Firms in International Trade: Global Sourcing, Research Investments and Foreign Direct Investment

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Chapter 1

Introduction

One of the most influential books in the last decade is entitled "The World Is Flat". Thomas L. Friedman chose this title to vividly illustrate a deeply economic phenomenon that characterizes our daily lifes and shapes firms' business strategies today: globalization. Induced by lower transport costs and tariffs or new technologies like the internet, firms' production networks are nowadays spread around the globe. As a result, trade volumes have increased dramatically in the last decades and the world economy today is more globalized than ever before. The underlying question, what actually drives international trade, has been fundamental in economic analysis for a long time. Economists would never argue that there is one unique determinant of international trade. However, a common canon would contain that technology differences, factor endowments, consumer preferences, institutions and market conditions across countries are important.

One of the earliest insights is Ricardo's famous theory of comparative advantage. Trade between countries emerges due to technological differences and countries specialize in the production of the good for which they have a comparative advantage, i.e., lower opportunity costs of production. Unsatisfied with the assumption of immobile factors of production Heckscher and Ohlin developed a complementary theory leading to the famous Heckscher and Ohlin theorem. It states that countries export goods in which they are relatively abundant, i.e., they export capital-intensive products if they are capital abundant. Besides the influential impact these early theories had, they are at odds with empirical facts. They predict large trade flows between countries with different technologies and factor endowments while trade data reveals large trade flows between countries that are rather similar. From today's perspective, those theories also abstract from something that is central for trade economists today: the firm. Modern trade models put the firm in the center of the analysis since the data shows that firms' decisions are *heterogeneous* along various dimensions. Starting in the mid-nineties, new detailed firm-level data sets revealed that, even within a narrowly defined industry, firms differ substantially across dimensions such as size, productivity, wages paid to workers, organization of production and the participation in international trade. In particular, those studies highlighted that only a small fraction of firms export, that exporting firms are larger and more productive than non-exporters.

The first model that was capable of explaining those stylized facts about firm heterogeneity was the seminal contribution by Melitz (2003). It has changed international trade theory fundamentally and has become the cornerstone working horse of the so called "new" new trade theory. It forms the basis of all following chapters. To provide intuition why the model has become so successful I shortly summarize the model. Consider an industry in which firms produce horizontally differentiated varieties under monopolistic competition and with increasing returns to scale. The new element that radically separates the Melitz (2003) model from a standard Krugman model of monopolistic competition is that firms face ex-ante uncertainty about their firm specific productivity level. Only ex-post firms

realize, after they have drawn from a productivity lottery, whether they are productive enough to stay in their domestic industry or are even as productive as to enter new foreign markets. The timing of events is as follows. To enter the industry firms have to invest fixed entry costs in order to research and develop their product variety and to take part at the productivity lottery. After the investment firms discover their product variety and draw a firm specific productivity from a known productivity distribution. At this stage the fixed entry costs are sunk. Firms enter the industry until expected operating profits exactly compensate for the entry costs. To form expectations about operating profits, firms have to consider the cost structure of production. To serve the domestic market, firms have to bear fixed costs of production, while exporting to a foreign market is even more costly. Ice-berg type trade costs lead to higher variable costs since the shipping of goods from one country to another country leads to a vanishing of goods, while exporting also involves additional fixed costs. It will become clear that this cost structure will directly imply a productivity ranking that matches with the empirical evidence. Given this cost structure, a firm decides on an optimal firm strategy for every given productivity draw. These strategies specify three scenarios. The first one is the worst case scenario in which it is optimal for the firm to shut down. This is the case if the productivity draw is so low, that it is not profitable to invest the fixed costs of production to serve the domestic market since variable profits are lower. The second scenario is the case of a medium productivity draw. Here variable profits outweigh fixed costs and firms earn positive profits by serving the domestic market. The third one is the best case scenario with a high productivity draw. It is not only profitable to serve the domestic market, but also profitable to bear additional fixed costs to export. Even though trade is costly those highly productive firms engage in foreign trade by exporting. This productivity ranking of firms by export status is a major prediction of the Melitz model. However, it also provides important predictions of how trade liberalization impacts intra-industry reallocations.

Consider the thought experiment of lower variable trade costs, e.g. trade liberalization due to lower tariffs. Having the previous three scenarios in mind lower variable trade costs are only beneficial for exporters. These highly productive firms increase their export sales which leads to higher market shares for exporters and lower markets shares for non-exporters. As a result firms in the domestic market now also face tougher competition from foreign exporters. Those exporters compete for the only factor of production (labor) and additionally decrease the firms' individual demands for their varieties. Now consider the marginal firm that was indifferent between producing for the domestic market or shutting down before trade liberalization took place. Afterwards, costs increase and product demand decreases such that this cutoff firm exits the market. On the contrary, a firm which chooses to only serve the domestic market but was only marginally less productive than an exporter now starts exporting after trade liberalization. Hence, the

Melitz model predicts that trade liberalization leads to the exit of the least productive firms and to market share reallocations from low-productivity domestic firms to high-productivity exporters. The industry's average productivity rises, average prices decrease and welfare increases in turn. Studies by Tybout and Westbrook (1995) for Mexico, Pavcnik (2002) for Chile and Trefler (2004) for Canada have found robust empirical evidence for this selection effect of trade liberalization.

Although the Melitz model has dramatically deepened our understanding of international trade, it lacks one crucial element that is also prevalent in the data: the organizational choice of production. The model cannot explain why firms differ in their organization of production. This is due to the fact that it treats the single firm and the mapping between factors of production and the final-good as a "black box". However, firms' global sourcing strategies are a major driver of international trade. Intermediate inputs that are produced in foreign countries and shipped back to the headquarter's country of origin impact international trade accounts. It is vertical foreign direct investment (FDI) if the supplier is part of the headquarter's firm structure, i.e., is integrated within the boundaries of the firm or arm's length trade if the supplier is unaffiliated and independent, i.e., is outsourced. Many scholars examined firms' organizational choices in the context of international trade but one recent approach has become very popular as it can explain the data very well. Building up on the property rights approach of the firm, Antràs and Helpman (2004) provide a seminal model that combines firm heterogeneity à la Melitz with organizational choices as in Antràs (2003). The Antràs and Helpman model forms the basis of Chapter 2 and Chapter 3. Hence, I consider it useful to provide a brief non-technical description of the model's framework in the following.

Consider a final-goods production process with two intermediate inputs, namely headquarter services and a manufactured component. Headquarter services are provided by the final-good producer itself, the firm. With respect to the sourcing of the manufactured component the firm faces a two dimensional decision. First, the firm chooses the ownership structure, i.e., whether to produce in house with an integrated supplier or outsource the component production to an unaffiliated and independent supplier. Second, the firm decides on the global scale of production, i.e., whether to locate component production in the headquarter's country of origin or offshore production to a foreign country. In a setting with incomplete contracts and relationship specific investments those decisions matter. The explanation of the rational why they matter lies in the timing of events that can be summarized as follows. First, the headquarter decides on the optimal sourcing strategy that specifies a contract about the future distribution of the total sales revenue. Given this distribution of revenue both the component supplier and the headquarter start to produce the relationship specific components and headquarters services, respectively. Afterwards, production costs are sunk, and the supplier and the firm meet and renegotiate since contracts are incomplete. This expected ex-post bargaining and hold-up

problem yields to less than the efficient ex-ante contributions and to an underinvestment of inputs on both sides. In order to choose an optimal sourcing strategy it is now crucial to determine which side provides the relatively more important input and therefore is responsible for the relatively more severe underinvestment problem. As it is intuitive, the party which is relatively more important for the production process should receive better property rights to alleviate the underinvestment problem. It is assumed that those property rights are higher for an unaffiliated outsourced supplier while they are lower if the supplier is integrated. In the absence of the global scale decision, Antràs (2003) shows that there exists an unique headquarter-intensity cutoff, i.e., output elasticity of headquarter services, such that if headquarter services are relatively more important than components, the supplier should be integrated. Vice versa, if the production process is component-intensive the firm chooses to collaborate with an unaffiliated one. Now assume that firms are heterogeneous in their productivities as in Melitz (2003). Furthermore, production involves fixed production costs that are higher in a foreign country and if the supplier is integrated, while variable costs are lower if component production is offshored to a foreign country. Finally, property rights increase for the component supplier not only in case of outsourcing, but also if the supplier is offshored. These assumptions imply that sufficiently high productive firms always prefer foreign over domestic sourcing. The higher fixed costs of foreign production are outweighed by higher variable profits due to lower unit costs. Furthermore vertical FDI is most likely in sectors with high headquarter intensities (to transfer better property rights to the headquarter).

Having discussed the two basic model frameworks Melitz (2003) and Antràs and Helpman (2004) that are essential for the following chapters, I continue with a brief non-technical review of the chapters' results. I have to note that chapter 2 is published as Schwarz (2011). Chapter 3 is co-authored with Jens Suedekum and available as Schwarz and Suedekum (2010). Chapter 4 is a work co-authored with Anna Bohnstedt and Jens Suedekum and available as Bohnstedt et al. (2010). Chapter 5 is joined work with Kristian Giesen and available as Giesen and Schwarz (2011).

1.1 Chapter 2

In the second chapter I provide a note on the sector definitions proposed in Antràs and Helpman (2004). I start with a critical reconsideration of the definitions and argue that they are problematic due to three reasons. First, the definitions may lead to counter-intuitive sector classifications. Second, they do not classify each sector in principle and third, they rest on parameters that cannot be empirically observed. Antràs and Helpman (2004) define a sector as component-intensive (headquarter-intensive) whenever the firm would ideally like to transfer more (less) property rights to the component supplier as it is possible by organizational choice. As a result, in a component-intensive (headquarter-

intensive) sector variable profits are maximized with foreign outsourcing (integration). This suggests that a component-intensive (headquarter-intensive) sector is characterized by a low (high) headquarter-intensity. However, with the proposed definition the optimal organizational choice is *not* only a question whether the headquarter-intensity is high or low. It is also crucial to consider how the ownership specific property rights are distributed. The sector definitions focus only on the headquarter-intensity and neglect the second dimension of the distribution of property rights. As a result, I show that not all sectors are classified and moreover small changes in the headquarter-intensity may lead to counter intuitive sector switches.

As an alternative I propose a purely exogenous parameter based approach of sector definitions. I define a sector as component-intensive (headquarter-intensive) whenever the exogenously given headquarter-intensity is lower (higher) than the component-intensity. This approach overcomes the problems of counter-intuitive or missing sectors. The downside is that the clear cut analytical results as derived in Antràs and Helpman (2004) do not hold anymore. They are robust but a richer set of sourcing choices can arise in equilibrium. I find, for example, that even in component-intensive sectors integration may prevail if the supplier's property rights in case of outsourcing are tremendously high. This highlights the fact that in order to minimize the underinvestment problem, it is crucial not only to consider which side is responsible for the relatively more important input, but also what the distribution of the ownership specific property rights is. The major advantage of my approach is that the empirical literature also relies on parameter based sector classifications. Henceforth, it is important to show that the Antràs and Helpman (2004) results are robust such that the empirical evidence can be seen as a valid test of the theory.

1.2 Chapter 3

In the third chapter I provide a sourcing model in the spirit of Antràs and Helpman (2004). The novelty of the model is that firms decide not only on the organization (whether the supplier is integrated or outsourced) and the location (production in the home country or abroad) but also endogenously choose the number of inputs used in the production process. The latter decision refers to the "complexity" of production. This additional complexity decision is motivated by recent empirical evidence that firms actually rely not only on one single sourcing mode for all inputs but rather organize production using a variety of different sourcing modes, see e.g. Jabbour and Kneller (2010) or Kohler and Smolka (2009). Furthermore, firms that choose from a variety of sourcing modes are systematically more productive than firms that rely only one single mode, see Tomiura (2007). For those new empirical patterns the Antràs and Helpman (2004) model cannot account for since it relies on only one *single* component. The literature still misses such

a rich sourcing model that can explain these new stylized empirical facts.

The presented model provides a first step to analytically explain those empirical facts, since it allows for heterogeneity in the number of inputs used in the production process. The model actually predicts that even within a single firm such hybrid sourcing with a variety of different sourcing modes is possible, i.e., some inputs are outsourced while others are kept within the boundaries of the firm. This hybrid sourcing prevails in intermediate intensive sectors that are neither component-, nor headquarter-intensive and in firms that are highly productive. Within a given sector, I find that more productive firms increase complexity. For a given productivity, complexity is highest in component-intensive sectors like the automotive industry. With respect to the location, only the high productive firms take advantage of lower variable costs abroad. In this context, I find that opening up for trade boosts complexity and inputs are more likely to be outsourced.

In the second part of the chapter I relax the assumption of symmetric inputs that was convenient for the previous results. I rather study a production process where the complexity is fixed exogenously to two input suppliers. However, the suppliers may not only differ in their input intensities, but also in their respective ownership specific property rights. These asymmetries between inputs can provide a rational for the empirical evidence provided by Alfaro and Charlton (2009), which states that firms tend to outsource low-skill inputs from the early stages, while high-skill inputs from the final stages of the production process are likely to be manufactured in house.

1.3 Chapter 4

The model presented in the fourth chapter is motivated by the growing importance of public research and development ($R\&D$) spending in modern economies. First and foremost in the political discussion there seems to be a widespread perception that public $R\&D$ spending is crucial to maintain the global competitiveness of domestic firms. To study the governmental incentives of *strategically* investing into a country's technological potential, I develop a general equilibrium model of international trade with heterogeneous firms, where countries can invest into basic research to improve their technological potential.

The model is closely related to the Melitz (2003) framework. Firms can enter a monopolistically competitive sector subject to entry costs. Afterwards entry costs are sunk and firms randomly draw their productivity level from a known distribution. In contrast to a standard Melitz (2003) model countries may differ in the technological potential. In particular, the government of either country can invest into basic research. These research investments raise the country's technological potential, which is modeled as a right-shift of the support of the distribution from which the domestic entrants draw. Given that the countries can invest into basic research the model leads to *endogenous* technology differ-

ences across countries. Under autarky governments invest into basic research since the increase in the technological potential leads to tighter firm selection and higher average productivity of firms. As a result welfare increases since a higher average productivity implies lower prices. The government's strategic motive arises if countries open up for trade. Investments into basic research lead to the following negative cross-country externality: If one country invests more than the other, this yields tougher selection in the technological leading and softer selection in the laggard country. Exporting becomes easier for firms from the leading country, as the export market is now easier to capture. Firms from the laggard country face tougher competition in their home market, and exporting becomes more difficult.

From the normative perspective the model predicts that there are supranational gains from coordinated public research investments. The negative cross-country externality of investments induces single countries to over-invest and this more, the higher trade openness is. However, with considering direct R&D spillovers across countries, i.e., R&D spending raises also and at least partly the technological potential of the other country, this over-investment is reduced. Nevertheless, a brief look in the data reveals that the cross-sectional relationship between public R&D spending and trade intensity is positive and consistent with the prediction of the model. More open countries tend to invest more into basic research.

1.4 Chapter 5

The focus of the last chapter is set on horizontal foreign direct investment (FDI). The data reveals that FDI is an important determinant of international trade. In particular its growth rates in the last decade are remarkable and outpaced the growth in the worldwide gross domestic product, domestic investments and even exports. There is a widespread perception among politicians that there are positive welfare effects of FDI. The common arguments given are that FDI leads to industry knowledge spillovers or technology transfers and lower consumer prices due to cross-border transport cost savings. Therefore, politicians actively try to attract FDI with tax holidays, job-creation or facility subsidies.

I contribute to the discussion by developing a general equilibrium model of international trade with heterogeneous firms and horizontal greenfield FDI. In the spirit of Melitz (2003), firms choose, conditional on their productivity, whether to serve their domestic market and/or a foreign market. In the latter case they can do so either through exports or horizontal greenfield FDI. I use this framework to study the welfare effects of FDI. It is important to note that this framework is especially suitable to analyze the welfare effects of FDI, since it not only features endogenously determined firm entrants, wages, and productivity cutoffs but also allows for wage differentials across countries in equilibrium and flexible price markups.

I discuss two policy scenarios to examine a country's incentive to attract FDI. In the strategic FDI policy scenario, a country chooses the welfare maximizing degree of FDI-liberalization, while taking the FDI policy in the other country as given. In the cooperative scenario both countries jointly choose the total welfare maximizing degree of FDI-liberalization. If only one single country attracts FDI, this leads to a higher mass of consumed varieties and a lower price index. However, the other foreign country faces a decrease in the mass of consumed varieties and higher average prices. Welfare in the attracting country increases while it decreases in the other country. This cross-country comparison clearly illustrates that in the strategic Nash-equilibrium countries compete for FDI. Compared with the cooperative solution this strategic incentive to attract FDI leads to over-attraction. Hence, from a normative perspective there are welfare gains from supranational coordination of FDI-liberalization policies. However, since coordination is difficult to achieve, it is likely that countries over-attract FDI. For policy makers this is an important result as besides the indisputable positive aspects of FDI, it implies that there are also potential welfare losses from over-attraction.

Chapter 2

Global Sourcing - A Critical Reconsideration of Sector Definitions

2.1 Abstract

I introduce an alternative parameter-based definition of component- and headquarter-intensive sectors into the seminal model of global sourcing by Antràs and Helpman (2004). This approach overcomes problems of the original sector definition like counter intuitive classifications or industries that are not classified as either component- or headquarter-intensive. The strong empirical evidence for the model's predictions is also based on a similar sector definition. With a numerical approach I show that a richer set of sourcing modes can arise in equilibrium. Nonetheless, the main results of Antràs and Helpman are robust.

2.2 Introduction

In their seminal contribution Antràs and Helpman (2004) introduce a North-South model of international trade where firms choose from a variety of organizational forms, depending on their individual productivity and sector characteristics. Their framework, which combines firm heterogeneity in spirit of Melitz (2003) with organizational structures as in Antràs (2003), is especially helpful for coming to grips with newly emerged empirical facts about arm's length outsourcing and intra-firm trade. The main result by Antràs and Helpman is that firms in headquarter-intensive sectors are more likely to choose integration strategies, whereas in component-intensive sectors they solely focus on outsourcing strategies.

To derive their main result Antràs and Helpman (2004) study how the contract choice varies for different levels of productivity, given the following two exogenous parameters: i.) the headquarter intensity (i.e., the headquarter's input share in the assumed Cobb-Douglas production function) and ii.) the share of ex post gains from the contract relationship (i.e., the bargaining power of the final-good producer). The derivation of their main result is potentially problematic, however, because their sector cutoffs solely focus on only one of the two parameters, the headquarter's input share. This leads to the fact that sectors with a very low (high) factor share in components may actually be defined as component-intensive (headquarter-intensive). Furthermore and more importantly, the parameter regions classified as either component- or headquarter-intensive may be quite small. I consider it intuitive to define a sector as component-intensive when the exogenous factor share of components is high, and vice versa. With my parameter-based definition all possible sectors can be classified without having to refer to the ex post gains.

Empirical evidence for sourcing modes of multinational firms is scarce due to the fact that firm-level data on outsourcing is rare. Nevertheless, recent empirical literature on multinational firms provides strong empirical evidence for the theoretical predictions of

the Antràs and Helpman model.[1] However, since the ex post gains from the contract relationship are hard to observe those studies also rely on a parameter-based sector definition.

With the alternative sector definitions the main results of Antràs and Helpman remain robust. Using numerical methods I derive the organizational forms in equilibrium. In sectors with low headquarter intensity firms tend to focus on outsourcing while in sectors with high headquarter intensity a coexistence of integration and outsourcing prevails. Concerning the location high productive firms tend to engage in foreign sourcing while the low productive firms centre the production in their home country. Yet, my approach allows for a richer menu of possible outcomes. For example, I discover that firms may choose an integration strategy although the sector is component-intensive. Hence, the orginal classification where only outsourcing prevails in component-intensive sectors may be misleading as to the relationship between firm productivity and contract choice.

2.3 Analysis

I start with a brief review of the Antràs and Helpman model. Output x of the final-good is given by a Cobb-Douglas type production function

$$x = \theta \cdot \left(\frac{h}{\eta}\right)^{\eta} \cdot \left(\frac{m}{1-\eta}\right)^{1-\eta} \quad \text{with} \quad \eta \in (0,1) \tag{2.1}$$

and depends on the two inputs headquarter services h and manufactured components m. The productivity θ is firm-specific whereas the sector specific parameter η is the input intensity in headquarter services. Headquarter services h can exclusively be provided by the final-good producer while for the production of the component m the final-good producer faces a two dimensional decision. Firstly, component production can be integrated within the boundaries of the firm or outsourced to an unaffiliated supplier. Secondly, component production can be accomplished in the domestic or a foreign country.

The final-good producer's share β of ex post gains differs for the sourcing modes. The final-good producer receives a higher fraction in case of integration than under outsourcing. When integration takes place, this fraction is lower in the foreign country than in the home country. The ranking of the ex post shares is given by

$$\beta_V^N = \left(\delta^N\right)^{\alpha} + \beta\left[1 - \left(\delta^N\right)^{\alpha}\right] \geq \beta_V^S = \left(\delta^S\right)^{\alpha} + \beta\left[1 - \left(\delta^S\right)^{\alpha}\right] > \beta_O^S = \beta_O^N = \beta \tag{2.2}$$

with $\alpha \in (0,1)$ and $1 > \delta^N \geq \delta^S > 0$. The index V and O indicates whether the

[1] See Feenstra and Hanson (2005), Yeaple (2006), Defever and Toubal (2007), Tomiura (2007), Nunn and Trefler (2008), Jabbour (2008), Corcos et al. (2008), Kohler and Smolka (2009), Alfaro and Charlton (2009), Bernard et al. (2010) and Federico (2010) for recent empirical studies.

intermediate input production is integrated (V) or outsourced (O). Foreign production is denoted by S while domestic production is denoted by N. If the final-good producer could freely choose the fraction $\beta^*(\eta)$ that maximizes the total value of the relationship (total revenue), $\beta^*(\eta)$ would be given by

$$\beta^*(\eta) = \frac{\eta(\alpha\eta + 1 - \alpha) - \sqrt{\eta(1-\eta)(1-\alpha\eta)(1+\alpha\eta-\alpha)}}{2\eta - 1}. \tag{2.3}$$

Antràs and Helpman define a sector as component intensive (see p.565) whenever the headquarter-intensity η is so small, such that $\beta > \beta^*(\eta)$ holds. A sector is considered headquarter intensive (see p.567) whenever η is large enough such that $\beta^*(\eta) > \beta_V^N$ holds. I use the ordering of revenue shares (2.2) to rearrange the condition $\beta^*(\eta) > \beta_V^N$, which is then equivalent to

$$\beta < \frac{\beta^*(\eta) - \left(\delta^N\right)^\alpha}{1 - \left(\delta^N\right)^\alpha} \equiv \bar{\beta}(\eta). \tag{2.4}$$

Each possible sector is a point in the (β, η) plane. The set of sectors is therefore the whole surface indicated in Figure 2.1. I provide $\beta^*(\eta)$ and $\bar{\beta}(\eta)$ in Figure 2.1 to illustrate the two main theoretical criticisms of the sector definitions: Firstly, it is obvious that for medium levels of η and β no sector classification as Antràs and Helpman propose is valid. Take for example point X where both conditions $\beta > \beta^*(\eta)$ and $\beta^*(\eta) > \beta_V^N$ are simultaneously violated. Secondly, the definition of sectors can lead to a quite counterintuitive classification of sectors. Consider, e.g., the point Y in Figure 2.1. Antràs and Helpman would consider this sector as component-intensive, even though the headquarter-intensity η is very high. It is natural to argue that the set of sectors which are not classified have medium levels of headquarter intensity η. Hence, it is suggestive to only consider sectors with either a very high or a very low headquarter intensity. However, since $\lim_{\eta\to 0, \eta\to 1} \partial\beta^*/\partial\eta \to \infty$, an arbitrary small change in η may lead to a switch in the sector classification. Take for example point A and B in Figure 2.1. The sector associated with point A is component-intensive although only a small increase in η to point B leads to a sector switch.[2]

Parameter-based sector definitions

Due to the rationale above, I propose an alternative parameter-based definition of sectors. I consider it intuitive to define a sector as component intensive when the exogenous factor share of components is high, i.e. if $\eta < 0.5$. A sector is defined headquarter-intensive when it is not component-intensive. This definition of sectors avoids counter intuitive sector characterizations and classifies each sector. The empirical evidence for the model's predictions are also based on an parameter-based sector definition. I call

[2]However, it is clear that for any cutoff in continuous parameter space an infinitesimal parameter change can alter the resulting sector classification.

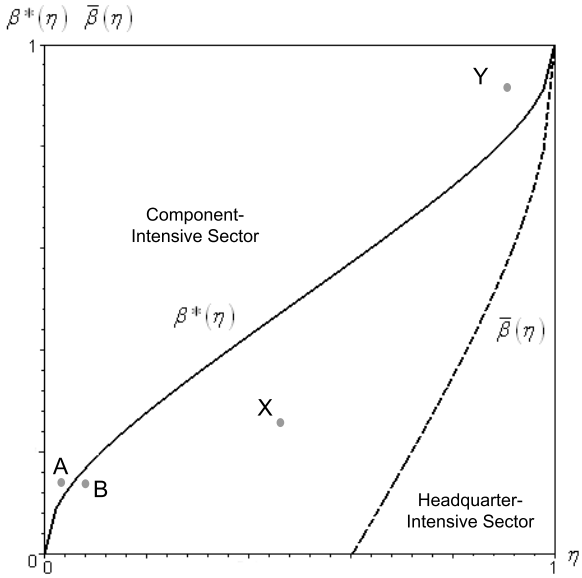

Figure 2.1: Sector classifications

the following numerical example "benchmark" case since all sorting patterns Antràs and Helpman derive for their headquarter- and component-intensive sector are incorporated. Figure 2.2 depicts for each (β, θ) pair the sourcing mode with the highest profits.[3]

Consider the left graph in Figure 2.2 with $\eta = 0.25$. For a β within the black bars $\beta > \beta^*$ is fulfilled and this is the case which Antràs and Helpman consider as their component-intensive sector. All firms that do not immediately exit due to a low productivity draw θ choose either domestic or foreign outsourcing. The relatively more productive firms within these bars outsource in the foreign country (see, e.g., point X) and the not so productive firms outsource domestically (see, e.g., point Y). Notice however, that a richer pattern of possible sourcing modes is valid. In particular, if β is below the lower bound of the bars even in component-intensive sectors firms may choose integration strategies (see, e.g., point Z). Next, I discuss the headquarter-intensive sector. Consider the right graph in Figure 2.2 with $\eta = 0.75$. For a β within the black bars the sorting pattern is identical to the one Antràs and Helpman identify for the headquarter-intensive sector. The most productive firms use foreign direct investment while slightly less productive firms use foreign outsourcing. Within the home country the relatively low productive firms use outsourcing while the high productive firms integrate. Yet again, a richer set of possible organizational forms can arise in equilibrium. In particular, if β is high even in headquarter-intensive sectors firms may only choose outsourcing strategies (e.g., point P). If β is below the lower bounds of the bars firms may solely focus on integration (e.g., point Q). Hence, a sufficiently low β leads to integration regardless of the headquarter

[3] I use $\eta = 0.25$ for the component-intensive sector and $\eta = 0.75$ for the headquarter-intensive sector. Other parameters: $f_V^S = 0.15$, $f_O^S = 0.095$, $f_V^N = 0.05$, $f_O^N = 0.025$, $\omega^N = 1$, $\omega^S = 0.7$, $\delta^N = 0.5$, $\delta^S = 0.4$ and $\alpha = 0.75$.

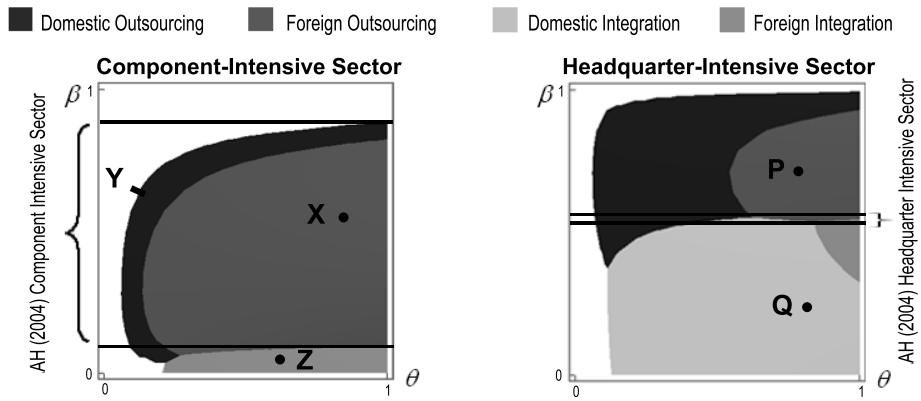

Figure 2.2: Profit maximizing sourcing modes

intensity η. In this case $\beta^* > \beta_V^N \geq \beta_V^S > \beta_O^S = \beta_O^N = \beta$ holds and the final-good producer supplies less than efficient headquarter services, regardless of the contract choice. This underinvestment problem is magnified in case of outsourcing and relatively less severe with integration. In both benchmark sectors sufficiently high productive firms offshore the component production.[4]

2.4 Conclusion

The numerical results illustrate that the prevalence of integration strategies increases with the headquarter intensity. For a given bargaining power β and input intensity η sufficiently high productive firms prefer foreign sourcing while the low productive firms focus on domestic production. Yet, my approach delivers a richer set of possible outcomes. I find, e.g., that firms in component-intensive sectors may also choose integration strategies if β is sufficiently low. This leads to the fact that the original sector classification may be misleading as to the relationship between firm productivity and contract choice.

My results have direct implications for the related empirical studies. Due to the fact that the bargaining powers are hard to observe, empirical studies that examine the theoretical predictions of the model also rely on an parameter-based sector definition. They find strong empirical evidence for the prediction that foreign integration is largest when both headquarter intensity and productivity is high.

[4]Note that both graphs of Figure 2.2 could be easily drawn for higher levels of productivity. In this case foreign sourcing dominates domestic sourcing for every given β. However, the graphical indication of the Antràs and Helpman headquarter-intensive sector would then be unnecessarily tiny.

Chapter 3

Global Sourcing of Complex Production Processes

3.1 Abstract

We develop a theory of a firm in an environment with incomplete contracts. The firm's headquarter decides on the complexity, the organization, and the global scale of its production process. Specifically, it decides: i) on the mass of symmetric intermediate inputs that are part of the value chain, ii) if the supplier of each component is an external contractor or an integrated affiliate, and iii) if the supplier is offshored to a foreign low-wage country. Afterwards we consider a related scenario where the headquarter contracts with a given number of two asymmetric suppliers. Our model is consistent with several stylized facts from the recent literature that existing theories of multinational firms cannot account for.

3.2 Introduction

The production of most final goods requires intermediate inputs. How thinly the value chain is "sliced", i.e., how many different inputs are combined in the production process for a particular final product, is a choice made by firms (Acemoglu et al., 2007): Some choose a setting with multiple highly specialized components and narrowly defined tasks, while other firms from the same industry rely on a substantially lower division of labor. We refer to the chosen mass of intermediate inputs as the degree of *complexity* of a firm's production process. For each component, a firm then needs to decide whether to manufacture that input inhouse or to outsource it to an external contractor. As is well known since Grossman and Hart (1986) and Hart and Moore (1990), these organizational decisions ("*make or buy*") matter in an environment with incomplete contracts, as they affect the suppliers' incentives to make relationship-specific investments. Finally, in a globalized world, firms also need to decide on the international scale of their value chain. Some firms only source domestically, while others collaborate with foreign suppliers either through arm's length transactions or through intra-firm trade (Grossman and Helpman, 2002).

An example that illustrates those different dimensions of a global value chain is the "Swedish" car *Volvo S40*, as discussed in Baldwin (2009). The production of this final good certainly is a complex process that consists of multiple intermediate inputs. A substantial share of those inputs is produced by independent suppliers, many of them from foreign countries: the navigation control is made by Japanese contractors, the side mirror and fuel tank by German, the headlights by American ones, and so on, while the airbag and the seats are outsourced domestically within Sweden. Yet other inputs are manufactured inhouse. Of those tasks, some are performed within the Swedish parent plants, while other components are manufactured by foreign subsidiaries which are directly owned and controlled by *Volvo*. Further examples of global sourcing strategies of multinational

enterprises (MNEs) include *Nike*, which relies heavily on foreign outsourcing, or *Intel* which mainly engages in vertical foreign direct investment (FDI), see Antràs and Rossi-Hansberg (2009).

In this paper, we develop a theory of a firm which decides on the complexity, the organization, and the global scale of its production process. We build on the seminal approach by Antràs and Helpman (2004), who were the first to study global sourcing decisions under incomplete contracts. Their model is restricted to a setting with a headquarter and *one single* supplier, however. We extend that framework and consider multiple intermediate inputs. Our model is consistent with several stylized facts from the recent empirical literature that neither Antràs and Helpman (2004, 2008), nor other papers on the structure of MNEs can account for. It therefore further reconciles the theory and the empirics of multinational firms.[1]

Specifically, we first consider a model where the headquarter (the "producer") decides on the mass of (differentiated but symmetric) intermediate inputs that are part of the value chain, similar as in Ethier (1982) or Acemoglu et al. (2007). The larger this mass of components is, the more sliced is the value chain and the more specialized is the task that each single supplier performs. This specialization leads to efficiency gains, but it also generates endogenously larger fixed costs as it necessitates contracting with more input suppliers. The producer furthermore decides, separately for each component, if the respective supplier is an external contractor or an integrated affiliate, and if the supplier is offshored to a (low-wage, low-cost) foreign country. Our model firstly predicts that firms differ in the complexity of their production process, both within and across industries. Higher productivity and lower headquarter-intensity tend to increase the mass of suppliers that a firm chooses to contract with. Second, firms may outsource *some* of their inputs but vertically integrate others. This "hybrid sourcing" mode is prevalent in firms with medium-to-high productivity from sectors with low-to-medium headquarter-intensity. Third, firms may decide to offshore only *some* components, and this offshoring share tends to be higher in more productive firms and in less headquarter-intensive industries.

Afterwards, we turn to a related scenario where the producer contracts with a given and discrete number of *two* suppliers providing *asymmetric* components. These components can differ along two dimensions: i) the technological importance for the final product as measured by the input intensity, and ii) the bargaining power of the respective supplier. We show that firms from sectors with high (low) headquarter-intensity tend

[1]Spencer (2005) provides a survey of the literature on international sourcing under incomplete contracts. In this literature, there has been no contribution that jointly analyzes the complexity, the organization, and the global scale of MNEs. A different model of multinational firms is Grossman and Rossi-Hansberg (2008). That model focuses particularly on the offshoring decision, but it is not based on incomplete contracts and it neglects the complexity and organizational choices of MNEs. Helpman (2006) presents a comprehensive overview of the recent literature on trade, FDI and firm organization.

to integrate (outsource) both suppliers, particularly if the asymmetry across components is not too strong. With intermediate headquarter-intensity and for stronger asymmetries there is "hybrid sourcing", i.e., one integrated and one external supplier. The component with the higher input intensity is per se more likely to be outsourced, as this reduces the underinvestment problem for the supplier. Yet, that supplier is also likely to have higher bargaining power vis-a-vis the producer. If this latter effect is sufficiently strong, which may be the case for highly sophisticated and specific intermediate inputs, our model then predicts that the producer keeps the "more important" component, which generates more value added, within the boundaries of the firm.

The predictions of our model are then discussed in the light of the recent empirical literature on multinational firms.[2] That literature has started to carefully explore the internal structure of MNEs, and also to test particular aspects of the baseline model by Antràs and Helpman (2004) and the extension in Antràs and Helpman (2008). Several predictions of these models are supported by the empirical evidence.[3] Other features of the data are harder to understand with those baseline frameworks, however, while our model can account for these stylized facts.

For example, Kohler and Smolka (2009), Jabbour (2008) and Jabbour and Kneller (2010) show that most MNEs collaborate with *many* suppliers and often choose different sourcing modes for different inputs – as in the *Volvo*-example discussed above. In particular, Tomiura (2007) finds that firms which outsource *some* inputs while keeping others vertically integrated are more productive than firms which rely on a single sourcing mode in the global economy. Furthermore, Alfaro and Charlton (2009) show that firms tend to outsource low-skill inputs from the early stages, while high-skill inputs from the final stages of the production process are likely to be manufactured inhouse. Consistently, Corcos et al. (2009) find that inputs with a higher degree of specificity are less likely to be outsourced.

The rest of this chapter is organized as follows. In section 3.3 we present the basic structure of our model. Section 3.4 is devoted to the scenario with an endogenous mass of

[2]The empirical literature has emphasized the significance of MNEs for world trade, which according to Corcos et al. (2009) are involved in about two thirds of all current international trade transactions. Feenstra (1995) and Feenstra and Hanson (1996) show that trade in intermediate inputs has increased much faster than trade in final goods over the last decades, which suggests a substantial increase in international outsourcing. The importance of intra-firm trade is stressed by Alfaro and Charlton (2009) and Badinger and Egger (2010), who consistently find that vertical FDI tends to dominate horizontal FDI.

[3]Consistent with Antràs and Helpman (2004), the study by Nunn and Trefler (2008) finds that intra-firm trade is most pervasive for highly productive firms in headquarter-intensive sectors, and Defever and Toubal (2007) find that highly productive firms tend to choose foreign outsourcing for components with high input intensity. Consistent with Antràs and Helpman (2008), who consider partial contractibility and cross-country differences in contracting institutions, the study by Corcos et al. (2009) finds that firms are more likely to offshore in countries with good contracting institutions, and Bernard et al. (2010) report that institutional improvements favor foreign outsourcing. The studies by Feenstra and Hanson (2005), Yeaple (2006), Marin (2006), and Federico (2010), among others, are also concerned with the internal structure of MNEs and obtain empirical findings broadly in line with those baseline models.

symmetric components, while section 3.5 looks at the case with two asymmetric inputs. In section 3.6 we conclude and contrast the predictions of our model with stylized facts on the structure of MNEs. In that section, we also point out some further testable predictions that have not yet been explored, in order to motivate future empirical research.

3.3 Model

3.3.1 Demand and technology

We consider a firm that produces a final good y for which it faces the following iso-elastic demand function:

$$y = Y \cdot p^{1/(\alpha-1)}. \tag{3.1}$$

The variable p denotes the price of this good, and $Y > 1$ is a demand shifter. The demand elasticity is given by $1/(1-\alpha)$ and is increasing in the parameter α (with $0 < \alpha < 1$). Production of this good requires headquarter services and manufacturing components, which are combined according to the following Cobb-Douglas production function:

$$y = \theta \cdot \left(\frac{h}{\eta^H}\right)^{\eta^H} \cdot \left(\frac{M}{1-\eta^H}\right)^{1-\eta^H}. \tag{3.2}$$

The parameter $\theta > 0$ is a productivity shifter; the larger θ is, the more productive is the firm. Headquarter services are denoted by h and are provided by the "producer". The parameter η^H (with $0 < \eta^H < 1$) is the exogenously given headquarter-intensity, and reflects the technology of the sector in which the firm operates. Consequently, $\eta^M = 1 - \eta^H$ is the overall component-intensity of production. There is a continuum of manufacturing components, with measure $N \in \mathbb{R}_+$. Each component is provided by a separate supplier. The supplier $i \in [0, N]$ delivers m_i units of its particular input, and the aggregate component input M is given by:

$$M = \exp\left\{\int_0^N \ln\left(\frac{m_i}{\eta_i}\right)^{\eta_i} \mathrm{d}i\right\}. \tag{3.3}$$

The parameter $\eta_i \in (0, 1)$ reflects the intensity of component i within the aggregate M, with $\int_0^N \eta_j \mathrm{d}j = 1$. The total input intensity of component i for final goods production is therefore given by $\eta^M \cdot \eta_i$.[4] Using equations (3.1), (3.2) and (3.3), total firm revenue can

[4] If all components are symmetric, as will be assumed in Section 3.4, then each one has an individual input intensity equal to $(1-\eta^H)/N$.

be written as follows:

$$R = \theta^{\alpha} \cdot Y^{(1-\alpha)} \cdot \left[\left(\frac{h}{\eta^H} \right)^{\eta^H} \cdot \left(\frac{M}{\eta^M} \right)^{\eta^M} \right]^{\alpha}, \tag{3.4}$$

which is increasing in the firm's productivity and demand level.

3.3.2 Firm structure

The producer decides on the structure of the firm, and this choice involves three aspects: i) *complexity*, ii) *organization*, and iii) *global scale* of production. *Complexity* refers to the mass of components that are part of the production process. Recall that overall component-intensity η^M is exogenous and sector-specific. For example, intermediate inputs generally account for a larger share of total value added in the automobile than, say, in the software industry. Yet, within a sector, a producer can still decide on how thinly she wants to slice the value chain. If she chooses a "low" level of complexity, she relies on a setting with relatively few and broad components with a high average input intensity η_i. An increase in complexity lowers the average input intensity across the single components at constant overall component-intensity η^M. The inputs then become more specialized, and the respective suppliers have more narrowly defined tasks. For example, the carburetor system in car production may then no longer be provided by a single supplier, but different parts (like the choke and the throttle valve) are provided by different suppliers.

Secondly, turning to the organizational decision, the producer decides separately for each component if the respective supplier is integrated as a subsidiary within the boundaries of the firm, or if that component is outsourced to an external supplier. The crucial assumption is that the investments for all inputs are not contractible, as in Antràs and Helpman (2004). This may be due to the fact that the precise characteristics of the inputs are difficult to specify *ex ante* and also difficult to verify *ex post*. As a result of this contract incompleteness, the producer and the suppliers end up in a bargaining situation, at a time when their input investments are already sunk. Following the property rights approach of the firm, see Grossman and Hart (1986) or Hart and Moore (1990), we assume that bargaining also takes place within the boundaries of the firm in the case of vertical integration. This bargaining leads to a division of the total firm revenue as given in eq.(3.4) among the producer and the suppliers, where the bargaining power of the involved parties depends crucially on the firm structure, as will be explained below.

Finally, the producer decides on the global scale of production, i.e., on the location where each component is manufactured. The headquarter itself is located in a high-wage country 1, where final assembly of good y is carried out. Both under outsourcing and vertical integration, the respective input suppliers may either also come from country

1, or from a foreign low-wage country 2. In terms of the cross-country trade pattern, there is an arm's length transaction if the producer outsources a component to a foreign contractor, and intra-firm trade (vertical FDI) if a foreign supplier is vertically integrated.

3.3.3 Structure of the game

We consider a game that consists of seven stages. Our aim is to solve this game by backward induction for the subgame perfect Nash equilibrium. The timing of events is as follows:

1. The final goods producer enters and learns about the firm-specific productivity θ.

2. The producer decides whether to exit immediately, or to remain active in the market.

3. If the firm remains active, the producer simultaneously decides on: i) the complexity, ii) the organization, and iii) the global scale of the production process. In particular, i) she chooses the mass N of manufacturing components. ii) For each $i \in [0, N]$ the organizational choice is given by $\xi_i = \{O, V\}$. Here, $\xi_i = O$ denotes "outsourcing" and $\xi_i = V$ denotes "vertical integration" of supplier i. We order the mass N such that each supplier $j \in [0, N^O]$ is outsourced, and each supplier $k \in (N^O, N]$ is vertically integrated. Then, $\xi = N^O/N$ (with $0 \leq \xi \leq 1$) denotes the outsourcing share, and $(1 - \xi) = N^V/N$ is the share of vertically integrated suppliers/components. Finally, iii) for each $i \in [0, N]$ the producer decides on the country $r = \{1, 2\}$ where that component is manufactured. We order the mass of outsourced suppliers N^O such that each supplier $j \in [0, N_2^O]$ is offshored to the low-wage country 2, and each supplier $k \in (N_2^O, N^O]$ is located in the high-wage country 1. Then, $\ell^O = N_2^O/N^O$ denotes the offshoring share among all outsourced suppliers (with $0 \leq \ell^O \leq 1$). Similarly, $\ell^V = N_2^V/N^V$ (with $0 \leq \ell^V \leq 1$) is the offshoring share among all integrated suppliers, and the total offshoring share of the firm is given by $\ell = \xi \cdot \ell^O + (1 - \xi) \cdot \ell^V$.

4. Given the choice $\{N, \xi, \ell^O, \ell^V\}$, the producer offers a contract to potential input suppliers for every component $i \in [0, N]$. This contract includes an upfront payment τ_i (positive or negative) to be paid by the prospective supplier.

5. There exists a large pool of potential applicant suppliers for each manufacturing component in both countries. These suppliers have an outside opportunity (wage) equal to w_r^M in country $r = \{1, 2\}$. They are willing to accept the producer's contract if their payoff is at least equal to w_r^M. The payoff consists of the upfront payment τ_i and the revenue share β_i that supplier i anticipates to receive at the bargaining stage, minus the investment costs (which may differ across applicants).

Potential suppliers apply for the contract, and the producer chooses one supplier (either from country 1 or from country 2) for each component $i \in [0, N]$.

6. The producer and the suppliers independently decide on their non-contractible input levels for the headquarter service (h) and the components (m_i), respectively.

7. Output is produced and revenue is realized according to (3.2), (3.3), and (3.4). The producer and the suppliers bargain over the division of the surplus value.

Starting with stage 7, following Grossman and Hart (1986) we assume that the producer and the suppliers cannot write down enforcable contracts that specify the division of revenue. The producer rather has to decide on the structure of the firm (complexity, organization, global scale) in order to affect the revenue distribution, since the firm structure pins down the bargaining power of the involved agents. We assume that the bargaining process follows a generalized simultaneous multi-party Nash bargaining.[5] The surplus value over which the $N + 1$ agents bargain is the total revenue R as given in eq.(3.4), and the agents receive revenue shares that are reflective of their respective bargaining power. The revenue share of component supplier i is given by β_i, and $\beta^M = \int_0^N \beta_j \mathrm{d}j$ denotes the joint revenue share of all component suppliers. The revenue share realized by the producer is written as β^H, and we have $\beta^H = 1 - \beta^M$. The headquarter revenue share β^H reflects the *effective bargaining power* of the producer vis-a-vis the component suppliers. How the firm structure influences the bargaining power of the involved parties is analyzed later.

In stage 6, each component supplier i chooses m_i so as to maximize $\beta_i R - c_{i,r}^M m_i$ for each $i \in [0, N]$, where $c_{i,r}^M$ denotes the unit cost level of the supplier for component i that the producer has offered the contract. The producer chooses h in order to maximize $\beta^H R - c^H h$, where c^H denotes the unit cost of providing headquarter services. We show in Appendix A.1. that the agents choose the following levels of input provision:

$$m_i^* = \alpha \cdot \eta^M \cdot \eta_i \cdot \beta_i \cdot R^* \;/\; c_{i,r}^M \quad \text{and} \quad h^* = \alpha \cdot \eta^H \cdot \beta^H \cdot R^* \;/\; c^H, \tag{3.5}$$

with total revenue given by

$$R^* = (\alpha\theta)^{\alpha/(1-\alpha)} \cdot Y \cdot \left[\left(\frac{\beta^H}{c^H} \right)^{\eta^H} \cdot \left(\exp \left\{ \int_0^N \ln \left(\frac{\beta_j}{c_{j,r}^M} \right)^{\eta_j} \mathrm{d}j \right\} \right)^{\eta^M} \right]^{\frac{\alpha}{1-\alpha}}. \tag{3.6}$$

Everything else equal, the investment by supplier i relative to that of some other supplier j, (m_i^*/m_j^*), is increasing in supplier i's revenue share β_i and input intensity η_i. Similarly, the producer invests relatively more the higher β^H and η^H are.

[5] We propose a Nash bargaining as in Antràs and Helpman (2004), since the mass of suppliers N is already determined at stage 7. We rule out the possibility of partial cooperation as in Acemoglu et al. (2007), where the Shapley value is used to account for potential coalition formation.

Next, in order to receive applications for each desired component input in stage 5, the producer must offer contracts in stage 4 that satisfy the suppliers' participation constraints. For supplier i this implies that the individual payoff from forming the relationship, given (3.5) and (3.6), must at least be equal to the attainable outside wage:

$$\beta_i R - c_{i,r}^M m_i + \tau_i \geq w_r^M. \tag{3.7}$$

In stage 3, the producer then chooses the structure of the firm so as to maximize her individual payoff, $\beta^H R - c^H h - \int_0^N \tau_j \mathrm{d}j$, subject to the revenue given in eq.(3.4), the incentive compatibility constraints (3.5), and the participation constraints (3.7). Since the producer can freely adjust the upfront payments τ_i, these participation constraints are satisfied with equality for all suppliers $i \in [0, N]$. Rearranging $\tau_i = w_r^M - \beta_i R + c_{i,r}^M m_i$, substituting this into the individual payoff of the producer, and recalling that $\beta^M = 1 - \beta^H$, it follows that the producer's problem is equivalent to maximizing the total payoff for all $N+1$ involved parties, i.e.: $\pi = R^* - \int_0^N c_{j,r}^M m_j^* \mathrm{d}j - c_H h^* - f$, where f is the outside opportunity w_r^M aggregated across all (domestic and foreign) suppliers. Notice that the term f is increasing in N as long as $w_r^M > 0$, i.e., the participation constraints generate a "fixed cost" that is endogenously increasing in complexity, as this necessitates contracting with more suppliers.[6] We additionally allow for exogenous fixed costs $\bar{f}$ which arise independently of the participation constraints, e.g. for general overhead costs. With overall fixed costs given by $F = f + \bar{f}$, we can rewrite the total payoff as follows by using (3.4) and (3.5):

$$\pi = \Theta \cdot Y \cdot \Psi - F, \tag{3.8}$$

$$\Psi \equiv \left[1 - \alpha\left(\beta^H \eta^H + \eta^M \int_0^N \beta_j \eta_j \mathrm{d}j\right)\right]\left[\left(\frac{\beta^H}{c^H}\right)^{\eta^H}\left(\exp\left\{\int_0^N \ln\left(\frac{\beta_j}{c_{j,r}^M}\right)^{\eta_j} \mathrm{d}j\right\}\right)^{\eta^M}\right]^{\frac{\alpha}{1-\alpha}}, \tag{3.9}$$

where $\Theta = (\alpha\theta)^{\alpha/(1-\alpha)}$ is an alternative productivity measure.

Finally, similar as in Melitz (2003), a firm learns about its productivity level θ upon entry, which is drawn from some density function $g(\theta)$ with support $[\underline{\theta}, \infty]$, where $\underline{\theta} > 0$ denotes a lower bound. The firm only stays in the market (in stage 2) when the variable payoff $\Theta \cdot Y \cdot \Psi$ is sufficiently large to cover the fixed costs F.

3.4 Symmetric components

In this section we consider the case of *symmetric* components. We assume that the individual input intensities of the single components are given by $\eta^M \cdot \eta_i = \left(1 - \eta^H\right)/N$

[6] We assume that outside opportunities may differ across countries, but not across suppliers from the same country. This assumption could be relaxed without affecting our main results. Our main results only require that overall fixed costs for the firm are increasing in complexity N.

for all $i \in [0, N]$. We first abstract from the global scale dimension, and focus on the complexity and organization decision when all suppliers are located in country 1.

3.4.1 Closed economy

Notice that an increase in the complexity level N is associated with a uniform reduction of the individual input intensities of all suppliers, as each supplier now performs a more narrowly defined task. We assume that this specialization leads to efficiency gains, similar as in Acemoglu et al. (2007). Specifically, we assume that unit costs are the same for all suppliers, and are given by $c^M = c/N^s$, with $0 < s < 1$. The unit costs c^M are thus decreasing in N for all suppliers, and these cost savings are more substantial the larger s is. Without loss of generality, we normalize the parameter c to unity ($c = 1$).

With symmetric components, and using (3.5), (3.8) and (3.9), the producer's problem is to maximize the following total payoff:

$$\pi = \Theta \cdot Y \cdot \Psi - N \cdot w_1^M - \bar{f}, \tag{3.10}$$

$$\Psi \equiv \left[1 - \alpha \left(\beta^H \eta^H + \frac{\beta^M \eta^M}{N}\right)\right] \left[\left(\frac{\beta^H}{c^H}\right)^{\eta^H} \left(N^s \cdot \exp\left\{\frac{1}{N} \int_0^N \ln(\beta_j)\, dj\right\}\right)^{\eta^M}\right]^{\frac{\alpha}{1-\alpha}}. \tag{3.11}$$

In subsection 3.4.1.1 we first study the case where enforcable contracts on the ex ante division of revenue are possible. In that case, the producer maximizes eqs.(3.10) and (3.11) simultaneously with respect to N and β^H. In subsection 3.4.1.2 we then study the incomplete contracts scenario where the producer cannot freely decide on the ex ante division of the surplus, but has to choose the complexity and the organization of the production process in order to affect the division of revenue that results in the bargaining stage.

3.4.1.1 Optimal mass of suppliers and revenue division

When the producer can freely choose the headquarter revenue share β^H, then each supplier receives a revenue share $\beta_i = (1 - \beta^H)/N$ due to symmetry. Using (3.10) and (3.11), the firm's variable payoff $\Theta \cdot Y \cdot \Psi\left(N, \beta^H\right)$ can then be simplified as follows:

$$\Theta \cdot Y \cdot \Psi = \Theta \cdot Y \cdot \left[1 - \alpha \left(\beta^H \eta^H + \frac{(1-\eta^H)(1-\beta^H)}{N}\right)\right] \left[\left(\frac{\beta^H}{c^H}\right)^{\eta^H} \left(\frac{1-\beta^H}{N^{1-s}}\right)^{1-\eta^H}\right]^{\frac{\alpha}{1-\alpha}}. \tag{3.12}$$

a) Zero outside opportunity. When setting the suppliers' outside opportunities to zero ($w_1^M = 0$), the producer's problem is equivalent to maximizing the variable payoff as

given in (3.12). For this case, we can derive the following unique solution (see Appendix A.2.1.i):

$$N^*\left(w_1^M=0\right) = \frac{\rho - s\left(1-\eta^H\right)\left(1+\alpha\eta^H\right)}{2\left(1-s\right)\eta^H} \equiv N_0^*, \tag{3.13}$$

$$\beta^{H*}\left(w_1^M=0\right) = \frac{2\eta^H - \rho + s\left(1-\eta^H\right)\left(1-\alpha\eta^H\right)}{2\eta^H} \equiv \beta_0^{H*} \tag{3.14}$$

with $\rho = \sqrt{s\left(1-\eta^H\right)\left(1-\alpha\eta^H\right)\left(4\eta^H + s\left(1-\eta^H\right)\left(1-\alpha\eta^H\right)\right)}$. Notice that $0 < \beta_0^{H*} < 1$ and $N_0^* > 0$ for all $0 < s < 1$, $0 < \eta_H < 1$, and $0 < \alpha < 1$. It directly follows from the solution in (3.13) and (3.14) that:

$$\frac{\partial \beta_0^{H*}}{\partial \eta^H} > 0, \qquad \frac{\partial N_0^*}{\partial \eta^H} < 0, \qquad \frac{\partial \beta_0^{H*}}{\partial s} < 0, \qquad \frac{\partial N_0^*}{\partial s} > 0.$$

Higher headquarter-intensity of final goods production leads to a larger optimal revenue share for the producer. The intuition for this result is similar as in Antràs and Helpman (2004, 2008): both the headquarter and the suppliers underinvest in the provision of their respective inputs, and this underinvestment problem is more severe for the headquarter (the mass of suppliers) the smaller (the larger) the revenue share β^H is. Ensuring ex ante efficiency requires that the producer should receive a larger share of the surplus in sectors where headquarter services are more intensively used in production.

The basic trade-off with respect to the complexity choice N is novel in our framework. It can be seen from (3.12) that the impact of N on the variable payoff is, *a priori*, ambiguous. Intuitively, higher complexity leads to stronger specialization (i.e., lower unit costs c^M), which tends to increase the firm's revenue and payoff. On the other hand, for a given share β^H, higher complexity also "dilutes" the investment incentives for every single supplier, because the individual input intensities decrease and the overall revenue share $\beta^M = 1 - \beta^H$ has to be split among more parties. This negatively impacts on the firm's payoff. The optimal complexity N_0^* balances the "cost saving" and the "dilution" effect. Higher headquarter-intensity η^H leads to a lower optimal complexity. The reason is the following: The optimal joint revenue share for the suppliers (β^{M*}) is decreasing in η^H, which tends to jeopardize their investment incentives. To countervail this problem, the producer can concentrate on relatively few components with a high individual input intensity. Although the gains from specialization are smaller in that case, the resulting increases of β_i and η_i again raise the suppliers' incentives (see eq. (3.5)).[7]

[7] It is, thus, not clear if the optimal revenue share of a *single* supplier (β_{i0}^*) is increasing or decreasing in headquarter-intensity η^H; there is a larger joint revenue share β^M when η^H is low ("component-intensity effect"), but this share is then split among many suppliers ("complexity effect"). Using (3.13) and (3.14), it can be shown that $\beta_{i0}^* = (1-\beta_0^{H*})/N_0^*$ is in fact hump-shaped over the range of η^H and achieves a maximum at some level η_{crit}^H (see Appendix A.2.1.ii). In other words, single suppliers receive the highest revenue shares in sectors with medium headquarter-intensity.

The stronger the cost savings from specialization are (the larger s is), the more profitable is it to add components to the value chain, i.e., the higher is N_0^*. This increase in complexity is then accompanied by a decrease in the optimal revenue share β_0^{H*}, since the incentives for all component manufacturers must be maintained.[8] When s becomes very small, so does N_0^*. Intuitively, the "cost saving" effect disappears if s tends to zero. The "dilution effect" for the suppliers is still present, however, so that the optimal mass of components would then also become very small.[9] Notice that this is true even though contracting with more suppliers leads to no increase in fixed costs as long as $w_1^M = 0$.

Finally, notice that the payoff-maximizing choices (3.13) and (3.14) do not depend on Θ. Still, a firm needs to be sufficiently productive in order to remain in the market, since the variable payoff must be large enough to cover the fixed costs $\bar{f}$. Hence, only such firms survive whose productivity level is above some threshold $\hat{\Theta}_0$ given in Appendix A.2.1.v.

b) Positive outside opportunity. Turning to the case with $w_1^M > 0$, recall that a more complex production process leads to larger fixed costs $f = N \cdot w_1^M$, since the suppliers' participation constraints must be taken into account. With a positive outside opportunity there is thus an additional endogenous "complexity penalty" embedded in our model.

With $w_1^M > 0$, we cannot explicitly solve for N^* and β^{H*}. However, using the two first-order conditions for payoff maximization, it is possible to solve $\partial\pi/\partial\beta^H = 0$ for $\beta^H(N)$ with $\partial\beta^H/\partial N < 0$, which does not depend on w_1^M (see eq.(3.23) in Appendix A.2.2.i). Substituting this into the other first-order condition, we can derive the following function:

$$\frac{\partial\pi}{\partial N} = \Theta \cdot Y \cdot \underbrace{\frac{\partial\Psi}{\partial N}\Big|_{\beta^H=\beta^H(N)}}_{\equiv\Psi'} - w_1^M = 0 \quad \Leftrightarrow \quad \Psi' = \frac{w_1^M}{\Theta \cdot Y}.$$

Ψ' depends only on N and represents the marginal change in the total payoff when raising complexity, taking into account that $\beta^H(N)$ is optimally adjusted. We know that $\Psi' = 0$ is solved by N_0^* as given in (3.14). With $w_1^M > 0$, the optimal mass of producers N^* is determined by setting Ψ' equal to $w_1^M/(\Theta \cdot Y) > 0$, and since $\partial\Psi'/\partial N < 0$ it follows

[8] We show in Appendix A.2.1.iii that $N_0^* = 1$ if s is equal to some s_{crit}. Suppose for the moment that the set of suppliers N is discrete, by assuming that the unit mass of inputs on the interval $[0, 1]$ is provided by a single supplier. In fact, if $s = s_{crit}$, choosing a unit mass of inputs is optimal for the producer. The corresponding optimal revenue share $\beta_0^{H*}(s = s_{crit})$ in that case is identical to eq. (10) in Antràs and Helpman (2004), where it is imposed exogenously that there is just one single component supplier. Their baseline model is thus included in our framework as a special case. When s is smaller (larger) than s_{crit}, it is optimal to have less (more) than a unit mass of inputs.

[9] See Appendix A.2.1.iv for an analytical decomposition that illustrates the trade-off between these effects more formally.

that $0 < N^* < N_0^*$ and $0 < \beta_0^{H*} < \beta^{H*} < 1$, with:

$$\frac{\partial N^*}{\partial \Theta} > 0, \qquad \frac{\partial N^*}{\partial \eta^H} < 0, \qquad \frac{\partial N^*}{\partial w_1^M} < 0, \qquad \frac{\partial \beta^{H*}}{\partial \Theta} < 0, \qquad \frac{\partial \beta^{H*}}{\partial \eta^H} > 0, \qquad \frac{\partial \beta^{H*}}{\partial w_1^M} > 0.$$

The downward-sloping thick curve in Figure 3.1 illustrates the function Ψ'. The optimal mass of suppliers is where this curve cuts the horizontal line. An increase of w_1^M leads to an upward shift, and an increase of Θ to a downward shift of this horizontal line. For given values of w_1^M and η^H, more productive firms thus collaborate with more suppliers, since they can easier cope with the requirement to match their outside opportunities. Still, all firms choose a complexity level below N_0^*, i.e., the optimal complexity N^* is bounded. Furthermore, the Ψ'-curve shifts to the left as η^H increases. Hence, when comparing equally productive firms, those from headquarter-intensive industries have lower optimal complexity than those from component-intensive industries (see Appendix A.2.2.i).

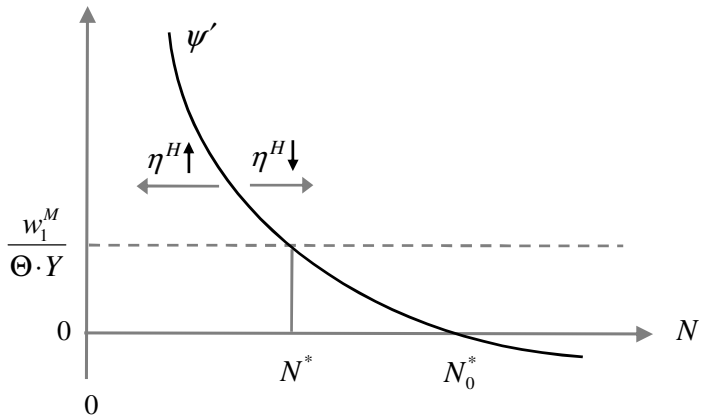

Figure 3.1: Optimal complexity with (N^*) and without (N_0^*) increasing fixed costs.

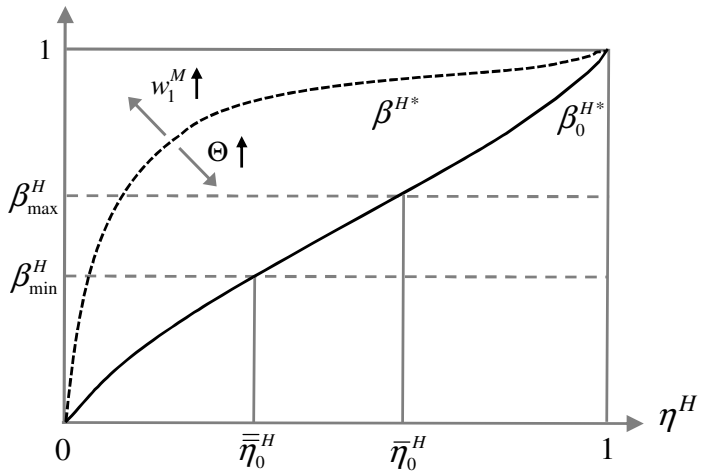

Figure 3.2: Distribution of revenue

In Figure 3.2 we illustrate the corresponding optimal headquarter revenue share. The figure firstly depicts the β_0^{H*}-curve for the benchmark case with $w_1^M = 0$. Since we know from the first-order conditions that $\partial\beta^H/\partial N < 0$ (see Appendix A.2.2.i), it is clear that the β^{H*}-curve stretches out to the left if $w_1^M > 0$, which implies a higher β^{H*} throughout the entire range of η^H. The reason is that an increase in w_1^M, by reducing the optimal complexity level, leads to a higher individual input intensity $\eta_i = \eta^M/N$ for each supplier. This raises the suppliers' incentives and thereby allows for a larger optimal revenue share β^{H*}. Yet, this share is lower in firms with higher productivity, i.e., the firm-specific β^{H*}-curve moves closer to the β_0^{H*}-curve. The intuition is that more productive firms operate more complex production processes, and to maintain the investment incentives, they need to leave a larger revenue share β^M for the suppliers. In the limit, β^{H*} converges to β_0^{H*}.

A stronger cost saving effect s naturally leads to more suppliers (a higher N^*) and, thus, to a lower β^{H*}.[10] Furthermore, higher productivity implies a higher total payoff π, despite the fact that more productive firms have more complex production processes and, thus, higher fixed costs. Higher productivity thus raises the variable payoff $\Theta \cdot Y \cdot \Psi$ stronger than the fixed costs $F = N^* \cdot w_1^M + \bar{f}$ (see Appendix A.2.2.ii). Ultimately, a firm only survives if it is sufficiently productive to cover these fixed costs, which are unambiguously larger than in the previous case with $w_1^M = 0$. It is thus clear that the threshold productivity $\hat{\Theta}$ is larger than the benchmark level $\hat{\Theta}_0$ given in Appendix fA.2.1.v, even though we cannot solve for $\hat{\Theta}$ in closed form.

3.4.1.2 The make-or-buy decision under incomplete contracts

We now turn to the incomplete contracts scenario where the producer cannot "freely" decide on the ex ante division of the surplus, but has to choose the complexity and the organization of the firm in order to affect the division of revenue that results in the bargaining stage. Following Antràs and Helpman (2004), we assume that external suppliers are in a better bargaining position than integrated suppliers vis-a-vis the producer. This is due to the fact that the producer has no ownership of the assets of external suppliers, while she does have residual control rights over the assets of those suppliers that are integrated within the boundaries of the firm.

Specifically, we assume that if the producer has outsourced *all* suppliers ($\xi = 1$), she is able to realize an exogenously given revenue share β_{min}^H. Vice versa, if she has integrated *all* suppliers ($\xi = 0$), she is able to realize a larger revenue share, $\beta_{max}^H > \beta_{min}^H$, as a result of her asset ownership. For intermediate cases with $0 < \xi < 1$, her realized revenue share (her "effective bargaining power") can be written as:

$$\beta^H = \xi \cdot \beta_{min}^H + (1 - \xi) \cdot \beta_{max}^H. \tag{3.15}$$

[10] Graphically, the Ψ'-curve in Figure 3.1 shifts to the right as s increases. In the corresponding Figure 3.2, both the β_0^{H*}- and the β^{H*}-curve stretch out to the right.

The producer can thus affect her revenue share via the outsourcing share $\xi = N^O/N$, but she is contrained to the range between β^H_{min} and β^H_{max}.[11] The remaining share $\beta^M = 1-\beta^H$ is left for the suppliers, and the individual revenue share of an outsourced and an integrated supplier is denoted by β^O_i and β^V_i, respectively. Since $\beta^M = N^O \cdot \beta^O_i + N^V \cdot \beta^V_i$ must hold, it follows that $N^O \cdot \beta^O_i = \xi \cdot (1 - \beta^H_{min})$ is the revenue share of the external contractors, and $N^V \cdot \beta^V_i = (1-\xi) \cdot (1 - \beta^H_{max})$ the share of the integrated affiliates.[12]

a) Zero outside opportunity. As before we start with the case where the suppliers' outside opportunities are set to zero ($w^M_1 = 0$). In this case, the producer's problem is equivalent to maximizing the variable payoff $\Theta \cdot Y \cdot \Psi\left(N, \beta^H(\xi)\right)$ with respect to N and ξ, subject to the constraint (3.15). The term Ψ is given by eq.(3.11).

As long as the constraint $\beta^H \in \left[\beta^H_{min}, \beta^H_{max}\right]$ is not binding, this maximization problem leads to an equivalent solution as described in subsection 3.4.1.1 In particular, if the producer is able to choose the outsourcing share ξ in such a way that β^H exactly matches β^{H*}_0 as given in (3.14), she would target this payoff-maximizing revenue distribution with her organizational choice, and hence the corresponding complexity N^*_0 given in (3.13). Since $\xi \cdot \beta^H_{min} + (1-\xi) \cdot \beta^H_{max} = \beta^{H*}_0$ in that case, this implies the following outsourcing share:

$$\xi^*_0 = \left(\beta^H_{max} - \beta^{H*}_0\right) / \left(\beta^H_{max} - \beta^H_{min}\right) \qquad \text{for} \quad \beta^H_{min} \leq \beta^{H*}_0 \leq \beta^H_{max}. \tag{3.16}$$

Notice, however, that this outsourcing share is feasible if and only if $\beta^H_{min} \leq \beta^{H*}_0 \leq \beta^H_{max}$. Otherwise, if $\beta^{H*}_0 < \beta^H_{min}$ or $\beta^{H*}_0 > \beta^H_{max}$, she cannot achieve the unconstrained payoff-maximizing firm structure. She would then aim for an outsourcing share ξ that aligns the β^H given in eq. (3.15) as closely as possible with the optimal β^{H*}_0, and for the corresponding constrained optimal complexity level – also see Appendix A.3.

Figure 3.2 illustrates this problem. The figure depicts the payoff-maximizing β^{H*}_0 that the producer aims for. If the firm operates in a headquarter-intensive sector, more precisely a sector with $\eta^H > \bar{\eta}^H_0$ where the threshold $\bar{\eta}^H_0$ is defined in Appendix A.3.1., we have $\beta^{H*}_0 > \beta^H_{max}$ so that the producer cannot achieve β^{H*}_0. Firms from those sectors choose complete vertical integration, $\tilde{\xi}_0 = 0$, as this leads to the maximum possible rev-

[11] Notice that β^H_{min} and β^H_{max} are *independent* of N. The complexity of the production process, therefore, does not directly affect the bargaining power of the producer, which is plausible since the headquarter-intensity is also exogenous and independent of N. It is possible to analyze cases where complexity systematically affects the bargaining power (the realized revenue share) of the headquarter, but this complicates the analysis without adding many further insights.

[12] The joint revenue share of all suppliers (β^M) is thus unambiguously larger with complete outsourcing ($\xi = 1$) than with complete integration ($\xi = 0$). However, a single outsourced contractor in the first scenario does not necessarily obtain a larger revenue share than a single integrated affiliate in the second scenario. That is, β^O_i with $\xi = 1$ need not be larger than β^V_i with $\xi = 0$, because N^O and N^V need not be the same. Yet, in a constellation where outsourcing and integration coexist, it is clear that an external supplier receives a larger revenue share than an integrated supplier ($\beta^O_i > \beta^V_i$ with $0 < \xi < 1$).

enue share β^H_{max} for the headquarter; the corresponding constrained optimal complexity level is analyzed soon. Vice versa, if the firm operates in a component-intensive sector, more precisely a sector with $\eta^H < \bar{\bar{\eta}}^H_0$ where the threshold $\bar{\bar{\eta}}^H_0$ is defined in Appendix A.3.1., the producer also cannot achieve β^{H*}_0, and she then aims for the highest possible revenue share for the suppliers by choosing complete outsourcing ($\tilde{\xi}_0 = 1$). In sectors with $\bar{\bar{\eta}}^H_0 \leq \eta^H \leq \bar{\eta}^H_0$, the producer is not constrained by $\beta^H_{min} \leq \beta^{H*}_0 \leq \beta^H_{max}$, and she therefore sets $\tilde{\xi}_0 = \xi^*_0$ as given in (3.16). In those sectors with medium headquarter-intensity we thus observe a coexistence of both organizational forms within the same firm (hybrid sourcing), with a higher outsourcing share in relatively more component-intensive industries within that range ($\partial\xi^*_0/\partial\eta^H < 0$ since $\partial\beta^{H*}_0/\partial\eta^H > 0$).[13]

Turning to the corresponding complexity decision, let $\tilde{N}_0$ denote the complexity choice under incomplete contracts for the case with $w^M_1 = 0$. To compute $\tilde{N}_0$, notice that in sectors with $\eta^H > \bar{\eta}^H_0$ and $\eta^H < \bar{\bar{\eta}}^H_0$, firms choose the same organizational form for *all* suppliers (complete vertical integration and, respectively, complete outsourcing). For these cases with a uniform organizational structure, we can simplify Ψ as given in eq.(3.11) by setting $\beta_j = (1 - \tilde{\beta}^H_0)/N$ where $\tilde{\beta}^H_0 = \{\beta^H_{min}, \beta^H_{max}\}$. Solving $\Psi' = \partial\Psi/\partial N = 0$ then yields:

$$\tilde{N}_0 = \frac{\left(1 - \tilde{\beta}^H_0\right)\left(1 - s\alpha\left(1 - \eta^H\right) - \alpha\eta^H\right)}{(1 - s)\left(1 - \alpha\tilde{\beta}^H_0\eta^H\right)}. \tag{3.17}$$

It follows directly from (3.17) that $\tilde{N}^O_0 \equiv \tilde{N}_0\left(\tilde{\beta}^H_0 = \beta^H_{min}\right) > \tilde{N}_0\left(\tilde{\beta}^H_0 = \beta^H_{max}\right) \equiv \tilde{N}^V_0$. That is, vertical integration is endogenously associated with less complexity than outsourcing, as the producer can reduce the underinvestment problem for the suppliers by choosing fewer intermediate inputs. Next, for the unconstrained firms in sectors with medium headquarter-intensity $\bar{\bar{\eta}}^H_0 \leq \eta^H \leq \bar{\eta}^H_0$, where $\beta^H = \beta^{H*}_0$ and $0 \leq \tilde{\xi}_0 \leq \xi^*_0 < 1$ holds, the mass of suppliers is given by (3.13), since it can be shown that $\tilde{N}_0\left(\tilde{\beta}^H_0 = \beta^{H*}_0\right) = N^*_0$.[14]

Figure 3.3 summarizes the results. Active firms in sectors with low headquarter-intensity have a huge mass of suppliers ($\tilde{N}^O_0$), all of which are outsourced. Gradually moving to more headquarter-intensive sectors, we first see no change in the firms' organizational structures or the producer's revenue shares, since $\tilde{\xi}_0 = 1$ and $\beta^H = \beta^H_{min}$ as long as $\eta^H < \bar{\bar{\eta}}^H_0$. Yet, such a gradual increase of η^H leads to a decreasing mass of suppliers $\tilde{N}^O_0$, hence the most complex production processes prevail in the most component-intensive sectors.[15] Once we turn to sectors with a headquarter-intensity above $\bar{\bar{\eta}}^H_0$, there is a

[13] Du, Lu and Tao (2009) consider an extension of Antràs and Helpman (2004) where the *same* input can be provided by two suppliers. "Bi-sourcing" (one supplier integrated and the other outsourced) can arise in their model out of a strategic motive, because it systematically improves the headquarter's outside option and, thus, her effective bargaining power. Our model relies on an entirely different (non-strategic) mechanism why firms may choose different organizational modes for different inputs.

[14] $\tilde{N}_0$ is continuous in η^H and $\tilde{\beta}^H_0$, so that it can be easily shown that $\tilde{N}^O_0 > N^*_0 > \tilde{N}^V_0$ holds.

[15] For a given ξ, higher headquarter-intensity is thus inversely related to complexity, similar as in

coexistence of both organizational forms within the same firm. The headquarter revenue share is gradually increasing, and the outsourcing share is gradually decreasing in η^H. Complexity $\tilde{N}_0$ continues to decrease in η^H and is equal to N_0^* in that range. Finally, once η^H goes beyond $\bar{\eta}_0^H$, further increasing the headquarter-intensity has again no impact on organizational structures or the producers' revenue shares, since $\tilde{\xi}_0 = 0$ and $\beta^H = \beta_{max}^H$ if $\eta^H > \bar{\eta}_0^H$. It still leads to a decreasing mass of suppliers, which is now given by $\tilde{N}_0^V$. Firms in the most headquarter-intensive sectors are thus the least complex ones, and fully vertically integrated.

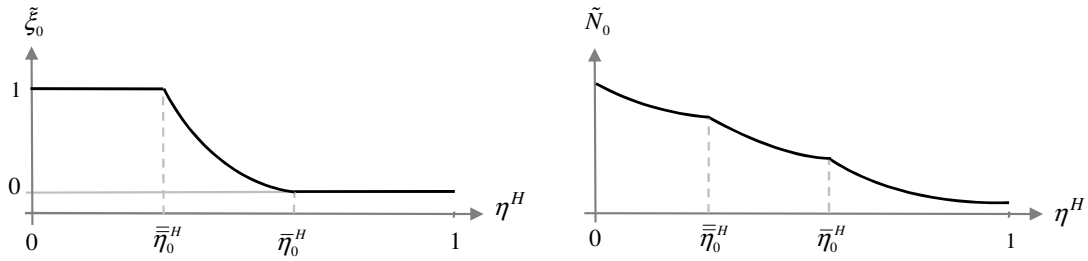

Figure 3.3: Organization and complexity decision for the case with $w_r^M = 0$.

The complexity and the organizational decision therefore have opposite incentive effects for the suppliers. Complete outsourcing (vertical integration) leaves a large (small) combined revenue share for the suppliers, but this share is then divided among many (few) of them. A stronger cost saving effect (a higher value of s) is associated with a larger mass of suppliers, other things equal.[16] Moreover, the β_0^{H*}-curve in Figure 3.2 stretches out to the right, and both $\bar{\eta}_0^H$ and $\bar{\bar{\eta}}_0^H$ go up when s increases (see Appendix A.3.1.i). Complete outsourcing is then chosen over a larger, and complete integration over a smaller domain of η^H the larger s is, as it becomes relatively more attractive to choose the organizational form that is endogenously associated with higher complexity, i.e., to choose outsourcing.

Finally, it is important to note that, as long as the suppliers' outside opportunities are set to zero ($w_1^M = 0$), there are no intra-sectoral differences in the complexity and the organization of firms. That is, for a given headquarter-intensity, all active firms in that industry (regardless of productivity) would choose the same mass of suppliers and the same outsourcing share. This is shown in the left panel of Figure 3.4. Here we depict the total payoff π as a function of Θ and η^H. A darker color indicates a higher complexity level. Within every sector (i.e., moving parallel to the Θ-axis), we see that higher productivity implies a higher total payoff, but it does not affect the

subsection 3.4.1.2 where we have shown that the optimal mass of suppliers N_0^* also depends negatively on η^H. Formally, $\partial \tilde{N}_0^O / \partial \eta^H < 0$ only holds if $s < (1-\tilde{\beta}_0^H)/(1-\alpha\tilde{\beta}_0^H)$. To avoid undue case distinctions, we assume that the exogenous β_{max}^H is sufficiently small so that this restriction on s is satisfied.

[16]Formally, eq.(3.17) implies $\partial \tilde{N}_0 / \partial s > 0$ which applies for the ranges $\eta^H < \bar{\bar{\eta}}_0^H$ and $\eta^H > \bar{\eta}_0^H$, and eq.(3.13) implies $\partial N_0^* / \partial s > 0$ which applies for the range $\bar{\bar{\eta}}_0^H \leq \eta^H \leq \bar{\eta}_0^H$.

firms' complexity or organization. Both differ only across sectors, such that a higher headquarter-intensity is associated with less suppliers and more vertical integration (as also shown in Figure 3.3). Figure 3.4a furthermore illustrates the decision whether to remain active in the market. For all firms in the hybrid range $\bar{\bar{\eta}}_0^H \leq \eta^H \leq \bar{\eta}_0^H$, the threshold producitivity for survival, $\tilde{\Theta}_0$, is identical to $\hat{\Theta}_0$ given in Appendix A.2.1.v, while $\tilde{\Theta}_0 > \hat{\Theta}_0$ must hold for all other firms, as they face the binding constraint $\beta^H \in \left[\beta_{min}^H, \beta_{max}^H\right]$ and cannot achieve the unconstrained payoff maximum. They hence need a higher productivity to break even.

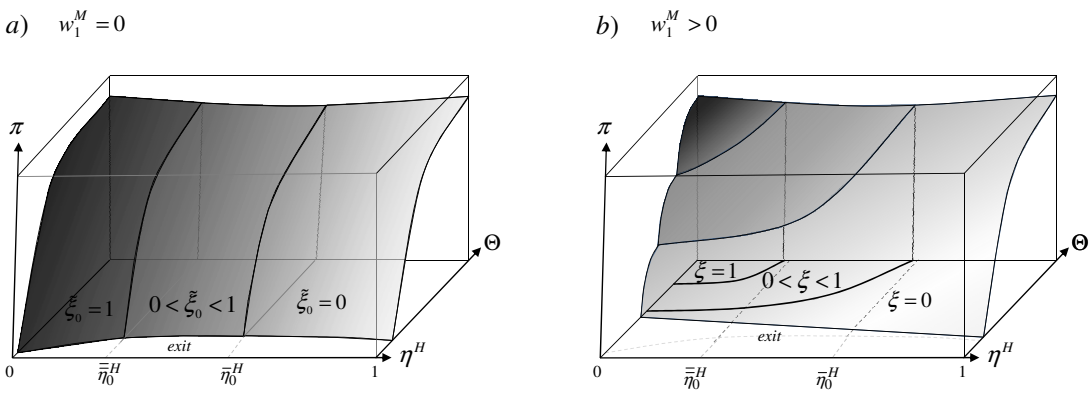

Figure 3.4: Total firm payoff, complexity and organization.

b) Positive outside opportunity. We now focus on the case with endogenous fixed costs ($w_1^M > 0$). We cannot explicitly solve for $\tilde{N}$ and $\tilde{\xi}$ in this case, but similar as in subsection 3.4.1.1 it is again possible to infer important comparative static results.

As in the previous case with $w_1^M = 0$, a single producer chooses the outsourcing share ξ so as to realign the revenue share β^H from eq. (3.15) as closely as possible with the payoff-maximizing revenue share β^{H*}, which then implies a corresponding complexity choice $\tilde{N}$. Comparing β^{H*} with the available range of revenue shares, $\beta^H \in \left[\beta_{min}^H, \beta_{max}^H\right]$, we can classify every firm into one of the following three groups:

1. firms with $\beta^{H*}\left(\eta^H, w_1^M, \Theta\right) > \beta_{max}^H$,

2. firms with $\beta^{H*}\left(\eta^H, w_1^M, \Theta\right) < \beta_{min}^H$,

3. firms with $\beta_{min}^H \leq \beta^{H*}\left(\eta^H, w_1^M, \Theta\right) \leq \beta_{max}^H$.

For the firms in group 3, the constraint $\beta^H \in \left[\beta_{min}^H, \beta_{max}^H\right]$ is not binding. These firms can choose an outsourcing share $\tilde{\xi} = \xi^* = \left(\beta_{max}^H - \beta^{H*}\right) / \left(\beta_{max}^H - \beta_{min}^H\right)$ so as to exactly match β^{H*}. For the other groups the constraint is binding, and all firms in group 1 choose complete vertical integration, while all firms in group 2 choose complete outsourcing.

The corresponding complexity choice can then be derived as follows: From eqs.(3.10) and (3.11) we know that $\tilde{N}$ is determined according to $\Psi' = w_1^M/(\Theta \cdot Y)$. For the unconstrained firms, which are able to achieve β^{H*} by setting $\tilde{\xi} = \xi^*$, their complexity choice $\tilde{N}$ is thus equivalent to the payoff-maximizing N^* described above. For the constrained firms, we can define the following functions: $\Psi^{O\prime} \equiv \Psi'\left(N, \beta^H = \beta^H_{min}, \beta_j = (1-\beta^H_{min})/N\right)$ and $\Psi^{V\prime} \equiv \Psi'\left(N, \beta^H = \beta^H_{max}, \beta_j = (1-\beta^H_{max})/N\right)$, which depend negatively on N and depict the marginal change in the variable payoff for fixed values of β^H that correspond to the headquarter revenue share under complete outsourcing and integration, respectively. In Figure 3.5 we illustrate the curves $\Psi^{O\prime}$ and $\Psi^{V\prime}$, and it can be easily shown that the former curve always runs to the right of the latter (see Appendix A.3.2.).[17]

The complexity choice that corresponds to every possible organizational decision is determined by the intersection point of the respective downward-sloping Ψ'-curve with the horizontal line at $w_1^M/(\Theta \cdot Y)$. In Figure 3.5 we depict two firms from the same industry, one with "high" and one with "low" productivity. Suppose both firms have the same organizational structure. The highly productive firm then collaborates with more suppliers. More importantly, for given Θ and η^H, we have $\tilde{N^O} > \tilde{N}^{0<\xi<1} > \tilde{N^V} > 0$. Hence, vertical integration is endogenously associated with lower complexity. The intuition is similar as above: Since the suppliers receive a relatively small joint revenue share with vertical integration, decreasing complexity is a device to countervail their underinvestment problems.[18]

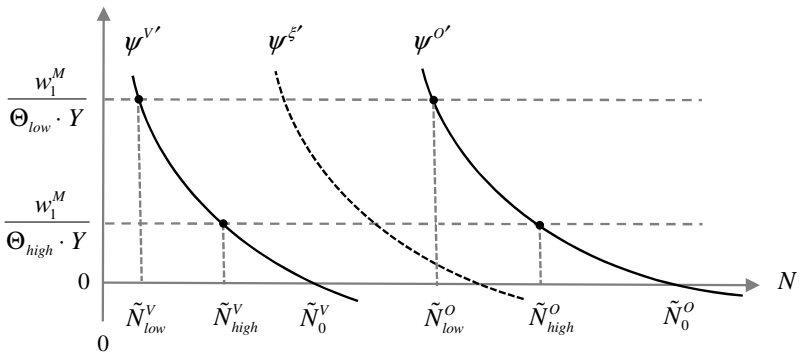

Figure 3.5: Payoff-maximizing mass of suppliers: The complexity decision.

To pin down the final complexity and organization decisions of firms in different industries, it is crucial to note that the three groups of firms defined above can no longer be delineated by the sectoral headquarter-intensity η^H alone. Recall from Figure 3.2 that the β_0^{H*}-curve is increasing in η^H, and that $w_1^M > 0$ leads to an increase of β^{H*} that is

[17]Since Ψ is continuous in β^H, it follows immediately that the Ψ'-curves for the intermediate cases with $0 < \tilde{\xi} < 1 \rightarrow \beta^H_{min} < \beta^H < \beta^H_{max}$ are located in between the $\Psi^{V\prime}$- and the $\Psi^{O\prime}$-curve.

[18]Notice that $\tilde{N}$ always remains below the respective $\tilde{N}_0$ for the same organizational structure, which is located at the intersection of the respective Ψ'-curve with the horizontal axis. Furthermore, it can be shown that an increase in the headquarter-intensity η^H shifts all Ψ'-curves to the left and, thus, leads to a smaller mass of suppliers for all possible productivities and organizational forms.

larger for less productive firms. In other words, $\beta^{H*}\left(\eta^H, w_1^M, \Theta\right)$ is no longer the same for all firms from the same industry (with the same η^H), but it is now firm-specific as it depends on Θ. Hence, firms from the same industry no longer need to choose identical firm structures.

The final complexity and organization decisions are summarized above in the right panel of Figure 3.4. First, consider headquarter-intensive sectors with $\eta^H > \bar{\eta}_0^H$. All firms from those sectors belong to group 1, and thus choose complete vertical integration. This is for two reasons. This organization leads to the highest possible revenue share β_{max}^H for the producer. Now this choice is reinforced, since vertical integration is also associated with fewer suppliers and with lower fixed costs. There is, hence, no change in the organizational decision of firms in headquarter-intensive industries compared to the previous case with $w_1^M = 0$, which is depicted in Figure 3.4a. In other words, in sectors with $\eta^H > \bar{\eta}_0^H$, all firms (regardless of productivity) choose complete vertical integration. Figure 3.4b also shows that not only the total payoff π, but also the complexity level $\tilde{N}^V$ is now increasing in Θ. That is, within a given headquarter-intensive sector, more productive firms vertically integrate *more* suppliers. Furthermore, comparing two equally productive firms from two industries A and B with $\eta_A^H > \eta_B^H > \bar{\eta}_0^H$, it turns out that the firm in sector A chooses less complexity than the firm in the relatively more component-intensive sector B.

Now consider component-intensive sectors where $\eta^H < \bar{\bar{\eta}}_0^H$. Without the endogenous "complexity penalty", all firms in those sectors would belong to group 2 and choose complete outsourcing (see Figure 3.4a). With $w_1^M > 0$, we observe that some firms now switch to group 1, and this is more likely: i) the lower productivity is, since the increase of β^{H*} is then most substantial, and ii) the closer η^H is to the upper bound $\bar{\bar{\eta}}_0^H$, since the β^{H*} can then easier exceed β_{max}^H. Those firms now choose complete vertical integration, and this organizational form is chosen to keep the fixed costs f low. There are also firms whose β^{H*} increases by less, so that it now falls inside the range between β_{min}^H and β_{max}^H. These firms then belong to group 3, and can choose the unconstrained payoff-maximizing ξ^* (with $0 \leq \xi^* \leq 1$) and N^*. This is more likely to occur for firms with medium productivity, and in sectors with headquarter-intensity not too close to the upper bound $\bar{\bar{\eta}}_0^H$. For firms with high productivity, the increase of β^{H*} due to $w_1^M > 0$ is negligible, and they remain in group 2 and continue to choose complete outsourcing. Intuitively, the higher fixed cost under outsourcing play a minor role for these highly productive firms. Their main aim is to maximize the residual rights of the suppliers, whose inputs are intensively used in those sectors. Similarly, firms from highly component-intensive sectors are also more likely to remain in group 2, i.e., to choose complete outsourcing. Summing up, the organization of firms in component-intensive industries now varies over the range of Θ, particularly if η^M is not too low. Low productive firms have few suppliers which are fully vertically integrated. With rising productivity, there is a gradual increase

of complexity $\tilde{N}$ and the outsourcing share $\tilde{\xi}$, and the most productive firms collaborate with a huge mass of suppliers and choose complete outsourcing.[19]

Finally, the organizational decision of firms from sectors with medium headquarter-intensity, $\bar{\bar{\eta}}_0^H \leq \eta^H \leq \bar{\eta}_0^H$, is now also tilted towards more vertical integration. More precisely, all firms in those industries decrease their outsourcing share in response to an increase of w_1^M. Firms with low productivity see a larger increase in β^{H*}, so they are more likely to become constrained by β_{max}^H and thus choose $\tilde{\xi} = 0$. This switch from group 3 to group 1 is also more likely to happen in sectors where η^H is only slightly below $\bar{\eta}^H$, since the outsourcing share was already low there. Firms with high productivity and with headquarter-intensity relatively close to $\bar{\bar{\eta}}^H$ are, in contrast, more likely to continue to remain in the range between β_{min}^H and β_{max}^H. Those firms would then still belong to group 3 and choose hybrid sourcing. Yet, since β^{H*} has increased, this necessarily implies an outsourcing share $\xi^* = (\beta_{max}^H - \beta^{H*})/(\beta_{max}^H - \beta_{min}^H) < \xi_0^*$.[20] Overall, Figure 3.4b suggests that the coexistence of integration and outsourcing is most pervasive in firms with medium-to-high productivity in sectors with low-to-medium headquarter-intensity.

3.4.2 Open economy

We now incorporate the global scale dimension into the producer's problem, who now also decides on the country $r \in \{1, 2\}$ where each component $i \in [0, N]$ is manufactured. We assume that unit costs of foreign suppliers are lower than for domestic suppliers, while the efficiency gains from specialization do not depend on the suppliers' country of origin. Specifically, domestic and foreign suppliers have unit cost equal to $c_1^M = 1/N^s$ and $c_2^M = \delta(\ell)/N^s$, respectively, with $0 < \delta(\ell) < 1$.

We assume the following specification for the "offshoring gain": $\delta(\ell) = \left(1 + \bar{\delta} \cdot \ell\right)^{-1/\ell}$, with $\bar{\delta} > 0$ (also see Appendix B.1.).[21] Using $\delta(\ell)$ and eq.(3.5), the producer's problem is to maximize the total payoff $\pi = \Theta \cdot Y \cdot \Psi - (1 - \ell)N \cdot w_1^M - \ell N \cdot w_2^M - \bar{f}$, where Ψ is

[19] Antràs and Helpman (2004) obtain the opposite result, namely that headquarter-intensive sectors are those where organizational structures are different across the productivity spectrum. That result is driven by the ad-hoc assumption that integration is associated with *exogenously* higher fixed costs than outsourcing. Grossman, Helpman and Szeidl (2005) consider the alternative ad-hoc assumption that outsourcing is associated with exogenously higher fixed costs. Our model is qualitatively more consistent with the latter paper, but in our model fixed cost differences between organizational modes emerge *endogenously* as they imply different optimal complexity levels. We could generate a similar sourcing pattern as Antràs and Helpman (2004) when assuming that $\bar{f}$ is sufficiently higher under integration than under outsourcing.

[20] If an increase of w_1^M overall leads to more or less hybrid sourcing is unclear, since there is exit from group 3 to group 1 but also entry from group 2 to group 3. To unambiguously sign the overall change would require more specific assumptions about the distribution of Θ and η^H across firms.

[21] This particular functional form is chosen for analytical simplicity only. It implies that there are decreasing marginal returns from offshoring, i.e., the reduction of unit costs are most substantial for the first offshored component, and then become smaller as the offshoring share ℓ is increased. The strength of the offshoring gain is also stronger the larger the parameter $\bar{\delta}$ is. Our qualitative results would be similar for other specifications of the offshoring gain, though mathematically the model would become more difficult.

now given by:

$$\Psi \equiv \left[1-\alpha\left(\beta^H\eta^H+\frac{\beta^M\eta^M}{N}\right)\right]\left[\left(\frac{\beta^H}{c^H}\right)^{\eta^H}\left((1+\bar{\delta}\ell)N^s\cdot\exp\left\{\frac{1}{N}\int_0^N \ln\left(\beta_j\right)\mathrm{d}j\right\}\right)^{\eta^M}\right]^{\frac{\alpha}{1-\alpha}} \tag{3.18}$$

3.4.2.1 Optimal mass of suppliers, revenue division, and offshoring share

Analogous to the closed economy case, we first analyze the scenario where the producer can freely assign the ex ante distribution of revenue. Taking into account that the optimal N^* and β^{H*} pin down $\beta_i^* = (1-\beta^{H*})/N^*$ due to symmetric input intensities, we can simplify the variable payoff $\Theta\cdot Y\cdot\Psi\left(N,\beta^H,\ell\right)$ from eq. (3.18) as follows:

$$\Theta\cdot Y\cdot\Psi = \Theta\cdot Y\cdot\left[1-\alpha\left(\beta^H\eta^H+\frac{\left(1-\eta^H\right)\left(1-\beta^H\right)}{N}\right)\right]\left[\left(\frac{\beta^H}{c^H}\right)^{\eta^H}\left(\frac{\left(1-\beta^H\right)\cdot\left(1+\bar{\delta}\ell\right)}{N^{1-s}}\right)^{1-\eta^H}\right]^{\frac{\alpha}{1-\alpha}}.$$

Suppose the outside opportunity in both countries is equal to zero ($w_1^M = w_2^M = 0$). In that case, the producer's problem is equivalent to maximizing this variable payoff. We show in Appendix B.2. that the optimal complexity N_0^* and revenue share β_0^{H*} are identical to their closed economy counterparts given in eqs.(3.13) and (3.14). Furthermore, it directly follows that the variable payoff is unambigiously increasing in the offshoring share, i.e., $\partial\Psi/\partial\ell > 0$. Hence, in that case where endogenous fixed costs play no role, the optimal decision is to offshore *all* suppliers ($\ell_0^* = 1$) in order to take advantage of the lower unit costs in the foreign country. Now suppose that $w_1^M = w_2^M > 0$, i.e., fixed costs matter but there are no cross-country differences in the endogenous "complexity penalty". In that case we would also obtain analogous results for N^* and β^{H*} as in the closed economy case, and again have $\ell^* = 1$ since offshoring only generates advantages but no disadvantages.

However, as is widely known, offshoring in fact has disadvantages in terms of higher communication and transportation costs, more expensive managerial oversight, and so on. To take this into account, we assume that there is an extra fixed cost $f^X > 0$ per offshored component, capturing those higher transaction costs for the firm. Overall fixed cost are then given by $F = w_1^M\cdot(1-\ell)N + (w_2^M + f^X)\cdot\ell N + \bar{f}$, and we assume that $\Delta \equiv w_2^M + f^X - w_1^M > 0$, which allows us to rewrite fixed costs as $F = (w_1^M + \ell\Delta)N + \bar{f}$.[22] When it comes to the maximization of the total payoff $\pi = \Theta\cdot Y\cdot\Psi - F$ with respect to ℓ, there is thus a trade-off between the higher variable payoff ($\partial\Psi/\partial\ell > 0$) and the larger fixed costs ($\partial F/\partial\ell > 0$) under offshoring. The positive effect on the variable payoff is stronger the higher the productivity level is, while the fixed cost increase does not depend

[22] Suppliers from country 1 probably have a better outside opportunity than those from the poor country 2. Assuming $\Delta > 0$ ensures that the offshoring cost f^X outweighs the difference in outside opportunities.

on Θ. This suggests that offshoring is relatively more attractive for highly productive firms. In fact, in Appendix B.2.2. we formally prove the following results:

$$\frac{\partial N^*}{\partial \Theta} > 0, \qquad \frac{\partial \beta^{H*}}{\partial \Theta} < 0, \qquad \frac{\partial \ell^*}{\partial \Theta} \geq 0, \qquad \frac{\partial N^*}{\partial \eta^H} < 0 \quad , \quad \frac{\partial \beta^{H*}}{\partial \eta^H} > 0, \qquad \frac{\partial \ell^*}{\partial \eta^H} \leq 0.$$

More productive firms thus have a higher optimal offshoring share ℓ^* (with $0 \leq \ell^* \leq 1$). Furthermore, as in the closed economy, they have a smaller optimal headquarter revenue share and more suppliers, hence larger fixed costs. Still, it can be shown that the total payoff is increasing in productivity, $\partial\pi/\partial\Theta > 0$. Second, firms from more headquarter-intensive industries have less suppliers and a larger optimal headquarter revenue share, as in the closed economy case. Other things equal, the optimal offshoring share is also lower in firms from more headquarter-intensive industries. Finally, it is also possible to show that $\partial\ell^*/\partial\Delta \leq 0$, $\partial N^*/\partial\Delta < 0$, and $\partial\beta^{H*}/\partial\Delta > 0$ (see Appendix B.2.2.). That is, lower offshoring costs Δ (holding domestic fixed costs w_1^M constant) not only lead to a higher optimal offshoring share, but they also boost complexity and thereby imply a lower optimal headquarter revenue share.

3.4.2.2 The make-or-buy decision under incomplete contracts

Turning now to the incomplete contracts environment, first suppose that fixed cost considerations play no role at all (i.e., $w_1^M = w_2^M = f^X = 0$). In that case, the producer would offshore *all* components ($\tilde{\ell}^O = \tilde{\ell}^V = 1$) while making the exact same complexity and organization decisions as shown in Figure 3.4a.[23] Put differently, all firms with $\eta^H < \bar{\bar{\eta}}_0^H$ would completely rely on arm's length transactions, those with $\eta^H > \bar{\eta}_0^H$ on intra-firm trade, and those with $\bar{\bar{\eta}}_0^H \leq \eta^H \leq \bar{\eta}_0^H$ on a combination of the two global sourcing modes. Suppose now that fixed costs matter, $w_1^M > 0$, but there are no cross-country differences in overall fixed costs, $\Delta = 0$. In that case, the same pattern as in Figure 3.4b emerges, where more productive firms choose higher complexity and where the organizational decisions are tilted towards vertical integration in order to keep fixed costs low. Yet, all firms (regardless of productivity or headquarter-intensity) would only have foreign suppliers in that case.

The case with with $w_1^M > 0$ and $\Delta > 0$ is the most interesting one. We then have the aforementioned trade-off between higher fixed costs and higher variable payoffs under offshoring. The higher Θ is, the more important is the latter aspect, hence productivity and offshoring are positively related ($\partial\tilde{\ell}/\partial\Theta \geq 0$, see Appendix B.3.2.). Furthermore, since this trade-off does not depend on whether a supplier is external or internal, there are no differences in the organization-specific offshoring shares in our model with symmetric components, but $\tilde{\ell} = \tilde{\ell}^O = \tilde{\ell}^V$ holds. Summing up, the overall sourcing pattern in the

[23] This follows from the facts that: i) N_0^* and β_0^{H*} are the same as in the closed economy, and ii) that the available range $\beta^H \in \left[\beta_{min}^H, \beta_{max}^H\right]$ also does not change – see Appendix B.3.1. for more details.

open economy can be described as follows:

i.) *Headquarter-intensive industries*: All firms choose complete vertical integration of all suppliers. The least productive among the surviving firms collaborate with few suppliers and only source domestically. As productivity rises, firms gradually increase the mass of suppliers and the offshoring share. The most productive firms collaborate with a huge mass of foreign suppliers that are integrated into the firm's boundaries.

ii.) *Component-intensive industries*: The least productive among the surviving firms have few suppliers, all of which are domestic and vertically integrated. As productivity increases, firms tend to increase the complexity $\tilde{N}$, the outsourcing share $\tilde{\xi}$, and the offshoring share $\tilde{\ell}$. The most productive firms collaborate with a huge mass of suppliers, all of which are outsourced and offshored.

iii.) *Industries with medium headquarter-intensity*: Low productive firms collaborate with few suppliers and tend to choose vertical integration and domestic sourcing. For given headquarter-intensity, increasing productivity is then associated with an increasing offshoring share and higher complexity. With respect to the organizational decision, firms in those sectors tend to choose hybrid sourcing, i.e., a coexistence of outsourcing and vertical integration within the same firm. Both the outsourcing and the offshoring share tend to be lower in relatively more headquarter-intensive industries within that range. The most productive firms have many suppliers and completely rely on foreign suppliers; they choose a combination of foreign outsourcing and intra-firm trade.

If this pattern with respect to $\tilde{N}$ and $\tilde{\xi}$ is similar as in the closed economy, it must still be noted that the possibility to engage in offshoring is positively correlated with complexity and outsourcing. To see this, consider a firm with given Θ and η^H, and compare the complexity and organization decision of that firm under autarky (with $w_1^M > 0$ and where $\ell = 0$ is imposed) and in the open economy (with the same $w_1^M > 0$, and given $\Delta > 0$). As shown in Appendix B.3.2., no firm would choose a lower mass of components or a lower outsourcing share after the economy has opened up, while some firms would choose a higher $\tilde{N}$ and $\tilde{\xi}$. In other words, opening up to trade in intermediate inputs boosts the slicing of the value chain and favors outsourcing. Notice that this "time series" correlation (identical firms tend to choose more outsourcing after the economy has opened up to trade) is consistent with a "cross-sectional" pattern across firms, where many choose vertical integration and domestic sourcing in order to keep fixed costs low.

3.5 Asymmetric components

In this last step of the analysis we consider a discrete setting with two asymmetric suppliers denoted by a and b.[24] These suppliers can differ along two dimensions in our model: i) with respect to their input intensities $\eta^M \cdot \eta_i$ for $i = a, b$ (with $\eta_a + \eta_b = 1$), and ii) with respect to their bargaining powers β_i^ξ, where $\xi = O, V$, which pin down the revenue shares that they ultimately receive. With our Cobb-Douglas production function, $\eta^M \cdot \eta_i$ is the partial output elasticity of component i and thus measures its technological importance for final goods production. If components differ in their input intensities, this is likely to be reflected in the bargaining power of the respective suppliers as well. Suppose one component is technologically more important than the other. The supplier of the more important input is then also likely to reap a larger revenue share from the producer than the supplier of the less important component.

To give a real world example, consider the production of perfume. Alcohol is the base material in this production process, and is needed in large quantities. But even though the quality of the alcohol (the binder) also matters, it still generates low value added as it is rather standardized. More value added is generated by the tiny amounts of the essential oils and aroma compounds (such as *ambra*) which are highly specific and characteristic as they differentiate the fragrances. In terms of our model, if a and b stand for ambra and alcohol in perfume production, we thus have $\eta_a > \eta_b$ and $\beta_a^\xi > \beta_b^\xi$. That is, ambra is not only the technologically "more important" input, but its supplier also has higher bargaining power (and receives a larger revenue share) due to the indispensability of this particular component for the final product. Specifically, we assume that the exogenous revenue shares are such that $\beta_i^V > \beta_i^O$ for $i = a, b$, and $\beta_a^\xi > \beta_b^\xi$ for $\xi = O, V$. That is, outsourcing yields a larger revenue share than integration for each supplier, and the "more important" supplier a reaps a larger revenue share than b in either organizational form.[25]

It is useful to first analyze the impact of these two types of asymmetries separately, before considering them jointly. For brevity, we abstract from the global scale dimension in this last section and assume that both suppliers are located in country 1.[26] Given eqs.

[24] It is straightforward to transform our model structure with a continuum of intermediate inputs into a discrete notation. Divide the intervall $[0, N]$ into X equally spaced subintervalls with all the intermediate inputs in each subintervall of length N/X performed by a single supplier. We restrict our attention to the case where complexity is exgenously given by $N = 2$, so that we neglect the cost saving effect s.

[25] Notice that this assumption is consistent both with $\beta_a^V > \beta_b^O$ and $\beta_a^V < \beta_b^O$. In Figures 3.19 and 3.7b below we depict the latter case, but all results would be similar with the alternative ranking $\beta_a^V > \beta_b^O$.

[26] It is possible to embed this model in an open economy context, where the producer may offshore both, one or none of the components to the low-wage country 2. One can again split the total payoff into two parts: the variable payoff and the fixed costs, which are both higher under offshoring. Yet, the former effect is magnified by firm productivity while the latter effect is not. This again implies that low productive firms source only domestically, while highly productive firms offshore both suppliers. Firms with medium productivity would offshore *one* component, and we can show that the producer would first tend to offshore the component with the higher input intensity.

(3.5), (3.8) and (3.9) with $c^H = c_a = c_b = 1$, the producer's problem is to optimize the total firm payoff $\pi = \Theta \cdot Y \cdot \Psi - 2 \cdot w_1^M - \bar{f}$, where the term Ψ can now be written as follows:

$$\Psi \equiv \left[1 - \alpha \left(\beta^H \eta^H + \beta_a \eta^M \eta_a + \beta_b \eta^M \eta_b\right)\right] \left[\left(\beta^H\right)^{\eta^H} \left(\beta_a^{\eta_a} \cdot \beta_b^{\eta_b}\right)^{1-\eta^H}\right]^{\frac{\alpha}{1-\alpha}}. \tag{3.19}$$

The producer has to choose among four possible organizational forms, which we denote as follows: $\{O, O\}$, $\{O, V\}$, $\{V, O\}$ and $\{V, V\}$, where the first (second) element depicts the organizational decision for input a (input b). This decision then pins down β_i^ξ and, residually, the producer's revenue share $\beta^H = 1 - \beta_a^\xi - \beta_b^\xi$.

First suppose that the input intensities η_a and η_b are the same, but that supplier a is ahead in terms of the exogenous bargaining power. We show in Appendix C.1. that β_i^* is identical for both suppliers since $\eta_a = \eta_b = 1/2$. Furthermore, $\beta_i^* = (1 - \beta^{H*})/2$ is increasing in the overall component-intensity $\eta^M = 1 - \eta^H$, as this raises the suppliers' total input intensity $\eta^M/2$. The producer's problem is equivalent to choosing the organization that aligns the β_i^ξ as closely as possible with the optimal revenue shares β_i^*. Figure 3.19 illustrates this problem. If component-intensity is sufficiently low, the producer vertically integrates both suppliers, $\{V, V\}$, as this leaves them with the lowest possible revenue shares and, in turn, maximizes $\beta^H = 1 - \beta_a^V - \beta_b^V \equiv \beta_{max}^H$. Conversely, if η^M is sufficiently high, she outsources both suppliers ($\{O, O\}$) as this leads to $\beta^H = 1 - \beta_a^O - \beta_b^O \equiv \beta_{min}^H$. For intermediate component-intensity the producer chooses hybrid sourcing, and she would then always outsource the "less important" input b while keeping the "more important" input a within the boundaries of the firm. That is, with $\beta_a^\xi > \beta_b^\xi$ and $\eta_a = \eta_b = 1/2$ there can be hybrid sourcing of the type $\{V, O\}$ but never of the type $\{O, V\}$. Asymmetry in bargaining powers thus favors integration of the "more important" input, as it increases the domain where the supplier can be properly incentiviced as an affiliated subsidiary.

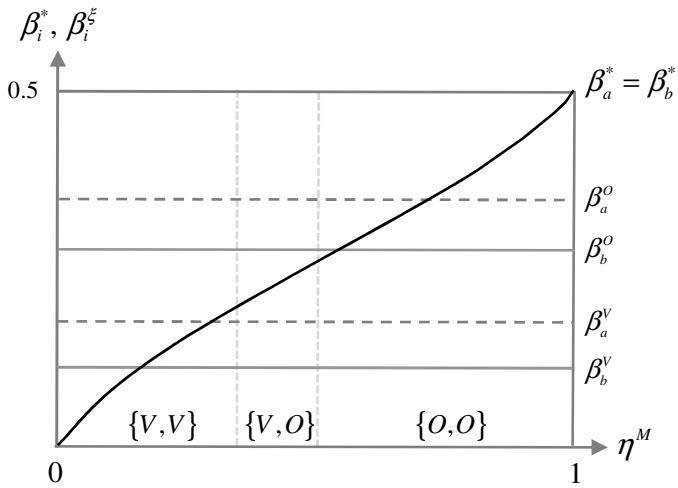

Figure 3.6: Revenue shares with two asymmetric components

Now consider the other case where the inputs a and b differ only in their input intensities, while the suppliers have identical bargaining powers $\beta_a^O = \beta_b^O > \beta_a^V = \beta_b^V$. In Appendix C.2. we provide an algorithm to derive closed form solutions for the optimal shares that the producer would choose if she could freely assign the ex ante revenue distribution (with $\beta_a^* + \beta_b^* = 1 - \beta^{H*}$). These solutions show that $\partial\beta^{H*}/\partial\eta^H > 0$, $\partial\beta_a^*/\partial\eta_a > 0$, and $\partial\beta_b^*/\partial\eta_b > 0$, which corroborates one key mechanism at work in this model: the higher the input intensity of a component, the higher is the optimal revenue share that should be assigned to its supplier. Clearly, with $\eta_a > \eta_b$ we have $\beta_a^* > \beta_b^*$. When the available revenue shares β^O and β^V are identical across suppliers, however, the producer would then easier outsource the "more important" component a in oder to reduce the underinvestment problem for the respective supplier.

This is illustrated in the left panel of Figure 3.7. On the horizontal axis we depict the headquarter-intensity of production, and on the vertical axis the technological asymmetry across inputs (where $\eta_a = 1/2$ is the symmetric benchmark case). The different colors indicate which organizational mode is payoff-maximizing. As before, the producer would vertically integrate (outsource) both suppliers for sufficiently high (low) values of η^H. Hybrid sourcing is chosen in sectors with intermediate headquarter-intensity, and within this range the producer tends to choose $\{O, V\}$ if $\eta_a > 1/2$.[27]

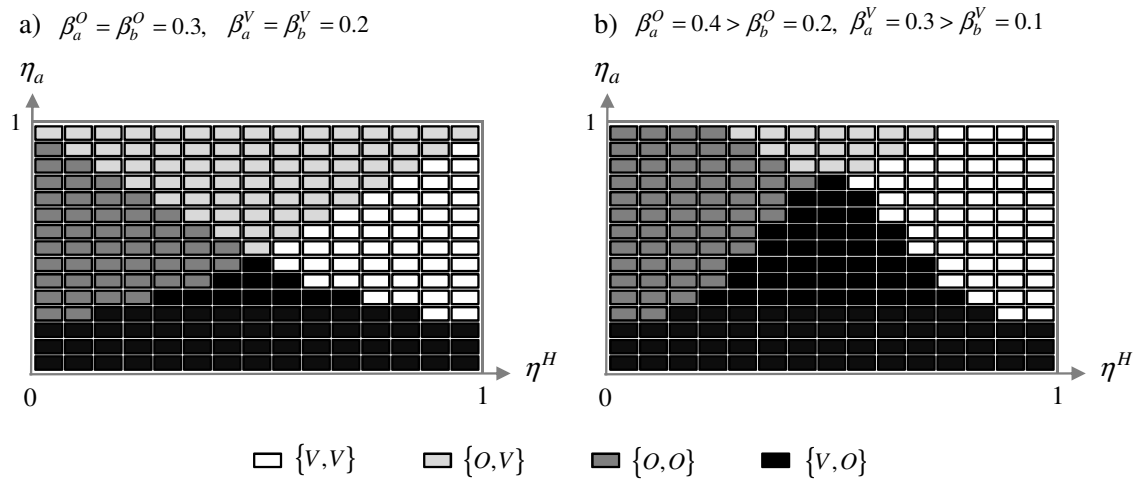

Figure 3.7: Organizational decision with two asymmetric components

The two different asymmetries thus have different implications for the firm structure in the hybrid range: While the asymmetry in bargaining powers favors vertical integration, the asymmetry in input intensities favors outsourcing of the "more important" component. As argued above, in practice both asymmetries are related and likely to emerge together. In the right panel of Figure 3.7 we consider such a case and illustrate the implications for

[27]Note that the producer's share is the same in both hybrid sourcing modes, $\beta^H = (\beta_{max}^H + \beta_{min}^H)/2$.

the final organizational decision. In this example, we have $(\beta_a^\xi - \beta_b^\xi) = 0.2$ for $\xi = O, V$, and we focus on the range of intermediate headquarter intensity where hybrid sourcing can occur. As can be seen, for high values of η_a the producer would choose the mode $\{O, V\}$ and thus outsource input a, because the asymmetry in input intensities is relatively stronger than the asymmetry in the suppliers' bargaining powers. Yet, if the technological asymmetry is smaller (closer to 1/2), there is instead vertical integration of the "more important" input a and outsourcing of the "less important" input b, i.e., the mode $\{V, O\}$.

3.6 Conclusion

In this paper, we have developed a theory of a firm which decides on the complexity, the organization, and the global scale of its production process. The main results of our model can be summarized as follows:

i.) *Complexity*: Within a given industry, more productive firms choose to have more suppliers, i.e., more thinly sliced value chains or – in the terminology of our paper – more complex production processes. When comparing equally productive firms, we show that complexity is higher in more component-intensive industries, and higher in firms that choose outsourcing than in vertically integrated firms.

ii.) *Organization*: The organizational structure differs across firms, both within and across industries. As in Antràs and Helpman (2004), higher component-intensity tends to favor outsourcing. Yet, in contrast to that model, our framework predicts that firms may also choose a hybrid sourcing mode where *some* components are outsourced while others are vertically integrated within the firm's boundaries. This hybrid sourcing mode is most prevalent in firms with medium-to-high productivity from industries with low-to-medium headquarter-intensity.

iii.) *Global scale*: More productive firms tend to offshore more components, but only the most productive firms rely completely on foreign suppliers. Firm with medium productivity offshore *some* components but keep others domestic. For a given productivity, the offshoring share tends to be higher in more component-intensive industries. Furthermore, our model predicts that "globalization" boosts the slicing of the value chain and is positively correlated with outsourcing. More specifically, moving from an autarkic scenario to an open economy setting where trade in intermediate inputs is possible, we show that identical firms would choose more complexity and outsourcing in the open economy.

iv.) *Asymmetric components*: Finally, different asymmetries across components have different implications for the organizational structure of firms. A technological difference per se favors outsourcing of the "more important" input, as this reduces the underinvestment problem for the respective supplier. Yet, that supplier is also likely to have a higher

bargaining power vis-a-vis the producer. Provided this latter effect is sufficiently strong, which may be the case for highly sophisticated and specific intermediate inputs, our model predicts that the producer keeps the "more important" component, which generates more value added, within the boundaries of the firm.

Several of those predictions are consistent with stylized facts from the recent empirical literature on multinational firms. For example, recent empirical work by Jabbour (2008) and Jabbour and Kneller (2010) shows that most MNEs are, in practice, characterized by a high degree of complexity (i.e., multiple suppliers) and by hybrid sourcing. Consistently, Kohler and Smolka (2009) emphasize that MNEs often choose different sourcing modes for different suppliers. In particular, Tomiura (2007) shows that firms which rely on hybdrid sourcing tend to be more productive than firms which rely on a single sourcing mode in the global economy. This finding is consistent with our framework for the case of intermediate headquarter-intensity, which is likely to encapsulate many industries in the data. Finally, Alfaro and Charlton (2009) show that firms tend to outsource low-skill inputs from the early stages, while high-skill inputs from the final stages of the production process – which generate a large share of total value added – are likely to be integrated. In line with this result, Corcos et al. (2009) find that inputs with a higher degree of specificity are less likely to be outsourced. Our theoretical framework is consistent with this finding if the technological importance of particular inputs is materialized in a high bargaining power of the respective suppliers. Our model may also motivate future empirical research, as it leads to several predictions that have – to the best of our knowledge – not been confronted with data yet. For example, it would be interesting to explore if trade integration has led to a stronger unbundling of the production chain, or if (conditional on productivity) firms from headquarter-intensive industries systematically have fewer suppliers than firms from component-intensive sectors.

The model in this paper is about single firms. It could potentially be embedded into a general equilibrium framework where firm interactions within and across industries are taken into account. Such a framework would be useful to explore more fully the repercussions of trade integration with cross-country differences in market conditions, factor prices and incomes, as well as their implications for global sourcing decisions. Furthermore, our model is based on a simple static Nash-bargaining. In practice, suppliers may care about long-term relationships, or may try to collude with other suppliers in order to induce pressure on the headquarter. Finally, we focus on horizontal "slicing" of the production chain in this paper, neglecting the fact that many components in reality consist themselves out of multiple intermediate inputs, as recently argued by Baldwin and Venables (2010). Exploring these and other extensions of our framework is left for future research.

3.7 Appendix

Appendix A: Closed Economy

Remark. To simplify notation, we denote the first-order partial derivative of a function f with respect to the argument x as f'_x in this Appendix. Analogously, the second-order partial derivative with respect to the argument y is denoted as f''_{xy}.

A.1. Input provision. Supplier $i \in [0, N]$ chooses the level of input provision m_i so as to maximize $\pi_i = \beta_i R - c_i^M m_i$. Using eqs.(3.3) and (3.4), the first-order-condition (FOC) for the maximization problem of supplier i can be written as follows:

$$\pi'_{m_i} = \beta_i \cdot R'_{m_i} - c_{i,r}^M = \beta_i \cdot \alpha \cdot \eta^M \cdot \eta_i \cdot R \,/\, m_i - c_{i,r}^M = 0. \tag{3.20}$$

It directly follows that $m_i^* = \alpha \cdot \eta^M \cdot \eta_i \cdot \beta_i \cdot R^* / \, c_{i,r}^M$ solves the FOCs, with R^* given by eq. (3.6). It remains to be shown that the second-order-conditions (SOC) are satisfied. Using the FOCs given by eq. (3.20), the SOCs simplify to

$$\pi''_{m_i m_i} = \beta_i \cdot \alpha \cdot \eta^M \cdot \eta_i \cdot \left(m_i \cdot R'_{m_i} - R\right) / m_i^2 = -\beta_i \cdot \alpha \cdot \eta^M \cdot \eta_i \cdot R \cdot \left(1 - \alpha \cdot \eta^M \cdot \eta_i\right) / \, m_i^2 < 0,$$

and are thus satisfied. Using a similar approach, it can be shown that $h^* = \alpha \cdot \eta^H \cdot \beta^H \cdot R^* / \, c^H$ maximizes the payoff for the producer, $\pi^H = \beta^H R - c^H h$.

A.2. Optimal mass of supplers and revenue division.

A.2.1. Zero outside opportunity

i.) Maximization problem: The first-order-conditions (FOCs) are given by $\pi'_N = \Theta \cdot Y \cdot \Psi'_N = 0$ and $\pi'_{\beta^H} = \Theta \cdot Y \cdot \Psi'_{\beta^H} = 0$. Using (3.12), the FOCs can simplified to:

$$\frac{\Psi'_N}{\Psi} = \frac{\alpha\eta^M \left(N\left(1-s\right)\left(1-\alpha\beta^H\eta^H\right) - \beta^M\left(1 - s\alpha\eta^M - \alpha\eta^H\right)\right)}{N\left(1-\alpha\right)\left(\alpha\beta^M\eta^M - N\left(1-\alpha\beta^H\eta^H\right)\right)} = 0, \tag{3.21}$$

$$\frac{\Psi'_{\beta^H}}{\Psi} = \frac{\alpha\left(\beta^H\left(N-\beta^M\right) - \left(N\left(1-\beta^H\left(\beta^M-\alpha\right)\right) - \beta^M\left(\alpha+\beta^H\right)\right)\eta^H - \alpha\left(\beta^M - N\beta^H\right)\eta^{H2}\right)}{\left(1-\alpha\right)\beta^H\beta^M\left(\alpha\beta^M\eta^M - N\left(1-\alpha\beta^H\eta^H\right)\right)} = 0. \tag{3.22}$$

With eqs. (3.21) and (3.22) it is straightforward to show that N_0^* and β_0^{H*} as given in (3.13) and (3.14) solve the FOCs. The matrix of SOCs can be expressed as follows:

$$\Gamma = \begin{bmatrix} \pi''_{NN} & , & \pi''_{N\beta^H} \\ \pi''_{\beta^H N} & , & \pi''_{\beta^H\beta^H} \end{bmatrix} = \Theta \cdot Y \cdot \begin{bmatrix} \Psi''_{NN} & , & \Psi''_{N\beta^H} \\ \Psi''_{\beta^H N} & , & \Psi''_{\beta^H\beta^H} \end{bmatrix}.$$

We now show that the matrix Γ is negative definite. We define $\Psi_0^* \equiv \Psi\left(N = N_0^*, \beta^H = \beta_0^{H*}\right)$ for notational convenience. The first diagonal element is given by $\Psi''_{NN} = -\Psi_0^* \cdot (T_1 \,/\, T_2)$, with

$$T_1 = 4\left(1-s\right)^3\alpha\eta^M\eta^{H2}\left(1-\alpha\left(s\eta^M+\eta^H\right)\right) > 0, \quad T_2 = \left(1-\alpha\right)^2\left(\rho - s\eta^M\left(1+\alpha\eta^H\right)\right)^2 > 0.$$

Hence, Ψ''_{NN} is negative. The second diagonal element is given by $\Psi''_{\beta^H\beta^H} = -\Psi_0^* \cdot (T_3 \,/\, T_4)$, with

$$\begin{aligned} T_3 &= 16\eta^M\eta^{H2}\left(1-\alpha\eta^H\right)\left(s^3\eta^{M2}\left(1-\alpha\eta^H\right)^2 - \eta^{H2}\rho - s^2\eta^M\left(1-\alpha\eta^H\right)\left(\eta^H\left(-5+2\eta^H\right)+\rho\right)\right) \\ &\quad +16\left(s\eta^H\left(\eta^M\eta^H\left(5-\alpha\eta^H\right) - 3\rho + 2\eta^H\rho\right)\right) < 0 \\ T_4 &= \left(1-\alpha\right)^2\left(s\eta^M\left(1-\alpha\eta^H\right)-\rho\right)^3\left(2\eta^H + s\eta^M\left(1-\alpha\eta^H\right)-\rho\right)^2 < 0. \end{aligned}$$

Hence, $\Psi''_{\beta^H\beta^H}$ is also negative. The determinant can be written as $|\Gamma| = \left(\Psi_0^*\right)^2 \cdot (T_5 \cdot T_6 \,/\, T_7)$,

with

$$
\begin{aligned}
T_5 &= -128\left(1-s\right)^3 s^2\alpha^2\eta^{M3}\eta^{H4}\left(1-\alpha\eta^H\right) < 0 \\
T_6 &= -s^3\eta^{M3}\left(1-\alpha\eta^H\right)^3 + s^2\eta^{M2}\left(1-\alpha\eta^H\right)^2\left(\eta^H\left(-7+\alpha\eta^H\right)+\rho\right) \\
&\quad +\eta^{H2}\left(5\rho+\eta^H\left(-4+4\alpha\eta^H-3\alpha\rho\right)\right)+s\eta^M\eta^H\left(1-\alpha\eta^H\right)\left(4\rho+\eta^H\left(-13+5\alpha\eta^H-\alpha\rho\right)\right) > 0 \\
T_7 &= -\left(1-\alpha\right)^3\left(2\eta^H+s\eta^M\left(1-\alpha\eta^H\right)-\rho\right)^2\left(-s\eta^M\left(1-\alpha\eta^H\right)+\rho\right)^4 \\
&\quad \left(s\eta^M\left(1-\alpha\eta^H\right)+\rho\right)^2 < 0.
\end{aligned}
$$

It directly follows that $|\Gamma| > 0$. Hence, Γ is negative definite, so that N_0^* and β_0^{H*} maximize (3.12).

ii.) Optimal revenue share of a single supplier. It is straightforward to show that β_{i0}^* is given by $\beta_{i0}^* = \left\{\left(1-s\right)\left(s\left(1-\eta^H\right)\left(1-\alpha\eta^H\right)-\rho\right)\right\} / \left\{s\left(1-\eta^H\right)\left(1+\alpha\eta^H\right)-\rho\right\}$. It can be verified that $\beta_{i0_{\eta^H}}^{*\prime} > 0$ for $\eta^H < \eta_{crit}^H$ and $\beta_{i0_{\eta^H}}^{*\prime} < 0$ for $\eta^H > \eta_{crit}^H$, where

$$
\eta_{crit}^H = \left\{2-\sqrt{\left(4-4\sqrt{s}+s\left(1-\alpha\right)\right)\left(-1+\alpha\right)}-\sqrt{s}\left(1+\alpha\right)\right\} / \left\{2\left(1-\sqrt{s}\right)\alpha\right\}
$$

Hence, β_{i0}^* is hump-shaped over the range of η^H. Note that η_{crit}^H is unambigiously decreasing in s.

iii.) Antràs and Helpman (2004) is a special case of our framework: We claim in footnote 8 that there exists a s_{crit} such that $N_0^* = 1$. This critical level is given by

$$
s_{crit} = \eta^H / \left\{\left(1-\alpha\left(1-\eta^H\right)\right)\eta^H + \sqrt{\left(1-\alpha\left(1-\eta^H\right)\right)\left(1-\eta^H\right)\left(1-\alpha\eta^H\right)}\right\},
$$

and it can be verified that the optimal revenue share $\beta_0^{H*}\left(s=s_{crit}\right)$ is identical to eq. (10) in Antràs and Helpman (2004): $\beta_0^{H*}\left(s=s_{crit}\right) = \frac{\eta^H\left(\alpha\eta^H+1-\alpha\right)-\sqrt{\eta^H(1-\eta^H)(1-\alpha\eta^H)(\alpha\eta^H+1-\alpha)}}{2\eta^H-1}$.

iv.) Cost saving versus dilution effect. In the following we restate operating profits as profit margin times the sold quantity. Profits are given by $\pi = \Theta\cdot Y\cdot\Psi = R-C$ where C denotes total variable costs. It follows from eq.(3.12) that optimal variable costs can be expressed as $C^* = \alpha\left[\beta^H\eta^H+\left(1-\beta^H\right)\left(1-\eta^H\right)/N\right]\cdot R^*$. We rewrite $\Psi = \left(1-C^*/R^*\right)\cdot R^* = \left(p^*-C^*/y^*\right)\cdot y^*$ where y^* and p^* denote the optimal quantity and price, respectively, and C^*/y^* are the average variable costs. The profit margin is given by $margin^* \equiv \left(p^*-C^*/y^*\right)$. Furthermore, R^* is given by

$$
R^* = \left[\left(\frac{\beta^H}{c^H}\right)^{\eta^H}\left(\frac{1-\beta^H}{N^{1-s}}\right)^{1-\eta^H}\right]^{\frac{\alpha}{1-\alpha}},
$$

so that we can restate p^* and y^* as: $y^* = \left(R^*\right)^{1/\alpha}Y^{(\alpha-1)/\alpha}$ and $p^* = \left(R^*\right)^{(\alpha-1)/\alpha}Y^{(-\alpha+1)/\alpha}$, and the average costs as $C^*/y^* = \alpha\left[\beta^H\eta^H+\left(1-\beta^H\right)\left(1-\eta^H\right)/N\right]\cdot p^*$.

To shed light on the two countervailing effects of raising complexity, we now we discuss comparative statics with respect to N for a given β^H. Since $R_N^{*\prime} < 0$ it directly follows $y_N^{*\prime} < 0$ and $p_N^{*\prime} > 0$. The profit margin can be written as

$$
margin^* = \left[1-\alpha\left(\beta^H\eta^H+\left(1-\beta^H\right)\left(1-\eta^H\right)/N\right)\right]\cdot p^*,
$$

which is unambigiously increasing in N. Hence, higher complexity leads to a smaller quantity but a larger profit margin. For $s\to 1$, both $y_N^{*\prime}\to 0$ and $p_N^{*\prime}\to 0$. However, the profit margin

is still strictly increasing in N. Hence, we have $N_0^* \to \infty$ for $s \to 1$. Although the dilution and the cost saving effect cannot be strictly decomposed analytically, we can still conclude that the cost saving effect dominates the dilution effect when we trace the impact of an increase in N on the profit margain, while the dilution effect dominates the cost saving effect when tracing the impact on the quantity.

v.) Cutoff productivity: The productivity threshold for survival is given by:

$$\hat{\Theta}_0 = \frac{\left(\frac{\bar{f}}{Y}\right) \cdot \left[\left(\frac{\beta_0^{H*}}{c^H}\right)^{\eta^H} \left(\frac{1-\beta_0^{H*}}{N_0^{*\,1-s}}\right)^{1-\eta^H}\right]^{-\alpha/(1-\alpha)}}{1 - \left(\alpha\beta_0^{H*}\eta^H + \left(1-\beta_0^{H*}\right)\left(1-\eta^H\right)/N_0^*\right)}$$

with N_0^* and β_0^{H*} given in (3.13) and (3.14). Note that $\hat{\Theta}_0$ is increasing in $\bar{f}$ and decreasing in Y.

A.2.2. Positive outside opportunity

i.) Maximization problem: The FOCs are given by $\pi'_N = \Theta \cdot Y \cdot \Psi'_N - w_1^M = 0$ and ${\pi'}_\beta^H = \Theta \cdot Y \cdot \Psi'_{\beta^H} = 0$. We can solve $\Psi'_{\beta^H} = 0$ for

$$\beta^H(N) = \frac{N - 1 + (1+N)(1-\alpha)\eta^H + (1+N)\alpha\left(\eta^H\right)^2 - \tilde{\rho}}{2\left(\eta^H(1+N) - 1\right)} \tag{3.23}$$

with $\tilde{\rho} = \sqrt{(1-\eta^H)(1-\alpha\eta^H)\left((1-N)^2 - (1+N)(1+N(-3+\alpha)+\alpha)\eta^H + (1+N)^2\alpha\left(\eta^H\right)^2\right)}$.

Note that $\beta^H(N)$ as stated in eq. (3.23) does not depend on w_1^M. Furthermore, it directly follows that $\beta_N^{H\prime} < 0$. Using $\beta^H(N)$ in $\Psi'_N = 0$ allows us to derive the implicit condition $\Psi' = w_1^M/(\Theta \cdot Y)$, which we can solve for N^*. It then directly follows from Appendix A.2.1.i), and from the fact that $\Psi''_{NN} < 0$ in the relevant domain, that N^* solves the first- and second-order conditions and is, thus, the optimal complexity level. This N^* (as depicted in Figure 1) is then associated with an optimal headquarter revenue share $\beta^{H*} = \beta^H(N = N^*)$ from (3.23) (as depicted in Figure 2) that solves $\Psi'_{\beta^H} = 0$. From the condition $\Psi' = w_1^M/(\Theta \cdot Y)$ it also directly follows that $N_\Theta^{*\prime} > 0$ and $N_{w_1^M}^{*\prime} < 0$ with $N^* < N_0^*$, and hence (since $\beta_N^{H\prime} < 0$): $\beta_\Theta^{H*\prime} < 0$ and $\beta_{w_1^M}^{H*\prime} > 0$ with $\beta^{H*} > \beta_0^{H*}$. Finally, notice that $\Psi''_{N\eta^H} < 0$, hence $N_{\eta^H}^{*\prime} < 0$ and, thus, $\beta_{\eta^H}^{H*\prime} > 0$.

ii.) Total profits: We claim that more productive firms earn a higher total payoff π, despite that they have higher fixed costs. Total profits are given by $\pi = \Theta \cdot Y \cdot \Psi - w_1^M N$. The optimal mass of suppliers is implicitly given by $\pi'_N = \Theta \cdot Y \cdot \Psi'_N - w_1^M = 0$. It then directly follows that $\pi'_\theta = Y \cdot \Psi + N'_\Theta \underbrace{\left(\Theta \cdot Y \cdot \Psi'_N - w_1^M\right)}_{=0} = Y \cdot \Psi > 0$.

A.3. The make-or-buy decision under incomplete contracts.

Maximization problem: We know from Appendix A.2. that β^{H*} and the associated N^* (β_0^{H*} and the associated N_0^* for the case with $w_1^M = 0$) are payoff-maximizing if the producer is unconstrained in the choice of the revenue shares. Under incomplete contracts, since $\pi'_{\beta^H} > 0$ if $\beta^H < \beta^{H*}$ and $\pi'_{\beta^H} < 0$ if $\beta^H > \beta^{H*}$, it follows from continuity that the choice of ξ that aligns $\beta^H = \xi \cdot \beta_{min}^H + (1-\xi) \cdot \beta_{max}^H$ as closely as possible with β^{H*} must be payoff-maximizing, given the constraint $\beta^H \in \left[\beta_{min}^H, \beta_{max}^H\right]$.

A.3.1. Zero outside opportunity

Definition of headquarter- and component-intensive industries: $\bar{\eta}_0^H$ and $\bar{\bar{\eta}}_0^H$ are given by

$$\bar{\eta}_0^H = \frac{1 + (s(1+\alpha) - 2)\beta_{max}^H + \left(\beta_{max}^H\right)^2 - \sqrt{\left(1 + \beta_{max}^H (s(1+\alpha) - 2 + \beta_{max}^H)\right)^2 - 4s^2\alpha\left(\beta_{max}^H\right)^2}}{2s\alpha\beta_{max}^H}$$

$$\bar{\bar{\eta}}_0^H = \frac{1 + (s(1+\alpha) - 2)\beta_{min}^H + \left(\beta_{min}^H\right)^2 - \sqrt{\left(1 + \beta_{min}^H \left(s(1+\alpha) - 2 + \beta_{min}^H\right)\right)^2 - 4s^2\alpha\left(\beta_{min}^H\right)^2}}{2s\alpha\beta_{min}^H}$$

with $\beta_{min}^H < \beta_{max}^H \rightarrow \bar{\bar{\eta}}_0^H < \bar{\eta}_0^H$. Furthermore, $\bar{\eta}_{0\beta_{max}^H}^{H\prime} > 0$, $\bar{\bar{\eta}}_{0\beta_{min}^H}^{H\prime} > 0$, $\bar{\eta}_{0s}^{H\prime} > 0$, and $\bar{\bar{\eta}}_{0s}^{H\prime} > 0$.

A.3.2. Positive outside opportunity

Notice from eq.(3.11) that $\Psi''_{N\beta^H} = T_8/T_9$, with:

$$\begin{aligned} T_8 &= -N(1-s)\alpha\beta^H + (1-s\alpha)\beta^M\beta^H + \alpha\left(\beta^{H2} - 1 + s\beta^M\left(\alpha + \beta^H\right)\right) + \\ &\quad \alpha\eta^H N(1-s)\left(\beta^M + \beta^H\left(\alpha + \beta^H\right)\right) + (1-s)\alpha^2\left(1 - \beta^H(1+N)\right)\eta^2 > 0, \\ T_9 &= (1-\alpha)\beta^M\beta^H\left(-\beta^M\left(1 - s\alpha\eta^M - \alpha\eta^H\right) + N(1-s)\left(1 - s\beta^H\eta^H\right)\right) < 0. \end{aligned}$$

Hence, $\Psi''_{N\beta^H} < 0$. Since $\beta^H = \beta_{max}^H$ for $\Psi^{V\prime}$ and $\beta^H = \beta_{min}^H$ for $\Psi^{O\prime}$, the former curve must thus run to the left of the latter in Figure 5. Hence, we have $\tilde{N}^V < \tilde{N}^O$. The comparative static results for $\tilde{N}$ are similar as for N^* where the restriction $\beta^H \in \left[\beta_{min}^H, \beta_{max}^H\right]$ is not binding, see Appendix A.2.2.i). In particular, we have $\tilde{N}'_\Theta > 0$, $\tilde{N}'_{w_1^M} < 0$ and $\tilde{N}'_{\eta^H} < 0$ with $\tilde{N} < \tilde{N}_0$.

Appendix B: Open Economy

B.1. Cross-country cost difference. We assume the following specification for the "offshoring" gain: $\delta(\ell) = \left(1 + \bar{\delta}\cdot\ell\right)^{-1/\ell}$ with $\bar{\delta} > 0$. We have positive but decreasing marginal returns from offshoring since

$$\delta'_\ell = -\left(1 + \bar{\delta}\cdot\ell\right)^{-(1+\ell)/\ell} < 0 \quad \text{and} \quad \delta''_{\ell\ell} = (1+\ell)\left(1 + \bar{\delta}\cdot\ell\right)^{-(1+2\ell)/\ell} > 0.$$

It directly follows from $\delta(\ell = 0) = e^{-\bar{\delta}}$ and $\delta(\ell = 1) = 1/\left(1 + \bar{\delta}\right)$ that $0 < \delta(\ell) < 1$. Furthermore, the strength of the offshoring gain is stronger the larger the parameter $\bar{\delta}$ is.

B.2. Optimal mass of suppliers and revenue division.

B.2.1. Zero outside opportunity

Maximization problem: Using eq.(3.18) we have: $\pi'_N = \Theta\cdot Y\cdot\Psi'_N$, $\pi'_{\beta^H} = \Theta\cdot Y\cdot\Psi'_{\beta^H}$, and $\pi'_\ell = \Theta\cdot Y\cdot\Psi'_\ell$. Since $\Psi'_\ell = \Psi\cdot\left(\alpha\left(1-\eta^H\right)\right)/\left((1-\alpha)(1+\ell)\right) > 0$, we hence have $\ell_0^* = 1$. It is then straightforward to see that the other two FOCs, $\pi'_N = 0$ and $\pi'_{\beta^H} = 0$, can be expressed as in eqs.(3.21) and (3.22) from Appendix A.2.1.i.), since the ℓ cancels out from those expressions. Hence, N_0^* and β_0^{H*} are the same as in the closed economy case. Furthermore, using a similar approach as in Appendix A.2.1.i, we can show that the SOCs are also satisfied.

B.2.2. Positive outside opportunity

i.) Maximization problem: Total profits are given by $\pi = \Theta\cdot Y\cdot\Psi - \left(w_1^M + \ell\Delta\right)N + \bar{f}$. The

three FOCs are given by:

$$\pi'_N = \Theta \cdot Y \cdot \Psi'_N - \left(w_1^M + \ell\Delta\right) = 0, \quad \pi'_{\beta^H} = \Theta \cdot Y \cdot \Psi'_{\beta^H} = 0 \quad , \quad \pi'_\ell = \Theta \cdot Y \cdot \Psi'_\ell - \Delta N = 0.$$

As in the closed economy, it is possible to solve $\Psi'_{\beta^H} = 0$ for $\beta^H(N)$ with $\beta_N^H < 0$, which does not depend on w_1^M or Δ. Substituting $\beta^H(N)$ into the other two FOCs leads to:

$$\pi'_N = \Theta \cdot Y \cdot \underbrace{\Psi'_N \Big|_{\beta^H = \beta^H(N)}}_{\equiv \Psi'_N} - \left(w_1^M + \ell\Delta\right) = 0, \quad \pi'_\ell = \Theta \cdot Y \cdot \underbrace{\Psi'_\ell \Big|_{\beta^H = \beta^H(N)}}_{\equiv \Psi'_\ell} - \Delta N = 0. \tag{3.24}$$

For sufficiently productive firms we have $\pi'_\ell > 0$ for all $\ell \in [0,1]$, since $\Psi'_\ell > 0$ and N^* approaches N_0^* and is bounded from above. Hence, the global maximum is given by $\ell^* = 1$. Vice versa, for firms with sufficiently low productivity, $\pi'_\ell < 0$ and hence $\ell^* = 0$.

We are now interested in the SOC for the case where $\ell^* \in (0,1)$. Assume that N^* and ℓ^* solve the system of FOCs given in (3.24). The SOCs are given by the following matrix K:

$$K = \begin{bmatrix} \pi''_{NN} & , & \pi''_{N\ell} \\ \pi''_{\ell N} & , & \pi''_{\ell\ell} \end{bmatrix} = \begin{bmatrix} \Theta \cdot Y \cdot \Psi''_{NN} & , & \Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta \\ \Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta & , & \Theta \cdot Y \cdot \Psi''_{\ell\ell} \end{bmatrix},$$

For negative definiteness of K we have to ensure that $\pi''_{\ell N} = \Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta$ is small, which can be achieved by setting the exogeneous parameter Δ sufficiently high. If this parameter restriction holds, Ψ''_{NN} and $\Psi''_{\ell\ell}$ are negative while the determinant $|K| = \Theta^2 \cdot Y^2 \cdot \Psi''_{NN}\Psi''_{\ell\ell} - \left(\Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta\right)^2 > 0$ is positive, so that the SOCs are unambiguously satisfied.

ii.) Comparative statics: We now use the implicit function theorem to derive the comparative statics $N_\Theta^{*\prime}$ and $\ell_\Theta^{*\prime}$:

$$N_\Theta^{*\prime} = \frac{\begin{vmatrix} -Y \cdot \Psi'_N & , & \Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta \\ -Y \cdot \Psi'_\ell & , & \Theta \cdot Y \cdot \Psi''_{\ell\ell} \end{vmatrix}}{|K|} = \frac{-\Theta \cdot Y^2 \cdot \Psi'_N \cdot \Psi''_{\ell\ell} + Y \cdot \Psi'_\ell \left(\Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta\right)}{|K|} > 0$$

$$\ell_\Theta^{*\prime} = \frac{\begin{vmatrix} \Theta \cdot Y \cdot \Psi''_{NN} & , & -Y \cdot \Psi'_N \\ \Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta & , & -Y \cdot \Psi'_\ell \end{vmatrix}}{|K|} = \frac{-\Theta \cdot Y^2 \cdot \Psi''_{NN} \cdot \Psi'_\ell + Y \cdot \Psi'_N \cdot \left(\Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta\right)}{|K|} \geq 0.$$

In words, more productive firms have more suppliers and a non-decreasing offshoring share (strictly increasing if $\ell^* \in (0,1)$). We can use these results to derive a relationship between the endogenous variables N^* and ℓ^*. With the help of the chain rule we can conclude that $N_{\ell^*}^{*\prime} = N_\Theta^{*\prime}/\ell_\Theta^{*\prime} > 0$ if $\ell^* \in (0,1)$ and zero otherwise. Furthermore, we know from solving the FOCs that $\beta_N^H < 0$. Hence, it directly follows that $\beta_{N^*}^{H^*\prime} < 0$, and since $N_{\ell^*}^{*\prime} > 0$, it also follows that $\beta_{\ell^*}^{H^*\prime} \leq 0$ if $\ell^* \in (0,1)$ and zero otherwise. For the comparative statics with respect to Θ it thus follows that $\beta_\Theta^{H^*\prime} < 0$, i.e., more productive firms have a lower headquarter revenue share. Next, we derive the comparative statics of N^* with respect to η^H:

$$\begin{aligned} N_{\eta^H}^{*\prime} &= \frac{\begin{vmatrix} -\Theta \cdot Y \cdot \Psi''_{N\eta^H} & , & \Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta \\ -\Theta \cdot Y \cdot \Psi''_{\ell\eta^H} & , & \Theta \cdot Y \cdot \Psi''_{\ell\ell} \end{vmatrix}}{|K|} \\ &= \frac{-\Theta^2 \cdot Y^2 \cdot \Psi''_{N\eta^H} \cdot \Psi''_{\ell\ell} + \Theta \cdot Y \cdot \Psi''_{\ell\eta^H} \cdot \left(\Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta\right)}{|K|} < 0, \end{aligned}$$

since $\Psi''_{N\eta^H} < 0$. The optimal complexity is thus lower in more headquarter-intensive industries.

The comparative static results for β^{H*} and ℓ^* follow directly, since $\beta^{H*\prime}_{N^*} < 0$ implies $\beta^{H*\prime}_{\eta^H} > 0$, and $N^{*\prime}_{\ell^*} > 0$ implies $\ell^{*\prime}_{\eta^H} < 0$ if $\ell^* \in (0,1)$ and zero otherwise. In words, the optimal offshoring share is smaller, while the optimal headquarter revenue share is larger in more headquarter-intensive industries. Finally, we derive

$$N^{*\prime}_{\Delta} = \frac{\begin{vmatrix} \ell & , & \Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta \\ N & , & \Theta \cdot Y \cdot \Psi''_{\ell\ell} \end{vmatrix}}{|K|} = \frac{\Theta \cdot Y \cdot \ell \cdot \Psi''_{\ell\ell} - N\left(\Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta\right)}{|K|} < 0.$$

The comparative static results for β^{H*} and ℓ^* follow again directly, since $\beta^{H*\prime}_{N^*} < 0$ implies $\beta^{H*\prime}_{\Delta} > 0$, and $N^{*\prime}_{\ell^*} > 0$ implies $\ell^{*\prime}_{\Delta} < 0$ if $\ell^* \in (0,1)$ and zero otherwise.

iii.) Total profits: We claim that more productive firms earn a higher total payoff π, despite that they have higher fixed costs. The total payoff is given by $\pi = \Theta \cdot Y \cdot \Psi - \left(w_1^M + \ell\Delta\right) N + \bar{f}$. Recall that the FOCs are $\pi'_N = \Theta \cdot Y \cdot \Psi'_N - \left(w_1^M + \ell\Delta\right) = 0$ and $\pi'_\ell = \Theta \cdot Y \cdot \Psi'_\ell - \Delta N = 0$. It directly follows that $\pi'_\theta = Y \cdot \Psi + N'_\Theta \underbrace{\left(\Theta \cdot Y \cdot \Psi'_N - \left(w_1^M + \Delta\ell\right)\right)}_{=0} + \ell'_\Theta \underbrace{\left(\Theta \cdot Y \cdot \Psi'_\ell - \Delta N\right)}_{=0} = Y \cdot \Psi > 0.$

B.3. The make-or-buy decision under incomplete contracts.

B.3.1. Zero outside opportunity

Maximization problem: As shown in Appendix B.2.1., N_0^* and β_0^{H*} are identical to the closed economy case, see eq. (3.13) and eq. (3.14). The constraint $\beta^H \in \left[\beta^H_{min}, \beta^H_{max}\right]$ is also indentical as in the closed economy case. The constrained optimal complexity and organization choices are thus identical to the closed economy case, while the global scale choice is given by $\tilde{\ell}_0 = 1$. The thresholds $\bar{\eta}_0^H$ and $\bar{\bar{\eta}}_0^H$ as given in Appendix A.3.1. apply.

B.3.2. Positive outside opportunity

Maximization problem: In sectors with medium headquarter-intensity ($\bar{\bar{\eta}}_0^H < \eta^H < \bar{\eta}_0^H$) the producer can set the outsourcing share $\tilde{\xi} = (\beta^H_{max} - \beta^{H*})/(\beta^H_{max} - \beta^H_{min})$ such that $\beta^H = \beta^{H*}$. This implies $\tilde{N} = N^*$ and $\tilde{\ell} = \ell^*$. The comparative static results are derived in Appendix B.2.2.ii. Since $\beta^{H*\prime}_{\eta^H} > 0$ and $\tilde{\xi}'_{\beta^{H*}} < 0$ the outsourcing share is relatively lower the more headquarter-intensive the industry is. In headquarter-intensive ($\eta^H > \bar{\eta}_0^H$) and component-intensive industries ($\eta^H < \bar{\bar{\eta}}_0^H$), the outsourcing share is constant and given by $\tilde{\xi} = 0$ and $\tilde{\xi} = 1$, respectively. Conditional on $\tilde{\xi} = 0$ or $\tilde{\xi} = 1$ with $\beta^H = \beta^H_{min}$ and $\beta^H = \beta^H_{max}$, respectively, the optimal complexity level $\tilde{N}$ and offshoring share $\tilde{\ell}$ are determined according to

$$\pi'_N = \Theta \cdot Y \cdot \Psi'_N - \left(w_1^M + \ell\Delta\right) = 0 \quad \text{and} \quad \pi'_\ell = \Theta \cdot Y \cdot \Psi'_\ell - \Delta N = 0. \tag{3.25}$$

As in Appendix B.2.2., for sufficiently highly productive firms we have $\pi'_\ell > 0$ for all $\ell \in [0,1]$, since $\Psi'_\ell > 0$ and $\tilde{N}$ approaches $\tilde{N}_0$ and is bounded from above. Hence, the global maximum is given by $\tilde{\ell} = 1$. Vice versa, for firms with sufficiently low productivity: $\pi'_\ell < 0$ so that $\tilde{\ell} = 0$.

We are now interested in the SOC for the case where $\tilde{\ell} \in (0,1)$. Assume that $\tilde{N}$ and $\tilde{\ell}$ solve the system of FOCs given in (3.25). The SOCs are given by the following matrix $\tilde{K}$:

$$\tilde{K} = \begin{bmatrix} \pi''_{NN} & , & \pi''_{N\ell} \\ \pi''_{\ell N} & , & \pi''_{\ell\ell} \end{bmatrix} = \begin{bmatrix} \Theta \cdot Y \cdot \Psi''_{NN} & , & \Theta \cdot Y \cdot \Psi''_{N\ell} - \Delta \\ \Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta & , & \Theta \cdot Y \cdot \Psi''_{\ell\ell} \end{bmatrix},$$

For negative definiteness of $\tilde{K}$ we have to ensure that $\pi''_{\ell N} = \Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta$ is small, as in Appendix B.2.1.i, which can be achieved by setting Δ high enough. If this parame-

ter restriction holds, the diagonal elements Ψ''_{NN} and $\Psi''_{\ell\ell}$ are negative while the determinant $\left|\tilde{K}\right| = \Theta^2 \cdot Y^2 \cdot \Psi''_{NN}\Psi''_{\ell\ell} - (\Theta \cdot Y \cdot \Psi''_{\ell N} - \Delta)^2 > 0$ is positive, so that the SOCs are unambiguously satisfied. Furthermore, if this parameter restriction holds, it is straightforward to prove the following comparative static results, which can be derived in a similar way as in Appendix B.2.2.ii: $\tilde{N}'_{\Theta} > 0$, $\tilde{\beta}^{H\prime}_{\Theta} < 0$, $\tilde{\ell}'_{\Theta} \geq 0$; $\tilde{N}'_{\eta^H} < 0$, $\tilde{\beta}^{H}_{\eta^H}{}' > 0$, $\tilde{\ell}'_{\eta^H} \leq 0$; $\tilde{N}'_{\Delta} < 0$, $\tilde{\beta}^{H\prime}_{\Delta} > 0$, $\tilde{\ell}'_{\Delta} \leq 0$.

Appendix C: Asymmetric components

C.1. Symmetric input intensities. The unique closed form solution for $\beta^*_a = \beta^*_b = \beta^*_i$ is given by:

$$\beta^*_i = \frac{3\left(1-\alpha\eta^H\right)\left(1-\eta^H\right) - \sqrt{\left(1-\eta^H\right)\left(1-\alpha\eta^H\right)\left(16-3\eta^H\left(5+3\alpha\left(1-\eta^H\right)\right)\right)}}{12\left(1-\eta^H\right)-8}. \tag{3.26}$$

It directly follows from (3.26) that $\beta^{*\prime}_{i\,\eta^H} < 0 \rightarrow \beta^{*\prime}_{i\,\eta^M} > 0$. Notice that $\beta^*_i = \left(1-\beta^{H*}\left(N=2, s=0\right)\right)/2$, with β^{H*} as given in eq. (3.14), leads to the same solution as (3.26).

C.2. Asymmetric input intensities. The FOCs reduce to $\Psi'_{\beta^H} = 0$ and $\Psi'_{\beta_a} = 0$. It is possible to solve $\Psi'_{\beta^H} = 0$ for $\beta^H\left(\beta_a\right)$. Using $\beta^H\left(\beta_a\right)$ in $\Psi'_{\beta_a} = 0$ leads to $\Psi'_{\beta_a}|_{\beta^H=\beta^H(\beta_a)} = 0$ and solely depends on β_a. To illustrate the alogrithm we assume in the following $\eta^H = \alpha = 1/2$. Then $\Psi'_{\beta_a}|_{\beta^H=\beta^H(\beta_a)} = 0$ is equivalent to finding a root β^*_a of the polynominal R given by

$$R = \beta^3_a - \beta^2_a \cdot \frac{-2+\left(\eta_a\right)^2\left(4+\eta_a\right)}{2\left(1-\eta_a\right)\left(1-2\eta_a\right)} + \beta_a \cdot \frac{9\left(\eta_a\right)^2\left(3+\eta_a\right)}{16\left(1-\eta_a\right)\left(1-2\eta_a\right)} - \frac{3\left(\eta_a\right)^2\left(3+\eta_a\right)}{16\left(1-\eta_a\right)\left(1-2\eta_a\right)}.$$

We propose the following change in variables that eliminates β^2_a in R: $\beta^3_a = Z - A/3$ with $A = \left[2-\left(\eta_a\right)^2\left(4+\eta_a\right)\right] / \left[2\left(1-\eta_a\right)\left(1-2\eta_a\right)\right]$. This leads to $R = Z^3 + Z \cdot P + Q$ where P and Q are given by:

$$P = \frac{\left(\eta_a\right)^2\left(145+\eta_a\left(\eta_a\left(17+22\eta_a-4\left(\eta_a\right)^2\right)-200\right)\right)-16}{48\left(1-3\eta_a+2\left(\eta_a\right)^2\right)^2},$$

$$Q = -\frac{\left(4-\eta_a\right)^2\left(\eta_a\left(-2+\eta_a\left(84+\eta_a\left(-205+\eta_a\left(148+\eta_a\left(1+2\eta_a\right)\left(4\eta_a-3\right)\right)\right)\right)\right)-4\right)}{864\left(1-3\eta_a+2\left(\eta_a\right)^2\right)^3},$$

respectively, which solely depend η_a. Cardano's formula leads to the solution Z^* that solves $R = 0$. Since the discriminant $D = P^3/27 + Q^2/4$ is negative, the unique closed form solutions is piecewise defined from:

$$Z^*_1 = \sqrt{-\frac{4P}{3}}\cos\left[\frac{1}{3}\arccos\left(-\frac{Q}{2}\sqrt{-\frac{27}{P^3}}\right)\right],$$

$$Z^*_2 = -\sqrt{-\frac{4P}{3}}\cos\left[\frac{1}{3}\arccos\left(-\frac{Q}{2}\sqrt{-\frac{27}{P^3}}+\frac{\pi}{3}\right)\right],$$

$$Z^*_3 = -\sqrt{-\frac{4P}{3}}\cos\left[\frac{1}{3}\arccos\left(-\frac{Q}{2}\sqrt{-\frac{27}{P^3}}-\frac{\pi}{3}\right)\right]$$

valid in corresponding η_a-domains which can be explicitly solved. Then, Z_1^*, Z_2^* and Z_3^* can be subsituted to yield $\beta_{a,1}^*$, $\beta_{a,2}^*$ and $\beta_{a,3}^*$. Taken together, these $\beta_{a,1}^*$-$\beta_{a,3}^*$ define the unique piecewise solution for β_a^*. The corresponding optimal share β^{H^*} can then be derived by using β_a^* in $\beta^H(\beta_a)$, derived from $\Psi'_{\beta^H} = 0$. The optimal share is then given by $\beta^{H^*} = \beta^H(\beta_a = \beta_a^*)$. The optimal share β_b^* for the other supplier is the residual share given by $\beta_b^* = 1 - \beta^{H*} - \beta_a^*$.

We have here illustrated the alogrithm for the example of $\eta^H = \alpha = 1/2$. Other parameter examples also reduce to a similar term as given by R (with polynomial degree of 3) and can be solved analogously with the help of Cardano's formula. Upon request we provide a *Mathematica* file with the algorithm.

Chapter 4

Globalization and Strategic Research Investments

4.1 Abstract

We develop a general equilibrium model of international trade with heterogeneous firms, where countries can invest into basic research to improve their technological potential. These research investments tighten firm selection and raise the average productivity of firms in the market, thereby implying lower consumer prices and higher welfare. In an open economy, there is also a strategic investment motive since a higher technological potential gives domestic firms a competitive advantage in trade. Countries tend to over-invest due to this strategic motive. There are thus welfare gains from coordinating research investments. The over-investment problem turns to an under-investment problem if there are sufficiently strong cross-country spillovers of basic research investments.

4.2 Introduction

Investments into research and development are an important spending item. Table 4.1 reports the gross domestic expenditure on research and development (*GERD*) as a share of gross domestic product (GDP) in 21 OECD countries. These R&D spending shares differ vastly even within the OECD: some countries spend just about 1 per cent, while countries like Sweden, Finland or Korea devote much larger shares of their national income to R&D expenditures. A substantial share of these expenditures is financed publically with taxpayers' money. This includes purely public research projects and higher education spending, as well as subsidies to private R&D, innovation funds, and so on. Typically, the public share of the total GERD exceeds one third and moves up to more than two thirds in some countries, which adds up to considerable per-capita amounts that governments spend annually for R&D purposes. As Table 4.1 shows, this public research expenditure has increased in almost all OECD countries during the recent time period from 2000 to 2007/08, the Netherlands and Japan being two exceptions. That is, public spending on research and development has apparently become more important over time, and now looms higher on policy agendas than it was the case about 10 years ago.

It is well understood that R&D investments are a key ingredient of sustained economic growth, as they raise the amount of innovation in an economy (Grossman and Helpman 1991). It is also well understood why governments are heavily involved in the financing of basic research, since the public good characteristics of knowledge and ideas tend to jeopardize private investment incentives (Nelson 1950). What is less well understood in the literature, however, is how international trade affects the incentives of a government to *strategically* invest into the country's technological potential by supporting basic research or conducting public R&D. There seems to be a widespread perception among policymakers that such public R&D investments become increasingly important in a world with falling trade barriers, since developed countries perceive the need to support

	2007/2008		2000	
	GERD % GDP	**PubGERD** per capita in USD	**GERD** % GDP	**PubGERD** per capita in USD
United States	2.8	381.3	2.4	293.3
Norway***	1.6	355.5	1.6	291.8
Sweden***	3.6	352.8	3.4	257.6
Finland	3.5	334.1	3.4	276.1
Australia**,***	2.1	305.4	1.5	245.7
Denmark	2.7	288.0	2.2	254.7
Switzerland*	2.9	280.7	2.6	227.0
France	2.0	276.1	2.0	254.5
Korea	3.5	272.6	2.2	156.2
Japan	3.4	258.2	3.0	261.3
Netherlands	1.7	253.6	1.9	261.8
Belgium	1.9	241.7	2.0	212.4
United Kingdom	1.9	241.5	1.6	181.5
Germany	2.5	239.3	2.4	205.6
Luxembourg	1.6	206.7	1.7	96.1
New Zealand	1.2	176.8	1.0	157.3
Spain	1.3	170.9	0.8	110.1
Italy***	1.1	164.5	1.0	133.2
Czech Republic	1.5	146.2	1.2	96.2
Portugal	1.2	121.0	0.8	117.0
Slovak Republic	0.5	52.2	0.6	25.4
Weighted average	2.5	286.9	2.1	232.5

Source: Own calculations based on OECD data. The table reports: i) gross domestic expenditure on R&D (GERD) as a share of GDP for the years 2007/08 and 2000; ii) absolute public research expenditure per capita in constant USD prices of 2000. These amounts are calculated as follows: From the absolute GERD we subtract the business expenditure on research and development (BERD) excluding direct and indirect government subsidies to private firms. This leaves us with the public expenditure on research and development (PubGERD) which we then divide by population size in the respective year. In the last row we report the average across all countries weighted by population size. Due to missing data we use different years in some cases: * data for 2004 and ** data for 2006, *** data for 1999.

Table 4.1: R&D spending in selected OECD countries

domestic firms in maintaining competitiveness on global markets.[1] Yet, to the best of our knowledge, there is no theoretical literature which has formally studied these issues.

In this paper, we develop a two-country general equilibrium model of trade with heterogeneous firms à la Melitz (2003).[2] In our framework, entrepreneurs can enter a monopolistically competitive manufacturing industry subject to a sunk cost. Upon entry, they randomly draw their productivity level from a known distribution. As in Demidova (2008), we consider this distribution to be country-specific, but in contrast to that paper we allow for *endogenous* technology differences across countries. In particular, the government of either country can invest into basic research. These research investments raise the country's technological potential, which is modelled as a right-shift of the support of the distribution from which the domestic entrants draw their productivity level. By raising the technological potential of a country, these public investments initially lead to an increase in the expected value of entry. Entrepreneurs still face uncertainty about their individual productivity, and may end up with a draw that is too low to be able to remain in the market. The public research investments therefore do not offset idiosyncratic risks of business failure, which is consistent with the evidence that even the most highly developed and advanced economies (like the US, Germany or Japan) are characterized by substantial exit and churning rates among firms (Geroski 1995). If these investments do not benefit every firm ex post, they do raise the ex ante premises for entrepreneurs, however. Understanding the underlying mechanisms of this policy thus necessarily requires a model with firm heterogeneity and ex ante uncertainty among entrants.[3]

The motive for public research investments in our model is that the increase in the country's technological potential eventually leads to tighter firm selection and higher average productivity of firms, which in turn lowers prices and raises welfare in equilibrium. In the open economy, there is an additional *strategic* motive. If one country invests more than the other, this yields tougher selection in the leading and softer selection in the laggard country. Exporting becomes easier for firms from the leading country, as the export market is now easier to capture. Firms from the laggard country face

[1]See, for example, the Conclusions of the Council of the European Union (2008): "Providing high-quality education and investing more and more efficiently in human capital and creativity throughout people's lives are crucial conditions for Europe's success in a globalized world" (p.9). Also see Zhou and Leydesdorff (2006) for a discussion that particularly emphasizes the role of China's rise in the world economy in that regard.

[2]It is a well-established empirical fact that there is substantial firm heterogeneity even in narrowly defined industries in such dimensions as productivity, size, or export activity. See, e.g., the empirical studies by Bernard and Jensen (1999), Aw et al. (2000), or Clerides et al. (1998). This empirical observation has triggered a large theoretical literature on trade with heterogeneous firms, e.g. Melitz (2003), Bernard et al. (2003), Melitz and Ottaviano (2008), Demidova (2008). Strategic investments into a country's technological potential have not yet been considered in that literature, however.

[3]In a model with homogeneous firms and without ex ante uncertainty, such as Krugman (1980), a technological improvement would be tantamount to a decrease in marginal costs of all firms. Our model highlights different features, as it is crucially based on the extensive margin of firms' entry, survival, and exporting activities.

tougher competition in their home market, and exporting becomes more difficult. Public research investments thus give domestic firms – on average – a competitive advantage, and countries tend to invest more the higher the level of trade openness is. This result is consistent with the empirical observation that almost all OECD countries have raised R&D spending during a period that was characterized by falling trade barriers. From a normative perspective, the investments induce a negative cross-country externality so that single countries over-invest. There are thus welfare gains from supranational coordination of public research investments. We also allow for direct R&D spillovers across countries, following a huge literature that has studied R&D spillovers across firms.[4] That is, the public research investment in one country may, to some extent, also raise the technological potential of the other country, because the generated knowledge becomes at least partly accessible across the border. With cross-country spillovers the socially optimal investment level is higher the freer trade is, and the over-investment problem is reduced and may even turn to an under-investment problem if the spillover is strong enough.

This chapter is related to the large literature on public investments into research and development, e.g., Gonzales and Pazo (2008), Kleer (2008). We add to this literature by analyzing the positive and normative consequences of those investments in an open economies context, and by studying how trade liberalization affects the strategic investment incentives in general equilibrium. Our paper is also related to the small but growing literature on policy issues in models of international trade with heterogeneous firms, e.g. Demidova and Rodriguez-Clare (2009), Chor (2009), or Pflueger and Suedekum (2009). However, no paper has so far considered government investments into basic research and endogenous cross-country differences in technological potentials. Finally, our paper is related to the literature on international tax competition. The typical setup of those models is that jurisdictions compete for mobile factors or firms, and there is an extensive discussion whether tax competition then leads to under- or over-provision of public goods (e.g., Zoodrow and Mieszkowski 1986, Bénassy-Quéré et al. 2005). Our framework differs in two important respects. First, there is no cross-country mobility but all policy effects are transmitted via (costly) trade. Second and more importantly, though one may think of the research investments as the provision of a public good that makes firms (on average) more productive, our analysis relies crucially on firm heterogeneity and ex ante uncertainty – features that have been rarely studied in the tax competition literature so far.[5]

The rest of this chapter is organized as follows. In section 4.3 we consider a closed economy version of our model, and in section 4.4 we introduce the open economy setting. Section 4.5 derives the Nash-equilibrium and the cooperative policy for the case without

[4]See, e.g., Cohen and Levinthal (1989), Jaffe (1989), Adams (1990), Jaffe et al. (1998), O'Mahony and Vecci (2009).

[5]The recent papers by Davies and Eckel (2009) and Krautheim and Schmidt-Eisenlohr (2010) are exceptions, but they do not consider public research investments and their trade-mediated effects.

direct cross-country spillovers, while section 4.6 considers the case with spillovers. Section 4.7 concludes.

4.3 Closed economy

We first consider a closed economy which is populated by L workers who inelastically supply one unit of labor each. Labor is the only factor of production and perfectly mobile across two industries: a homogeneous goods sector A with constant returns to scale and perfect competition, and a manufacturing industry C which is monopolistically competitive and consists of a continuum of differentiated varieties. Each variety is produced by a single firm under increasing returns to scale, and the firms are heterogeneous in their productivities.

4.3.1 Preferences

The preferences of a household h are defined over the homogeneous good, which is used as the numeraire, and the set of differentiated varieties Ω. Utility is represented by a quasi-linear, logarithmic function with constant elasticity of substitution (CES) subutility over the set of varieties:

$$U = \beta \ln C^h + A^h \quad \text{with} \quad C^h = \left(\int_{z \in \Omega} q^h(z)^\rho \, \mathrm{d}z \right)^{1/\rho},$$

where $0 < \rho < 1$ and $\beta > 0$. The household's consumption of a variety z is given by $q^h(z)$. The elasticity of substitution between any two varieties is given by $\sigma \equiv 1/(1-\rho)$. The CES price index for the bundle of varieties can then be derived in the standard way, and reads as $P = \left(\int_{z \in \Omega} p(z)^{1-\rho} \, \mathrm{d}z\right)^{1/(1-\sigma)}$. Utility maximization implies per-capita expenditures $PC^h = \beta$ and $A^h = y^h - \beta$ for the manufacturing aggregate and the homogeneous good, respectively. We assume that $\beta < y^h$, i.e., that the preference for varieties is not too large. Indirect utility is then given by:

$$V^h = y^h - \beta \ln P + \beta (\ln \beta - 1). \tag{4.1}$$

We drop the index h from now on as all households are identical. Total demand and revenue for a single variety z can then be computed as $q(z) = \beta L p(z)^{-\sigma} P^{\sigma-1}$ and $r(z) = p(z) q(z) = \beta L (P/p(z))^{\sigma-1}$, respectively.

4.3.2 Production and firm behavior

In sector A one unit of labor is transformed into one unit of output. Since the price for that good is normalized to one, and since workers are mobile across sectors, this implies that the wage in the closed economy is also equal to one. In the manufacturing industry,

a firm needs $l = f + q/\varphi$ units of labor to produce q units of output. The overhead cost f is the same, but the marginal costs $1/\varphi$ are heterogeneous across firms. A higher value of φ represents a higher firm-level productivity. Firms have zero mass and thus take the price index P as given. Since consumers have iso-elastic demands, it is straightforward to see that firms charge prices which are constant mark-ups over firm-specific marginal costs, $p(\varphi) = 1/(\rho\varphi)$. As firms differ only in productivity, total demand and revenue for a single variety can be rewritten as $q(\varphi) = \beta L (\rho\varphi)^{\sigma} P^{\sigma-1}$ and $r(\varphi) = \beta L (\rho\varphi P)^{\sigma-1}$, respectively, and profits are given by $\pi(\varphi) = r(\varphi)/\sigma - f$. It is evident that a firm with a higher productivity charges a lower price, sells a larger quantity, and has higher revenue and profits. The CES price index can be rewritten as follows:

$$P = M^{1/(1-\sigma)} p(\widetilde{\varphi}) = M^{1/(1-\sigma)} \frac{1}{\rho\widetilde{\varphi}} \quad \text{with} \quad \widetilde{\varphi} \equiv \left[\int_0^{\infty} \varphi^{\sigma-1} \mu(\varphi) \, \mathrm{d}\varphi \right]^{1/(\sigma-1)}, \tag{4.2}$$

where M is the mass of manufacturing firms (consumption variety), $\mu(\varphi)$ is the productivity distribution, and $\widetilde{\varphi}$ is the average productivity across those firms in the market.

4.3.3 Entry, exit and the technological potential

We now embed this static model into a dynamic framework in continuous time. Entrepreneurs can enter the manufacturing industry subject to a sunk entry cost f_e. The mass of entrants is given by M^E at each point in time. Upon entry, they learn about their productivity level φ, which is randomly drawn from a common and known distribution. In this paper, we assume that entrants draw their productivity from a Pareto distribution: $G(\varphi) = 1 - \left(\varphi^{MIN}/\varphi\right)^k$, with density $g(\varphi) = k \left(\varphi^{MIN}\right)^k \varphi^{-(k+1)}$. Here, $k > 1$ is the shape parameter and $\varphi^{MIN} > 0$ is the lower bound.[6]

Figure 4.1 illustrates the fat-tailed shape of the Pareto distribution, and it particularly focuses on the economic meaning of the parameter φ^{MIN}. We depict two Pareto distributions with different lower bounds φ^{MIN}_{high} and φ^{MIN}_{low}. As can be seen, with φ^{MIN}_{high} firms draw their idiosyncratic productivity from a "better" ex ante distribution, as the mass within the entire distribution is shifted to the right. We shall henceforth refer to the parameter φ^{MIN} as the country's *technological potential*.

After learning about the idiosyncratic productivity draw, every firm decides whether to remain active in the market or to exit immediately. If a firm remains active, it earns constant per-period profits as described above. Since a firm cannot cover the per-period fixed costs f when φ is too low, it turns out that all firms with a productivity draw below some cutoff level φ^* decide to exit, while all firms with a draw above φ^* remain active. As

[6] This modelling strategy where firms randomly draw their productivity follows Hopenhayn (1992) and Melitz (2003). It has become the seminal approach for studying firm heterogeneity in a general equilibrium model. The Pareto distribution is widely used in this literature, see Bernard et al. (2003) or Melitz and Ottaviano (2008), and also fits empirical firm size distributions fairly well, see Axtell (2001).

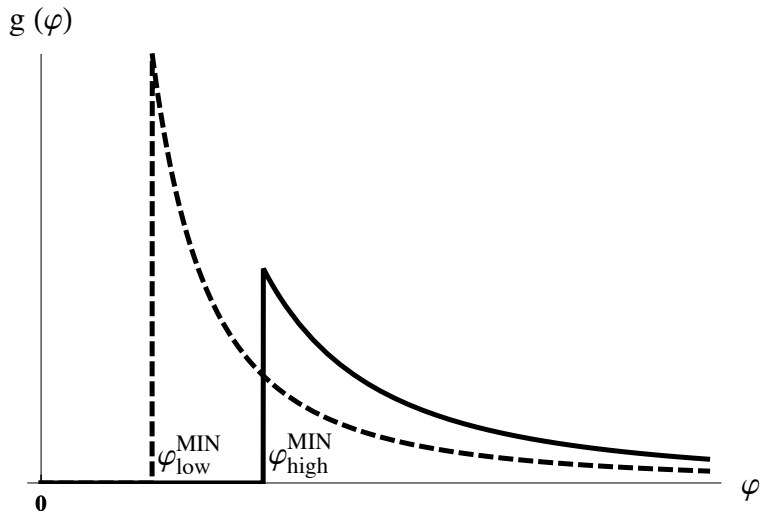

Figure 4.1: Pareto distribution with different lower bounds

in Melitz (2003), every active firm can then be hit by a bad shock with probability $\delta > 0$ at each point of time, which is assumed to be uncorrelated with the firms' productivity draws. If this shock occurs, the firm must shut down. In a stationary equilibrium without time discounting, the mass of entrants which successfully enter the market equals the mass of firms which are forced to exit: $p_{in}M^E = \delta M$, where $p_{in} = 1 - G(\varphi^*)$ is the ex ante survival probability of entrants. The endogenous productivity distribution among active firms, $\mu(\varphi)$, is then the conditional ex ante distribution $g(\varphi)$ on the domain $(\varphi^*, \infty]$, which in the present case is also a Pareto distribution with shape parameter k.

4.3.4 Equilibrium

Equilibrium can be characterized by two conditions. The free entry condition (FEC) states that the value of entry, $v^E = E\left[\sum_{t=0}^{\infty}(1-\delta)^t \pi(\varphi)\right] - f_e$, is driven to zero. This in turn implies that:

$$\overline{\pi} = \frac{\delta f_e}{1 - G(\varphi^*)} = \delta f_e \left(\frac{\varphi^*}{\varphi^{MIN}}\right)^k. \tag{FEC}$$

The zero cutoff profit condition (ZCPC) pins down the revenue of the cutoff firm, $r(\varphi^*) = \sigma f$, which by using $r(\widetilde{\varphi})/r(\varphi^*) = (\widetilde{\varphi}/\varphi^*)^{\sigma-1}$ and $\overline{\pi} = r(\widetilde{\varphi})/\sigma - f$ leads to:

$$\overline{\pi} = f\left[\left(\frac{\widetilde{\varphi}}{\varphi^*}\right)^{\sigma-1} - 1\right] = \frac{f(\sigma-1)}{k+1-\sigma}, \tag{ZCPC}$$

with $k > \sigma + 1$. Using (FEC) and (ZCPC), we obtain the following equilibrium cutoff productivity under autarky, denoted by φ^*_{AUT}:

$$\varphi^*_{AUT} = \Gamma \cdot \varphi^{MIN}, \qquad \Gamma \equiv \left(\frac{f(\sigma - 1)}{\delta f_e (k + 1 - \sigma)} \right)^{1/k}, \tag{4.3}$$

where δf_e must be sufficiently low and/or f sufficiently high to ensure that $\Gamma > 1$, which is required for consistency. Under the Pareto distribution, the average productivity among all active firms is then proportional to the cutoff productivity, $\widetilde{\varphi}_{AUT} = \left(\frac{k}{k+1-\sigma}\right)^{1/(\sigma-1)} \varphi^*_{AUT}$. Furthermore, since aggregate expenditure on varieties, βL, must equal aggregate revenue of manufacturing firms, $R = M\overline{r} = Mr(\widetilde{\varphi})$, we obtain $M = \beta L/\overline{r}$, where $\overline{r} = \sigma(\overline{\pi} + f)$, and consequently $M^E = \delta M/(1 - G(\varphi^*_{AUT}))$. The equilibrium masses of entrants and of surviving firms can thus be expressed explicitly as:

$$M_{AUT} = \left(\frac{k + 1 - \sigma}{\sigma k f} \right) \beta L \qquad \text{and} \qquad M^E_{AUT} = \left(\frac{\sigma - 1}{\sigma k f_e} \right) \beta L. \tag{4.4}$$

Finally, using (4.1), (4.2), (4.3) and (4.4), indirect utility can be computed as follows:

$$V_{AUT} = y + \beta \ln \varphi^*_{AUT} + \frac{\beta}{\sigma - 1} \ln L + \kappa_1, \tag{4.5}$$

where $\kappa_1 = \beta(\ln(\beta\rho) - 1) + \frac{\beta}{\sigma-1} \ln(\beta/\sigma f)$ is a constant. Notice that welfare is increasing in the population size L and in the cutoff productivity φ^*_{AUT}. Notice further that an increase in the technological potential leads to a proportional increase in the cutoff and the average productivity, and hence to a welfare gain, while the masses of entrants M^E_{AUT} and of surviving firms M_{AUT} are independent of φ^{MIN}. To understand this, consider the effect of an increase in the technological potential in the short run. For a given cutoff productivity, this raises the survival probability and, hence, the firms' expected profits. More entry is induced, and more firms appear in the market in the short run. This increases competition and causes exit of the least productive incumbent firms, which in turn raises the cutoff, lowers again the ex ante survival probability, the expected profits and, hence, the value of entry. Under the assumed Pareto distribution, these opposite effects turn out to be of equal magnitude, so that an increase in the technological potential eventually leaves the masses of entrants and surviving firms unaffected in the long run, but increases the cutoff and average productivity among the surviving firms. In other words, an increase in the technological potential does not lead to *more* but to *better* firms in the long run equilibrium. These better firms charge lower prices and sell more output, which implies a welfare gain for consumers. Aggregate spending on varieties (i.e., aggregate revenue of manufacturing firms) remains constant at βL, however.

4.3.5 Investments into basic research and the technological potential

We now consider the government which levies a lump-sum tax on households and spends the tax revenue on basic research, i.e., on public research foundations, labs, innovation funds, higher education, and so on. In our model, those public research investments lead to an increase in the country's technological potential φ^{MIN}. Notice that this provision of basic research does not lead to ex post gains for all firms, which still face idiosyncratic risks of business failure. The gains of this policy arise from an ex ante perspective, by improving the premises for domestic entrepreneurs.

For simplicity we normalize the country size to one, $L = 1$. The tax rate is denoted by t, and since $w = 1$ and $L = 1$, total tax revenue is given by $T = t$. The variable T also denotes the total public research expenditure, since we assume a balanced budget and an efficient government. The total amount of basic research is denoted by $H(T)$, and in the case of zero expenditure we have $H(0) = 0$. For positive expenditure levels, we assume that there are positive but decreasing marginal returns, i.e., $H' = \partial H/\partial T > 0$, and $H'' = \partial H'/\partial T < 0$, and we impose a mild condition on the curvature of this schedule, $(H')^2 < -H''$, which facilitates our analysis below. The country's technological potential depends positively on the level of basic research, and for concreteness we assume the following specification:[7]

$$\varphi^{MIN} = \exp\{H(T)\}, \tag{4.6}$$

which normalizes the technological potential to unity if the country conducts no basic research. It is then straightforward to show that public research expenditure raises the technological potential with decreasing marginal returns:

$$\varphi^{MIN\prime} = \frac{\partial \varphi^{MIN}}{\partial T} = H'\varphi^{MIN} > 0 \quad \text{and} \quad \varphi^{MIN\prime\prime} = \frac{\partial \varphi^{MIN\prime}}{\partial T} = \varphi^{MIN}\left[(H')^2 + H''\right] < 0.$$

Finally, turning to welfare in the closed economy, we can rewrite expression (4.5) in the following way by using (4.3), $L = 1$, and $y = 1 - T$:

$$V = 1 - T + \beta \cdot \ln \varphi^{MIN}(T) + \kappa_2, \tag{4.7}$$

where $\kappa_2 = \kappa_1 + \beta \ln \Gamma$ is a constant. The government maximizes this expression with respect to T. The condition for a welfare maximum is given by

$$\frac{\partial V}{\partial T} = -1 + \beta \frac{\varphi^{MIN\prime}}{\varphi^{MIN}} = -1 + \beta H' = 0, \tag{4.8}$$

and from equation (4.8) we can disentangle the different effects of higher research ex-

[7] The exponential specification of φ^{MIN} in (4.6) is analytically convenient, but our subsequent results do not crucially hinge on this functional form.

penditure on welfare. A higher T raises the technological potential of the country, and thereby the cutoff and the average productivity of firms in the market. This in turn lowers the price index, increases physical consumption of the differentiated varieties, and eventually leads to a welfare gain at the margin $\beta H'$. On the other hand, the required lump-sum taxes have a negative unit welfare burden at the margin, since the consumption of the homogenous good is reduced. Using (4.8), we can state the following result:

Proposition 1 *i) The government invests into basic research if $\beta H' > 1$ for any $0 < T < 1$, which is the case if consumers have a sufficiently strong preference for varieties β. ii) The higher β is, the higher is the optimal expenditure level and tax rate T^*_{AUT}.*

The proof of part i) follows directly from (4.8). The comparative static result ii) can be derived by the implicit function theorem. Define $\zeta \equiv H' - 1/\beta$, so that we have:

$$\frac{\partial T^*}{\partial \beta} = -\frac{\partial \zeta}{\partial \beta}\left(\frac{\partial \zeta}{T^*}\right)^{-1} = -\frac{1}{\beta^2 H''} > 0. \tag{4.9}$$

To illustrate proposition 1, consider the example $H = \sqrt{T}$ which satisfies the aforementioned curvature condition. In that case we have $H' = 1/\left(2\sqrt{T}\right)$, and solving $H' = 1/\beta$ then leads to $T^*_{AUT} = \beta^2/4 > 0$.

Notice that the implementation of this policy affects the manufacturing sector only at the intensive margin in the long run equilibrium: firms become more productive but consumption variety M_{AUT} does not change. In the short run there are instantaneous changes at the extensive margin, however, as we have discussed above. Notice also that this policy affects the resource allocation as it increases the share of the workforce that is employed in the manufacturing sector.[8]

4.4 Open economy

We now consider a scenario with two countries $r = 1, 2$. These countries are identical in population size ($L_1 = L_2 = 1$), but may differ in their technological potentials. Ultimately we are interested in the determination of the endogenous public research investments that imply those differences, see sections 4.5 and 4.6 below. In this section, we first neglect taxes and analyze the open economy equilibrium when the countries' technological potentials are exogenously given. Specifically, we assume that entrants in both countries

[8] In the homogeneous goods sector, aggregate revenue needs to equal aggregate factor payments due to perfect competition. Since the tax lowers the consumers' disposable incomes, and since all income effects of demand accrue in the A-sector, this implies that $(1 - \beta - t)\, L = (1 - \gamma)\, L$, where γ is the manufacturing employment share. This implies $\gamma = \beta + t$, i.e., higher taxes increase the manufacturing share because aggregate physical output of the manufacturing sector increases which requires more labor there.

draw their productivity from a Pareto distribution with the same shape parameter k, but country 1 has a higher technological potential than country 2, i.e., $\varphi_1^{MIN} > \varphi_2^{MIN}$.

In the A-sector there are no trade costs. This ensures factor price equalization provided both sectors are active in both countries after trade. In sector C there are two types of trade costs. First, there are per-period fixed costs of exporting, f_x, that arise if a firm decides to serve the market in the other country. Second, there are the standard iceberg trade costs, i.e., for one unit of output to arrive the firm needs to ship $\tau > 1$ units. The open economy equilibrium can be determined similarly as in the closed economy case, also see Melitz (2003), Demidova (2008), and Pflueger and Suedekum (2009) for more details. The (FEC) remains unchanged for country r, and reads as $\overline{\pi}_r = \delta f_e \left(\varphi_r^* / \varphi_r^{MIN}\right)^k$. The (ZCPC) changes due to the fact that firms can now engage in exporting. Ex ante expected profits in country r (conditional on survival) can now be written in the following way: $\overline{\pi}_r = \pi_r\left(\widetilde{\varphi}_r\right) + p_{xr}\pi_{xr}\left(\widetilde{\varphi}_{xr}\right)$, where $p_{xr} = \left(\varphi_r^* / \varphi_{xr}^*\right)^k$ is the probability to be an exporter among all active firms from country r, $\pi_{xr}\left(\widetilde{\varphi}_{xr}\right)$ is the corresponding expected export profit level, $\widetilde{\varphi}_r$ is the average productivity among all active domestic firms, and $\widetilde{\varphi}_{xr}$ is the average productivity among all exporting firms from country r.

Using $\widetilde{\varphi}_r / \varphi_r^* = \widetilde{\varphi}_{xr} / \varphi_{xr}^* = \left(\frac{k}{k+1-\sigma}\right)^{1/(\sigma-1)}$, which holds under the Pareto distribution, the (ZCPC) can be rewritten as follows, $\overline{\pi}_r = \frac{f(\sigma-1)}{k+1-\sigma}\left(1 + \phi\left(\varphi_r^* / \varphi_s^*\right)^k\right)$, where $s = \{1, 2\} \neq r$ and where $\phi \equiv \tau^{-k}\left(f / f_x\right)^{\frac{k+1-\sigma}{\sigma-1}}$ is a measure of trade openness. Substituting the (FEC) into the (ZCPC) then leads to a system of two equations, which can be solved for the equilibrium cutoff productivities in the two countries:

$$\varphi_1^* = \left[\frac{\chi\left(1-\phi^2\right)}{\chi - \phi}\right]^{\frac{1}{k}} \cdot \Gamma \cdot \varphi_1^{MIN} \qquad \text{and} \qquad \varphi_2^* = \left[\frac{1-\phi^2}{1-\phi\chi}\right]^{\frac{1}{k}} \cdot \Gamma \cdot \varphi_2^{MIN}, \tag{4.10}$$

where $\Gamma > 1$ is as defined above, and where $\chi = \left(\varphi_2^{MIN} / \varphi_1^{MIN}\right)^k < 1$ measures the relative technological potential of country 2. We assume $f_x \geq f$, which is sufficient for $0 < \phi < 1$. A higher ϕ then indicates a higher level of trade openness, with $\phi \to 1$ and $\phi \to 0$ capturing the borderline cases of free trade and autarky, respectively. We need to impose that the technological asymmetry is sufficiently small relative to the level of trade openness, namely $\chi > \phi$, to ensure that $\varphi_r^* > 0$ for $r = 1, 2$. Provided this condition holds, we also have $\varphi_r^* > \Gamma \cdot \varphi_r^{MIN}$ for $r = 1, 2$, i.e., both countries have a higher cutoff productivity in the open economy than under autarky, which illustrates the selection effect of trade emphasized by Melitz (2003). Furthermore, domestic and export cutoffs can be linked as follows: $\varphi_{xs}^* = \Lambda \varphi_r^*$, with $\Lambda \equiv \tau\left(f_x / f\right)^{1/(\sigma-1)} > 1$ due to $f_x \geq f$. This, in turn, implies the following ranking of productivity cutoffs: $\varphi_{x2}^* > \varphi_{x1}^* > \varphi_1^* > \varphi_2^*$. In words, there is tougher selection in the technologically leading country 1. Firms from country 1 hence have a higher cutoff and average productivity than firms from country 2.

To complete the description of the equilibrium we need to determine the share of the workforce that is employed in the manufacturing sector in either country. As in Demidova (2008) and Pflueger and Suedekum (2009) we use the aggregate trade balance condition for country 1 to solve for γ_r for $r = 1, 2$. In the Appendix we show that they are given by:

$$\gamma_1 = \beta \left(\frac{1 - 2\phi\chi}{1 - \phi\chi} + \frac{\phi}{\chi - \phi} \right) \quad \text{and} \quad \gamma_2 = \beta \left(\frac{1}{1 - \phi\chi} - \frac{\phi}{\chi - \phi} \right). \tag{4.11}$$

It follows from (4.11) that $\gamma_1 = \gamma_2 = \beta$ if countries are symmetrical ($\chi = 1$), or if trade costs are prohibitive ($\phi \to 0$). In the asymmetrical case ($\chi < 1$) we need to impose parameter restrictions such that both sectors are active in both countries after trade, $0 < \gamma_r < 1$ for $r = 1, 2$. These conditions are spelled out in the Appendix. Using γ_1 and γ_2 as given in (4.11), it is then straightforward to derive the equilibrium masses of entrants (M_r^E), surviving firms (M_r), exporting firms (M_{xr}), and consumption variety ($M_{tr} = M_r + M_{xs}$) for both countries – also see the Appendix. The CES price index in the open economy is given by $P_r = M_{tr}^{1/(1-\sigma)} / (\rho \widetilde{\varphi}_{tr})$, where $\widetilde{\varphi}_{tr}$ is the average productivity among all (domestic and foreign) firms active in market r. Finally, welfare in country r can be written as follows:

$$V_r = 1 + \beta \cdot \ln \varphi_r^* \left(\varphi_r^{MIN} \right) + \kappa_1, \tag{4.12}$$

which is sufficiently described by the domestic cutoff productivity φ_r^* that, in turn, depends positively on the country's technological potential φ_r^{MIN}, as can be seen from (4.10). Proposition 2 summarizes the main insights for the case where the two countries differ exogenously in their technological potentials. The proof is also relegated to the Appendix.

Proposition 2 *Suppose country 1 has a higher technological potential than the identically large country 2. Furthermore, assume that the parameter restrictions (A3) hold (see the Appendix), so that* $0 < \gamma_r < 1$ *for* $r = 1, 2$. *The technologically leading country 1 then has: i) more entrants* ($M_1^E > M_2^E$), *ii) more surviving firms* ($M_1 > M_2$), *iii) more exporting firms* ($M_{x1} > M_{x2}$) *and a higher exporting probability* ($p_{x1} > p_{x2}$), *iv) greater consumption diversity* ($M_{t1} > M_{t2}$), *v) higher average productivity of domestic firms* ($\widetilde{\varphi}_1 > \widetilde{\varphi}_2$), *vi) higher productivity of firms active in the domestic market* ($\widetilde{\varphi}_{t1} > \widetilde{\varphi}_{t2}$), *and vii) higher welfare* ($V_1 > V_2$).

These results illustrate the benefits of having a higher technological potential in an open economy setting. Those benefits play a crucial role when thinking about the government incentives for basic research investments that will be analyzed in the next section. It is also instructive to consider the role of trade in amplifying those benefits. Specifically, consider two autarkic economies 1 and 2 that are identical, except

that country 1 has a higher technological potential. Using (4.3) the relative cutoff productivity across the two countries, which is a measure for relative welfare, is given by $(\varphi_1^*/\varphi_2^*) = (\varphi_1^{MIN}/\varphi_2^{MIN}) > 1$ under autarky. When the two countries trade with each other, it follows from (4.10) that the relative cutoff becomes $(\varphi_1^*/\varphi_2^*) = \Phi \cdot (\varphi_1^{MIN}/\varphi_2^{MIN})$, with $\Phi \equiv [\chi(1-\phi\chi)/(\chi-\phi)]^{(1/k)} > 1$ and $\partial\Phi/\partial\phi > 0$. That is, the difference in domestic cutoffs (and, hence, in welfare) is larger with trade than under autarky, and is increasing in the level of trade openness.

The reason is that the technological difference leads to a competitive advantage for the firms from the leading country: Since the market in country 1 has tougher selection, it is more difficult for firms from country 2 to export to the market in 1 than vice versa. This, in turn, reduces the incentives for entry in country 2 and leads to looser selection in that market, which even boosts the expected exporting profits for firms from country 1. The freer trade is, the more important are these considerations, and the stronger is the endogenous welfare difference for a given exogenous disparity in φ_r^{MIN} across countries.

4.5 Basic research investments without spillovers

We now turn to the analysis of endogenous basic research investments among two identically large countries (with $L_1 = L_2 = 1$). The tax revenue and public expenditure level in country r is denoted by T_r. Analogous to the closed economy case, the amount of basic research is given by $H(T_r)$ with $H(0) = 0$, $H' > 0$ and $H'' < 0$. We assume in this section that there are no spillovers across countries. That is, the research conducted in country r does *not* affect the technological potential of the other country s, or vice versa. The technological potential in country r is consequently described by $\varphi_r^{MIN} = \exp\{H(T_r)\}$.

4.5.1 Nash-equilibrium

We first consider the scenario where both countries set their public research investments non-cooperatively. Taking into account (4.12) and the lump-sum taxes, welfare in country r can be written as follows:

$$V_r = 1 - T_r + \beta \cdot \ln \varphi_r^* + \kappa_1 = 1 - T_r + \beta \cdot \ln\left(\varphi_r^{MIN}\right) + \frac{\beta}{k} \cdot \ln\left(\frac{\hat{\chi}_r}{\hat{\chi}_r - \phi}\right) + \kappa_3, \quad (4.13)$$

where $\kappa_3 = \kappa_1 + \beta \ln \Gamma + \frac{\beta}{k} \ln(1-\phi^2)$ is a constant and $\hat{\chi}_r = \left(\varphi_s^{MIN}/\varphi_r^{MIN}\right)^k$ is a measure of the relative technological potential of country r, with $\hat{\chi}_r > \phi$ to ensure $\varphi_r^* > 0$ for $r = 1, 2$. The condition for a welfare optimum is given by:

$$\frac{\partial V_r}{\partial T_r} = -1 + \beta H'(T_r) + \frac{\phi\beta H'(T_r)}{\left(\exp\{H(T_s) - H(T_r)\}\right)^k - \phi} = 0. \quad (4.14)$$

There exists a symmetric Nash-equilibrium where both countries set the same tax rate $T_r = T_s = T$. In that case, (4.14) simplifies to:

$$\frac{\partial V}{\partial T} = -1 + \beta H' + \underbrace{\frac{\phi}{(1-\phi)}\beta H'}_{\text{trade effect}} = 0. \tag{4.15}$$

Using (4.15) we can disentangle the different effects of higher research investments on welfare. First, the required lump-sum taxes imply a marginal cost equal to unity. Second, the investments increase the own technological potential, which tends to raise the domestic cutoff and average productivity as well as welfare. This is the marginal benefit $\beta H'$ that we have already discussed in the closed economy case. Finally, there is a new "trade effect", $\phi\beta H'/(1-\phi)$, which depicts the marginal effect of the research investments on the *relative* technological potential of the two countries. As discussed above, a higher relative technological potential is beneficial for country r, as it leads to a competitive advantage for domestic firms relative to their competitors from the other country s. This mirrors the strategic incentive for governments to invest into basic research. The higher the trade openness ϕ is, the greater is the governments' incentive to give domestic firms this competitive advantage. Trade liberalization thus increases the research investments in the Nash-equilibrium. To see this analytically, define $\zeta = \beta H'/(1-\phi) - 1$ and use the implicit function theorem to obtain:

$$\frac{\partial T}{\partial \phi} = -\frac{\partial \zeta}{\partial \phi}\left(\frac{\partial \zeta}{\partial T}\right)^{-1} = -\frac{H'}{(1-\phi)\,H''} > 0. \tag{4.16}$$

We can hence state the following result:

Proposition 3 *i) The tax and public research expenditure in the open economy Nash-equilibrium with two identical countries, T^*, is higher than under autarky. ii) Trade liberalization leads to higher taxes and public research expenditure T^*.*

To illustrate proposition 3, consider again the example where $H_r = \sqrt{T_r}$. We then have $H' = 1/\left(2\sqrt{T}\right)$, and solving (4.15) which reads as $H' = (1-\phi)/\beta$, leads to $T^* = \beta^2/(4(1-\phi)^2)$ in the Nash-equilibrium, which is larger than T^*_{AUT} derived above.

4.5.2 Cooperative policy

Now consider the scenario where the countries cooperatively set their policies. Given the quasi-linear preferences with identical marginal utility of income, joint welfare can be

precisely measured by a utilitarian social welfare function. Joint welfare Ω is given by:

$$\Omega = V_1 + V_2 = 2 - T_1 - T_2 + \beta \ln \varphi_1^{MIN} + \beta \ln \varphi_2^{MIN} + \frac{\beta}{k} \cdot \ln \left[\frac{\hat{\chi}_1 \hat{\chi}_2}{(\hat{\chi}_1 - \phi)(\hat{\chi}_2 - \phi)} \right] + 2\kappa_3, \quad (4.17)$$

where the interaction term in squared parentheses encapsulates the cross-country externalities of the research investments. The condition for a welfare optimum is given by

$$\frac{\partial \Omega}{\partial T_r} = -1 + \beta H'(T_r) + \frac{\phi \beta H'(T_r)}{(\exp\{H(T_s) - H(T_r)\})^k - \phi} - \frac{\phi \beta H'(T_r)}{(\exp\{H(T_r) - H(T_s)\})^k - \phi} = 0$$

for $r = 1, 2$. Imposing $T_1 = T_2 = T$ due to symmetry, the last two terms on the right hand side of this equation just cancel out, so that the simplified first-order condition for the cooperative policy simply reads as

$$\frac{\partial \Omega}{\partial T} = -1 + \beta H' = 0. \quad (4.18)$$

We can hence state

Proposition 4 *Consider two identical open economies that cooperatively set their basic research investments. Without cross-country spillovers the cooperative policy is equivalent to the policy that each country would choose under autarky.*

A comparison of propositions 3 and 4 directly implies that the Nash-equilibrium policy is characterized by over-investments into basic research from a social perspective, and that trade liberalization exacerbates this problem. The reason is that every government tries to give domestic firms a competitive advantage in trade, but the effects of the own research investments are just offset by the impact of the foreign investments. When coordinating the research expenditures, those negative cross-country externalities are internalized. With policy coordination the average productivity of firms is thus lower than in the Nash-equilibrium, but this is optimal since the excessively high research investments in the non-cooperative scenario imply too little consumption of the homogenous good.

4.6 Basic research investments with spillovers

We now turn to the analysis where the basic research conducted in one country *does* affect the technological potential of the other country. We assume that the technological potential in country r is described by $\varphi_r^{MIN} = \exp\{H(T_r) + \phi \cdot F(T_s)\}$, where the amount of basic research in the foreign country s is given by $F(T_s)$. Analogously as before we assume that $F(0) = 0, F' > 0$ and $F'' < 0$. Notice that the strength of the spillover depends on the level of trade openness, ϕ, which we consider to be a broad measure of

the level of economic integration between the two countries.[9]

4.6.1 Nash-equilibrium

Considering first the non-cooperative policy determination, the necessary condition for a welfare maximum can now be written as

$$\frac{\partial V_r}{\partial T_r} = -1 + \beta H'(T_r) + \frac{\phi\beta H'(T_r) - \phi^2\beta F'(T_r)}{\left(\exp\left\{H(T_s) - H(T_r) + \phi F(T_r) - \phi F(T_s)\right\}\right)^k - \phi} = 0. \quad (4.19)$$

There exists a symmetric Nash-equilibrium policy where both countries set the same tax rate $T_r = T_s = T$, in which case (4.19) simplifies to

$$\frac{\partial V}{\partial T} = -1 + \overbrace{\frac{1}{(1-\phi)}\beta H' - \underbrace{\frac{\phi^2}{(1-\phi)}\beta F'}_{\text{spillover effect}}}^{\text{marginal benefit}} = 0. \quad (4.20)$$

It follows from (4.20) that the marginal benefit is composed of two terms, i) the term $\beta H'/(1-\phi)$ that is already known from the case without spillovers (see section 4.1), and the new "spillover effect". Both terms increase in trade openness but have opposite signs. Comparing (4.20) with (4.15), it immediately follows that the Nash-equilibrium expenditure T^* is lower with direct cross-country spillovers than without it. The reason is that the competitive advantage for domestic firms is smaller when foreign entrepreneurs also benefit from the domestic public research expenditure.[10]

With higher trade openness this "free rider" problem becomes more severe, which dampens the government incentive to invest. On the other hand, freer trade raises the term $\beta H'/(1-\phi)$ which tends to increase the Nash-equilibrium expenditure. The question is thus if trade liberalization leads to an overall increase or decrease of T^* when direct cross-country spillovers play a role. To address this question, let $\Delta \equiv H' - F'$. One would typically expect that domestic research expenditure has a stronger impact on the domestic than on the foreign technological potential, i.e., $\Delta > 0$. We refer to this case as the "weak spillover" scenario. For this case it is straightforward to show that the Nash-equilibrium expenditure level is increasing in ϕ. Define $\zeta = \frac{\beta}{1-\phi}H' - \frac{\beta\phi^2}{1-\phi}F' - 1$ and use the implicit function theorem to obtain:

$$\frac{\partial T}{\partial \phi} = \frac{\partial \zeta}{\partial \phi}\left(\frac{\partial \zeta}{\partial T}\right)^{-1} = \frac{H' + (-2+\phi)\phi F'}{(1-\phi)(\phi^2 F'' - H'')} = -\frac{H'(1-\phi^2) + \Delta(2-\phi)\phi}{(1-\phi)(1-\phi^2)H''}. \quad (4.21)$$

[9] See Adams (1990), Jaffe (1989) and Branstetter (2001) for empirical evidence that knowledge spillovers (e.g. from patent citations) exhibit a rapid spatial decay, but flow more rapidly across ecomically well integrated areas.

[10] This parallels the well known result that single firms have lower incentives to invest into R&D when there are direct spillovers to other firms, see Spence (1984) as a seminal reference.

This term is unambiguously positive with $\Delta > 0$. Nevertheless, there may be instances where domestic research investments have a stronger impact on the foreign than to the home country.[11] For situations like this we have $\Delta < 0$ and refer to it as the "strong spillover" case. Solving $\partial T/\partial\phi = 0$ for ϕ leads to $\bar{\phi} = 1 - \sqrt{-\Delta/F'}$ with $\bar{\phi} < 1$ if $\Delta < 0$. The Nash-equilibrium expenditure level T^* is increasing (decreasing) in ϕ if the level of trade openness is below (above) $\bar{\phi}$. In other words, there is a hump-shaped pattern between ϕ and T^* when $\Delta < 0$, and the downward-sloping range starts earlier the stronger the spillover is (the lower Δ is). Summing up, we can state the following result:

Proposition 5 *i.) For any given ϕ the Nash-equilibrium research expenditure, T^*, is lower with direct cross-country spillovers than without it. ii.) Trade liberalization increases T^* if spillovers are weak. iii.) In the case of strong spillovers, trade liberalization first leads to an increase and then to a decrease of T^*.*

To illustrate this result, suppose that $H = \sqrt{T}$ and $F = s\sqrt{T}$, where s denotes the strength of the spillover. With $0 < s < 1$ we have a weak, and with $s > 1$ we have a strong spillover. Solving (4.20) yields $T^* = \frac{\beta^2\left(1-s\phi^2\right)^2}{4(1-\phi)^2}$, which achieves a global maximum at $\phi = \sqrt{1/s}$. Hence, there only exists a maximum for T^* in the admissible range $0 < \phi < 1$ if $s > 1$, while T^* is monotonically increasing in ϕ for all $s < 1$.

4.6.2 Cooperative policy

Finally, turning to the cooperative policy determination for the case with direct cross-country spillovers, it follows from (4.17) that the condition for a welfare optimum now reads as

$$\frac{\partial\Omega}{\partial T_r} = -1 + \beta H'(T_r) + \frac{\phi\beta H'(T_r) - \phi^2\beta F'(T_r)}{\exp\{\cdot\} - \phi} + \frac{\phi\beta F'(T_r) - \phi\beta H'(T_r)\exp\{\cdot\}}{1 - \exp\{\cdot\}\phi} = 0, \tag{4.22}$$

for $r = 1, 2$, where the argument of the exponential function is suppressed to simplify notation and is given by $\exp\{\cdot\} = \exp\{k(H(T_s) - H(T_r) + \phi F(T_r) - \phi F(T_s))\}$. Imposing $T_r = T_s = T$ due to symmetry, this expression simplifies to

$$\frac{\partial\Omega}{\partial T} = -1 + \beta H' + \beta\phi F' = 0. \tag{4.23}$$

Define $\zeta = \beta H' + \beta\phi F' - 1$ and use the implicit function theorem to derive $\partial T^{opt}/\partial\phi = -F'/(\phi F'' + H'') > 0$. We hence have

[11] What we have in mind here are small countries like Hong Kong with a strong inflow of Chinese and other foreign students. Depending on the degree of economic integration, research investments in Hong Kong may actually lead to stronger effects in those foreign countries than in Hong Kong itself.

Proposition 6 *Consider two identical open economies that cooperatively set their basic research investments. With direct cross-country spillovers, trade liberalization leads to a higher optimal research expenditure T^{opt}.*

The reason is that investments not only improve the domestic technological potential, but they now also generate a positive externality for the foreign entrepreneurs. The latter effect is stronger the higher the level of trade openness is. In comparison to the Nash-equilibrium policy, the spillover thus does not dampen the incentive to invest. Exactly the opposite it true. Due to the positive externality, the optimal research expenditure level is actually higher with than without spillovers. To compare the cooperative with the Nash-equilibrium policy, we can rewrite the first-order conditions (4.20) and (4.23) as follows:

$$\frac{\partial V}{\partial T} = -1 + \beta H' + \beta\phi F' + \frac{\phi}{1-\phi}\beta\Delta = 0 \quad \text{and} \quad \frac{\partial \Omega}{\partial T} = -1 + \beta H' + \beta\phi F' = 0.$$

Those expressions differ only in the last term of $\partial V/\partial T$. The sign of this term depends on Δ, i.e., on whether the spillover is weak or strong. If the spillover is weak (strong), the public research expenditure in the Nash-equilibrium, T^*, is higher (lower) than the optimal expenditure level, T^{opt}. Summing up, we have

Proposition 7 *i.) The Nash-equilibrium is characterized by over-investments into basic research if the direct cross-country spillover is weak, $T^* > T^{opt}$ with $\Delta > 0$. ii.) When the spillover is strong, there are too little basic research investments from a social perspective in the Nash-equilibrium, $T^* < T^{opt}$ with $\Delta < 0$.*

This result represents the interplay between two cross-country externalities. Domestic basic research hurts the foreign entrepreneurs as it gives domestic firms a competitive advantage in trade. On the other hand there is a positive impact on the foreign technological potential. Depending on which impact dominates there is either a net over-investment or a net under-investment problem from a social perspective, and proposition 7 shows that the latter arises when the spillover is strong.

4.7 Conclusion

In this paper we have developed a two-country model with heterogeneous firms where governments can invest into basic research. These public research investments improve the country's technological potential and thereby benefit domestic entrepreneurs who start up a business. They do not equally benefit all domestic firms from an ex post perspective, however, since firms are still exposed to idiosyncratic risks of business failure. There are two motives for this public research policy. First, the benevolent motive

(present already in an autarky scenario) is to tighten firm selection which in turn raises the average productivity of firms in the market, decreases the average price, and ultimately benefits consumers. Second, there is a strategic motive in an open economy setting, as firms obtain a competitive advantage in trade when the domestic country has a higher technological potential. Due to this strategic motive, countries invest too much from a social perspective, so that there are welfare gains from coordinating public research investments. This over-investment problem only disappears, and turns to an under-investment problem, when there are sufficiently strong direct spillovers of research investments across countries.

We observe in the data that most OECD countries have increased public research spending over the last ten years. Our model provides a possible theoretical rationale for this empirical observation. The recent decade was certainly characterized by falling trade barriers and a deepening of globalization. The model predicts that this tendency of higher trade freeness raises the strategic incentives for governments to invest into basic research, and it is thus well consistent with the stylized facts. From a normative perspective, however, it is unclear if this tendency is welfare improving. Our model predicts that global competition induces single countries to over-invest into basic research, and trade liberalization tends to exacerbate this problem.

However, in practice further trade liberalization probably also leads to a stronger diffusion of basic knowledge across countries. That is, cross-country knowledge spillovers may also become more important as globalization proceeds. These spillovers have two basic consequences: They lower the incentives for single countries to invest due to a standard free rider problem, but they also tend to reduce the over-investment problem. From a policy perspective, the optimal regime seems to be one where countries coordinate their research investments in order to internalize cross-country externalities, and where they also try to foster the cross-country diffusion of the knowledge created in those coordinated public research efforts.

4.8 Appendix

Appendix: Open Economy Model

Equilibrium Firm Masses in the Open Economy

Aggregate earnings in the manufacturing sector must equal aggregate revenue of manufacturing firms in each country, $\gamma_r = M_r \bar{r}_r$, where $\bar{r}_r = r_r(\widetilde{\varphi}_r) + p_{xr} r_{xr}(\widetilde{\varphi}_{xr})$. This yields $M_r = \gamma_r / \bar{r}_r$ for $r = 1, 2$. Plugging these terms into the aggregate trade balance condition for country 1, $M_1 p_{x1} r_{x1}(\widetilde{\varphi}_{x1}) = M_2 p_{x2} r_{x2}(\widetilde{\varphi}_{x2}) + (1-\beta) - (1-\gamma_1)$, and into the analogous trade balance condition for country 2 yields:

$$\frac{\gamma_1}{1+b_1} = \frac{\gamma_2}{1+b_2} + \gamma_1 - \beta \qquad \frac{\gamma_2}{1+b_2} = \frac{\gamma_1}{1+b_1} + \gamma_2 - \beta, \tag{A1}$$

where

$$b_1 = \frac{r_1(\widetilde{\varphi}_1)}{p_{x1} r_{x1}(\widetilde{\varphi}_{x1})} = \frac{\tau^{\sigma-1}}{p_{x1}} \left(\frac{\widetilde{\varphi}_1 \varphi_2^*}{\varphi_1^* \widetilde{\varphi}_{x1}} \right)^{\sigma-1} = \frac{1}{\phi} \left(\frac{\varphi_2^*}{\varphi_1^*} \right)^k = \frac{1}{\phi} \left(\frac{\chi - \phi}{1 - \phi\chi} \right)$$

$$b_2 = \frac{r_2(\widetilde{\varphi}_2)}{p_{x2} r_{x2}(\widetilde{\varphi}_{x2})} = \frac{\tau^{\sigma-1}}{p_{x2}} \left(\frac{\widetilde{\varphi}_2 \varphi_1^*}{\varphi_2^* \widetilde{\varphi}_{x2}} \right)^{\sigma-1} = \frac{1}{\phi} \left(\frac{\varphi_1^*}{\varphi_2^*} \right)^k = \frac{1}{\phi} \left(\frac{1 - \phi\chi}{\chi - \phi} \right).$$

Solving (A1) for γ_r yields:

$$\gamma_1 = \beta \frac{(1+b_1)(1-b_2)}{1-b_1 b_2} \qquad \gamma_2 = \beta \frac{(1-b_2)(1-b_1)}{1-b_1 b_2}, \tag{A2}$$

and plugging in b_1 and b_2 then leads to the expressions given in (4.11). To ensure that $0 < \gamma_r \leq 1$ for $r = 1, 2$ we need to impose the following parameter restrictions:

$$0 < \beta < \beta_{max} \equiv \frac{(\chi - \phi)(1 - \phi\chi)}{\chi(1 + \phi^2 - 2\phi\chi)} \quad \text{and} \quad \frac{2\phi}{(1+\phi^2)} < \chi < 1. \tag{A3}$$

The conditions in (A3) require that the per-capita manufacturing expenditure, β, is sufficiently small, and they put an even stricter limit on the degree of asymmetry, χ, relative to the level of trade openness, ϕ, than the previously mentioned condition $\phi < \chi$, which is automatically satisfied when (A3) holds. Using $M_r = \gamma_r / \bar{r}_r$ and γ_1, γ_2 then yields the masses of entrants, surviving firms, and exporting firms for both countries:

$$M_1^E = \frac{\delta M_1}{\left(\varphi_1^{MIN} / \varphi_1^*\right)^k} = \frac{(\sigma-1)\beta}{\sigma k f_e} \frac{\chi(1 + \phi^2 - 2\phi\chi)}{(\chi - \phi)(1 - \phi\chi)} \tag{A4}$$

$$M_2^E = \frac{\delta M_2}{\left(\varphi_2^{MIN} / \varphi_2^*\right)^k} = \frac{(\sigma-1)\beta}{\sigma k f_e} \frac{(\chi(1+\phi^2) - 2\phi)}{(\chi - \phi)(1 - \phi\chi)}$$

$$M_1 = \frac{\gamma_1}{\sigma(\bar{\pi}_1 + f + p_{x1} f_x)} = \frac{(k + 1 - \sigma)\beta}{\sigma k f} \frac{1 + \phi^2 - 2\phi\chi}{(1 - \phi^2)(1 - \phi\chi)} \tag{A5}$$

$$
\begin{aligned}
M_2 &= \frac{\gamma_2}{\sigma\left(\bar{\pi}_2 + f + p_{x2} f_x\right)} = \frac{(k+1-\sigma)\,\beta}{\sigma k f} \frac{\left(\chi\left(1+\phi^2\right) - 2\phi\right)}{\left(1-\phi^2\right)(\chi-\phi)} \\
M_{x1} &= \left(\frac{\varphi_1^*}{\Lambda \varphi_2^*}\right)^k M_1 = \frac{(k+1-\sigma)\,\beta}{\sigma k f_x} \frac{\phi\left(1+\phi^2-2\phi\chi\right)}{\left(1-\phi^2\right)(\chi-\phi)} \\
M_{x2} &= \left(\frac{\varphi_2^*}{\Lambda \varphi_1^*}\right)^k M_2 = \frac{(k+1-\sigma)\,\beta}{\sigma k f_x} \frac{\phi\left(\chi\left(1+\phi^2\right)-2\phi\right)}{\left(1-\phi^2\right)(1-\phi\chi)}
\end{aligned}
\tag{A6}
$$

From these expressions, the mass of firms active in country r, $M_{tr} = M_r + M_{xs}$, (i.e., consumption variety) can then be easily obtained.

Proof of Proposition 2

Consider the scenario in which country 1 has a higher technological potential than country 2, i.e., $\varphi_1^{MIN} > \varphi_2^{MIN}$. Under the parameter restrictions (A3) we can show that:

$$
(i) \quad \frac{M_1^E}{M_2^E} = \frac{\chi\left(1+\phi^2-2\phi\chi\right)}{\chi+\phi(\phi\chi-2)} > 1 \tag{A7}
$$

$$
(ii) \quad \frac{M_1}{M_2} = \frac{(\chi-\phi)\left(1+\phi^2-2\phi\chi\right)}{(1-\phi\chi)(\chi+\phi(\phi\chi-2))} > 1 \tag{A8}
$$

$$
(iii) \quad \frac{M_{x1}}{M_{x2}} = \frac{(1-\phi\chi)\left(1+\phi^2-2\phi\chi\right)}{(\chi-\phi)(\chi+\phi(\phi\chi-2))} > 1 \quad \text{and} \tag{A9}
$$

$$
\frac{p_{x1}}{p_{x2}} = \frac{(1-\phi\chi)^2}{(\chi-\phi)^2} > 1
$$

$$
(iv) \quad \frac{M_{t1}}{M_{t2}} = \frac{(\chi-\phi)\left(f_x\left(1+\phi^2-2\phi\chi\right)+f\phi(\chi+\phi(\phi\chi-2))\right)}{(1-\phi\chi)\left(f\phi\left(1+\phi^2-2\phi\chi\right)+f_x(\chi+\phi(\phi\chi-2))\right)} > 1. \tag{A10}
$$

Furthermore, since the relative cutoff productivities can be written as follows:

$$
\frac{\varphi_1^*}{\varphi_2^*} = \Phi \cdot \frac{\varphi_1^{MIN}}{\varphi_2^{MIN}} \qquad \text{with} \quad \Phi \equiv \left[\chi(1-\phi\chi)/\left(\chi-\phi\right)\right]^{(1/k)} > 1, \tag{A11}
$$

it follows directly that (v) $\tilde{\varphi}_1/\tilde{\varphi}_2 = \Phi \cdot \left(\varphi_1^{MIN}/\varphi_2^{MIN}\right) > 1$, (vi) $\tilde{\varphi}_{t1} > \tilde{\varphi}_{t2}$, since $\tilde{\varphi}_1 > \tilde{\varphi}_2$ and $\tilde{\varphi}_{x2} > \tilde{\varphi}_{x1}$, and (vii) $V_1 > V_2$, since V_r is proportional to φ_r^*.

Chapter 5

Trade, Wages, FDI and Productivity

5.1 Abstract

We extend the Behrens et al. (2009) general equilibrium heterogeneous firms framework by horizontal foreign direct investment. The model features endogenously determined firm entrants, wages, productivity cutoffs, flexible price markups and allows for wage differentials across countries in equilibrium. The framework is especially suitable to analyze the welfare consequences of attracting FDI since it allows to study through which channels FDI might raise welfare - including the not yet explored impact on the wage differential and the price markups. From a policy perspective we compare a strategic and a cooperative FDI policy scenario and find that supranational coordination leads to welfare gains.

5.2 Introduction

The growth of foreign direct investment (FDI) has been one of the major trends in the global economy for decades. As the World Investment Directory of the UNCTAD in 2002 reports, the world FDI stock has increased to over $7 trillion in 2002, which is about ten times the level of 1985. The tremendous expansion in worldwide FDI outflows since the mid-1980s was so remarkable that it outpaced the growth in the worldwide gross domestic product, domestic investments and even exports. According to the data, the sales of all FDI firms in 2001 are about $18 trillion, whereas the sales of all exporting firms amount to only $7 trillion. The empirical stylized facts about the growth of FDI go hand in hand with policy interventions that promote FDI. As reported in UNCTAD (2003) politicians try to attract FDI with tax holidays, job-creation or facility subsidies. Politicians do so, since they typically assume positive welfare effects of FDI. The arguments given are that FDI-liberalization leads to industry knowledge spillovers or technology transfers and lower consumer prices due to cross-border transport cost savings. Although the positive welfare arguments in favor of FDI are predominant, UNCTAD (2001) also notes that "assessing the consequences of promoting FDI for national welfare is a big task [...]."

We contribute to this discussion by constructing a rich general equilibrium framework and call into question, whether promoting FDI is able to raise welfare, and if so, through what channels. In order to examine this question we develop a general equilibrium model of international trade with heterogeneous firms that differ in their marginal labor requirement. Those heterogeneous firms choose, conditional on their productivity, whether to serve their domestic market and/or a foreign market either through exports or horizontal greenfield FDI. Our framework is especially suitable to analyze the welfare consequences of attracting FDI since it features endogenously determined firm entrants, wages and productivity cutoffs. In particular, it allows for wage differentials across countries in equilibrium and flexible price markups. Such a "rich" general equilibrium framework with

heterogeneous firms and FDI has, to the best of our knowledge, not been established yet.

The focus of our paper is to study the welfare effects of FDI-liberalization. Along the lines of Chor (2009) we examine a country's incentive to lower the fixed costs of FDI. We distinguish between two policy scenarios. In the strategic FDI policy scenario, a country chooses the welfare maximizing degree of FDI-liberalization, taking the FDI policy in the other country as given. In the cooperative scenario both countries jointly choose the total welfare maximizing degree of FDI-liberalization. In the strategic FDI policy scenario we find that a country has an incentive to unilaterally attract FDI. The intuition is that lower fixed costs of FDI lead to a greater mass of consumed varieties and a lower normed average price (which is the average price over the choke price). Both effects unambiguously raise welfare in the FDI attracting country. Conversely, in the other country consumption varieties shrink, the normed average price increases and welfare decreases. This cross-country comparison clearly illustrates the benefits of attracting FDI firms. In the Nash-equilibrium both countries choose a FDI-liberalization policy that brings down fixed costs of FDI to zero.

In the cooperative scenario we find that countries also do have an incentive to lower the fixed costs of FDI, however not down to zero. Compared to the Nash-equilibrium, countries jointly maximize total welfare by choosing a strictly positive level for the fixed costs of FDI. The economic intuition is as follows. FDI-liberalization raises the mass of consumed varieties but does not unambiguously decrease the normed average price. To illustrate this ambiguous price change consider an initial scenario where fixed costs of FDI are prohibitively high. FDI-liberalization now leads to the creation of the first multinational that charges a relatively low price since this firm is highly productive compared to the average domestic firm. However, further reductions in the fixed costs of FDI also induce relatively underproductive firms to become multinationals. As a result, the normed average price increases and FDI-liberalization can actually decrease welfare if the new consumption varieties do not compensate for the higher normed average price.

Comparing the strategic with the cooperative scenario, we can clearly conclude that there are welfare gains from supranational coordination. However, since coordination is difficult to achieve, it is likely that countries over-invest into attracting FDI. For policy makers this is an important result since it implies that besides the indisputable positive aspects of FDI there are also potential welfare losses. Our model also identifies a clear difference between trade- and FDI-liberalization that leads to different policy recommendations. Jointly decreasing variable trade costs unambiguously increase welfare while our model predicts that for the fixed costs of FDI countries should rather commit for a strictly positive level to restrict the mass of multinationals.

5.2.1 Related literature

First, our model is closely related to the seminal contribution on heterogeneous firms by Melitz (2003). His work incorporates heterogeneous firms, i.e. firms that differ in their marginal labor requirement, into the monopolistic competition framework by Krugman (1980). In particular, Melitz shows that trade liberalization leads to a selection effect such that only the most productive firms start exporting, firms with intermediate productivity serve the domestic market only, and the least productive firms exit.[1]

Although the Melitz model has substantially deepened our understanding of intra-industry reallocations, it relies on two restrictive assumptions: factor price equalization (FPE) and constant price markups. The assumption of symmetric countries induces FPE while a constant elasticity of substitution (CES) preference specification implies constant markups. The more recent heterogeneous firms literature has focused to forego either one of those assumptions. Bernard et al. (2003) introduce exogenous wage differences across countries in a Ricardian framework with Bertrand competition. Melitz and Ottaviano (2008) provide a model with endogenous markups, where markups decrease with trade liberalization. Although trade liberalization now leads to pro-competitive effects, the model does not allow for income effects as in Melitz (2003). Behrens et al. (2009) propose a new general equilibrium model of international trade that avoids both of the previous restrictive assumptions. It incorporates heterogeneous firms, endogenously determined firm entrants, wages and productivity cutoffs. Furthermore, the model does not rely on CES but instead uses a variable elasticity of substitution (VES) specification, introduced by Behrens and Murata (2007). Moreover, the model does not feature FPE in equilibrium. It therefore incorporates endogenous wages and flexible markups in which trade integration leads to both income and pro-competitive effects. From a theoretical point of view our model builds up on Behrens et al. (2009) and extends it by introducing horizontal greenfield FDI.

Second, the Melitz model was also influential for the FDI literature. The seminal contribution is provided by Helpman, Melitz and Yeaple (2004). Building up on the original Melitz framework they develop the first general equilibrium model with heterogeneous firms and horizontal FDI as an alternative to exporting. They are able to show that only firms with a relatively high productivity are able to serve a foreign market by exporting and only the most productive firms are able to adopt the FDI strategy. The latest strand of the heterogeneous firms literature is concerned about the welfare effects of

[1]The Melitz framework was motivated by an enormous literature that explored empirical patterns of firms' behavior. Starting from the mid-nineties, Bernard and Jensen (1999) observe that firms serving the foreign market via exporting are larger and exhibit a higher productivity than firms that refrain from foreign trade. Aw et al. (2000) verify that plants with a higher productivity take part in exporting whilst plants with low productivity exit the export market. Mayer and Ottaviano (2007) show that international operating firms are rare, bigger, pay higher wages, generate higher added value and employ more capital per worker. Furthermore, multinationals are on average even more productive than exporting firms.

FDI-liberalization. The important contribution by Chor (2009) analyzes the implications of governments' subsidies to attract FDI. The key result is that a country can raise its welfare by unilaterally introducing a small subsidy. This leads to a consumption gain similar as in our approach. Our model enriches the FDI-liberalization discussion since it allows for additional, potentially welfare increasing channels such as lower price markups or a higher relative wage. Although these arguments are often used in the political discussion, the Chor (2009) model cannot account for these arguments, due to the fact of CES preferences and FPE in equilibrium. Moreover, our approach is also different from a normative perspective. Chor (2009) does not discuss competition among countries for FDI while we focus on that issue and differentiate between a strategic and cooperative policy. As a result, our approach allows the identification of supranational gains from coordination.

The paper is organized as follows. Section 5.3 establishes the model framework while in section 5.4 we discuss the strategic and the cooperative FDI policy regime. Section 5.5 concludes.

5.3 The model

5.3.1 Preferences and demand

In our model, we consider two potentially asymmetric countries. Consumers derive utility from the consumption of a final good which is provided as a continuum of horizontally differentiated varieties. The mass of consumers in country r is denoted by L_r. Let $p_{sr}(i)$ and $q_{sr}(i)$ denote the price and the per capita consumption of variety i when it is produced in country s and consumed in country r. In the following we differentiate between three types of firms: Domestic firms that solely produce for their domestic market, exporters that additionally sell in the foreign market and FDI multinationals. To avoid confusion we note that with respect to consumption varieties in country r, both domestic and FDI firms produce in country r and sell in country r while export varieties are produced in s and consumed in r. Hence, the per capita consumption in country r of a domestic or FDI variety i is denoted by $q_{rr}(i)$ while for an export variety i per capita consumption is denoted by $q_{sr}(i)$. Similar the price of a variety i in country r is denoted by $p_{rr}(i)$ if it is provided by a domestic or FDI firm while the price of an export variety i from country s is given by $p_{sr}(i)$.

The underlying preference structure, established in Behrens and Murata (2007), displays love-for-variety and is the same for all consumers. The utility maximization problem of consumers in country r is given by

$$\max_{q_{sr}(j), j\in\Omega_{sr}} U_r \equiv \sum_s \int_{\Omega_{sr}} \left[1 - \mathrm{e}^{-\alpha q_{sr}(j)}\right] \mathrm{d}j \quad \text{s.t.} \quad \sum_s \int_{\Omega_{sr}} p_{sr}(j) q_{sr}(j) \mathrm{d}j = E_r, \tag{5.1}$$

where E_r denotes expenditure, $\alpha > 0$ is a parameter measuring the strength of love-for-variety and Ω_{sr} denotes the set of varieties produced in country s and consumed in country r. The solution of the maximization problem given in (5.1) yields the following demand functions

$$q_{sr}(i) = \frac{E_r}{N_r^c \overline{p}_r} - \frac{1}{\alpha}\left\{\ln\left[\frac{p_{sr}(i)}{N_r^c \overline{p}_r}\right] + h_r\right\}, \quad \forall i \in \Omega_{sr}, \tag{5.2}$$

where N_r^c is the mass of consumed varieties in country r, and

$$\overline{p}_r \equiv \frac{1}{N_r^c}\sum_s \int_{\Omega_{sr}} p_{sr}(j)\mathrm{d}j \quad \text{and} \quad h_r \equiv -\sum_s \int_{\Omega_{sr}} \ln\left[\frac{p_{sr}(i)}{N_r^c \overline{p}_{sr}}\right]\frac{p_{sr}(j)}{N_r^c \overline{p}_{sr}}\mathrm{d}j \tag{5.3}$$

denote the average price and the differential entropy of the price distribution of all varieties consumed in country r. With the help of (5.2) and (5.3) we can derive the country specific reservation price p_r^d. The demand for variety i in country r will be positive if and only if the price of the respective variety is lower than this reservation price, no matter whether the variety is produced by a domestic firm, a foreign FDI firm or is exported from abroad. Formally,

$$q_{rr}(i) > 0 \quad \Leftrightarrow \quad p_{rr}(i) < p_r^d \quad \text{and} \quad q_{sr}(j) > 0 \quad \Leftrightarrow \quad p_{sr}(j) < p_r^d, \tag{5.4}$$

where the reservation price

$$p_r^d \equiv N_r^c \overline{p}_r \mathrm{e}^{\alpha E_r/(N_r^c \overline{p}_r) - h_r} \tag{5.5}$$

is a function of the price aggregates $\overline{p}_r$ and h_r. Using (5.2) and (5.5), the demands can be expressed as follows

$$q_{rr}(i) = \frac{1}{\alpha}\ln\left[\frac{p_r^d}{p_{rr}(i)}\right] \quad \text{and} \quad q_{sr}(j) = \frac{1}{\alpha}\ln\left[\frac{p_r^d}{p_{sr}(i)}\right]. \tag{5.6}$$

The price elasticity of demand for a variety i, derived from (5.6), is given by $1/[\alpha q_{rr}(i)]$ and $1/[\alpha q_{sr}(i)]$, respectively. Hence, if individuals consume more of any variety (which is e.g. the case if their expenditure increases), they become less price sensitive. With the help of (5.6), the utility function in (5.1) simplifies using $\mathrm{e}^{\alpha q_{sr}(i)} = p_{sr}(i)/p_r^d$ and we can rewrite indirect utility as

$$U_r = N_r^c - \sum_s \int_{\Omega_{sr}} \frac{p_{sr}(j)}{p_r^d}\mathrm{d}j = N_r^c\left(1 - \frac{\overline{p}_r}{p_r^d}\right). \tag{5.7}$$

5.3.2 Technology and market structure

On the firm side, each producer provides one unique final good variety. The only factor used for production is labor, with each consumer supplying one unit of labor. The total

labor force in country r is therefore given by its country size L_r. The labor market is assumed to be characterized by perfect competition such that firms in country r take the wage w_r as given. In order to discover a product variety, firms invest the country's specific fixed costs F_r for research and development (R&D) paid in labor at the market wage. This investment enables the firm to discover its unique variety along with its firms specific marginal labor requirement $m(i) \geq 0$, where a lower $m(i)$ reflects a higher productivity. This productivity is drawn from a country-specific distribution G_r. Besides serving the domestic market, the firm may choose to serve the foreign market either by exporting or greenfield FDI. As will be shown, the decision whether and how to serve the foreign market depends on a firm's productivity draw. Exports from country s to r are subject to iceberg type trade costs $\tau_{sr} > 1$, which incur in terms of labor. Setting up a new production plant in the foreign country r is assumed to increase the fixed costs of production by P_r. Hence, as it is discussed at length in the literature the classical "proximity-concentration" trade-off emerges: FDI saves variable trade costs, while exporting saves additional overhead costs for building up a foreign production plant.

In our model, there are three possible sources for operating profits. First, the operating profits of firm i originated in country s from domestic sales are given by

$$\pi_s^D(i) = L_s q_{ss}(i)\left[p_{ss}(i) - \tau_{ss} m(i) w_s\right]. \tag{5.8}$$

Second, the operating profits from exporting to country r are given by

$$\pi_s^X(i) = L_r q_{sr}(i)\left[p_{sr}(i) - \tau_{sr} m(i) w_s\right]. \tag{5.9}$$

Third, the operating profits for using FDI in country r are given by

$$\pi_s^F(i) = L_r q_{rr}(i)\left[p_{rr}(i) - \tau_{rr} m(i) w_r\right] - m(i) w_r P_r. \tag{5.10}$$

where $q_{ss}(i)$, $q_{sr}(i)$ and $q_{rr}(i)$ in equations (5.8)-(5.10) are given by (5.6). Note that in our specification FDI "fixed" costs decrease in a firm's productivity level. We do so to countervail the fact that the most productive exporters have zero marginal costs in the limit. This implies that also the iceberg type trade costs vanish in the limit. To balance this artifact of iceberg type trade costs, we assume fixed FDI costs dependent on the marginal labor requirement as given by (5.10). Both, the variable trade costs and the fixed FDI costs now decrease with a lower marginal labor requirement. With this assumption, the model exhibits the "classical" ranking that the most productive firms use FDI while the medium productive firms export to foreign markets.[2]

[2] At first sight, a more classical definition of FDI profits would be $\hat{\pi}_s^F(i) = L_r q_{rr}(i)\left[p_{rr}(i) - \tau_{rr} m(i) w_r\right] - w_r P_r$ with fixed costs independent of the productivity level. However, if we consider the most productive firms we get $\lim_{m\to 0} \pi_s^X = \frac{L_r w_r \tau_{rr}}{e\alpha} m_r^D$, $\lim_{m\to 0} \hat{\pi}_s^F = \frac{L_r w_r \tau_{rr}}{e\alpha} m_r^D - P_r w_r$, $\lim_{m\to 0} \pi_s^F = \frac{L_r w_r \tau_{rr}}{e\alpha} m_r^D$. Hence, with the classical definition the most productive firms would use

We assume segmented markets without the possibility of arbitrage or resale. Hence, firms maximize profits with respect to their price $p_{sr}(i)$ separately for each market, taking into account the demand function as given by (5.6). The continuum of firms takes the reservation price p_r^d as given and the first-order condition for (operating) profits are

$$\ln\left[\frac{p_r^d}{p_{sr}(i)}\right] = \frac{p_{sr} - \tau_{sr} m(i) w_s}{p_{sr}(i)}, \quad i \in \Omega_{sr}. \tag{5.11}$$

Using (5.11) we can now show how productivity maps into the firm's price setting, sales revenue and profits.

Lemma 1 *For a given type of firm (domestic, export, FDI), more productive firms i.) charge lower prices, ii.) sell larger quantities and iii.) earn higher operating profits in each market.*

Proof. Using the Lambert W function, defined as $\varphi = W(\varphi)\,\mathrm{e}^{W(\varphi)}$, the first-order condition (5.11) can be solved for the profit-maximizing prices, quantities and operating profits. Those values can be expressed in terms of m, as firms differ only in their marginal labor requirement.[3] For a firm originated in country s they are given by

$$p_{ss}(m) = \frac{\tau_{ss} m w_s}{W_s^D}, \quad q_{ss}(m) = \frac{1}{\alpha}\left(1 - W_s^D\right), \quad \pi_s^D = \frac{L_s \tau_{ss} m w_s}{\alpha} \frac{\left(1 - W_s^D\right)^2}{W_s^D}, \tag{5.12}$$

$$p_{sr}(m) = \frac{\tau_{sr} m w_s}{W_s^X}, \quad q_{sr}(m) = \frac{1}{\alpha}\left(1 - W_s^X\right), \quad \pi_s^X = \frac{L_r \tau_{sr} m w_s}{\alpha} \frac{\left(1 - W_s^X\right)^2}{W_s^X}, \tag{5.13}$$

$$p_{rr}(m) = \frac{\tau_{rr} m w_r}{W_s^F}, \quad q_{rr}(m) = \frac{1}{\alpha}\left(1 - W_s^F\right), \quad \pi_s^F = \frac{L_r \tau_{rr} m w_r}{\alpha} \frac{\left(1 - W_s^F\right)^2}{W_s^F} - m w_r P_r, \tag{5.14}$$

where we suppressed the arguments of the Lambert W function in order to alleviate notation.[4] The arguments are given by

$$W_s^D = W\left(\frac{\mathrm{e}\tau_{ss} m w_s}{p_s^d}\right), \quad W_s^X = W\left(\frac{\mathrm{e}\tau_{sr} m w_s}{p_r^d}\right) \quad \text{and} \quad W_s^F = W\left(\frac{\mathrm{e}\tau_{rr} m w_r}{p_r^d}\right) \tag{5.15}$$

Since $W' > 0$, we readily obtain $\partial p/\partial m > 0$, $\partial q/\partial m < 0$ and $\partial \pi/\partial m < 0$. ■

An important issue in the heterogeneous firms literature is to determine the so-called cutoff productivity for each market. A firm with a lower productivity as the respective cutoff productivity would set a price above the reservation price and would therefore face zero demand. Hence, serving this market is not profitable. To derive the cutoff

exporting instead of FDI. See also Behrens and Ottaviano (2009) for a related problem within an FDI extension of the Melitz and Ottaviano (2008) framework.¸

[3]See Corless et al. (1996) for a survey concerning the properties of the Lambert W function.

[4]It is shown by Behrens et al. (2009) that $W' > 0$ increases for all non-negative arguments and that $W(0) = 0$ and $W(\mathrm{e}) = 1$. Hence, $0 \leq W \leq 1$ if and only if $0 \leq m \leq m^D$.

productivity we need the sales quantity of a firm, conditional on its productivity. Using (5.6) and (5.11) the sales quantity is given by

$$q_{sr}(i) = (1/\alpha)\left[1 - \tau_{sr} m(i) w_s / p_{sr}(i)\right]. \tag{5.16}$$

The sales quantity given by (5.16) helps us to determine the maximum output of a firm, which is given by $q_{sr}(i) = 1/\alpha$ for a firm with the highest productivity draw $m = 0$. Contrary, the upper bound for m is given by the minimum output $q_{sr}(i) = 0$ at $p_{sr}(i) = \tau_{sr} m(i) w_s$. It then follows from (5.11) that $p_r^d = \tau_{sr} m(i) w_s$.

For domestic firms, this gives their cutoff marginal labor requirement, defined as $m_s^D \equiv p_s^d / w_s \tau_{ss}$. A domestic firm that draws m_s^D is indifferent between producing and not producing, whereas only firms with a draw below m_s^D remain active in the market. For exporters, this condition tells us that a firm located in s with a productivity draw $m_{sr}^x \equiv p_r^d / (\tau_{sr} w_s)$ is just indifferent between selling and not selling in country r via exporting. All firms in s with productivity draws below m_{sr}^x are productive enough to export to country r. In what follows, we refer to $m_{rr}^x \equiv m_r^D$ as the *domestic cutoff* in country r, whereas $m_{sr}^x \equiv m_s^X$ with $s \neq r$ is the *export cutoff*. Export and domestic cutoffs are linked as follows

$$m_s^X = \frac{\tau_{rr}}{\tau_{sr}} \frac{w_r}{w_s} m_r^D. \tag{5.17}$$

It is now clear from expression (5.17) that the "classical" ranking, namely that exporting requires a higher productivity than selling domestically, does not necessarily hold anymore. The usual ranking only prevails if and only if $\tau_{rr} w_r < \tau_{sr} w_s$. An example for that case would be if wages are equalized ($w_s = w_r$) and internal trade is costless while trade between countries is costly.

We cannot use (5.16) to determine the FDI cutoff for two reasons. First, the profit maximizing quantity does not secure positive profits for FDI firms due to the fixed costs P_r. Second, FDI will not be chosen as soon as exporting is the more profitable strategy. Therefore, we need to determine the productivity level above which a firm would choose FDI instead of exporting. As it can be seen by Figure 5.1, firms will choose exporting over FDI for a productivity draw $m > m_s^T$ since the transport cost savings do not compensate for the fixed costs of FDI.[5] For this we have to compare FDI versus export profits, conditional on the productivity draw. Therefore, the *FDI cutoff* m_s^T is the solution of $\pi_s^F(m_s^T) = \pi_s^X(m_s^T)$. However, we cannot solve for m_s^T in general and have to rely

[5]It remains to show that m_s^T exists (in the positive range) and is unique. First, from $m_s^T > 0$ it directly follows that $\partial \pi_s^F / \partial m < \partial \pi_s^X / \partial m$, i.e. profits increase stronger with a higher productivity for FDI than for exporting in the domain of $m > m_s^T$. Due to the fact that we have iceberg type trade costs a higher productivity also leads to a vanishing of trade costs and we have $\partial \pi_s^F / \partial m > \partial \pi_s^X / \partial m$ for very high productivities (m close to zero). Second, there might exist a second threshold. We can ensure that this threshold is the corner solution at $m = 0$ from (5.13) and (5.14). Now we can conclude that the threshold m_s^T is unique. Firms with a productivity draw $m < m_s^T$ ($m > m_s^T$) consistently choose FDI (exporting) over exporting (FDI).

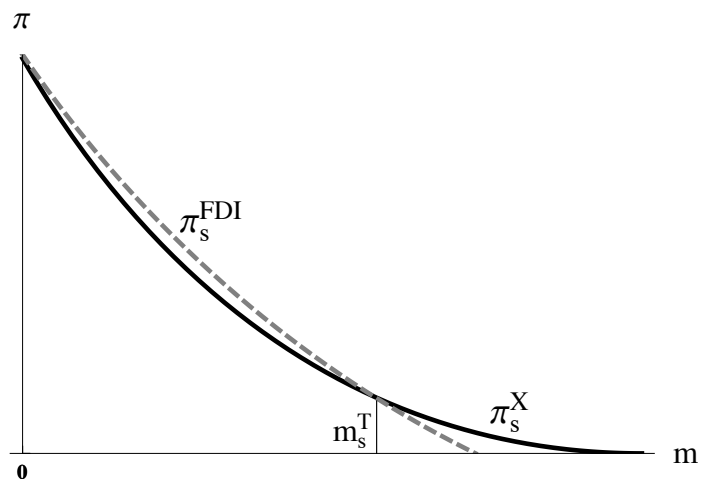

Figure 5.1: Export and FDI profits conditional on the marginal labor requirement m.

on numerical methods.[6] Using this information about the cutoff productivities, we can reconsider the mass of firms. Given a mass of entrants N_s^E and export cutoffs m_{sr}^X (recall that $m_{ss}^X = m_s^D$) as in (5.17), only $N_s^p = N_s^E G_s (\max\{m_{sr}^x\})$ firms survive in country s, namely those which are productive enough to sell at least in one market (which does not have to be the local market).[7] Furthermore, we can determine the mass of varieties consumed in country s as

$$N_s^c = \sum_r N_r^E G_r (m_{rs}^x), \tag{5.18}$$

which is the sum of all firms that are productive enough to serve market s. Multiplying both sides of (5.11) by $p_{rs}(i)$, integrating over Ω_{sr} and summing the resulting expressions across s, the average price across all varieties sold in market r can be written as

$$\overline{p}_s \equiv \frac{1}{N_s^c} \sum_r \int_{\Omega_{rs}} p_{rs}(j)\,\mathrm{d}j = \frac{1}{N_s^c} \sum_r \tau_{rs} w_r \int_{\Omega_{rs}} m_r(j)\,\mathrm{d}j + \frac{\alpha E_s}{N_s^c}, \tag{5.19}$$

where the first term is the average marginal delivered costs, and the second term is the average markup in the market s. Expression (5.19) shows that the average markup is decreasing in the mass N_s^c of firms competing in country s and increasing in expenditure E_s. Hence, similar to Melitz and Ottaviano (2008), the average price displays a pro-competitive effect for a greater mass of firms. Furthermore, the average markup rises with expenditure because demand becomes less price elastic for larger quantities.

[6] We cannot solve for m_s^T since the Lambert W function has different arguments, see Corless et al. (1996).

[7] Since $m_s^T < m_s^X$ we do not need to consider FDI firms for this reasoning.

5.3.3 Equilibrium

The equilibrium of our model is characterized by the mass of entrants N_s^E, the domestic cutoff m_s^D in each country and the relative wage $\omega \equiv \omega_s/\omega_r$ between the two countries. Those determinants are derived by solving the zero expected profit condition, the labor market clearing condition and the current account balance.

In the Appendix we state the general equilibrium conditions without assuming a specific assumption about the productivity distribution. In what follows, we adopt the commonly made assumption that firms' productivity draws follow a Pareto distribution.[8] We assume identical shape parameters $k \geq 1$, but to capture differences in technological possibilities, we allow the upper bounds to vary across countries, i.e. $G_s(m) = (m/m_s^{max})^k$. A lower m_s^{max} implies that firms in country s have a higher probability of drawing a better productivity. With the Pareto distribution and the help of equations (5.12)-(5.15), we can simplify the equilibrium conditions. First, using the general equilibrium conditions given in the Appendix the labor market clearing condition can be written as

$$\begin{aligned} L_s &= N_s^E \left[\frac{\kappa_1}{\alpha \left(m_s^{max}\right)^k} \left[L_s \tau_{ss} \left(m_s^D\right)^{k+1} + L_r \tau_{sr} \left(\left(m_s^X\right)^{k+1} - \left(m_s^T\right)^{k+1} \right) \right] + F_s \right] \\ &+ \frac{N_r^E \kappa_1 L_s \tau_{ss}}{\alpha \left(m_r^{max}\right)^k} \left(m_r^T\right)^{k+1} + \frac{N_r^E P_r \kappa_4}{\left(m_r^{max}\right)^k} \left(m_r^T\right)^{k+1}. \end{aligned} \tag{5.20}$$

The terms κ_1 to κ_4 are positive constants that solely depend on the shape parameter k of the Pareto distribution and are also stated in the Appendix. Second, zero expected profits imply

$$\begin{aligned} \mu_s^{max} &\equiv \frac{F_s \left(m_s^{max}\right)^k \alpha}{\kappa_2} \\ &= L_s \tau_{ss} \left(m_s^D\right)^{k+1} + L_r \tau_{sr} \left(m_s^X\right)^{k+1} \\ &- L_s \tau_{sr} \left(m_s^T\right)^{k+1} + L_r \tau_{rr} w_r/w_s \left(m_s^T\right)^{k+1} - \frac{\kappa_4}{\kappa_2} \alpha P_r w_r/w_s \left(m_s^T\right)^{k+1}, \end{aligned} \tag{5.21}$$

where the term μ_r^{max} can be interpreted as a measure of "technological possibilities": the lower the fixed labor requirement for entry F_r or the lower the upper bound m_r^{max}, the lower will be μ_r^{max}. Third, the current account balance requires that $CA_{rs} = CA_{sr}$ with

$$\begin{aligned} CA_{sr} &= \frac{N_s^E L_r \tau_{sr} w_s \kappa_3}{\alpha \left(m_s^{max}\right)^k} \left[\left(m_s^X\right)^{k+1} - \left(m_r^T\right)^{k+1} \right] \\ &+ \frac{N_r^E w_s}{\alpha \left(m_r^{max}\right)^k} \left[L_s \tau_{ss} \left(m_r^T\right)^{k+1} \kappa_2 - \alpha P_s \left(m_r^T\right)^{k+1} \kappa_4 \right]. \end{aligned} \tag{5.22}$$

[8] The Pareto distribution is motivated by studies that examine the firm size distribution, see Axtell (2001), and often used in the theoretical literature, for instance in Melitz and Ottaviano (2008) or Bernard et al. (2003).

Note that if we consider infinitely high fixed costs of FDI, the threshold productivity m_s^T approaches zero. In this case the zero expected profit condition, labor market clearing and trade balance reduce to the terms that are given in Behrens et al. (2009).

5.4 FDI-liberalization

In the previous section we have developed the theoretical framework to study the welfare effects of FDI. In this section, we use this framework to examine a country's incentive to lower the fixed costs of FDI. We distinguish between two policy scenarios. In the strategic FDI policy scenario, a country chooses the welfare maximizing degree of FDI-liberalization, taking the FDI policy in the other country as given. In the cooperative scenario both countries jointly choose the total welfare maximizing degree of FDI-liberalization.

In the following we solve the model by using both analytical and numerical methods to derive comparative static results with respect to the fixed costs of FDI. To develop the economic intuition for the rich set of general equilibrium effects we start in section 5.4.1 and section 5.4.2 with the assumption of prohibitively high trade costs. With this assumption the classical productivity ranking of firms, i.e., low productive firms only serve their domestic market, medium productive firms export and high productive firms become multinationals, still prevails but the mass of exporters shrinks to zero. Therefore, firms that are productive enough to serve the foreign market become multinationals. In section 5.4.1 we consider the cooperative policy scenario where countries can commit to a specific degree of FDI-liberalization, e.g. to jointly grant the same level of tax holidays for foreign FDI firms. In section 5.4.2 we study the incentive to deviate from the cooperative policy and determine the strategic Nash-equilibrium policy. In the following sections 5.4.3 and 5.4.4 we consider low trade costs, such that a positive mass of firms exports. We derive the strategic FDI policy in section 5.4.3 and finish the welfare analysis in section 5.4.4 where we study the cooperative policy.

5.4.1 High trade costs: cooperative policy

We start with the following assumptions that lead to closed form solutions of the equilibrium determinants: First, we assume that inter-country trade costs are prohibitively high such that $m_r^X < m_r^F$ holds where m_r^F is given by $\pi_r^F\left(m_r^F\right) = 0$. As a result, the mass of exporters shrinks to zero and only multinationals serve a foreign market. Second, we consider symmetrical countries, i.e., countries are identical in their country sizes, technological possibilities, internal and external trade costs, entry costs and fixed costs of FDI. This directly implies that all endogenously determined cutoffs, wages and masses of firms are also identical and the relative wage is one. Finally, to simplify the notation

we assume zero intra-country trade costs and set the income to one, i.e. $\tau_{rr} = \tau_{ss} = 1$ and $E_r = E_s = 1$. Given these assumptions we can drop the indices and the FDI cutoff can be derived by solving $\pi^F\left(m^F\right) = 0$ for m^F. The solution is given by

$$m^F = m^D \cdot (\xi + 1) \cdot \mathrm{e}^{\xi} \quad \text{with} \quad \xi \equiv \frac{\alpha P - \sqrt{\alpha P\left(\alpha P + 4L\tau\right)}}{2L\tau}. \tag{5.23}$$

In the following it is convenient to use the following monotonic transformation of (5.23): $\left(m^F\right)^{k+1} = \chi \cdot \left(m^D\right)^{k+1}$ with $\chi^{1/(1+k)} \equiv (\xi + 1) \cdot \mathrm{e}^{\xi}$. It directly follows from (5.23) that $\partial\chi/\partial P < 0$. Hence, infinitely high fixed costs $P \to \infty$ lead to $m^F \to 0$ while infinitesimally low fixed costs $P \to 0$ lead to $m^F \to m^D$. In words, if the fixed costs of FDI are large no firm uses FDI while if the fixed costs vanish all surviving firms are multinationals. Using this transformation, the labor market clearing condition (5.20) and the zero expected profit condition (5.21) reduce to

$$\mu^{max} = L\left(m^D\right)^{k+1} + L\chi\left(m^D\right)^{k+1} - \frac{\kappa_4}{\kappa_2}\alpha P\chi\left(m^D\right)^{k+1}, \tag{5.24}$$

and

$$L = N^E\left[\frac{\kappa_1 L}{\alpha\left(m^{max}\right)^k}\left(m^D\right)^{k+1}(1+\chi) + F + \frac{\kappa_4}{\left(m^{max}\right)^k}P\chi\left(m^D\right)^{k+1}\right]. \tag{5.25}$$

Using (5.24) and (5.25) we can uniquely solve for the mass of entrants N^E and the domestic cutoff m^D given by

$$\left(m^D\right)^{k+1} = \frac{\mu^{max}\kappa_2}{L\kappa_2(1+\chi) - P\alpha\kappa_4\chi} \quad \text{and} \quad N^E = \frac{\kappa_2}{(\kappa_1+\kappa_2)}\frac{L}{F} - \frac{\alpha\kappa_4}{(\kappa_1+\kappa_2)}\frac{\chi P}{(1+\chi)F}. \tag{5.26}$$

Note that N^E, as given by (5.26), differs fundamentally from $N^E = \kappa_2 L/\left[(\kappa_1+\kappa_2)F\right]$ as derived in Behrens et al. (2009). In particular, they find the mass of entrants to be independent of any trade costs. We can directly conclude from (5.26) that in the presence of some FDI the mass of entrants is always lower since the second term of N^E in (5.26) is strictly positive for $P > 0$. Intuitively, the easier it is for highly productive firms to penetrate foreign markets, the lower will be the expected profits of all firms. Furthermore, FDI firms behave like domestic firms in their price setting and do not have to account for variable trade costs like exporters. This accelerated competition effect leads to the fact that lower expected profits yield to a lower mass of entrants.

After having derived the mass of entrants and the domestic cutoff, the mass of consumed varieties N^C and the average price $\overline{p}$ are crucial for a welfare analysis. Both are given by

$$N^C = \frac{\alpha\left(1+\chi^{\frac{k}{1+k}}\right)}{(\kappa_1+\kappa_2)(1+\chi)} \cdot \frac{1}{m^D} \quad \text{and} \quad \overline{p} = \frac{(1+\chi)}{\left(1+\chi^{\frac{k}{1+k}}\right)} \cdot \frac{k}{1+k} \cdot p^d + \frac{\alpha}{N^C}, \tag{5.27}$$

where the first term of $\overline{p}$ in (5.27) are the average marginal costs, and the second term is the average markup. Finally, using (5.26), (5.27) and the term $\kappa_3 \equiv \kappa_1 + \kappa_2$ we can define

$$p^N \equiv \frac{\overline{p}}{p^d} = \frac{(\kappa_3 + k(1+\kappa_3))(1+\chi)}{(1+k)\left(1+\chi^{\frac{k}{k+1}}\right)} \tag{5.28}$$

as the *normed* average price. Using this we can simplify indirect utility to

$$U = N^C\left(1-p^N\right) = \frac{\alpha}{m^D}\left[\frac{1-k\chi+(1+k)\chi^{\frac{k}{1+k}}}{(1+\chi)(k+1)\kappa_3} - 1\right]. \tag{5.29}$$

It is evident from (5.29) that welfare increases in the mass of consumed varieties N^C and a lower normed average price p^N. In the following we show that for some parameter values FDI-liberalization leads to an unambiguous welfare increase while for others there exists a trade-off between the normed average price and the mass of consumed varieties.

We now analyze how the fixed costs of FDI impact the equilibrium mass of entrants, surviving firms, consumed varieties, average and normed average price, markup and most important welfare. For all variables we state two polar cases in Table 5.1. First, the free trade scenario where FDI is costless ($P \to 0$ denoted by $OPEN$) and second the autarkic scenario where FDI is infinitely costly ($P \to \infty$ denoted by AUT). A comparison of the autarky and free trade scenario is summarized in Proposition 1.

Proposition 1

i.) The domestic cutoff m^D is higher under autarky than under free trade.

ii.) The masses of entrants N^E under autarky and under free trade are equal.

iii.) The mass of surviving firms N^S under autarky is higher than under free trade.

iv.) The mass of consumed varieties N^C under autarky is lower than under free trade.

v.) The average price $\overline{p}$ under autarky is higher than under free trade.

vi.) The normed average prices p^N under autarky and under free trade are equal.

vii.) Welfare under autarky is lower than under free trade.

Starting from an initial autarkic scenario and introducing FDI-liberalization, i.e. a gradual reduction of P, leads to the following comparative static results summarized in Proposition 2.

Proposition 2

FDI-liberalization leads to

i.) an ambiguous change in the domestic cutoff: $m^D(P)$ is humped-shaped.

ii.) an ambiguous change in the in the mass of entrants: $N^E(P)$ is U-shaped.

iii.) a lower mass of surviving firms N^S.

iv.) a higher mass of consumed varieties N^C.

v.) a lower average price $\overline{p}$.

vi.) an ambiguous change in the normed average price: $p^N(P)$ is U-shaped.

vii.) an ambiguous change in welfare: $U(P)$ is humped-shaped.

Some comparative static results of Proposition 2 are different compared to bilateral trade liberalization in Behrens et al. (2009). First, consider statement i.) in Proposition 2. Starting from an initial autarkic scenario, FDI-liberalization first leads to softer competition, i.e. a higher domestic cutoff m^D. The reason is that for fixed costs of FDI larger than a threshold $P > P^*$, FDI-liberalization allows some rare multinationals to break-even at a lower productivity level.[9] As a result, the domestic cutoff m^D increases at first. Below this threshold P^*, further decreases in the fixed costs of FDI trigger the classic competition effect of trade liberalization (lower domestic cutoff), like it would be the case with falling variable trade costs in Behrens et al. (2009), Melitz (2003) or Melitz and Ottaviano (2008). This new non-monotonic effect how FDI-liberalization impacts the equilibrium productivity cutoff has, to the best of our knowledge, not been explored in the literature yet.

Second, consider statement vii.) of Proposition 2. Welfare as given by (5.29) increases in the mass of consumed varieties and a lower normed average price. As illustrated in the left graph of Figure 5.2, FDI-liberalization rises the mass of consumed varieties but does not unambiguously lower the normed average price. The normed average price actually increases for sufficiently low levels of P and has a negative impact on welfare everything else equal. How can we explain this U-shaped normed average price? Consider an initial scenario where fixed costs of FDI are prohibitively high. FDI-liberalization now leads to the creation of the first multinational that charges a relatively low price since this firm is highly productive compared to the average domestic firm. However, further reductions in the fixed costs of FDI also induce relatively underproductive firms to become multinationals. As a result, the normed average price increases. This trade-off between relatively underproductive multinationals that introduce new consumable varieties but also increase the normed average price uniquely determines the welfare maximizing degree of FDI-liberalization. The right graph of Figure 5.2 clearly illustrates, that if countries can cooperatively commit themselves for a total welfare maximizing FDI policy, countries

[9] The threshold level is given by $P^* = (L/\alpha)\left(6\kappa_2 + \kappa_4 - \sqrt{4\kappa_2^2 + 12\kappa_2\kappa_4 + \kappa_4^2}\right)/(4\kappa_4)$.

i.)	$m^D_{AUT} = \left(\frac{\mu^{max}}{L}\right)^{\frac{1}{k+1}}$	$m^D_{OPEN} = \left(\frac{\mu^{max}}{2L}\right)^{\frac{1}{k+1}}$
ii.)	$N^E_{AUT} = \frac{\kappa_2}{\kappa_3}\frac{L}{F}$	$N^E_{OPEN} = \frac{\kappa_2}{\kappa_3}\frac{L}{F}$
iii.)	$N^S_{AUT} = \frac{\alpha}{\kappa_3}\left(\frac{L}{\mu^{max}}\right)^{\frac{1}{k+1}}$	$N^S_{OPEN} = \frac{\alpha}{\kappa_3}\left(\frac{L}{2^k\mu^{max}}\right)^{\frac{1}{k+1}}$
iv.)	$N^C_{AUT} = \frac{\alpha}{\kappa_3}\left(\frac{L}{\mu^{max}}\right)^{\frac{1}{k+1}}$	$N^C_{OPEN} = \frac{\alpha}{\kappa_3}\left(\frac{2L}{\mu^{max}}\right)^{\frac{1}{k+1}}$
v.)	$\overline{p}_{AUT} = \frac{\kappa_3+k(1+\kappa_3)}{1+k}\left(\frac{\mu^{max}}{L}\right)^{\frac{1}{k+1}}$	$\overline{p}_{OPEN} = \frac{\kappa_3+k(1+\kappa_3)}{1+k}\left(\frac{\mu^{max}}{2L}\right)^{\frac{1}{k+1}}$
vi.)	$p^N_{AUT} = \frac{\kappa_3+k(1+\kappa_3)}{1+k}$	$p^N_{OPEN} = \frac{\kappa_3+k(1+\kappa_3)}{1+k}$
vii.)	$U_{AUT} = \alpha\left[\frac{1}{\kappa_3(k+1)} - 1\right]\left(\frac{L}{\mu^{max}}\right)^{\frac{1}{k+1}}$	$U_{OPEN} = \alpha\left[\frac{1}{\kappa_3(k+1)} - 1\right]\left(\frac{2L}{\mu^{max}}\right)^{\frac{1}{k+1}}$

Table 5.1: Comparison of the autarky and free trade scenario.

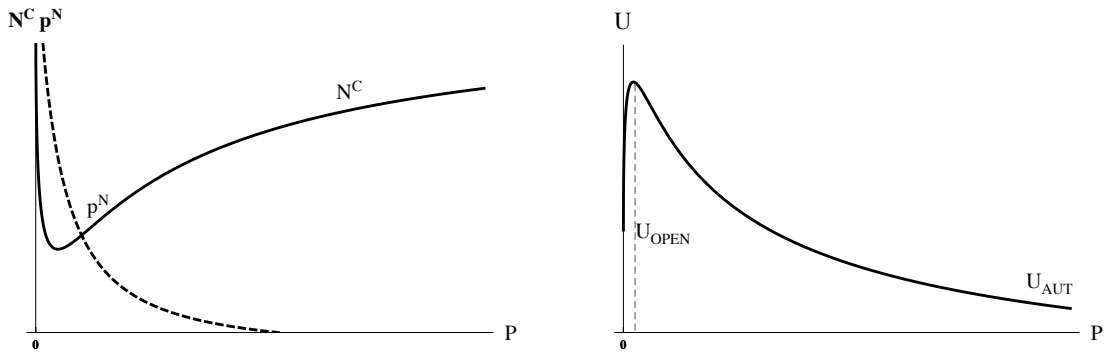

Figure 5.2: Welfare, normed average price and consumed varieties.

would set a strictly positive level for the fixed costs of FDI. That is, they would *not* reduce the fixed costs of FDI to zero. In the following Section 5.4.2 we now explore whether countries have a unilateral incentive to deviate from a cooperative policy by further decreasing fixed costs of FDI.

5.4.2 High trade costs: Nash-equilibrium

In this section we examine the strategic FDI policy and determine the Nash-equilibrium. To derive a home country H's best response, i.e., the welfare maximizing fixed cost level P_H for a given fixed cost FDI level P_F in the other foreign country F, we have to study asymmetrical countries that differ in their fixed costs of FDI. Similar as in Section 5.4.1 we can express the foreign country's FDI cutoff by solving $\pi^F_F\left(m^F_F\right) = 0$ for m^F_F in terms of the home country's domestic cutoff m^D_H. Under the assumption that countries differ

solely in their fixed costs of FDI the cutoff m_F^F is given by

$$m_F^F = m_H^D \cdot (\xi_F + 1) \cdot \mathrm{e}^{\xi_F} \quad \text{with} \quad \xi_F \equiv \frac{\alpha P_H - \sqrt{\alpha P_H (\alpha P_H + 4L)}}{2L}. \tag{5.30}$$

Again it is convenient to use a monotonic transformation of (5.30): $\left(m_F^F\right)^{k+1} = \chi_F \cdot \left(m_H^D\right)^{k+1}$ with $\chi_F^{1/(1+k)} \equiv (\xi_F + 1) \cdot \mathrm{e}^{\xi_F}$ and $\partial \chi_F / \partial P_H < 0$. Similar to the case of bilateral changes, attracting FDI by the home country H leads to the fact that firms in the foreign country F, that are at least as productive as the domestic cutoff firm in the home country, become multinationals.[10] Using the labor market clearing condition (5.20) and the zero expected profit condition (5.21), we can solve for the domestic cutoff in the home country H that is given by

$$\left(m_H^D\right)^{k+1} = \frac{F \left(m^{max}\right)^k \alpha \left[P_F w_F \alpha \kappa_4 \chi_H + L\kappa_2 \left(w_F - w_H \chi_H\right)\right]}{w_F L^2 \kappa_2^2 - w_F \left(L\kappa_2 - P_H \alpha \kappa_4\right)\left(L\kappa_2 - P_F \alpha \kappa_4\right) \chi_H \chi_F}, \tag{5.31}$$

which still is a function of the countries' wages. However, for a complete characterization of the model we need the relative wage for which we cannot derive closed form solutions. Therefore we rely on numerical simulations.

In Figure 5.3 we have depicted the case of constant fixed costs of FDI P_F in the foreign country while the home country marginally deviates and attracts FDI by lowering fixed costs P_H. The cross country comparison reveals that further decreasing the fixed costs of FDI P_H leads to a greater mass of consumed varieties and a lower normed average price in the FDI attracting home country H. Both channels unambiguously increase welfare. Hence, there exists an incentive for the country H to marginally attract more FDI firms than the foreign country F. The intuition is that lower fixed costs of FDI in country H increase expected profits for country F's firms. This leads to a greater mass of entrants and tougher competition in the foreign country. For country H firms, serving country F is now less attractive, due to the tougher competition in country F. Therefore, the mass of entrants in country H decreases and the domestic cutoff increases. As a result, the relative wage in the country with a greater mass of entrants is higher. Nevertheless, more FDI firms in the home country H increase the mass of consumption varieties and decrease the normed average price. We can conclude that in a policy scenario where both countries set the level of fixed costs of FDI independently, the Nash-equilibrium policy is zero fixed costs of FDI in both countries. To further check whether there is no incentive to deviate from the Nash-equilibrium policy we provide Figure 5.4 where we have depicted the case of zero fixed costs of FDI in both countries. Marginally increasing fixed costs of FDI P_H in the home country lowers welfare in both countries and we can therefore conclude that the Nash-equilibrium is stable.

[10] Note that in case of perfect FDI-liberalization all domestic firms are multinationals since $P_H \to 0$ implies $m_F^F \to m_H^D$.

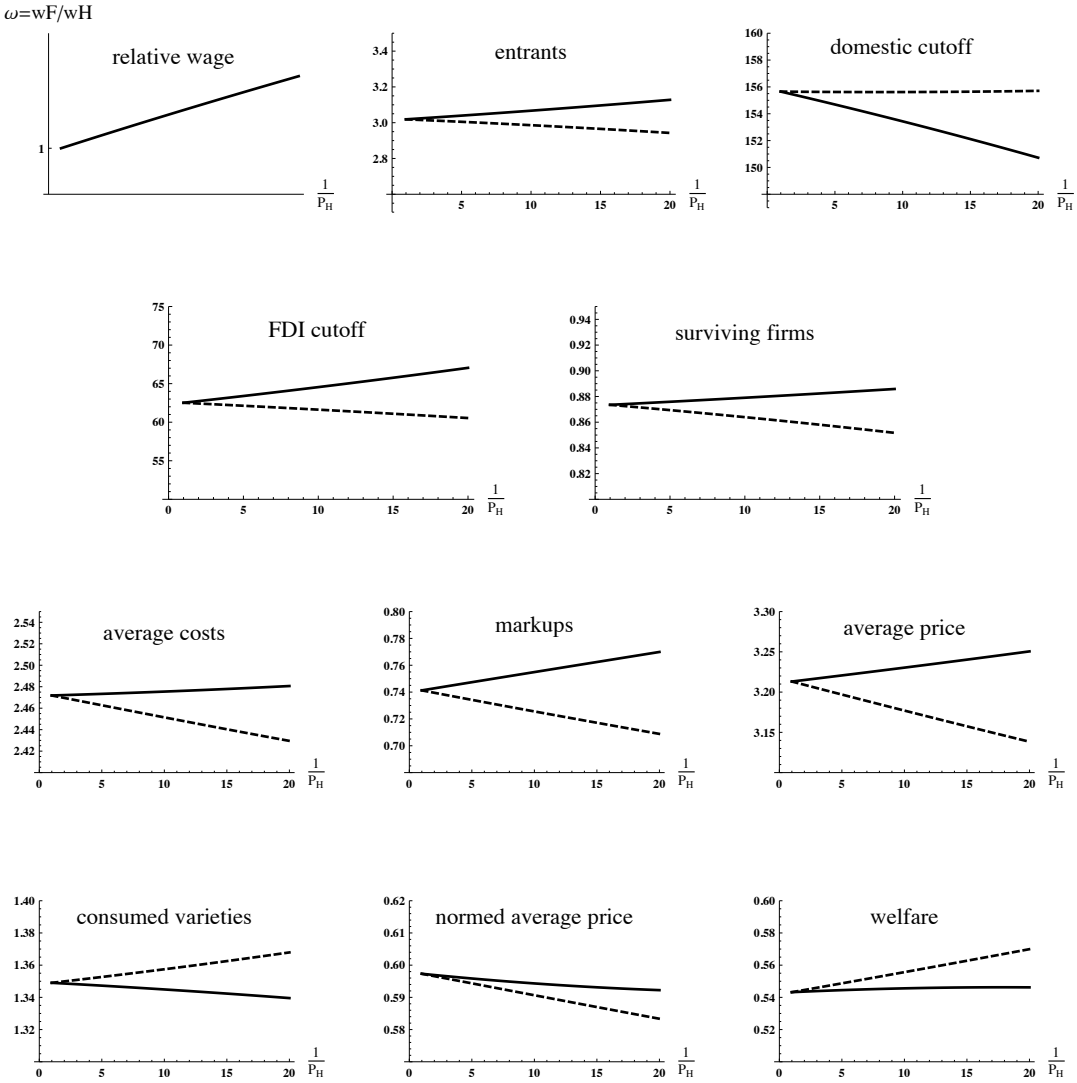

Figure 5.3: Comparative statics, lower fixed costs of FDI in country H. The black solid line indicates country F, the dashed line indicates country H. Parameters: $L_H = L_F = 10$, $\tau_{HH} = \tau_{FF} = 1$, $\tau_{HF} = \tau_{FH} = 1.3$, $F_F = F_H = 1$, $P_F = 0.25$, $\alpha = 1$, $k = 2$, $m_H^{max} = m_F^{max} = 10$. Note that the productivity cutoffs are monotonically transformed to m^{k+1}.

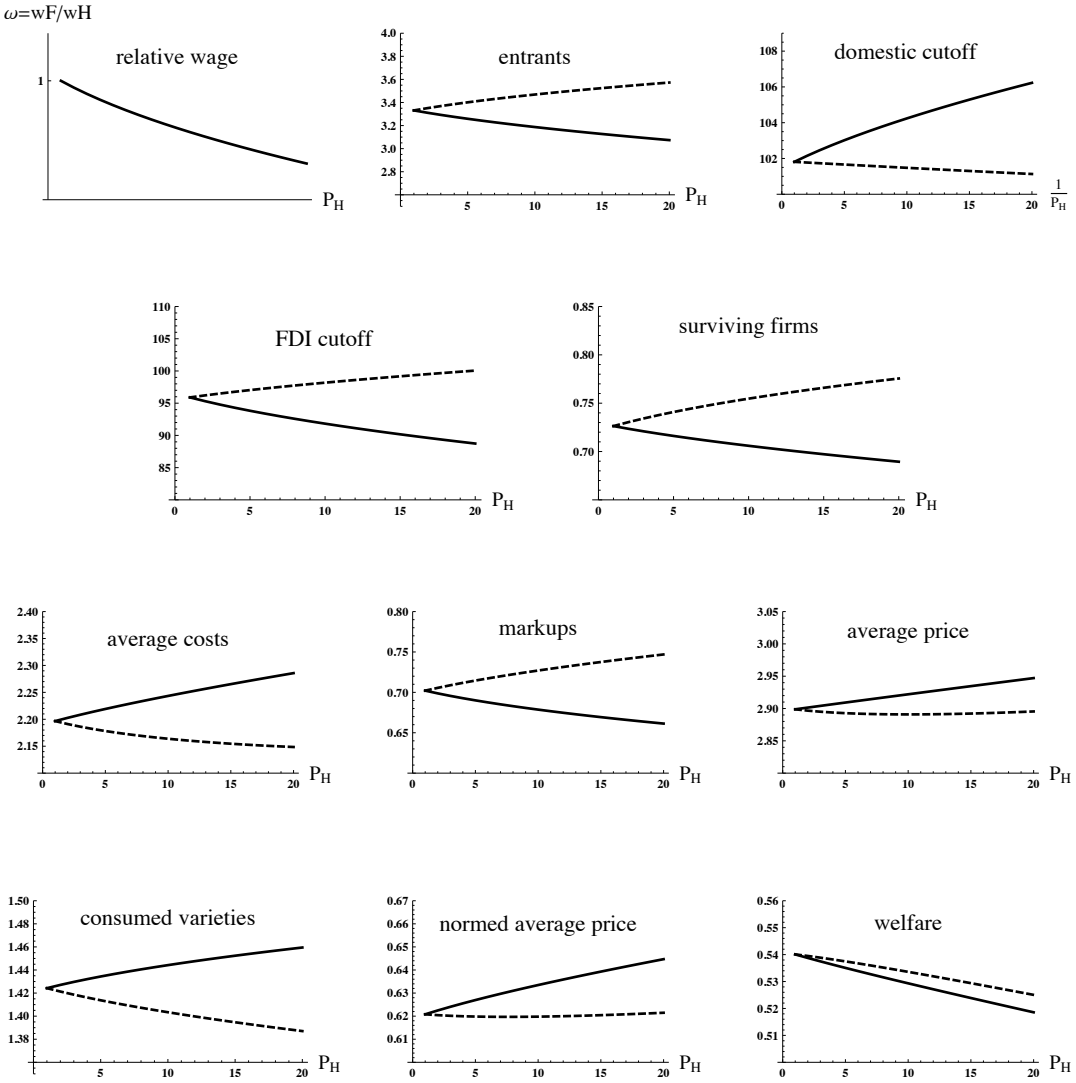

Figure 5.4: Comparative statics, lower fixed costs of FDI in country H. The black solid line indicates country F, the dashed line indicates country H. Parameters: $L_H = L_F = 10$, $\tau_{HH} = \tau_{FF} = 1$, $\tau_{HF} = \tau_{FH} = 1.3$, $F_F = F_H = 1$, $P_F = 0$, $\alpha = 1$, $k = 2$, $m_H^{max} = m_F^{max} = 10$. Note that the productivity cutoffs are monotonically transformed to m^{k+1}.

5.4.3 Low trade costs: Nash-equilibrium

In the following we examine the case of low trade costs to secure that our results also holds in the presence of exporters. We now consider the comprehensive model where countries are potentially asymmetric with respect to their fixed costs of FDI and some firms choose exporting rather than FDI. Hence, we assume that inter-country trade costs are sufficiently low such that $m_s^X > m_s^T > 0$ with $s = H, F$ holds where m_s^X is given by $\pi_s^X\left(m_s^X\right) = 0$ and m_s^T is the solution of $\pi_s^F\left(m_s^T\right) = \pi_s^X\left(m_s^T\right)$. As discussed in Section 5.3.2 we cannot solve $\pi_s^F\left(m_s^T\right) = \pi_s^X\left(m_s^T\right)$ for the FDI cutoff m_s^T. Hence, we cannot provide closed form solutions for the endogenously determined productivity cutoffs, wages and masses of firms. We rather provide numerical simulations.

As in the previous section 5.4.2, we consider the case that country H marginally lowers the fixed costs of FDI P_H below P_F and thereby attracts more FDI firms than country F. All the results are qualitatively summarized in the graphs provided by Figure 5.5. We conclude from the cross country comparison that marginally attracting more FDI firms than the foreign country leads to a greater mass of consumed varieties and a lower normed average price in the attracting country. Both channels unambiguously increase welfare in the attracting home country. Note that Figure 5.5 provides one numerical example, however further parameter constellations confirm this to be a stable pattern.

What follows is a detailed discussion of the comparative statics with respect to P_H. We start with a qualitative discussion of the domestic cutoffs and the mass of entrants. As the graphs indicate marginally lowering the fixed costs of FDI in the home country H translate into a higher (lower) domestic cutoff in country H (F). At the same time the mass of entrants in country H (F) decreases (increases). The economic intuition is that more firms are attracted to enter country F due to higher expected profits from serving the foreign market. Hence, the toughness of competition increases in country F while we find softer selection in country H. With regard to foreign market entry the export cutoff in country H (F) decreases (increases) while both FDI cutoffs unambiguously increase. Intuitively, the FDI strategy for country F firms becomes more profitable due to the lower fixed costs of FDI. Country F firms therefore substitute exports by FDI. This is the standard "proximity-concentration" trade-off prediction. However, with endogenous wage differentials in equilibrium, we can identify a new wage effect that dampens the reallocation: As production is shifted from the foreign country F to the attracting home country H, labor demand increases (decreases) in country H (F). This reallocation of production changes the relative wage, i.e. the relative wage level in country H (F) increases (decreases). This wage effect now leads to repercussions of FDI costs to the export cutoffs. The lower relative wage in country F favors exports since exporting firms located in country F now benefit from relatively lower labor costs. On the other hand, the lower relative wage in country F also favors FDI in that country while exporters from

$P_H = 0.55$	ω	m_F^T	m_H^T	N_F^E	N_H^E	U_F	U_H
-10%	-0.42	12.87	0.99	1.33	-1.58	-1.16	0.46
-20%	-0.89	27.81	1.79	3.09	-3.46	-2.64	0.57

Table 5.2: Percentage changes for the wage, cutoffs, entrants and welfare for lower fixed costs of FDI in country H. Other parameters: $L_H = L_F = 10$, $\tau_{HH} = \tau_{FF} = 1$, $\tau_{HF} = \tau_{FH} = 1.3$, $F_H = F_F = 1$, $P_F = 0.55$, $\alpha = 1$, $k = 2$, $m_H^{max} = m_F^{max} = 10$.

$P = 0.55$	m^T	N^E	U
-10%	13.81	-0.24	-0.09
-20%	29.23	-0.33	-0.43

Table 5.3: Percentage changes for the wage, cutoffs, entrants and welfare for lower fixed costs of FDI. Other parameters: $L_H = L_F = 10$, $\tau_{HH} = \tau_{FF} = 1$, $\tau_{HF} = \tau_{FH} = 1.3$, $F_H = F_F = 1$, $\alpha = 1$, $k = 2$, $m_H^{max} = m_F^{max} = 10$.

the attracting country H suffer from relatively higher labor costs.

It is crucial to note that this effect on the endogenously determined wage differential cannot be found in the strand of literature that incorporates factor price equalization as e.g. Helpman, Melitz and Yeaple (2004) or Chor (2009). In contrast to this strand of the literature we find that FDI-liberalization is a double-edged sword: FDI-liberalization introduces new FDI varieties but simultaneously yields to tougher foreign market entry for the own exporters. Now consider the welfare effects in detail. Everything else equal welfare in a country increases in the mass of consumed varieties and a lower normed average price. Since FDI in country H and exporting into country H (F) becomes easier (harder), the mass of consumed varieties increases (decreases) in country H (F). Average marginal costs and markups decrease (increase) in country H (F). As a result the normed average price decreases (increases) in country H (F). Both effects yield to the fact that welfare in country H (F) unambiguously increases (decreases). Hence, we confirm our result of Section 5.4.2 that countries actually have a unilateral incentive to marginally lower the fixed costs of FDI.[11]

Proposition 3 *The strategic Nash-equilibrium policy is zero fixed costs of FDI ($P_H^{Nash} = P_F^{Nash} = 0$) in both countries.*

[11] To provide some numerical reading examples, consider for example a 20% decrease in FDI costs as given in Table 2. The relative wage $\omega = w_F/w_H$ decreases only 0.42% while there is a strong effect on the FDI cutoff for country F with 27.81%, compared to a small increase of 1.79% in country H. Welfare in country H (F) increases (decreases) 0.57% (2.64%).

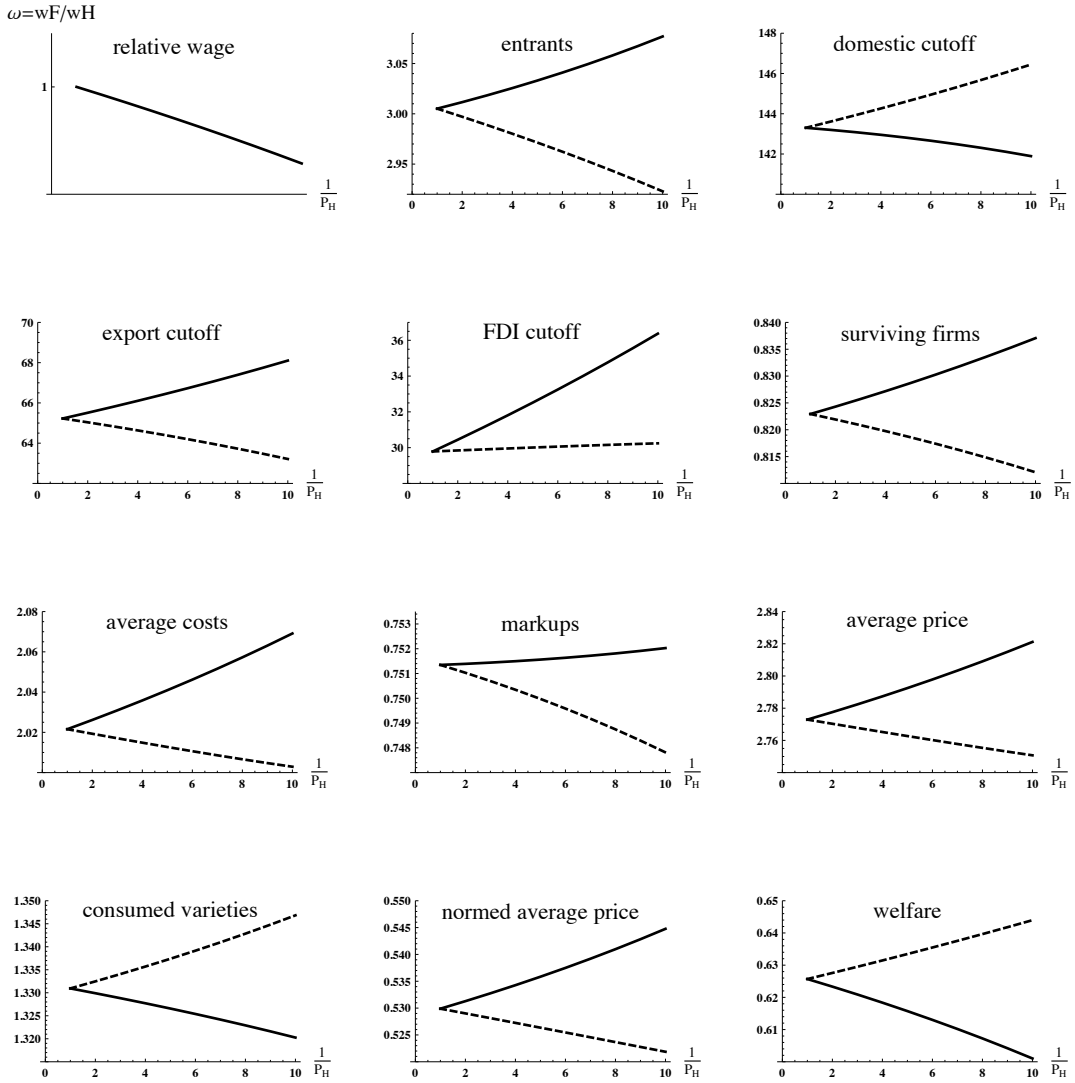

Figure 5.5: Comparative statics, lower fixed costs of FDI in country H. The black solid line indicates country F, the dashed line indicates country H. Parameters: $L_H = L_F = 10$, $\tau_{HH} = \tau_{FF} = 1$, $\tau_{HF} = \tau_{FH} = 1.3$, $F_H = F_F = 1$, $P_F = 0.55$, $\alpha = 1$, $k = 2$, $m_H^{max} = m_F^{max} = 10$. Note that the productivity cutoffs are monotonically transformed to m^{k+1}.

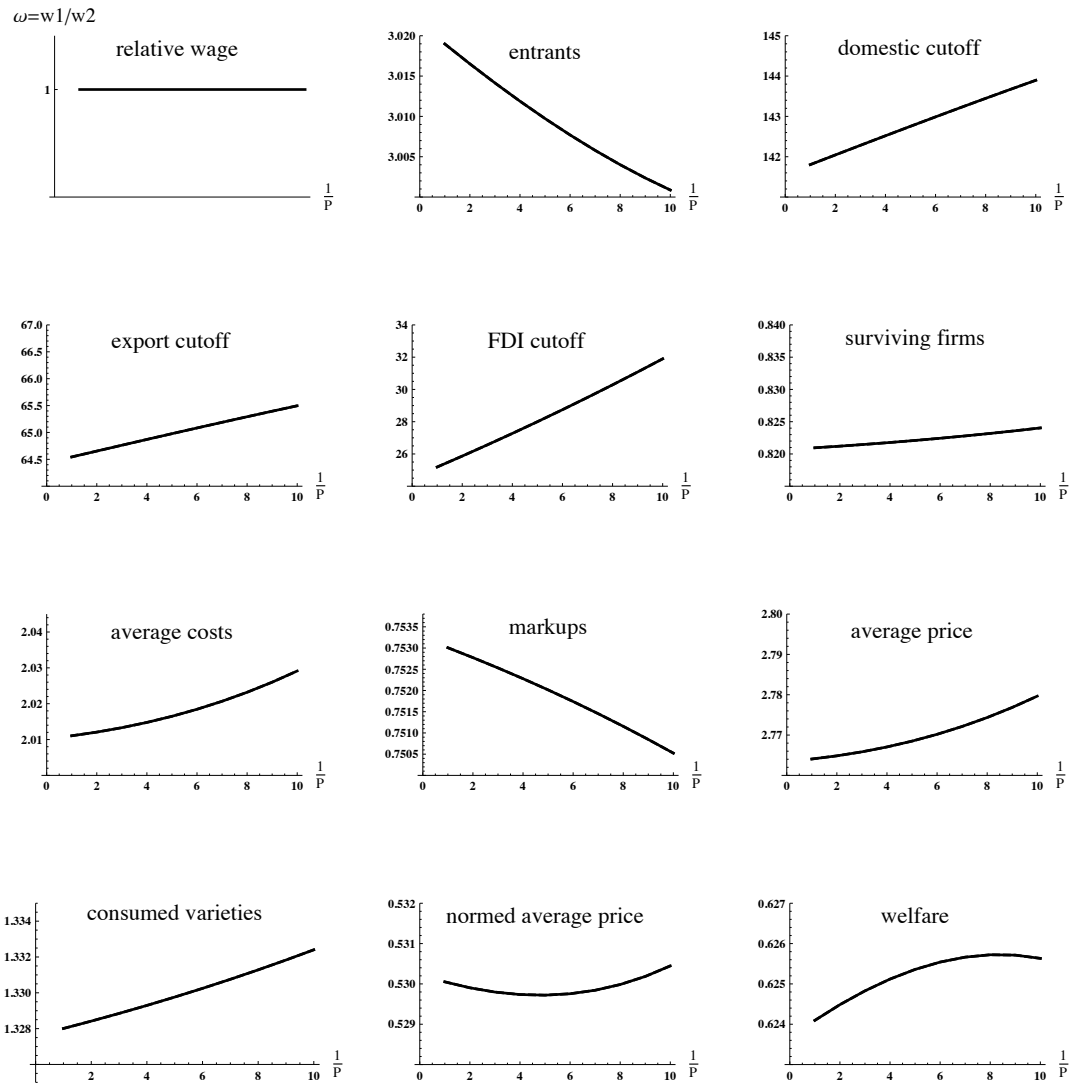

Figure 5.6: Comparative statics, lower fixed costs in both countries. We start with $P_H = P_F = 0.55$. Parameters: $L_H = L_F = 10$, $\tau_{HH} = \tau_{FF} = 1$, $\tau_{HF} = \tau_{FH} = 1.3$, $F_H = F_F = 1$,$\alpha = 1$, $k = 2$, $m_H^{max} = m_F^{max} = 10$. Note that the productivity cutoffs are monotonically transformed to m^{k+1}.

5.4.4 Low trade costs: cooperative policy

In the foregoing Sections 5.4.2 and 5.4.3 we found that there exists a unilateral incentive to marginally lower the fixed costs of FDI. The strategic Nash-equilibrium policy is zero fixed costs of FDI. In this section we study the cooperative policy that maximizes joint welfare to determine whether there are gains from supra national coordination. The qualitative results for $P \equiv P_H = P_F$ are given in Figure 5.6. Similar to Section 5.4.1, lower fixed costs of FDI lead to softer competition and less entrants. Concerning foreign market entry firms face less competition in each market. Therefore the export as well as the FDI cutoff increase.

Concerning the welfare analysis, FDI-liberalization unambiguously leads to a larger mass of consumed varieties while the change in the normed average price is ambiguous as in Section 5.4.1. The normed average price only decreases and leads to an unambiguous welfare decrease if the fixed costs of FDI are high. Further FDI-liberalization below a fixed cost threshold now attracts relatively underproductive multinationals that increase the normed average price. As a result, FDI-liberalization can lead to a welfare decrease, if too many multinationals are attracted. A cooperative policy would therefore set a strictly positive level for the fixed costs of FDI.[12]

Proposition 4 *The cooperative FDI policy sets a strictly positive fixed costs of FDI ($P_H^{Coop} = P_F^{Coop} > 0$) in both countries.*

5.5 Conclusion

We extended the Behrens et al. (2009) framework by horizontal FDI. This allows to assess the welfare consequences of FDI-liberalization in two, commonly not studied, channels: FDI-liberalization changes the relative wage and the price markup. Although both channels are commonly not studied in theoretical models they are present in the political discussion. As our model highlights, both channels are also important in a theoretical discussion. Wage differentials are important since they deepen our understanding of the classical "proximity-concentration" trade-off. We find that the unilateral attraction of FDI rises the relative wage in the attracting country, which in turn dampens the reallocation of production. As a result, foreign exporters benefit while domestic exporters suffer from relatively higher labor costs. Price markups are important since we can confirm the argument given by policy makers that FDI-liberalization can lead to trade cost savings. Those trade cost savings can lead to lower average marginal costs, markups,

[12] After having discussed the qualitative results, we again provide some numerical reading examples. Consider for example a 20% decrease in FDI costs as given in Table 3. Although the effect on FDI cutoff is strong (increases 29.23%) welfare in both countries decreases by 0.43%.

average prices and quite naturally might increase welfare in turn.

Compared to the existing theoretical literature, in particular Chor (2009), we consider strategic competition and collaboration among countries for FDI. This new element brings our model closer to the political discussion, where the dynamic aspects of competition for FDI are vividly discussed. In that context the comparison between the strategic FDI policy and the cooperative solution can be relevant for policy makers. Our model predicts that there a potential welfare gains from supranational coordination. However, since coordination is difficult to achieve, it is likely that countries over attract FDI. For policy makers this is an important result since it indicates that besides the indisputable positive aspects of FDI there are also potential welfare losses. However, our simple model relies on various critical assumptions. In reality, decreasing fixed costs of FDI involves some sort of subsidy that needs to be refinanced or implies a tax loss. With the assumption of a balanced budget the over attraction of FDI in the Nash-equilibrium will likely be dampened. Other simplifying assumptions like identical country size and technology potentials keep the analysis short, but are left for further research. As always, reality is much more complex but our simple model still clearly illustrates the potential welfare losses of FDI. Furthermore, our model also identifies a clear difference between trade- and FDI-liberalization that implies different policy recommendations. Jointly decreasing variable trade costs unambiguously increase welfare while our model predicts that for fixed costs of FDI countries should rather commit for a strictly positive level.

5.6 Appendix

Equilibrium conditions: In Section 5.3.3 we state the equilibrium conditions (5.20)-(5.22) assuming a Pareto distribution for the productivity distribution. Without assuming this specific distribution the zero expected profit condition for each firm in a country s is given by

$$\begin{aligned} F_s w_s &= \int_0^{m_s^D} L_s \left[p_{ss}(m) - \tau_{ss} w_s m\right] q_{ss}(m)\, \mathrm{d}G_s(m) \\ &+ \int_{m_s^T}^{m_s^X} L_r \left[p_{sr}(m) - \tau_{sr} w_s m\right] q_{sr}(m)\, \mathrm{d}G_s(m) \\ &+ \int_0^{m_s^T} \left(L_r \left[p_{rr}(m) - \tau_{rr} w_r m\right] q_{rr}(m) - P_r w_r m\right) \mathrm{d}G_s(m), \end{aligned}$$

where F_s is the country-specific fixed labor requirement. The first term are domestic profits, the second term are export profits and the third term are FDI profits. Furthermore, each country's labor market clears in equilibrium, which requires that in each country s

$$\begin{aligned} L_s &= N_s^E \left(L_s \int_0^{m_s^D} m \tau_{ss} q_{ss}(m)\, \mathrm{d}G_s(m) + F_s \right) \\ &+ N_s^E L_r \int_{m_s^T}^{m_s^X} m \tau_{sr} q_{sr}(m)\, \mathrm{d}G_s(m) \\ &+ N_r^E \left(\int_0^{m_r^T} \left(L_s m \tau_{ss} q_{ss}(m) + P_s m\right) \mathrm{d}G_r(m) \right) \end{aligned}$$

holds. The first term is "firms from country s serve their domestic country s", the second term is "firms from country s that serve foreign country r via exporting" and the third term is "firms from country r that serve country s via FDI". Last, the current account is balanced for each country if $CA_{sr} = CA_{rs}$ with

$$\begin{aligned} CA_{sr} &= N_s^E L_r \int_{m_s^T}^{m_s^X} p_{sr}(m)\, q_{sr}(m)\, \mathrm{d}G_s(m) \\ &+ N_r^E \int_0^{m_r^T} \left(L_s \left[p_{ss}(m) - \tau_{ss} w_s m\right] q_{ss}(m) - P_s w_s m\right) \mathrm{d}G_s(m). \end{aligned}$$

The first term is "exports from the domestic country s to the foreign country r" and the second term is "transfer of FDI profits from the foreign country s back to the domestic country r". To derive the equilibrium conditions (5.20)-(5.22) we separate integrals, use (5.12)-(5.14) and assume a Pareto distribution. Then we use the change in variables as proposed by Behrens et al. (2009): $z = W\left(\mathrm{e}^{\frac{m}{I}}\right)$, $\mathrm{e}^{\frac{m}{I}} = z e^z$, $m = I z \mathrm{e}^{z-1}$ and $\mathrm{d}m = (1+z)\, e^{z-1} I \mathrm{d}z$. We use the following abbreviations $\kappa_1 = \mathrm{e}^{-(k+1)} k \int_0^1 (1-z^2)\, z^k \mathrm{e}^{zk} \mathrm{e}^z \mathrm{d}z$, $\kappa_2 = \mathrm{e}^{-(k+1)} k \int_0^1 z^k \left(z^{-1} + z - 2\right)(1+z)\, \mathrm{e}^{zk} \mathrm{e}^z \mathrm{d}z$, $\kappa_3 = \mathrm{e}^{-(k+1)} k \int_0^1 z^k \left(z^{-1} - z\right) \mathrm{e}^{zk} \mathrm{e}^z \mathrm{d}z$ and $\kappa_4 = \mathrm{e}^{-(k+1)} k \int_0^1 z^k (1+z)\, \mathrm{e}^{zk} \mathrm{e}^z \mathrm{d}z$, to further simplify the expressions. Note that $\kappa_1 - \kappa_4$ are constants and only depend on the shape parameter k of the Pareto distribution. This directly yields to (5.20)-(5.22).

Algorithm: In Sections 5.4.2-5.4.4 we discuss various numerical simulations. We solve numerical by using the following algorithm: Let ω denote the relative wage. The zero expected profit conditions (5.21) only depend on the cutoffs and the relative wage, so we can solve for the cutoffs $m_r^D\left(\omega, m_r^T, m_s^T\right)$ with $r \neq s$. Then, using the labor market clearing conditions (5.20) we can solve for the mass of entrants $N_r^E\left(\omega, m_r^D, m_s^D, m_r^T, m_s^T\right)$. In the next step we use the cutoffs $m_r^D\left(\omega, m_r^T, m_s^T\right)$ in $N_r^E\left(\omega, m_r^D, m_s^D, m_r^T, m_s^T\right)$ to eliminate the domestic cutoffs. The mass of entrants simplifies to $N_r^E\left(\omega, m_r^T, m_s^T\right)$. Using the expression in the current account balance (5.22) and the two indifference conditions $Z_r \equiv \pi_r^F\left(\omega, m_r^T, m_s^T\right) - \pi_r^X\left(\omega, m_r^T, m_s^T\right) = 0$ we can solve for the equilibrium allocation numerically. We secure uniqueness of our allocation since we start in a symmetric scenario with $P_r = P_s$ where $\omega = 1$ and $m_r^T = m_s^T$ must hold.

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Erklärung gemäß § 8 Abs. 4

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