^S constitutes the base of technology spillover, and it depreciates at a rate $\delta_D > 0$. Lower δ_D thus means that the South can better utilize the knowledge from MNEs. For example better on-the-job training (OTJ) or education system could lead to a higher human capital rate, which makes a development jump possible from I to I' in the multiple steady state scenario. On the other hand, higher δ_L is also very desirable, because higher learning speed increases the efficiency or absorptive capacity of FDI. Figure 11(b) below illustrates the increasing change in parameter δ:

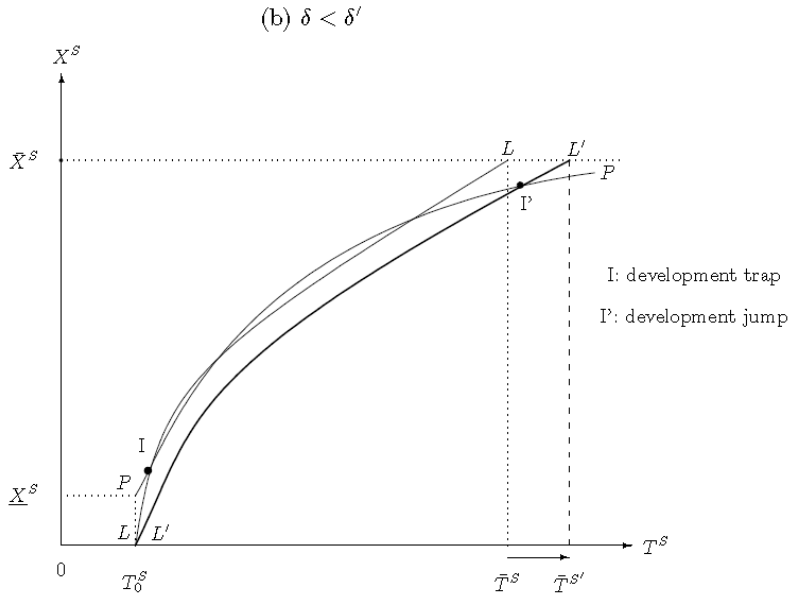

Figure 11(b): Comparative statics with δ and δ' (Source: Chang and Lu (2010))

Lastly we have w^S, f^S, z and ρ in closer review. The results are quite intuitive and are seen in Propositions 5 and 6. Lower southern wages or fixed costs always increase the technological frontier in the South and the aggregate production by MNEs. FDI flows increase both at the extensive and intensive margins with lower w^S, but lower fixed costs attract more FDI by MNEs only at the extensive margin. The intensive margin effect of w^S can be seen from Eq. (9). From the policy perspective, a FDI subsidy by a southern government could decrease w^S or f^S and thus lead to a higher steady state situation in a multiple steady state case. These two parameters and their effects on FDI inflows are illustrated with the following Figures 11(c) and 11(d):

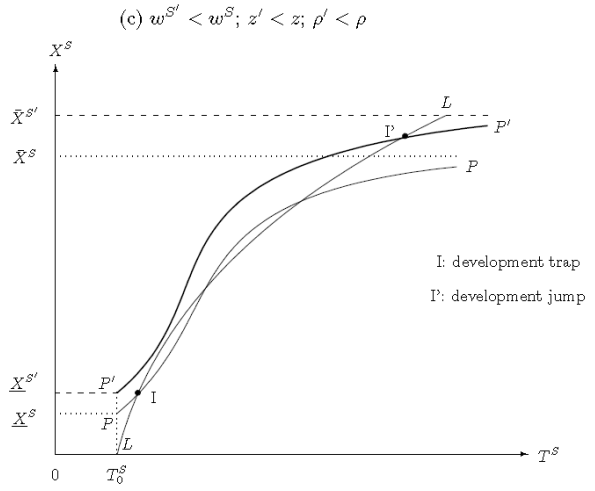

Figure 11(c): Comparative statics with $w^{S'}, w^S, z', z, \rho'$ and ρ (Source: Chang and Lu (2010))

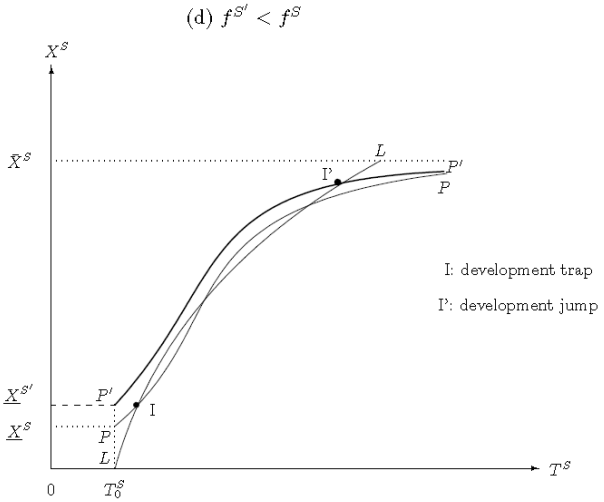

Figure 11(d): Comparative statics with $f^{S'}$ and f^S (Source: Chang and Lu (2010))

Then we have the risk parameter z and the technology parameter ρ, and the effects of these parameters can be interpreted by using the following Proposition 6:

Proposition 6.

Risk-sensitivity and industry-targeted FDI policies:

(i) $\frac{dT^S}{dz} < 0, \frac{dX^S}{dz} < 0, \frac{d\theta_1}{dz} < 0, \frac{d\theta_0}{dz} \geq 0$ with equality when $\theta_{NS} \leq T^S$

(ii) $\frac{dT^S}{d\rho} < 0, \frac{dX^S}{d\rho} < 0, \frac{d\theta_1}{d\rho} < 0, \frac{d\theta_0}{d\rho} > 0$

The proof of Proposition 6 is presented in Appendix A. Lower industry-specific z increases the technological frontier T^S, and also the production by MNEs at both the extensive and intensive margins. Higher T^S, on the other hand, decreases the risk sensitivity z. This kind of agglomeration process increases FDI inflows even more. Figures 11(c) and 11(d) also show that changes in z has similar effects as a lower w^S, f^S or ρ. The most important point this Proposition 6 tries to say is that the technological catch-up process may vary across industries, and thus FDI flows are probably also different across industries. Thus, an identical FDI-promoting policy for all different industries in an economy might be inefficient. A government of a developing country should definitely think about the proper targets of FDI policies to keep its FDI policy efficient.

The technology parameter ρ specifies the elasticity of substitution $\frac{1}{1-\rho}$ between intermediate steps of production. This parameter occurs in the cost function $c^l(\theta) = w^l\theta^{\frac{\rho-1}{\rho}}$, and it can be seen that higher ρ (the steps are more substitutable) increases costs for a FDI firm. This fact implies lower profits in the South. Higher ρ will have harmful effects for the marginal FDI firms (not yet moved production to the South) at the upper and lower bounds of FDI as the range of FDI firms will narrow. In addition to this extensive effect, an intensive effect will also occur. Firms already producing in the South will decrease their output because of higher ρ. All this leads to a lower multinational production and eventually lower technological frontier in the South. Figure 11(c) shows how lower ρ affects the economy in the South.

4.7 Predictions and a comparison with actual data

The theory of Chang and Lu (2012) leads to two major predictions:

1) Only firms with intermediate productivity levels (or intermediate technology levels) in the North will do FDI entry in relatively backward southern countries
2) Higher number of MNEs in the South decrease the risk sensitivity level, and the productivity spectrum of the intermediate firms doing FDI gets wider

The first prediction is quite an interesting one, because earlier theoretical literature, for example Helpman et al. (2004), has assumed that there is no risk of FDI failure. This leads to a prediction that firms with high technology levels do FDI. As we have learned, this is not the case at least in the big picture. In their model firms with intermediate technology levels choose foreign outsourcing instead of FDI. I am going to go through some earlier papers where empirical tests are made to test if the theory of Chang and Lu (2012) does really hold true.

Firstly I want to introduce a paper of Kimura and Kiyota (2006), where they make research on exports and FDI outflows of Japanese firms. Their data is a firm-level longitudinal panel data for Japan between 1994 and 2000. The most important finding in the context of this chapter is that the firms with medium productivity levels either export or do FDI. On the other hand, the least productive firms neither export nor do FDI whereas the high productive firms both export and do FDI. There is some controversy in these results with the theory of interest. One of the problems might be the fact that the dataset includes FDI to not only developing countries but developed countries also.

Another paper of Tomiura (2007) studies how productivity varies with different modes of globalization (outsourcing, exports and FDI). The data of this study includes all manufacturing industries in Japan, so this study is concentrated on the certain area of firms. I am interested to find what kind of productivity levels FDI firms have, so I concentrate on these particular firms. This study has also the same problem as Kimura and Kiyota (2006) related to the receiving firms of FDI. It would be optimal if the data had only FDI inflows to developing countries, but this data includes firms from all over the world.

The distribution of productivity can be seen in Figure 12 where O, X, I, and Dom are abbreviations of outsourcing, exports, FDI, and domestic firms, respectively. The scale of productivity is divided in 18 different intervals. It is easy to see that FDI firms are the most productive firms of all firms. Still they are not strikingly above the average level of the productivity spectrum. If the risk factor of Chang and Lu (2012) was included in this Figure 12 with taking all the less risky FDI flows away, the result could very well be in line with this theory. The higher productivity FDI firms should then decrease a lot, and

the firms with intermediate technologies should be the majority. Here it is of course assumed that higher productivity implies higher technology which theoretically should be the case in the long-run.

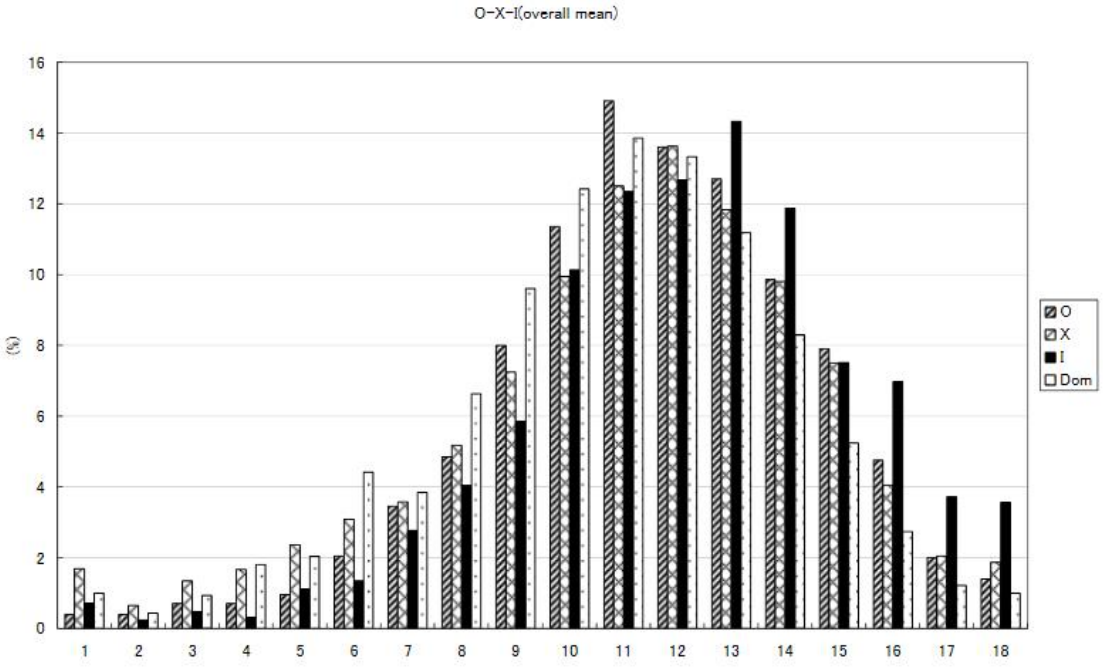

Figure 12: Productivity levels of outsourcing, exporting, FDI and domestic firms (Source: Tomiura (2007))

All in all the data is really scarce when talking about the technology levels of firms doing FDI from a developed to a developing country. It is however possible to make some conclusions about the connection between theory and empirics. Actually the empirical research of Chang and Lu (2012) might be the best in the context of this interest. Their finding of US-China and Taiwan-China data of FDI flows supports the theory of their own. Anyway, this is really an interesting topic to discuss in the future. More empirical research has to be done in order to get more supportive results in terms of this interesting theory.

4.8 Problems and possible extensions of the model

Every model has its own problems and this model is no different than any other models related to these issues. The core of the theory is the risk parameter z which has its own simplifications. The magnitude of this parameter is not opened very well in this study. It is assumed that $z \geq 0$ with no upper limit, and thus it is hard to interpret the realistic numbers of the risk parameter. It is also very simplistic way to include risk into a profit function which of course have good and bad sides to it.

Another worrying issue is the riskiness of labor force related to skills and knowledge. It can be seen that the profit functions are such that only local labor is expected to be used in the South. The idea is to utilize lower unit labor costs of southern workers. Empirical findings do not support this theory very well; in fact there are lots of cases where FDI firms use their own labor instead of local labor. These issues are presented more specifically in the subchapter 3.2. If a foreign firm uses its own labor force, it can be interpreted that there are no risks related to the technology content of managing the production successfully. The costs are of course also higher when using northern labor. The model is not able to take this into account.

To sum it up, this model is quite simple, but it does not necessarily make this model bad. Simpler models are usually able to present the main idea nicely, but they might lack some important features. This model can be expanded in many directions, if one wants to do deeper analysis with it. Chang and Lu (2012) bring up some suggestions; it is for example possible to allow the risk parameter to evolve over time. Then it is also possible to include multiple production stages in many different countries. Another interesting possibility would be to allow FDI firms to change their products or blueprints more in line with the technology frontier in the South. This would surely change the aggregate productivity of a certain industry. These extensions would make the model much more complicated, and they would not help me in any way with my particular interest of research. On the other hand, I will introduce the risk of southern imitation with southern innovation in the next chapter in order to broaden this study. I will also show how technology-neutral risks may hinder the decision of northern firms to do FDI.

5 Southern imitation with innovation and the risks of FDI

The model of Chang and Lu (2012) introduces only an exogenous risk parameter z, but in this chapter I will also introduce an imitation parameter of southern firms i which comes from the model of He and Maskus (2012). Their model is also a North-South model with labor as only factor of production. They find that initially high but decreasing imitation levels in the South might actually decrease multinationalization at the beginning of the development which is very interesting. This finding is based on a simulation of their model, and they get a result of a U-shaped curve between imitation and multinationalization rate. This can only happen though, if the South has an innovative R&D sector. There are two offsetting effects which affect the final outcome of FDI:

1) Southern labor allocated to innovation (direct *negative* effect on FDI)
2) Competition effect (*positive* effect on FDI)

The first effect refers to the fact that some potential labor for MNEs are allocated to southern innovation processes. This decreases the labor supply for MNEs and they find moving production to the South less profitable compared to the possibility of no southern innovation. The second effect is opposite compared to the first one. The competition effect takes away profits from the existing northern firms, because new southern varieties have lower prices compared to the northern ones. This makes northern firms to become MNEs in order to utilize lower production costs in the South.

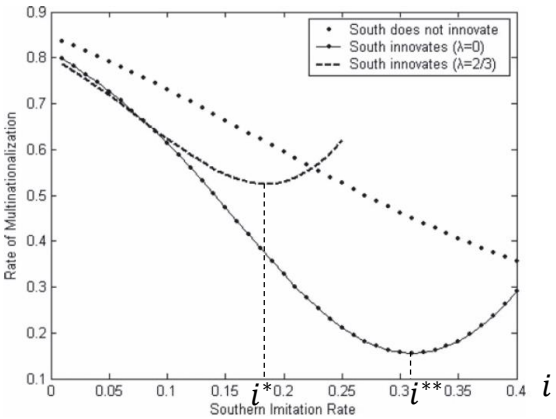

Figure 13: U-shaped curves of the innovative South (Source: Author's own variation of He and Maskus (2012))

There are actually two U-shaped curves depending on the spillover rate λ. This spillover rate is a reverse spillover rate which tells how easily knowledge flows to the North. The North is assumed to absorb knowledge from the South in addition to its own knowledge and learning-by-doing (LBD). Thus, higher λ implies lower unit labor cost for northern innovation. We can see from Figure 13 that a relatively high spillover level ($\lambda = 2/3$) makes the U-shape curve to bend upwards at lower imitation rates than without spillovers ($\lambda = 0$).

5.1 Imitation parameter i

This relatively unexpected feature of southern imitation i (with southern innovation) can now be combined with the exogenous risk parameter z. I am not going to include this imitation parameter of i into the southern profit function when $1 \leq \theta \leq T^S$, because there is assumed to be no risk of imitation in this case. I also assume that imitation or IPR levels within industries may differ like the risk parameter z, which is a reasonable and realistic assumption. For example a pharmaceutical industry have to put massive amounts of money creating drugs for people. It is thus logical that this particular industry needs a very strong IPR protection against imitation. This kind of industry is much more sensitive to IPR protection than some other industries are. These previous properties ensures that the imitation parameter i behaves similarly with the risk parameter z. Thus, the following profit functions are exactly similar to the profit functions in the paper of Chang and Lu (2012) except that the overall risk is now $z + i$ instead of z. The expected profits in the North and the South are now

$$\pi^N(\theta) = \psi^N \theta^{v\alpha} - w^N f^N, \qquad \forall \theta, \text{where } 1 \leq \theta$$

$$\pi^S(\theta; T^S, z) = \begin{cases} \psi^S \theta^{v\alpha} - w^N f^S, & \text{if } 1 \leq \theta \leq T^S \\ \psi^S \left(\frac{T^S}{\theta}\right)^{\frac{z+i}{1-\alpha}} \theta^{v\alpha} - w^N f^S, & \text{if } T^S < \theta \end{cases}$$

where $i \geq 0$ is the imitation of the southern firms with the properties of

$$\begin{cases} \frac{d(\pi^S - \pi^N)}{di} < 0 & \text{if } 0 < i < i^* \\ \frac{d(\pi^S - \pi^N)}{di} \geq 0 & \text{if } i^* \leq i \end{cases}$$ with high degree of spillovers and southern R&D

$$\begin{cases} \frac{d(\pi^S - \pi^N)}{di} < 0 & \text{if } 0 < i < i^{**} \\ \frac{d(\pi^S - \pi^N)}{di} \geq 0 & \text{if } i^{**} \leq i \end{cases}$$ without spillovers and with southern R&D

where i^* and i^{**} divide the low and high levels of imitation with their respective levels of spillovers in the innovative South. Those two particular levels of imitation i^* and i^{**} are just illustrating the features of the model of He and Maskus (2012).

The interpretation of these two properties is that for example increasing (initially) high imitation levels increase the profits more in the South than in the North. Southern innovation expands the variety of southern products and increases competition for more expensive northern varieties. The market share and profits of northern firms would go down, and that's why they would like to become MNEs to utilize lower unit labor costs. Northern R&D sector can innovate even more varieties in the case of high degree of spillovers, because the North can now utilize information and technology from southern products. This increases multinationalization because northern firms want to again utilize the lower unit labor costs in the South. Figure 13 shows this mechanism, and it can be seen that the curve with high degree of spillovers is bending much faster than the other U-shaped curve.

The basic literature assumes that higher imitation or weaker IPR always implies lower FDI flows to the host countries. He and Maskus (2012) find a U-shaped curve between these two which contradicts the standard literature. This interesting feature of imitation was plugged into the main model of Chang and Lu (2012) in this subchapter. Next I am going to open up the content of the risk parameter z a little more. Additionally some of the technology-neutral risks of FDI are analyzed and plugged into the main model. It is known that FDI firms with technology $1 \leq \theta \leq T^S$ do not have risks related to technology in the South, but these firms might have another type of risks in the South.

5.2 Risk parameter z and technology-neutral country risks r

Chang and Lu (2012) do not open up the content of the risk parameter z very much in their own article, but they basically talk about the risk of FDI quality failure in a more general level. On the other hand, the article of Chang and Lu (2009) define the evolvement of z in the following way:

$$z_t = \frac{1}{K + T_{t-1}} \, , K \geq 0, t = 1,2, \ldots$$

where the parameter K is the level of infrastructure in the South, which is same in all industries. T_{t-1} is the accumulated knowledge diffused from the North to the South in period $t-1$. The most important variables in K include physical infrastructure, social capital, human capital, and governance infrastructure. Infrastructure is an important factor here, because it can affect the threshold level of z^* with a given technology level.

The model of Chang and Lu (2012) has only the risk related to the technology gap between the North and the South. Even if the technology level of the South exceeds the level of a firm doing FDI, the production may not be completed if some outside risks come to negatively affect the production process. The most usual risk in the newer literature of FDI is a political risk which might adversely affect FDI flows. Other kind of risks include for example environmental catastrophes for all technological levels of FDI firms. These different risks are discussed in the following few sections.

The risk parameter z is connected to the technology gap between the North and the South which affects the final success probability of production, but there are other kind of risks that might have effects on every FDI firm regardless of their level of technology. These risks straightforwardly decrease the expected profits of all the FDI firms wanting to produce in the South. Hayakawa et al. (2013) describe these kind of risks as country risks which include different form of political and financial risks. They also point out that political risk increases the risk that the profits of a FDI firm might be negatively affected. FDI firms have high sunk (fixed) costs, so the future variable profits are extremely important for them. Another type of risk could be a risk of expropriation which is discussed more in this subchapter later.

Next I want to modify the profit functions of the previous subchapter 5.1 so that I add a parameter of r to illustrate the technology-neutral risks for a FDI firm. These risks might affect FDI firms regardless of their technology levels. The parameter r can be interpreted as a discount rate of the profits in the South, so that it decreases the expected profits or the value of a FDI firm. The parameter r is here some exogenous cost for a FDI firm, for example a risk of decrease in the future returns to investment because of expropriation risk in the South. The parameter r can also include risks of a war or a currency instability in addition to the risks of poor institutional quality or political instability. The difficulty for a firm is obviously to estimate the magnitude of these kind of risks when making a decision to move or not to move production to the South.

The expected profits in the North and the South are now

$$\pi^N(\theta) = \psi^N \theta^{v\alpha} - w^N f^N, \qquad \forall\theta, \text{where } 1 \leq \theta$$

$$\pi^S(\theta; T^S, z) = \begin{cases} \dfrac{1}{1+r}[\psi^S \theta^{v\alpha}] - w^N f^S, & \text{if } 1 \leq \theta \leq T^S \\ \dfrac{1}{1+r}\left[\psi^S \left(\dfrac{T^S}{\theta}\right)^{\frac{z+i}{1-\alpha}} \theta^{v\alpha}\right] - w^N f^S, & \text{if } T^S < \theta \end{cases}$$

where $r \geq 0$ is the exogenous discount parameter.

A research of Hayakawa et al. (2013) open up these risks a little bit more from the country-specific perspective. They made a research of 89 countries during the period from 1985 to 2007, and they investigate various elements of political and financial risks. Their data includes 56 developing countries, where one would especially assume that political risk is a potentially very harmful for FDI inflows. Many developing countries suffer from poor institutional quality which straightforwardly implies high political risk. Hayakawa et al. (2013) find that political risk is indeed adversely affected with FDI inflows. The more surprising finding is that the financial risk seems not to be adversely connected with FDI inflows. Countries with high political risk should be encouraged, because this research also points out that a decrease in the level of political risk also matters (a positive signal for FDI firms), not only the absolute level. Thus a very high risk

country is still able to attract some FDI, if the government is doing improvements related to these issues. Political risk may include many different components, and this research finds that especially internal conflict, corruption, military in politics, and bureaucracy quality have adverse effects for FDI inflows in developing countries. Political risk can therefore decrease the expected future profits for the FDI firms because of these harmful components. Another paper of Busse and Hefeker (2007) includes many indicators of political risk with data sample of 83 developing countries from year 1984 to 2003. They find that government stability and law and order have the most significant negative harmful effects for developing countries. Other significant indicators with negative impacts on FDI flows are internal and external conflict, corruption, ethnic tensions, democratic accountability of government, and quality of bureaucracy.

As mentioned earlier, financial risk may increase FDI flows (especially to developing countries) according to Hayakawa et al. (2013). Financial risk is the risk where the host country has difficulties to pay back its foreign liabilities. This surprising finding of financial risk should not be necessarily interpreted causally, because there is a reason behind this relationship. The FDI flows data of this research include not only green field FDI but also mergers and acquisitions (M&As). Local firms in financial trouble have a big chance to be merged with MNEs, and that's why financial risk is associated with more FDI inflows. This kind of FDI is called a fire-sale FDI which happens during recessions and financial crises. If M&As are taken out of the data of FDI flows, I would question the result of no adverse relationship between financial risk and FDI inflows. Of course different industries might have different connections between the financial risk and FDI flows.

Countries have to compete with each other in the field of country-specific risks, but it is very much possible that even industries within countries may vary when talking about risks of doing FDI. Many developing countries have vast natural resources and this makes resource-based sectors very attractive for foreign firms. One interesting industry-specific risk for the resource-based sector is expropriation. Expropriation means that "a host-country government seizes company assets without fair compensation", as Hajzler (2014) describes it. This kind of direct expropriation of a host government is becoming

less common in developing countries. On the other hand, Janeba (2002) mentions a term of “creeping expropriation” in his article which can imply high taxes or tariffs for the FDI firms. A wonderful example of this was Bolivia’s decision to suddenly raise tax levels of FDI revenues in two giant gas fields from 50 to 82 per cent in year 2006 (Washington Post). This event obviously decreased the future profits for the operating FDI firms in Bolivia. This particular risk exists in other industries too, but it is much more acute in resource-based sector as Hajzler (2014) mentions.

In spite of expropriation, the world has seen a continuing departments of FDI in risky resource-based sectors. Hajzler’s (2014) model actually suggests that FDI flows are higher in the extractive industries, when the expropriation risk is high. This suggests that there are some underlying incentives that attract the investments in these risky industries. This is exactly what Hajzler (2014) finds and points out that subsidies to foreign investments are an important part of the decision-making of FDI firms in this context. Janeba (2002) complements this finding by saying that the host governments give subsidies to FDI firms, so that these subsidies compensate the sunk costs of these firms. He also discusses the possibility of MNEs to have production in multiple countries simultaneously. In this case there might be competition between countries related to taxing or/and subsidizing FDI firms. The risk of a FDI firm to leave a country because of harmful policies can affect the thought process of the governments in developing countries.

The final conclusion from all of this discussion is that politically risky countries have to make good deals with the FDI firms, if they want them to invest in their countries. The comparison between the expected revenues and costs in potential MNEs are going on all the time. The excepted high costs might not be harmful, if the expected revenues also are high enough. Especially in the extractive industries FDI flows are not as sensitive to political and financial risks as in some other industries (Hayakawa et al. 2013). The expected profits especially from natural resources might be so high that the FDI firms are willing to take these kind of risks. These previous examples illustrate just few possible risks that might affect the revenues of the FDI firms. They are though very important factors when FDI firms are making their decision to invest in developing

countries. In this thesis these risks are completely exogenous, but it would be easier to approximate the effect of the risks, if they were endogenized. This kind of extension is hopefully done in the future.

6 Summary and discussion

This thesis has been discussing an interesting and current topic of FDI from the perspective of developing countries. FDI is not a new phenomenon, but new and different countries has started to receive these investments in recent years. The standard FDI literature have found that FDI inflows can really help the economic development in poor countries. However, it is found that these countries need absorptive capacity in order to utilize these flows in the best possible way. A minimum threshold stock of human capital and economic freedom are found to be two very important features of absorptive capacity.

The main model is supported by an empirical chapter of FDI from China to Sub-Saharan Africa (SSA). This relationship has become evident in the last ten or twenty years. Lots of different aspects of this particular case are discussed, and the main focus is in various risks and possibilities related to these FDI flows. China's interest in SSA has been concentrating on the extractive industry sectors, although the spectrum of different industries is widening all the time in China-SSA FDI. One of the most worrying case in SSA is found to be the lack of usage of local labor in Chinese MNEs. Chinese multinational firms might not want to reveal their newest technologies to the African workers, and this might hinder the technological spillover effect from Chinese MNEs to the local firms in developing countries. On the other hand, the possibilities in China-SSA FDI should be utilized for the benefit of people in SSA. The optimal solution could be a win-win situation where both Chinese FDI firms and people in SSA are better off. The worst case scenario is where Chinese FDI firms exploit resources, and the economic development in SSA suffers because of this event. The governments in SSA should impose laws and rules which prevent this kind of development.

The decision-making of FDI firms is a process of comparing costs and benefits in a foreign country. These firms can include many different factors into this process, but the technology frontier and the risk of FDI quality failure in a developing country are discussed more in detail in the main model of this thesis. This model is a North-South model with labor as only factor of production. A northern firm might have a higher technology level than the southern technology frontier is (in a given industry) which causes a risk of failure in production in the South. The lack of proper skills and knowledge of southern workers to use northern technologies is a risk for a possible MNE which might reduce the value of the production in the South. The most important finding of this model is that only northern firms with intermediate technology levels start doing FDI. Previous FDI models have not found this feature related to the technology levels of northern firms. They usually claim that firms with the highest technology move their production to the South.

The main model is extended with southern imitation risk (with an innovative R&D sector), and it is found that the relationship between multinationalization and imitation is U-shaped. This feature (imitation) can be plugged into the profit functions of the main model. Higher IPR or lower imitation is found to decrease or increase multinationalization depending on the initial level of IPR in a given industry. After this, an extension of technology-neutral risks is made to include risks which can be common for all MNEs regardless of their technology levels. For example a political risk in the South is found to have an adverse effect on the future expected profits in the South. These kind of risks have to be discounted in the profit function of the South.

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Appendix A

The calculations in this Appendix A is based on the proofs of Chang and Lu (2012, 2011 and 2010) apart from the proof of Proposition 3 which is done by the author of the thesis.

Proof of Proposition 1:

First we have to show that there exists a unique $z^*(T^S)$ such that $\tilde{\pi}^S(\widetilde{\theta};\ \tilde{T}^S, z)$ is tangent to $\tilde{\pi}^N(\tilde{\theta})$. Let $\tilde{\theta}^\dagger$ define the technology level where the two profit functions have the same slope. Therefore it follows that

$$\tilde{\theta}^\dagger(\tilde{T}^S, z) = \left[\left(1 - \frac{z}{\nu\alpha(1-\alpha)}\right)\frac{\psi^S}{\psi^N}\right]^{\frac{\nu\alpha(1-\alpha)}{z}} \tilde{T}^S \tag{29}$$

$\tilde{\theta}^\dagger$ exists and is bounded if and only if $0 < z < \bar{z}$, where $\bar{z} \equiv \left(1 - \frac{\psi^S}{\psi^N}\right)\nu\alpha(1-\alpha)$. Let $\phi(\tilde{T}^S, z)$ denote the distance between $\tilde{\pi}^S(\widetilde{\theta};\ \tilde{T}^S, z)$ and $\tilde{\pi}^N(\tilde{\theta})$ at the technology level $\tilde{\theta}^\dagger$. Then we have

$$\phi(\tilde{T}^S, z) = \psi^N\tilde{\theta}^\dagger(\tilde{T}^S, z)/g(z) - w^N(f^S - f^N) \tag{30}$$

where $g(z) \equiv \frac{\nu\alpha(1-\alpha)}{z} - 1$. For $\tilde{T}^S \in [1, \tilde{\theta}_{NS})$ and $z \in (0, \bar{z})$,

$$\frac{\partial\phi(\tilde{T}^S,z)}{\partial z} < 0, \lim_{z\to 0}\phi(\tilde{T}^S, z) \to \infty, \lim_{z\to\bar{z}}\phi(\tilde{T}^S, z)$$

$$= \tilde{T}^S(\psi^S - \psi^N) - w^N(f^S - f^N) < 0, \tag{31}$$

where the first limit follows by applying L´Hospital´s Rule to $\tilde{\theta}^\dagger$ and $g(z)$. The sign of the second limit follows by the fact that $\tilde{\pi}^S(\widetilde{\theta};\ \tilde{T}^S, z)$ is strictly dominated by $\tilde{\pi}^N(\tilde{\theta})$ at $\tilde{\theta} = \tilde{T}^S < \tilde{\theta}_{NS}$. By the fixed point theorem, there exists a unique $z^* \in (0, \bar{z})$, such that

$$\phi(\tilde{T}^S,\ z^*) = 0 \tag{32}$$

and $\tilde{\pi}^S$ is tangent to $\tilde{\pi}^N$. For $z < z^*$ it follows from equation (31) that $\phi(\tilde{T}^S, z) > 0$, and that leads to positive FDI flows. For $T^S = \theta_{NS}$, the profit function of the South rises above the profit function of the North to the right of $T^S = \theta_{NS}$ if and only if $z < \bar{z}$. This means that $z^*(\theta_{NS}) = \bar{z}$. For $T^S \in (\theta_{NS}, \infty)$, the profit function of the South lies strictly

above the profit function of the North at least for $\theta \in (\theta_{NS}, T^S + \epsilon]$, where $\epsilon > 0$. This leads to a result that FDI takes place regardless of z.

Next we show the existence and uniqueness of $T^{S^*}(z)$ for all z. From the above we know that $z^*(1)$ is the cap of the risk sensitivity when the South's technology frontier is at the lowest level $T^S = 1$. For z below the cap $z^*(1)$ FDI always takes place, which means same thing as $T^{S^*}(z) = 1$ for $z \in [0, z^*(1)]$. For large enough risk sensitivity ($z \geq \bar{z}$) the profit function of the South is flatter than the profit function in the North for all $\theta > T^S$. Thus, FDI will take place if and only if the technology frontier exceeds the risk-free cutoff level θ_{NS}, so $T^{S^*}(z) = \theta_{NS}$ for $z \geq \bar{z}$.

To show the existence of a unique $T^{S^*}(z)$ for $z \in (z^*(1),\ \bar{z})$ is equivalent to show the existence of a unique technology frontier level $T^{S^*} \in (1, \theta_{NS})$ such that $\tilde{\pi}^S$ is tangent to $\tilde{\pi}^N$ or equivalently

$$\phi\left(\tilde{T}^{S^*}, z\right) = 0 \tag{33}$$

It is straightforward to verify that for $\tilde{T}^S \in (1,\ \tilde{\theta}_{NS})$ and $z \in (z^*(1),\ \bar{z})$ that

$$\frac{\partial \phi(\tilde{T}^S, z)}{\partial \tilde{T}^S} > 0,\ \lim_{\tilde{T}^S \to 1} \phi(\tilde{T}^S, z) < 0,\ \lim_{\tilde{T}^S \to \tilde{\theta}_{NS}} \phi(\tilde{T}^S, z) > 0. \tag{34}$$

We get the negative sign of the first limit by the fact that $\phi(1,\ z^*(1)) = 0$ and $\frac{\partial \phi(1,z)}{\partial z} < 0$. To get the positive sign of the second limit we use the fact that $\phi(\tilde{T}^S, z)$ is the unique maximum of the profit difference $\tilde{\pi}^S\left(\tilde{\theta};\ \tilde{T}^S, z\right) - \tilde{\pi}^N(\tilde{\theta})$. We also know that $\tilde{\pi}^S\left(\tilde{\theta};\ \tilde{T}^S, z\right) - \tilde{\pi}^N\left(\tilde{\theta}\right) = 0$ holds at $\tilde{\theta} = \tilde{T}^S = \tilde{\theta}_{NS}$ and that $\tilde{\theta}^\dagger > \tilde{T}^S$ and therefore we get the result. Thus, by the fixed point theorem, there exists a unique $\tilde{T}^{S^*} \in (1,\ \tilde{\theta}_{NS})$ for $z \in (z^*(1), \bar{z})$, such that equation (33) is satisfied.

Finally we want to show the relationship between T^{S^*} and z by taking the total differentiation of equation (33):

$$\frac{d\tilde{T}^{S^*}}{dz} = -\left.\frac{\frac{\partial \phi\left(\tilde{T}^S, z\right)}{\partial z}}{\frac{\partial \phi(\tilde{T}^S, z)}{\partial \tilde{T}^S}}\right|_{\tilde{T}^S = \tilde{T}^{S^*}} > 0$$

It then follows that $\frac{dT^{S^*}}{dz} = \left(\frac{d\tilde{T}^{S^*}}{dz}\right)\left(\frac{dT^{S^*}}{d\tilde{T}^{S^*}}\right) > 0$ for $z \in (z^*(1), \bar{z})$. We also have $\frac{dT^{S^*}}{dz} = 0$ for $z \in [0, z^*(1)]$ and for $z \geq \bar{z}$.

Proof of Lemma 2:

We know from (12) and (13) that $\pi_\theta^N(\theta_1) - \pi_\theta^S(\theta_1) > 0$ and $\pi_\theta^N(\theta_0) - \pi_\theta^S(\theta_0) < 0$. Then we also note that $\pi_{T^S}^S > 0$ for $\theta > T^S$ and $\pi_{T^S}^S = 0$ for $\theta \leq T^S$. Now we get the signs of (14) and (15): $\frac{\partial \theta_1}{\partial T^S} = \frac{\oplus}{\oplus} > 0$ and $\frac{\partial \theta_0}{\partial T^S} = \begin{cases} \frac{\oplus}{\ominus} < 0 & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{0}{\ominus} = 0 & \text{if } \theta_{NS} \leq T^S \end{cases}$.

Proof of Proposition 3:

We have to verify the signs of $\frac{\partial \chi}{\partial \theta_0}$, $\frac{\partial \chi}{\partial \theta_1}$ and $\frac{\partial \chi}{\partial T^S}$. Let's first find the sign of $\frac{\partial \chi}{\partial \theta_0}$:

$$\frac{\partial \chi}{\partial \theta_0} = \begin{cases} -\Omega^S k (T^S)^{\frac{z}{1-\alpha}} [(\theta_0)^{-a-1}] < 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ -\Omega^S k \left[(\theta_0)^{-(k-\nu)-1}\right] < 0, & \text{if } \theta_{NS} \leq T^S \end{cases},$$

and thus it follows that $\frac{\partial \chi}{\partial \theta_0} < 0$ is always true. Next, let's find the sign of $\frac{\partial \chi}{\partial \theta_1}$:

$$\frac{\partial \chi}{\partial \theta_1} = \begin{cases} \Omega^S k (T^S)^{\frac{z}{1-\alpha}} [(\theta_1)^{-a-1}] > 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ \Omega^S k (T^S)^{\frac{z}{1-\alpha}} [(\theta_1)^{-a-1}] > 0, & \text{if } \theta_{NS} \leq T^S \end{cases},$$

and thus it follows that $\frac{\partial \chi}{\partial \theta_1} > 0$ is always true. Finally we have to find the sign of $\frac{\partial \chi}{\partial T^S}$:

$$\frac{\partial \chi}{\partial T^S} = \begin{cases} \frac{z}{1-\alpha}\frac{\Omega^S k}{a}(T^S)^{\frac{z}{1-\alpha}-1}[(\theta_0)^{-a} - (\theta_1)^{-a}] > 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ \Omega^S k\left[(T^S)^{-(k-\nu)-1}\right] + & \\ \frac{z}{1-\alpha}\frac{\Omega^S k}{a}(T^S)^{\frac{z}{1-\alpha}-1}[(T^S)^{-a} - (\theta_1)^{-a}] - \Omega^S k\left[(T^S)^{-(k-\nu)-1}\right], & \text{if } \theta_{NS} \leq T^S \end{cases}$$

$$\rightarrow \frac{\partial \chi}{\partial T^S} = \begin{cases} \frac{z}{1-\alpha}\frac{\Omega^S k}{a}(T^S)^{\frac{z}{1-\alpha}-1}[(\theta_0)^{-a} - (\theta_1)^{-a}] > 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{z}{1-\alpha}\frac{\Omega^S k}{a}(T^S)^{\frac{z}{1-\alpha}-1}[(T^S)^{-a} - (\theta_1)^{-a}] > 0, & \text{if } \theta_{NS} \leq T^S \end{cases}$$

and thus it follows that $\frac{\partial \chi}{\partial T^S} > 0$ is always true. Now we know all the crucial signs to give the proof of Λ, and it goes the following way:

$$\begin{cases} \frac{dX^S}{dT^S} = \ominus\ominus + \oplus\oplus + \oplus > 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{dX^S}{dT^S} = \ominus\, 0 + \oplus\oplus + \oplus > 0, & \text{if } \theta_{NS} \leq T^S \end{cases}$$

and the final result is obtained: $\frac{dX^S}{dT^S} = \Lambda > 0$ is always true.

Proof of Lemma 4:

We know from the properties of PP and LL curves that at a stable steady state PP crosses LL from above. Analytically this means that the inverse of the slope of PP has to be higher than the slope of LL. Thus, $\frac{d\chi}{dT^S} < \left[\frac{d\Gamma}{dX^S}\right]^{-1}$ or $\frac{d\Gamma}{dX^S}\frac{d\chi}{dT^S} < 1$. We know that $\frac{d\Gamma}{dX^S} = \delta\Gamma_Q$ and $\frac{d\chi}{dT^S} = \Lambda$. Thus we have $\delta\Gamma_Q\Lambda < 1$ at a stable steady state.

Proof of Propositions 5-6:

First of all we have to determine the signs of (25)-(28). We know from Lemma 4 that $\Sigma = 1 - \delta\Gamma_Q\Lambda > 0$ holds at a stable steady state. Also from earlier $\Lambda > 0$ and $\Gamma_Q > 0$, $\frac{\theta_1}{T^S} > 0$ and $\frac{\theta_0}{T^S} = \begin{cases} < 0 & \text{if } 1 \leq T^S < \theta_{NS} \\ 0 & \text{if } \theta_{NS} \leq T^S \end{cases}$. We also have to note that based on the definition in (12)-(13) for the upper and lower bounds of the technology content it follows that

$$\frac{\partial \theta_1}{\partial q} \equiv \left[\pi_\theta^N(\theta_1) - \pi_\theta^S(\theta_1)\right]^{-1}\left[\pi_q^S(\theta_1) - \pi_q^N(\theta_1)\right], \tag{35}$$

$$\frac{\partial \theta_0}{\partial q} \equiv \begin{cases} \left[\pi_\theta^N(\theta_0) - \pi_\theta^S(\theta_0)\right]^{-1}\left[\pi_q^S(\theta_0) - \pi_q^N(\theta_0)\right], & \text{if } 1 \leq T^S < \theta_{NS} \\ \left[\pi_\theta^N(\theta_{NS}) - \pi_\theta^S(\theta_{NS})\right]^{-1}\left[\pi_q^S(\theta_{NS}) - \pi_q^N(\theta_{NS})\right], & \text{if } \theta_{NS} \leq T^S \end{cases} \tag{36}$$

where $\pi_q^l \equiv \frac{\partial \pi^l}{\partial q}$ for $l \in \{N, S\}$. Next we want to determine the sign of $\Xi \equiv (\frac{\partial \chi}{\partial \theta_0}\frac{\partial \theta_0}{\partial q} + \frac{\partial \chi}{\partial \theta_1}\frac{\partial \theta_1}{\partial q} + \frac{\partial \chi}{\partial q})$. It is already known that $\frac{\partial \chi}{\partial \theta_0} < 0$ and $\frac{\partial \chi}{\partial \theta_1} > 0$. Thus, we have to show the signs of $\frac{\partial \theta_1}{\partial q}$, $\frac{\partial \theta_0}{\partial q}$ and $\frac{\partial \chi}{\partial q}$. This is done by using the profit functions (10) and (11), and the

FDI aggregate production function (16), for each parameter. The derivations are done below in every different case of q.

(i) $\boldsymbol{q = T_0^S}$:

T_0^S does not appear in the profit functions (10) and (11), and the FDI aggregate production function, so $\frac{\partial \theta_1}{\partial T_0^S} = 0, \frac{\partial \theta_0}{\partial T_0^S} = 0$ and $\frac{\partial \chi}{\partial T_0^S} = 0$. Thus we have $\Xi = \ominus 0 + \oplus 0 + 0 = 0$, and

$$\frac{dT^S}{dT_0^S} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial \delta}{\partial T_0^S} + \Sigma^{-1}\frac{\partial T_0^S}{\partial T_0^S} = \oplus 0 + \oplus 0 + \Sigma^{-1} > 0$$

$$\frac{dX^S}{dT_0^S} = \Xi + \Lambda\frac{dT^S}{dT_0^S} = 0 + \oplus\oplus > 0$$

$$\frac{d\theta_1}{dT_0^S} = \frac{\partial \theta_1}{\partial T_0^S} + \frac{\partial \theta_1}{\partial T^S}\frac{dT^S}{dT_0^S} = 0 + \oplus\oplus > 0$$

$$\frac{d\theta_0}{dT_0^S} = \begin{cases} \frac{\partial \theta_0}{\partial T_0^S} + \frac{\partial \theta_0}{\partial T^S}\frac{dT^S}{dT_0^S} = 0 + \ominus\oplus < 0 & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{\partial \theta_0}{\partial T_0^S} = 0, & \text{if } \theta_{NS} \leq T^S \end{cases}$$

(ii) $\boldsymbol{q = \delta_D}$:

δ_D does not appear in the profit functions (10) and (11), and the FDI aggregate production function (16) , so $\frac{\partial \theta_1}{\partial \delta_D} = 0, \frac{\partial \theta_0}{\partial \delta_D} = 0$ and $\frac{\partial \chi}{\partial \delta_D} = 0$. This gives us the sign of $\Xi = \ominus 0 + \oplus 0 + 0 = 0$, and

$$\frac{dT^S}{d\delta_D} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial \delta}{\partial \delta_D} + \Sigma^{-1}\frac{\partial T_0^S}{\partial \delta_D} = \oplus 0 + \oplus\ominus + \oplus 0 < 0$$

$$\frac{dX^S}{d\delta_D} = \Xi + \Lambda\frac{dT^S}{d\delta_D} = 0 + \oplus\ominus < 0$$

$$\frac{d\theta_1}{d\delta_D} = \frac{\partial \theta_1}{\partial \delta_D} + \frac{\partial \theta_1}{\partial T^S}\frac{dT^S}{d\delta_D} = 0 + \oplus\ominus < 0$$

$$\frac{d\theta_0}{d\delta_D} = \begin{cases} \frac{\partial \theta_0}{\partial \delta_D} + \frac{\partial \theta_0}{\partial T^S}\frac{dT^S}{d\delta_D} = 0 + \ominus\ominus > 0 & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{\partial \theta_0}{\partial \delta_D} = 0, & \text{if } \theta_{NS} \leq T^S \end{cases}$$

(iii) $\boldsymbol{q = \delta_L}$:

δ_L does not appear in the profit functions (10) and (11), and the FDI aggregate production function (16), so $\frac{\partial \theta_1}{\partial \delta_L} = 0, \frac{\partial \theta_0}{\partial \delta_L} = 0$ and $\frac{\partial \chi}{\partial \delta_L} = 0$. This gives us the sign of $\Xi = \ominus\, 0 + \oplus\, 0 + 0 = 0$, and

$$\frac{dT^S}{d\delta_L} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial \delta}{\partial \delta_L} + \Sigma^{-1}\frac{\partial T_0^S}{\partial \delta_L} = \oplus\, 0 + \oplus\oplus + \oplus\, 0 \; > 0$$

$$\frac{dX^S}{d\delta_L} = \Xi + \Lambda\frac{dT^S}{d\delta_L} = 0 + \oplus\oplus > 0$$

$$\frac{d\theta_1}{d\delta_L} = \frac{\partial \theta_1}{\partial \delta_L} + \frac{\partial \theta_1}{\partial T^S}\frac{dT^S}{d\delta_L} = 0 + \oplus\oplus > 0$$

$$\frac{d\theta_0}{d\delta_L} = \begin{cases} \frac{\partial \theta_0}{\partial \delta_L} + \frac{\partial \theta_0}{\partial T^S}\frac{dT^S}{d\delta_L} = 0 \; + \ominus\oplus < 0 & \text{if } 1 \le \; T^S < \theta_{NS} \\ \frac{\partial \theta_0}{\partial \delta_L} = 0, & \text{if } \theta_{NS} \; \le \; T^S \end{cases}$$

(iv) $\boldsymbol{q = w^S}$:

We have to use the profit functions (10) and (11) to find that

$$\pi^S_{w^S}(\theta) - \pi^N_{w^S}(\theta) = \frac{\partial \psi^S}{\partial w^S}(T^S)^{\frac{z}{1-\alpha}}\,\theta^{\nu\alpha - \frac{z}{1-\alpha}} < 0, \;\; \text{for } T^S < \theta$$

$$\pi^S_{w^S}(\theta) - \pi^N_{w^S}(\theta) = \frac{\partial \psi^S}{\partial w^S}\theta^{\nu\alpha} < 0, \;\; \text{for } \theta \le T^S$$

Let's plug the above signs into (35) and (36) to get the result that $\frac{\partial \theta_1}{\partial w^S} < 0$ and $\frac{\partial \theta_0}{\partial w^S} > 0$. Using (16) it is easy to see that

$$\frac{\partial \chi}{\partial w^S} = \frac{\partial \Omega^S}{\partial w^S}\frac{\chi}{\Omega^S} < 0,$$

because $\frac{\partial \Omega^S}{\partial w^S} < 0$. After these calculations we are ready to find the sign of

$\Xi = \ominus\oplus + \oplus\ominus + \ominus < 0$, and

$$\frac{dT^S}{dw^S} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial \delta}{\partial w^S} + \Sigma^{-1}\frac{\partial T_0^S}{\partial w^S} = \oplus\ominus + \oplus\, 0 + \oplus\, 0 \; < 0$$

$$\frac{dX^S}{dw^S} = \Xi + \Lambda\frac{dT^S}{dw^S} = \ominus + \oplus\ominus < 0$$

$$\frac{d\theta_1}{dw^S} = \frac{\partial\theta_1}{\partial w^S} + \frac{\partial\theta_1}{\partial T^S}\frac{dT^S}{dw^S} = \ominus + \oplus\ominus < 0$$

$$\frac{d\theta_0}{dw^S} = \begin{cases} \frac{\partial\theta_0}{\partial w^S} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{dw^S} = \oplus + \ominus\ominus > 0 & \text{if } 1 \le T^S < \theta_{NS} \\ \frac{\partial\theta_0}{\partial w^S} > 0, & \text{if } \theta_{NS} \le T^S \end{cases}$$

(v) $\boldsymbol{q = f^S}$:

Using the profit functions (10) and (11) we note that

$$\pi_{f^S}^S(\theta) - \pi_{f^S}^N(\theta) = -w^N < 0.$$

Plug the above sign into (35) and (36) to get the result that $\frac{\partial\theta_1}{\partial f^S} < 0$ and $\frac{\partial\theta_0}{\partial f^S} > 0$.

We also know that $\frac{\partial\chi}{\partial f^S} = 0$, because f^S does not exist in (16), and thus

$\Xi = \ominus\oplus + \oplus\ominus + 0 < 0$, and

$$\frac{dT^S}{df^S} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial\delta}{\partial f^S} + \Sigma^{-1}\frac{\partial T_0^S}{\partial f^S} = \oplus\ominus + \oplus\, 0 + \oplus\, 0 < 0,$$

$$\frac{dX^S}{df^S} = \Xi + \Lambda\frac{dT^S}{df^S} = \ominus + \oplus\ominus < 0,$$

$$\frac{d\theta_1}{df^S} = \frac{\partial\theta_1}{\partial f^S} + \frac{\partial\theta_1}{\partial T^S}\frac{dT^S}{df^S} = \ominus + \oplus\ominus < 0,$$

$$\frac{d\theta_0}{df^S} = \begin{cases} \frac{\partial\theta_0}{\partial f^S} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{df^S} = \oplus + \ominus\ominus > 0, & \text{if } 1 \le T^S < \theta_{NS} \\ \frac{\partial\theta_0}{\partial f^S} > 0, & \text{if } \theta_{NS} \le T^S \end{cases}$$

(vi) $\boldsymbol{q = z}$:

Using the profit functions (10) and (11) we note that

$$\pi_z^S(\theta) - \pi_z^N(\theta) = \frac{1}{1-\alpha}\psi^S(T^S)^{\frac{z}{1-\alpha}}\theta^{\nu\alpha-\frac{z}{1-\alpha}}(\ln T^S - \ln\theta) < 0, \text{for } T^S < \theta$$

$$\pi_z^S(\theta) - \pi_z^N(\theta) = 0, \qquad \text{for } \theta \le T^S$$

Plug the signs above into (35) and (36), and we find that $\frac{\partial\theta_1}{\partial z} < 0$, $\frac{\partial\theta_0}{\partial z} > 0$ if $1 \leq T^S < \theta_{NS}$ and $\frac{\partial\theta_0}{\partial z} = 0$ if $\theta_{NS} \leq T^S$.

Next we use (16) to note that if $1 \leq T^S < \theta_{NS}$,

$$\frac{\partial\chi}{\partial z} = -\frac{1}{1-\alpha}\frac{\Omega^S k}{\alpha}(T^S)^{\frac{z}{1-\alpha}}[J(\theta_0) - J(\theta_1)]$$

where $J(\theta) \equiv \left(\frac{1}{\alpha} - \ln\frac{T^S}{\theta}\right)\theta^{-a}$, which is flat at $\theta = T^S$ and decreasing everywhere for $1 \leq T^S < \theta$. Now, in this case we have $T^S < \theta_0 < \theta_1$, and it follows that $J(\theta_0) - J(\theta_1) > 0$ and $\frac{\partial\chi}{\partial z} < 0$. In the case of $\theta_{NS} \leq T^S$,

$$\frac{\partial\chi}{\partial z} = -\frac{1}{1-\alpha}\frac{\Omega^S k}{\alpha}(T^S)^{\frac{z}{1-\alpha}}[J(T^S) - J(\theta_1)],$$

We know that $J(T^S) - J(\theta_1) > 0$ because $T^S < \theta_1$, thus it follows that $\frac{\partial\chi}{\partial z} < 0$. Now we can find that $\Xi = \ominus\oplus + \oplus\ominus + \ominus < 0$, if $1 \leq T^S < \theta_{NS}$, and $\Xi = \ominus\, 0 + \oplus\ominus + \ominus < 0$, if $\theta_{NS} \leq T^S$. Finally we find the following results, which are

$$\frac{dT^S}{dz} = \Sigma^{-1}\delta\Gamma_Q\Xi + \Sigma^{-1}X^S\Gamma_Q\frac{\partial\delta}{\partial z} + \Sigma^{-1}\frac{\partial T_0^S}{\partial z} = \oplus\ominus + \oplus\, 0 + \oplus\, 0 < 0,$$

$$\frac{dX^S}{dz} = \Xi + \Lambda\frac{dT^S}{dz} = \ominus + \oplus\ominus < 0,$$

$$\frac{d\theta_1}{dz} = \frac{\partial\theta_1}{\partial z} + \frac{\partial\theta_1}{\partial T^S}\frac{dT^S}{dz} = \ominus + \oplus\ominus < 0,$$

$$\frac{d\theta_0}{dz} = \begin{cases} \frac{\partial\theta_0}{\partial z} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{dz} = \oplus + \ominus\ominus > 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{\partial\theta_0}{\partial z} = 0, & \text{if } \theta_{NS} \leq T^S \end{cases}$$

(vii) $\boldsymbol{q} = \boldsymbol{\rho}$:

First we use the profit functions (10) and (11) to obtain

$$\pi_\rho^S(\theta) - \pi_\rho^N(\theta) = \alpha\frac{\partial\nu}{\partial\rho}\left[\psi^S(T^S)^{\frac{z}{1-\alpha}}\theta^{\nu\alpha-\frac{z}{1-\alpha}} - \psi^N\theta^{\nu\alpha}\right]\ln\theta\,, \text{for } T^S < \theta,$$

$$= \alpha \frac{\partial \nu}{\partial \rho} [w^N (f^S - f^N)] \ln \theta < 0, \text{for } T^S < \theta = \{\theta_0, \theta_1\},$$

$$\pi_\rho^S(\theta) - \pi_\rho^N(\theta) = \alpha \frac{\partial \nu}{\partial \rho} [\psi^S \theta^{\nu\alpha} - \psi^N \theta^{\nu\alpha}] \ln \theta < 0, \text{for } \theta \leq T^S$$

where the fact of $\frac{\partial \nu}{\partial \rho} < 0$ is utilized. By plugging these two negative signs into (35) and (36) we get the results of $\frac{\partial \theta_1}{\partial \rho} < 0$ and $\frac{\partial \theta_0}{\partial \rho} > 0$. We yet need the sign of $\frac{\partial \chi}{\partial \rho}$ in order to get the sign of Ξ:

$$\frac{\partial \chi}{\partial \rho} = -\frac{\partial a}{\partial \rho} \frac{\Omega^S k}{a} (T^S)^{\frac{z}{1-\alpha}} \left[\hat{J}(\theta_0, a) - \hat{J}(\theta_1, a)\right], \qquad \text{if } 1 \leq T^S < \theta_{NS}$$

where $\frac{\partial a}{\partial \rho} > 0$ and $\hat{J}(\theta, r) \equiv \left(\frac{1}{r} + \ln \theta\right) \theta^{-r}$, which is a decreasing function of θ for any $r > 0$ and $\theta > 1$. Thus we know that $\hat{J}(\theta_0, a) - \hat{J}(\theta_1, a) > 0$ and $\frac{\partial \chi}{\partial \rho} < 0$. On the other hand, when $T^S \geq \theta_{NS}$ we have

$$\frac{\partial \chi}{\partial \rho} = -\frac{\partial (k - \nu)}{\partial \rho} \frac{\Omega^S k}{(k - \nu)} \left[\hat{J}(\theta_0, k - \nu) - \hat{J}(T^S, k - \nu)\right]$$

$$-\frac{\partial a}{\partial \rho} \frac{\Omega^S k}{a} (T^S)^{\frac{z}{1-\alpha}} \left[\hat{J}(T^S, a) - \hat{J}(\theta_1, a)\right]$$

where $\frac{\partial (k-\nu)}{\partial \rho} > 0$. The decreasing property of function $\hat{J}(\theta, r)$ gives us $\hat{J}(\theta_0, k - \nu) - \hat{J}(T^S, k - \nu) > 0$ and $\hat{J}(T^S, a) - \hat{J}(\theta_1, a) > 0$. The following result is $\frac{\partial \chi}{\partial \rho} < 0$. Now we know that $\Xi = \ominus\oplus + \oplus\ominus + \ominus < 0$ and

$$\frac{dT^S}{d\rho} = \Sigma^{-1} \delta \Gamma_Q \Xi + \Sigma^{-1} X^S \Gamma_Q \frac{\partial \delta}{\partial \rho} + \Sigma^{-1} \frac{\partial T_0^S}{\partial \rho} = \oplus\ominus + \oplus\, 0 + \oplus\, 0 \; < 0$$

$$\frac{dX^S}{d\rho} = \Xi + \Lambda \frac{dT^S}{d\rho} = \ominus + \oplus\ominus < 0$$

$$\frac{d\theta_1}{d\rho} = \frac{\partial \theta_1}{\partial \rho} + \frac{\partial \theta_1}{\partial T^S} \frac{dT^S}{d\rho} = \ominus + \oplus\ominus < 0$$

$$\frac{d\theta_0}{d\rho} = \begin{cases} \frac{\partial\theta_0}{\partial\rho} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{d\rho} = \oplus + \ominus\ominus > 0, & \text{if } 1 \leq T^S < \theta_{NS} \\ \frac{\partial\theta_0}{\partial\rho} > 0, & \text{if } \theta_{NS} \leq T^S \end{cases}.$$

Appendix B

This Appendix B is fully based on the author's calculations.

The minimized unit production cost in Eq. (3) is obtained by substituting $\lambda(s)$ into the cost function $\int_0^\theta w^l\,\lambda(s)ds$:

$$\int_0^\theta w^l\,\lambda(s)ds = w^l\int_0^\theta x\theta^{-\frac{1}{\rho}}ds = w^l\theta^{-\frac{1}{\rho}}\int_0^\theta x\,ds = w^l\theta^{1-\frac{1}{\rho}} = w^l\theta^{\frac{\rho-1}{\rho}}.$$

The optimal output level of country l in Eq. (7) is obtained by maximizing the profit function in Eq. (6):

$$\frac{\partial\pi^l(\theta)}{\partial x} = \alpha\gamma^l(\theta)x^{\alpha-1} - c^l(\theta) = 0$$

$$\rightarrow\ \alpha\gamma^l(\theta)x^{\alpha-1} = c^l(\theta)\ \rightarrow\ x^{\alpha-1} = \frac{c^l(\theta)}{\alpha\gamma^l(\theta)}\ \rightarrow\ x^l(\theta) = \left(\frac{c^l(\theta)}{\alpha\gamma^l(\theta)}\right)^{\frac{1}{\alpha-1}}$$

$$\rightarrow\ \boldsymbol{x^l(\theta)} = \left(\frac{\alpha\gamma^l(\theta)}{c^l(\theta)}\right)^{\frac{1}{1-\alpha}}.$$

The optimal output levels (8) and (9) for the North and South respectively are obtained by substituting Eq. (3), (4) and (5) into Eq. (7):

$$\boldsymbol{x^N(\theta)} = \left(\frac{\alpha}{w^N\theta^{\frac{\rho-1}{\rho}}}\right)^{\frac{1}{1-\alpha}} = \left(\frac{\alpha}{w^N}\right)^{\frac{1}{1-\alpha}}\left(\frac{1}{\theta^{\frac{\rho-1}{\rho}}}\right)^{\frac{1}{1-\alpha}} = \left(\frac{\alpha}{w^N}\right)^{\frac{1}{1-\alpha}}\theta^{\left(\frac{1-\rho}{\rho}\right)\left(\frac{1}{1-\alpha}\right)} = \Omega^N\theta^\nu$$

$$\boldsymbol{x^S(\theta)} = \begin{cases} \left(\frac{\alpha}{w^S \theta^{\frac{\rho-1}{\rho}}}\right)^{\frac{1}{1-\alpha}} = \Omega^S \theta^{\nu} & \text{, if } 1 \leq \theta \leq \mathrm{T^S} \\ \left[\frac{\alpha\left(\frac{T^S}{\theta}\right)^z}{w^S \theta^{\frac{\rho-1}{\rho}}}\right]^{\frac{1}{1-\alpha}} = \left(\frac{\alpha}{w^S}\right)^{\frac{1}{1-\alpha}} \left[\theta^{\left(\frac{1-\rho}{\rho}\right)} \left(\frac{T^S}{\theta}\right)^z\right]^{\frac{1}{1-\alpha}} = \Omega^S \left(\frac{T^S}{\theta}\right)^{\frac{z}{1-\alpha}} \theta^{\nu} & \text{, if } \mathrm{T^S} < \theta \end{cases}$$

where $\Omega^l \equiv \left(\frac{\alpha}{w^l}\right)^{\frac{1}{1-\alpha}}$ and $\nu \equiv \left(\frac{1-\rho}{\rho}\right)\left(\frac{1}{1-\alpha}\right) > 0$.

The aggregate production of the MNEs in a given industry in the South (Eq.(16)) is obtained by first integrating the first part of $\chi(\theta_0, \theta_1, T^S)$ in the area of $\mathrm{T^S} < \theta_{\mathrm{NS}}$ by using Eq.(9):

$$\chi(\theta_0, \theta_1, T^S) = \int_{\theta_0}^{\theta_1} x^S(\theta) dG(\theta) = \int_{\theta_0}^{\theta_1} \Omega^S (T^S)^{\frac{z}{1-\alpha}} \theta^{\nu - \frac{z}{1-\alpha}} dG(\theta)$$

$$= \int_{\theta_0}^{\theta_1} \Omega^S (T^S)^{\frac{z}{1-\alpha}} \theta^{\nu - \frac{z}{1-\alpha}} k\theta^{-k-1} d\theta$$

$$= \Omega^S (T^S)^{\frac{z}{1-\alpha}} k \int_{\theta_0}^{\theta_1} \theta^{\nu - \frac{z}{1-\alpha} - (k+1)} d\theta$$

$$= \Omega^S (T^S)^{\frac{z}{1-\alpha}} \frac{k}{\nu - \frac{z}{1-\alpha} - k} \int_{\theta_0}^{\theta_1} \theta^{\nu - \frac{z}{1-\alpha} - k}$$

$$= \frac{\Omega^S k}{a} (T^S)^{\frac{z}{1-\alpha}} \left({\theta_0}^{-a} - {\theta_1}^{-a}\right)$$

where $a \equiv \frac{z}{1-\alpha} + k - \nu$ and $a > \frac{z}{1-\alpha} > 0$.

The second part of $\chi(\theta_0, \theta_1, T^S)$ in the area of $\theta_{\mathrm{NS}} \leq \mathrm{T^S}$ we get again by using Eq.(9):

$$\int_{\theta_{NS}}^{T^S} \Omega^S \theta^{\nu} dG(\theta) + \int_{T^S}^{\theta_1} \Omega^S (T^S)^{\frac{z}{1-\alpha}} \theta^{\nu - \frac{z}{1-\alpha}} dG(\theta)$$

→ Let's now integrate these two parts separately:

$$\int_{\theta_{NS}}^{T^S} \Omega^S \theta^\nu dG(\theta) = \int_{\theta_{NS}}^{T^S} \Omega^S \theta^\nu \, k\theta^{-k-1} d\theta = \Omega^S k \int_{\theta_{NS}}^{T^S} \theta^{\nu-k-1} d\theta = \frac{\Omega^S k}{\nu - k} \int_{\theta_{NS}}^{T^S} \theta^{\nu-k} =$$

$$\frac{\Omega^S k}{(k-\nu)} \left[{\theta_{NS}}^{\nu-k} - (T^S)^{\nu-k} \right] = \frac{\Omega^S k}{(k-\nu)} \left[(\theta_0)^{-(k-\nu)} - (T^S)^{-(k-\nu)} \right]$$

→ Then the second part of this calculation:

$$\int_{T^S}^{\theta_1} \Omega^S (T^S)^{\frac{z}{1-\alpha}} \, \theta^{\nu - \frac{z}{1-\alpha}} \, dG(\theta) = \int_{T^S}^{\theta_1} \Omega^S (T^S)^{\frac{z}{1-\alpha}} \, \theta^{\nu - \frac{z}{1-\alpha}} \, k\theta^{-k-1} d\theta$$

$$= \Omega^S (T^S)^{\frac{z}{1-\alpha}} \, k \int_{T^S}^{\theta_1} \theta^{\nu - \frac{z}{1-\alpha} - k - 1} \, d\theta = \Omega^S (T^S)^{\frac{z}{1-\alpha}} \frac{k}{\nu - \frac{z}{1-\alpha} - k} \int_{T^S}^{\theta_1} \theta^{\nu - \frac{z}{1-\alpha} - k}$$

$$= \frac{\Omega^S k}{a} (T^S)^{\frac{z}{1-\alpha}} [(T^S)^{-a} - (\theta_1)^{-a}]$$

→ Now when we combine all these calculations we get the result we wanted:

$$\rightarrow \chi(\theta_0, \theta_1, T^S) = \begin{cases} \frac{\Omega^S k}{a} (T^S)^{\frac{z}{1-\alpha}} \, [(\theta_0)^{-a} - (\theta_1)^{-a}], & \text{if } 1 \leq \mathrm{T^S} < \theta_{\mathrm{NS}}, \\ \frac{\Omega^S k}{(k-\nu)} \left[(\theta_0)^{-(k-\nu)} - (T^S)^{-(k-\nu)} \right] + & \\ \frac{\Omega^S k}{a} (T^S)^{\frac{z}{1-\alpha}} [(T^S)^{-a} - (\theta_1)^{-a}], & \text{if } \theta_{\mathrm{NS}} \leq \mathrm{T^S} \end{cases} .$$

Eq.(25) can be calculated by taking the total differentiation of Eq.(21) wrt. X^S, T^S and q:

$$\frac{dX^S}{dq} = \frac{\partial X^S}{\partial q} + \frac{\partial X^S}{\partial X^S} \frac{dX^S}{dq} + \frac{\partial X^S}{\partial T^S} \frac{dT^S}{dq} = \Xi + \Lambda \frac{dT^S}{dq}$$

where Ξ and Λ are already known from the earlier analysis.

Eq.(26) we obtain by taking the total differentiation of Eq.(20) with respect to X^S, T^S and q, and by substituting the expression in Eq.(25) for $\frac{dX^S}{dq}$:

$$\frac{dT^S}{dq} = \frac{\partial T^S}{\partial q} + \frac{\partial T^S}{\partial X^S} \frac{dX^S}{dq} + \frac{\partial T^S}{\partial T^S} \frac{dT^S}{dq}$$

$$\rightarrow \frac{dT^S}{dq} = \delta \Gamma_Q \left(\Xi + \Lambda \frac{dT^S}{dq} \right) + \frac{\partial T^S}{\partial q}$$

$$\rightarrow \left(1 - \delta\Gamma_Q\Lambda\right)\frac{dT^S}{dq} = \delta\Gamma_Q\Xi + \Gamma_Q X^S\frac{\partial\delta}{\partial q} + \frac{\partial T_0^S}{\partial q}$$

$$\rightarrow \frac{dT^S}{dq} = \delta\Sigma^{-1}\Gamma_Q\Xi + \Sigma^{-1}\Gamma_Q X^S\frac{\partial\delta}{\partial q} + \Sigma^{-1}\frac{\partial T_0^S}{\partial q}$$

where $\Sigma = 1 - \delta\Gamma_Q\Lambda$.