Essays on Credit Frictions and Firm Heterogeneity in International Trade

Inaugural-Dissertation

zur Erlangung des Grades

Doctor oeconomiae publicae (Dr. oec. publ.)

an der Ludwig-Maximilians-Universität München

2015

vorgelegt von

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Promotionsabschlussberatung:	11. Mai 2016

Datum der mündlichen Prüfung: 26. April 2016
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Für meine Eltern.

Acknowledgements

My first and foremost thanks go to my supervisor, Carsten Eckel, for his insightful guidance and continuous support over the past years. Our collaboration on the first chapter of this thesis was inspiring and motivating. Furthermore, I really enjoyed the great and familiar atmosphere at the Chair of International Trade and Trade Policy.
My grateful thanks are also extended to Gabriel Felbermayr for kindly agreeing to become my second supervisor, as well as to Monika Schnitzer for joining my dissertation committee. I thankfully acknowledge the continuous advice and support during my doctoral studies.
Special thanks go to my colleagues at the Chair of International Trade and Trade Policy, Daniel Baumgarten, Matthias Beestermöller, Lisandra Flach, and Michael Irlacher, who have always been of great support academically and personally. I am especially grateful to my office colleague and coauthor Michael for the time and effort he invested in our joint project. I really enjoyed the teamwork concerning research and teaching, and I could learn a lot from his expertise in international trade theory and his experience of working at our chair. I gratefully acknowledge the research support provided by our student assistants Felix Röllig and Fabian Gräf. Further, I thank our secretary Marion Kobras for her great support and patience with all administrative issues. I also benefited from the exchange with the other PhD students at the Munich Graduate School of Economics who all contributed to a very productive and pleasant atmosphere.
Last but not least, a special word of thanks goes to my parents and my friends for their great support and understanding during the last years.

Florian Unger
Munich, December 2015

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Preface

Credit constraints are one of the most important obstacles to international trade. Economists have devoted a lot of attention to the question how financial frictions affect cross-border goods flows. However, the increasing availability of micro data has shifted the focus of research in international trade from a country and industry perspective to the firm and product level. While moving towards a more disaggregated analysis, the literature has emphasized different sources of gains from globalization, as well as various channels through which credit frictions affect international trade. At the country level, Beck (2002) shows that financial development is positively related to export flows. Moving towards a more disaggregated perspective, empirical papers exploit differences in the exposure to credit constraints across industries. Countries with better financial development export more in industries that highly depend on external finance and have fewer tangible assets (Beck, 2003; Svaleryd and Vlachos, 2005). These empirical findings are consistent with traditional theory that highlights specialization gains from trade liberalization, driven by technological differences across countries (Ricardo) or differences in factor endowments across industries (Heckscher-Ohlin). If credit market imperfections are present, the quality of financial institutions shapes trade flows between countries and represents a source of comparative advantage in sectors that rely on external finance (Kletzer and Bardhan, 1987; Matsuyama, 2005; Ju and Wei, 2011).
Motivated by the phenomenon of intra-industry trade (Grubel and Lloyd, 1975), the new trade theory emphasizes economies of scale and increased product variety as additional gains from globalization (Krugman, 1979, 1980; Helpman, 1981; Ethier, 1982). However, evidence from micro data has challenged the representative-firm view of this literature. Exporters are larger, more productive, and pay higher wages than non-exporters within the same industry (Bernard and Jensen, 1999; Bernard et al., 2007). Theories of firm heterogeneity explain the selection of the most productive firms into exporting in the presence of additional trade costs, and highlight

intra-industry reallocations of resources towards high-productivity firms as a new channel of gains from trade (Melitz, 2003; Bernard et al., 2003).

This thesis is inspired by the fact that research on credit frictions in international trade has followed the shift of focus from a country and industry perspective to the firm level. Empirical studies exploit the availability of micro data and show that credit constraints lead to negative effects on firm-level exports. For Italian firms, Minetti and Zhu (2011) find that credit-rationing reduces the probability of exporting by 39% and lowers foreign sales by 38%. A growing number of studies confirms the negative effects of financial frictions on foreign market entry and export performance of existing suppliers (Berman and Héricourt, 2010; Manova, 2013; Muûls, 2015). Whereas exporters show better ex-ante financial health, such as higher liquidity or lower leverage (Greenaway et al., 2007), credit frictions have stronger negative effects on trade flows compared to domestic sales (Manova, 2013; Feenstra et al., 2014). These results point to the importance of additional trade costs and up-front investments related to international activity. Besides that, financially constrained firms export less products to fewer destinations (Muûls, 2015). This evidence is complemented by studies that find positive effects of credit guarantees on exports (Egger and Url, 2006; Felbermayr et al., 2012; Felbermayr and Yalcin, 2013).

Motivated by new empirical evidence from micro data, theoretical models combine firm heterogeneity with credit frictions at the industry or country level. If external finance is needed for trade related up-front costs, financial frictions reduce the probability of exporting (Manova, 2013; Chaney, 2013). If variable trade costs have to be financed by external funds, credit constraints lower the volume of foreign sales as well. Especially less productive firms are affected by credit frictions, as low profits limit their potential repayment to investors (Manova, 2013) or their internal liquidity (Chaney, 2013). Hence, these models explain negative effects of financial frictions both at the firm level and on different margins of bilateral trade flows.

This thesis aims to contribute to the theoretical literature on credit frictions in international trade in two main aspects. The three chapters of the thesis (i) highlight new heterogeneous effects of credit constraints at the firm level, and (ii) analyze how these adjustments change the aggregate implications of financial shocks and trade liberalization in the presence of credit frictions. The theoretical analysis throughout this thesis takes into account general equilibrium adjustments. This is especially relevant for an evaluation of welfare effects and policy implications, but has received limited attention in the recent literature on financial frictions in international trade.

Existing trade models with credit constraints typically focus on partial equilibrium results. The main idea of the general equilibrium analysis in this thesis is as follows: if financial shocks lead to different responses of heterogeneous firms, this will change the degree of competition and will affect the selection of producers into exporting, as well as aggregate outcomes, such as product variety, average productivity, and welfare. Hence from a welfare and policy perspective, a general equilibrium analysis is crucial to account for selection effects of firms.

Building on the existing literature, this thesis combines firm heterogeneity with financial frictions. Producers require external credit for up-front investments or to finance production costs before revenues are realized. This assumption is based on a growing literature that documents negative effects of financial frictions on innovation activity and R&D expenditures (Hall and Lerner, 2010; Maskus et al., 2012; Aghion et al., 2012; Gorodnichenko and Schnitzer, 2013). Related work highlights the importance of investments in international trade, such as technology upgrading (Lileeva and Trefler, 2010; Bustos, 2011), foreign direct investment (Helpman et al., 2004) or quality innovations (Kugler and Verhoogen, 2012). To motivate credit frictions, theoretical models in international trade build on different approaches such as imperfect financial contractibility (Manova, 2013), liquidity constraints (Chaney, 2013) or information asymmetry (Feenstra et al., 2014). In this thesis, credit frictions emerge from moral hazard based on Holmstrom and Tirole (1997), whereas the success of investment projects depends on a managerial action which is non-verifiable for external lenders and thus prone to moral hazard. This agency problem reduces the pledgeability of firm profits and introduces access barriers to external finance. Combined with firm heterogeneity, the moral hazard approach allows to analyze the effects of credit frictions on individual producers, as well as on aggregate outcomes, in an intuitive and highly tractable way.

The three chapters of this thesis focus on different channels how credit constraints influence international trade, and derive new aggregate implications, which have attained no or limited attention in the existing literature. Chapter 1 analyzes the effects of credit frictions on within-firm adjustments and selection into exporting, when both cost-based productivity and product quality matter for the success of a producer. The main idea is that the scope for vertical product differentiation in a sector determines how financial shocks affect investment and price setting. Empirical studies find opposing effects of credit frictions and trade costs on free on board (fob) prices (Secchi et al., 2015; Fan et al., 2014, 2015). Consistent with this evidence, the model shows that prices decrease in credit and trade costs if the scope for vertical product differentiation is high, and vice versa. Furthermore, the analysis highlights that effects of financial shocks on the margins of international trade depend on sectoral technology characteristics. Credit tightening leads to firm exit, inefficiently high innovation activity among existing suppliers, and welfare losses that are larger in sectors with low investment intensity.

Chapter 2 shows that substitution effects between two types of external finance represent an additional channel of adjustment to credit shocks and trade liberalization. Consistent with empirical evidence, there is selection of the largest firms into exporting and unmonitored finance, such as corporate bonds or public debt. Smaller producers serve only the domestic market and have to rely on more expensive financial intermediation. Producers respond to financial shocks by switching the type of finance. These selection effects lead to reallocations of market shares across firms and additional adjustments on the margins of international trade. Furthermore, the model highlights a new source of gains from trade: average productivity increases as lower trade costs allow some exporters to select into cheaper unmonitored finance.

Chapter 3 develops a new international trade model, in which both the share of financially constrained firms, as well as the borrowing rate, is endogenously determined. A key element is that firm heterogeneity arises from the interaction of credit constraints at the firm level with financial frictions at the country level. Producers differ in their pledgeability of sales which results in firm heterogeneity if financial institutions are imperfect. The main result of this chapter is that endogenous adjustments of capital costs lead to an additional negative welfare channel that reduces common gains from globalization. Trade liberalization increases the borrowing rate, leads to a reallocation of market shares towards unconstrained producers, and a larger fraction of credit-rationed firms. This increases the within-industry variance of sales and reduces welfare gains as consumers dislike price heterogeneity. The implications of the model are consistent with new empirical patterns from World Bank Enterprise Surveys: credit frictions are positively related to the degree of product market competition, and to the variance of sales across firms.

In the following, I describe the main results of each chapter in more detail, and briefly discuss the contributions in relation to the existing literature. Chapter 1, which is based on joint work with Carsten Eckel, introduces credit frictions in a model of international trade with horizontal and vertical product differentiation. Besides productivity sorting suggested by Melitz (2003), empirical evidence emphasizes the importance of quality sorting in international trade. Firm-level studies document a positive relation of fob prices with firm size, which points to vertical differentiation (Baldwin and Harrigan, 2011; Kugler and Verhoogen, 2012). This chapter analyzes the effects of credit frictions on innovation, price setting and selection into exporting, when both cost-based productivity and product quality matter for the competitiveness of a producer. The literature on credit frictions in international trade usually focuses on one of the two determinants. We allow for both cost-based and quality-based sorting in a unified framework as firms differ in capabilities to conduct process and quality innovations. Investments are associated with endogenous sunk costs and innovation choices endogenously determine marginal production costs. The model explains positive as well as negative correlations of fob prices with credit frictions and variable trade costs. Consistent with empirical studies (Secchi et al., 2015; Fan et al., 2014, 2015), prices decrease in credit and trade costs if the scope for vertical product differentiation is high, and vice versa. This measure is determined by exogenous technology parameters in the theoretical model and closely related to proxies of quality differentiation as used in empirical work (Khandelwal, 2010; Kugler and Verhoogen, 2012). The price reactions are driven by opposing quality and cost effects on marginal production costs as firms adjust process and quality innovations.

Whereas the existing literature is typically based on partial equilibrium, we show that the effects of credit frictions crucially depend on general equilibrium adjustments. In general equilibrium, credit frictions reduce the number of producers and the degree of competition for existing suppliers. In contrast to partial equilibrium, the negative effect of credit frictions on the extensive margin leads to an equilibrium with larger firms and higher investment. There is an ongoing discussion in both the theoretical and empirical literature to which extent credit frictions affect the extensive and intensive margins of international trade (Berman and Héricourt, 2010; Minetti and Zhu, 2011; Manova, 2013; Muûls, 2015). This chapter contributes to this discussion by showing that the aggregate effects of financial shocks depend on the investment intensity. In sectors with low investment intensity, stronger credit frictions have a large impact on the extensive margin and result in high welfare losses. Furthermore, an increase in credit costs leads to strong negative reactions at the intensive margin and thus larger welfare losses in sectors with high investment intensity.

Chapter 2 is motivated by evidence from the corporate finance literature showing that firm size is an important determinant of access to different types of external credit. Large firms are more likely to use cheap finance provided with low-intensity monitoring, such as the issuance of public debt or corporate bonds. Smaller producers suffer more from credit-rationing (Rajan and Zingales, 1995; Beck et al., 2006), and rely heavily on bank finance with intensive monitoring and higher borrowing rates (Cantillo and Wright, 2000; Denis and Mihov, 2003). Existing theoretical trade models typically abstract from selection into different types of external debt.

The second chapter of this thesis develops a model that accounts for the selection of producers into exporting and two types of finance. Combining productivity sorting à la Melitz (2003) with credit frictions based on Holmstrom and Tirole (1997), the largest firms export and use unmonitored finance. Smaller producers serve only the domestic market and have to rely on more expensive bank finance. Selection effects depend on trade costs, borrowing rates and access barriers to external funds due to credit frictions. This model highlights that producers respond to financial shocks and trade liberalization by switching the type of finance. Accounting for these selection effects is important for any assessment of welfare implications.

The main message of this chapter is that substitution between the two types of finance leads to a reallocation of market shares across producers and new effects on the margins of international trade. The model is consistent with empirical evidence that documents the important role of substitution effects. Credit tightening leads to large adverse impacts on small, bank-dependent firms, and induces selection into other types of external debt (Kashyap et al., 1993; Faulkender and Petersen, 2006; Leary, 2009). During the financial crisis of 2008-2009, producers responded to contraction in credit supply by switching to public bonds and trade credit (Adrian et al., 2012; Coulibaly et al., 2013; Becker and Ivashina, 2014). Furthermore, the model highlights a new source of gains from trade: average productivity increases as falling trade costs allow some exporters to select into cheaper unmonitored finance.

To analyze the role of these selection effects, this chapter extends a Melitz (2003)-type model by endogenous investments and credit frictions. Heterogeneous firms decide on innovations that reduce marginal production costs, but have to be financed externally. This assumption is based on a large literature that shows the important role of external finance for innovation activity (Hall and Lerner, 2010; Maskus et al., 2012; Gorodnichenko and Schnitzer, 2013). Credit frictions emerge from moral hazard based on Holmstrom and Tirole (1997). Following this, the success of investments depends on a managerial project choice, which is non-verifiable for external lenders and thus prone to moral hazard. This agency problem reduces the pledgeability of firm profits and introduces access barriers to credit.

The key feature of the model is to allow for two types of external finance that differ in credit costs and accessibility. Passive lenders provide funds without monitoring, whereas financial intermediaries are able to imperfectly control the project choice of firms. On the one hand, access barriers to monitored funds are lower as financial intermediation alleviates moral hazard. On the other hand, monitoring is associated with additional costs resulting in higher borrowing rates relative to unmonitored finance. This approach is consistent with empirical evidence that shows the important role of banks in reducing agency costs (Gorton and Winton, 2003; Tirole, 2006). The selection mechanism stressed in this chapter is different from models with technology choice, in which the payment of additional fixed costs reduces marginal production costs (Lileeva and Trefler, 2010; Bustos, 2011). Unmonitored finance is associated with a lower borrowing rate, both for fixed and variable investments, but credit frictions impose an access barrier for smaller firms with low pledgeable income.

The framework nests a model with one type of finance as a special case, which allows to disentangle direct effects of shocks from substitution effects. Thus, the model features intra-industry reallocation and common gains of trade liberalization (Melitz, 2003), as well as negative effects of credit frictions as stressed in the existing literature (Manova, 2013; Muûls, 2015). However, new welfare implications arise because firms switch the type of finance. These additional selection effects change the degree of competition in general equilibrium and thus influence the margins of international trade. Compared to a model with only one type of credit, lower financial development leads to additional welfare losses, because firms select into more expensive financial intermediation. While this shock aggravates moral hazard and increases access barriers to both types of finance, monitoring of intermediaries reduces the negative impact compared to unmonitored funds. Consequently, there is selection into financial intermediation and a reallocation of market shares away from firms that rely on passive investors. As now a larger fraction of producers faces higher borrowing rates, the competitive pressure in general equilibrium is reduced. This selection effect mitigates the negative reaction at the extensive margin, but amplifies welfare losses due to lower average productivity.

From a welfare perspective, this chapter shows that policy measures, which are aimed at easing access to external funds, will induce reallocations of market shares across firms, and thus generate losers and winners. As a result, substitution effects between the two types of finance will change average productivity and welfare, besides the intended direct effect. Likewise, additional gains from trade liberalization arise because of selection effects. Falling trade costs increase the pledgeable income of exporters and facilitate access to cheaper unmonitored funds. This leads to two new adjustments that further increase average productivity compared to a model with only one type of credit. First, some exporters gain access to cheaper unmonitored finance and reduce prices. Second, increased competitive pressure leads to even stronger exit of low productivity firms that rely on more expensive bank finance.

The third chapter, which is based on joint work with Michael Irlacher, analyzes the effects of globalization on firm performance and welfare, when producers differ in their exposure to financial frictions and borrowing costs are endogenous. As the first two chapters of this thesis, existing theoretical work builds on the interaction of credit constraints at the industry or country level with ex-ante firm heterogeneity à la Melitz (2003). A novel feature of the third chapter is that firm heterogeneity results from the interaction between capital market imperfections at the country level and credit constraints at the firm level. Producers require external capital to cover production costs and differ in their incentive to divert external funds, while being homogenous in other respects. This firm-specific moral hazard problem reduces the pledgeability of sales and causes credit-rationing for some producers. Firm heterogeneity arises if financial institutions are imperfect, as only a fraction of firms can overcome credit frictions and behaves optimally. Producers with high incentives to misbehave face credit-rationing and have to restrict production. Hence, the share of financially constrained firms is an endogenous outcome in our model.

As a second departure from previous theoretical work, we explicitly model a capital market equilibrium which determines the interest rate. We analyze the effects of globalization and show that adjustments of capital costs represent an additional channel which reduces common gains from trade. Trade liberalization increases the market size as well as competition through entry of foreign firms. A positive market size effect induces output expansion of all firms, raises capital demand, and thus leads to upward pressure on the interest rate. Higher borrowing costs lead to a larger fraction of financially constrained producers. Hence, some initially unconstrained firms face credit-rationing and have to set higher prices. Further, existing constrained suppliers are hurt more by higher capital costs, leading to a reallocation of profits towards unconstrained firms. These adjustments increase the within-industry variance of prices. We consider the indirect utility associated with quadratic preferences as welfare measure. As consumers dislike heterogeneity in prices, a higher within-industry variance represents a negative welfare channel of globalization.

To motivate our theoretical model, we exploit enterprise survey data from the World Bank and highlight three novel empirical patterns. First, we use the ratio of tangible assets over total assets as a proxy for access to external finance, and show that the majority of variation in this measure is across firms within industries rather than between industries. This pattern is consistent with empirical studies, showing that financial health and access to external finance are important determinants of export and innovation activity, even after controlling for firm characteristics, such as size and productivity (Berman and Héricourt, 2010; Minetti and Zhu, 2011; Gorodnichenko and Schnitzer, 2013; Muûls, 2015). The high within-industry heterogeneity with respect to credit constraints motivates the analysis of firm-specific financial frictions in our theoretical model. Second, we show that, in industries with a higher degree of product market competition, a larger fraction of firms is financially constrained. Third, more financially constrained industries and countries with lower financial development show a larger variance of firm sales and a higher share of credit-rationed producers. All relationships hold after controlling for firm characteristics, such as productivity or size. Our theoretical model provides a rationale for these patterns. A higher degree of competition captures that consumers react more sensitive to price increases. This competition effect reduces firm sales and thus the pledgeable income such that more producers become financially constrained. Lower financial development corresponds to weaker contract enforcement which leads to stronger credit frictions. Hence, a higher fraction of producers faces financial constraints and firm-level differences in pledgeability translate into larger within-industry heterogeneity in prices and sales.

From a policy perspective, the analysis suggests that trade liberalization should be accompanied by financial reforms that aim to mitigate the increased within-industry heterogeneity. The negative welfare channel of globalization is especially relevant if financial development is low and credit frictions are significant. Consistent with our theoretical model, empirical studies suggest that the link between credit frictions and international trade is particularly important in developing countries where the quality of financial institutions is low (Banerjee and Duflo, 2005, 2014).

All three chapters of this dissertation are self-contained and include their own introductions and appendices such that they can be read separately. To facilitate reading, footnotes and equations are numbered independently in each chapter.

Chapter 1

Credit Constraints, Endogenous Innovations, and Price Setting in International Trade

This chapter analyzes the effects of credit frictions on within-firm adjustments and selection into exporting, when both cost-based productivity and product quality matter for the success of a producer. We show that the scope for vertical product differentiation in a sector determines how financial shocks affect investment and price setting. Our model explains positive as well as negative correlations of firm-level free on board prices with financial frictions and variable trade costs. Consistent with empirical evidence, prices decrease in credit and trade costs, if the scope for vertical product differentiation is high. Further, we show that effects of financial shocks on the margins of international trade depend on sectoral technology characteristics. Credit tightening leads to firm exit, inefficiently high innovation activity among existing suppliers, and welfare losses that are larger in sectors with low investment intensity. To analyze the effects of credit frictions, we allow for both cost-based and quality-based sorting in a unified framework. Firms differ in capabilities to conduct process and quality innovations, and external finance is needed for investments.

This chapter is based on joint work with Carsten Eckel. We are grateful to Daniel Baumgarten, Peter Egger, Lisandra Flach, Anna Gumpert, Andreas Moxnes, Peter Neary, Banu Demir Pakel, Monika Schnitzer and Erdal Yalcin, as well as participations of the 7th FIW-Research Conference "International Economics" in Vienna, 16th Annual Conference of the European Trade Study Group (ETSG) in Munich, "Mainz Workshop in Trade and Macroeconomics" 2014, 18th Conference of the SFB/TR 15 in Mannheim, 16th Göttingen Workshop "Internationale Wirtschaftsbeziehungen", 8th SFB/TR15 Workshop for Young Researchers at the University of Munich, and the Munich "IO and Trade seminar" for helpful comments and suggestions.

1.1 Introduction

A growing empirical literature documents negative effects of credit constraints on international trade. Exporting usually requires additional up-front costs for investments in marketing, capacity, product customization or distribution networks. Transportation leads to longer time lags between investment outlays and profit realization.[1] Empirical studies find that credit rationing decreases firm-level exports and reduces the probability of serving foreign markets (Berman and Héricourt, 2010; Minetti and Zhu, 2011; Muûls, 2015). Theoretical work, based on fixed up-front costs and firm heterogeneity à la Melitz (2003), shows that financial frictions prevent foreign market entry of low productivity firms (e.g. Manova, 2013). Besides intensified productivity sorting, credit constraints and leverage negatively affect exporters' choice of product quality (Bernini et al., 2013; Ciani and Bartoli, 2014; Fan et al., 2015). In contrast to cost-based productivity sorting à la Melitz (2003), empirical studies document a positive relation of prices with firm size, which points to the important role of vertical product differentiation in international trade (Baldwin and Harrigan, 2011; Johnson, 2012; Kugler and Verhoogen, 2012; Crozet et al., 2012).[2] This chapter analyzes the effects of credit frictions on within-firm adjustments and selection into exporting, when both cost-based productivity and product quality matter for the competitiveness of a producer. We show that the scope for vertical product differentiation in a sector determines how different financial shocks affect innovation choices and price setting at the firm level. Our model explains positive as well as negative correlations of free on board (fob) prices with credit frictions and variable trade costs. Consistent with empirical studies (Secchi et al., 2015; Fan et al., 2014, 2015), prices decrease in credit and trade costs, if the scope for vertical product differentiation is high, and vice versa. Furthermore, the chapter contributes to the discussion how credit frictions affect the intensive and extensive margins of trade. We show that the aggregate effects of financial shocks depend on the sectoral investment intensity. Stronger credit frictions intensify quality-based sorting of firms if the scope for vertical product differentiation is high. In particular, credit tightening leads to firm exit, inefficiently high innovation activity among existing suppliers, and welfare losses that are larger in sectors with low investment intensity.

[1] See Amiti and Weinstein (2011), Chor and Manova (2012), as well as Feenstra et al. (2014). Foley and Manova (2015) provide a review of the trade and finance literature.

[2] A negative relationship between firm size and prices is found by Roberts and Supina (1996) and Foster et al. (2008), which points to cost-based sorting.

To analyze the effects of trade and financial shocks, we develop a general equilibrium model of international trade with credit constraints, two sources of firm heterogeneity and endogenous sunk costs. We allow for both cost-based and quality-based sorting in a unified framework as producers differ in capabilities to conduct process and quality innovations. Investments are associated with endogenous sunk costs that decrease in firm-specific capabilities and innovation choices determine marginal production costs. Depending on their capabilities, firms choose different investment levels and prices. Process innovations decrease marginal costs and hence increase the cost-based productivity of a firm for any given quality level. Whereas this channel is closely related to productivity sorting in Melitz (2003), the second type of investment is motivated by the important role of vertical differentiation. Quality innovations shift demand up and increase marginal production costs.

Firms have to raise external capital for investment outlays, whereas labor is used for fixed and variable production costs. Based on Holmstrom and Tirole (1997), we motivate credit constraints by moral hazard between borrowing firms and outside lenders. In equilibrium, only the most capable firms overcome financial frictions and become exporters, whereas some low capability producers with profitable investment projects fail to borrow external capital and exit the market.

Our model is consistent with empirical studies that find opposing effects of credit frictions and trade costs on price setting. For Italian firm-level data, Secchi et al. (2015) show that financially constrained exporters charge higher prices than unconstrained firms within the same product-destination market. This positive relationship is reduced for product categories with high vertical differentiation. The authors follow Kugler and Verhoogen (2012) and measure the scope for vertical product differentiation as the ratio of advertising and R&D expenditures to total sales in U.S. industries. Using Chinese firm-level data, Fan et al. (2015) find negative effects of financial frictions on fob prices. Furthermore, Fan et al. (2014) show that tariff reductions induce quality upgrading associated with higher prices in highly differentiated sectors and lower prices in non-differentiated sectors.

In our model, an increase in the borrowing rate negatively affects both types of innovation and triggers opposing quality and cost effects on marginal production costs and prices. If the scope for vertical product differentiation is high, the quality effect dominates and tighter credit conditions lead to lower firm-level prices. The scope for quality differentiation is defined as the ratio of expenditures associated with product upgrades relative to investment outlays for processes. This measure is determined by exogenous technology parameters in the theoretical model, and is closely related to sectoral proxies of vertical differentiation as used in empirical studies.[3] Analogously, changes in variable trade costs lead to opposing quality and cost effects as well.

We analyze the impact of financial frictions in partial and general equilibrium. In partial equilibrium, which could be interpreted as a short-term scenario, the number of suppliers is fixed. In general equilibrium, stronger credit frictions reduce the mass of active producers, and in contrast to partial equilibrium, innovation activity as well as firm size of existing suppliers increases. Intuitively, the negative effect of credit frictions on the extensive margin decreases competition and enhances the benefits of investments for active firms. This results in an equilibrium with an inefficiently low number of producers that are larger on average. Furthermore, we show that credit tightening leads to welfare losses that differ across sectors, depending on the investment intensity (either quality or cost-based). In sectors with low investment intensity, credit frictions induce stronger reactions at the extensive margin, which results in larger welfare losses. An increase in the borrowing rate leads to negative reactions at the intensive margin. This cost shock causes stronger within-firm adjustments and larger welfare losses in sectors with high investment intensity.

Our model differs from the theoretical trade and finance literature in several important aspects. First, we analyze the impact of credit frictions in a framework with both cost-based and quality-based sorting. The scope for vertical product differentiation in a sector determines the selection pattern of firms and how financial shocks affect optimal investment and pricing behavior. Second, we consider external financing of investment outlays, instead of trade related up-front costs. Third, we allow for credit constraints among both exporters and non-exporters. Fourth, we do not restrict our analysis to partial equilibrium, but rather show that general equilibrium effects change firm responses to credit tightening. Finally, we investigate the welfare implications of financial shocks.

The chapter is structured as follows. The next section reviews related theoretical literature. Section 1.3 sets up the model and derives optimal firm behavior. In section 1.4, we analyze the effects of financial shocks and of trade liberalization on investment and price setting in partial equilibrium. The following two sections discuss the role of credit frictions in general equilibrium. Finally, section 1.7 concludes.

[3]See Sutton (2001) and Kugler and Verhoogen (2012), as well as the discussion in section 1.4.

1.2 Related theoretical literature

Most closely related to our theoretical setup with two dimensions of heterogeneity, Hallak and Sivadasan (2013) and Sutton (2007) develop two-attribute firm models of international trade with endogenous sunk costs. Besides Melitz-type productivity, Hallak and Sivadasan (2013) allow producers to differ in their ability to develop high-quality products at low fixed outlays. We additionally consider endogenous process investments and introduce credit frictions. Whereas our framework is based on monopolistic competition, Sutton (2007) considers Cournot competition and non-CES preferences and thus allows only for vertical product differentiation, but neglects horizontal differentiation. Similar to these papers, cost-based and quality-based capabilities jointly determine firms' competitiveness in our model and are summarized in a one-dimensional productivity measure related to Melitz (2003). Whereas we focus on single product manufacturers, Bernard et al. (2011) introduce heterogeneity in product attributes within the boundaries of multi-product firms that differ in productivity as in Melitz (2003). In a multi-product firm model with flexible manufacturing and quality investment, Eckel et al. (2015) show that prices fall with distance from the core product (quality-based competence) in differentiated-good sectors, but the opposite holds in non-differentiated sectors (cost-based competence).

Closely related to our analysis, Fan et al. (2014) extend a Melitz-type partial equilibrium model by endogenous quality choice to rationalize positive as well as negative relations of firm-level fob prices with trade costs, depending on the sectoral scope for vertical product differentiation. Fan et al. (2015) build on Arkolakis (2010) as well as Manova (2013) and differentiate between exogenous and endogenous quality. The authors show that financially constrained firms sell at higher prices when quality is exogenous, whereas the opposite holds in case of endogenous quality choice. In contrast, our model explains the prevalence of quality and cost effects, when firms endogenously choose two innovation types that affect marginal production costs and thus prices in opposite ways. Furthermore, we analyze the effects of financial shocks in general equilibrium.

Additionally, this chapter is related to work that considers investment decisions of heterogeneous firms. Bustos (2011), Lileeva and Trefler (2010) as well as Yeaple (2005) allow for process innovations that reduce marginal production costs. Consistent with our framework, these models predict that trade liberalization increases the incentives of technology upgrading. With respect to vertical differentiation, we build on papers that extend international trade models by quality sorting (Baldwin and Harrigan, 2011; Johnson, 2012), as well as endogenous quality and input choices (Kugler and Verhoogen, 2012; Antoniades, 2015).

Furthermore, this chapter is related to a growing literature on financial frictions and international trade with heterogeneous firms. These models are mainly based on productivity sorting à la Melitz (2003) and focus on financial constraints of exporters. In contrast, we assume that domestic as well as international sellers face credit frictions concerning endogenous innovation choices. Manova (2013) considers external financing of fixed and variable export costs and motivates credit constraints by imperfect financial contractibility. By introducing liquidity as a second source of heterogeneity, Chaney (2013) and Suwantaradon (2012) break up the one-to-one relationship between productivity and firm success in the presence of credit constraints. While we assume that endogenous innovations have to be financed by external capital, these models stress the role of internal funds for financing of fixed export costs (Chaney, 2013) and capital inputs (Suwantaradon, 2012). Feenstra et al. (2014) introduce financial frictions by information asymmetry between firms and a monopolistic bank. Instead, we assume perfect competition in the financial sector and symmetric information with respect to firm characteristics, but moral hazard, motivated by Holmstrom and Tirole (1997), introduces financial frictions. In a dynamic model of trade and finance, Felbermayr and Spiegel (2014) introduce heterogeneity in default probabilities which results in firm-specific borrowing rates. Closely related to our notion of credit constraints, four other papers introduce imperfect capital markets motivated by Holmstrom and Tirole (1997) in international trade settings. First, Ehrlich and Seidel (2015) analyze the impact of financial frictions on agglomeration of industries in a new economic geography model based on Krugman (1991). Second, Egger and Keuschnigg (2015) show how discrete R&D investment choices generate endogenous financial constraints. Third, the last chapter of this thesis, based on joint work with Michael Irlacher, introduces firm-specific credit frictions and endogenous borrowing costs in a model of international trade. Fourth, in the framework of Antràs et al. (2009), firms engage in foreign direct investment as a response to imperfect financial contracting and weak investor protection in the host country. Related to that, (Buch et al., 2010, 2014) analyze the impact of financial frictions on foreign direct investment based on Helpman et al. (2004). Other work considers credit frictions in the model of Melitz and Ottaviano (2008) with varying markups (Mayneris, 2011; Peters and Schnitzer, 2015).

1.3 Setup of the model

To analyze the impact of credit conditions on innovation and optimal price setting, this section presents a model of international trade with two sources of firm heterogeneity. We consider two symmetric countries with population of size L and capital endowment K, trading in differentiated varieties. Producers differ in their capabilities to introduce process and quality innovations at low costs. Motivated by a time lag between innovation activity and profit realization, we assume that investment outlays have to be financed by external capital, whereas labor is used for fixed and variable production costs. Capital costs are denoted by the gross interest rate $r > 1$, and the nominal wage is chosen as numéraire ($w = 1$). Following Holmstrom and Tirole (1997), we introduce a non-verifiable project choice of firms which leads to moral hazard and credit frictions. The following subsections discuss the optimal behavior of consumers and producers.

1.3.1 Consumers

Preferences of a representative consumer in one country are characterized by a CES utility function over a continuum of goods indexed by $i \in \Omega$:

$$X = \left[\int_{i \in \Omega} (q_i x_i)^{\frac{\sigma-1}{\sigma}} \, di \right]^{\frac{\sigma}{\sigma-1}}, \tag{1.1}$$

where $\sigma > 1$ is the elasticity of substitution and q_i denotes the quality of a product. The quality-adjusted price index is defined as:

$$P = \left[\int_{i \in \Omega} \left(\frac{p_i}{q_i} \right)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}. \tag{1.2}$$

From the consumer's maximization problem follows that demand for one differentiated variety i increases in the quality level q_i and decreases in the price p_i:

$$x_i = q_i^{\sigma-1} X \left(\frac{p_i}{P} \right)^{-\sigma}. \tag{1.3}$$

By introducing a quality component in the utility function of the representative consumer (1.1), we follow the quality and trade literature.[4] Product quality q_i is endogenously chosen by producers and shifts demand outwards for any given price. Additionally, firms decide on the level of process innovations. The next two subsections describe optimal firm behavior in the presence of credit frictions.

1.3.2 Production and investment with credit constraints

The production sector of the economy is characterized by monopolistic competition. Each firm manufactures one differentiated variety i and decides on process and quality innovations that are both associated with endogenous sunk costs increasing in investment levels:

$$f(q_i) = \frac{1}{\kappa_i} q_i^{\alpha};\ g(e_i) = \frac{1}{\varphi_i} e_i^{\beta}. \tag{1.4}$$

Parameters α and β determine the convexity of the investment cost functions and are exogenously given for producers in one sector. Hence, $\frac{1}{\alpha}$ and $\frac{1}{\beta}$ reflect the elasticities of quality and processes to innovation outlays. Low values of α and β imply that one additional unit of investment spending is very effective.[5] Producers differ in their capabilities to invest in process innovations φ_i and quality upgrades κ_i.[6] Higher values of these firm-specific draws scale down investment costs and hence increase incentives to innovate. The two types of innovation affect marginal production costs mc in opposite directions:

$$mc(q, e) = \frac{q^{\theta}}{e} \text{ with } 0 < \theta < 1. \tag{1.5}$$

The benefit of process innovations e is a reduction of marginal production costs which is closely related to the productivity draw in Melitz (2003). Quality innovations q increase demand for one variety (1.3), but are associated with higher labor requirements, where θ describes the sensitivity of marginal costs to changes in quality. The positive relation between product quality and marginal production costs can be motivated by advertising expenditures or marketing. Related to our approach, other papers endogenize firm's quality choice and consider additional product-specific

[4]See e.g. Baldwin and Harrigan (2011), Kugler and Verhoogen (2012), and Hallak and Sivadasan (2013).

[5]See Sutton (2012), section 1.10, for a comparable specification of quality outlays. In subsection 1.3.3 of this chapter, we impose a convexity assumption for technology parameters α and β.

[6]For notational simplicity we drop the firm's index i in what follows.

outlays or the use of higher-quality inputs.[7] As we allow for both cost-based and quality-based sorting with endogenous sunk costs, our model is closely related to Sutton (2007, 2012) and Hallak and Sivadasan (2013). Compared to previous work, we analyze the impact of credit conditions on two types of investment. Therefore, we assume that firms have to cover expenditures associated with endogenous innovations (1.4) by external capital before revenues are realized, whereas labor is used for variable and fixed production costs. The decision problem of a single firm consists of four stages:

1. **Entry stage**. A potential producer of a differentiated variety decides to enter the market and pays a fixed entry cost f_e. After entry, the firm draws both investment capabilities φ and κ from a joint probability distribution $h(\varphi, \kappa)$ with positive support over $[\underline{\varphi}, \overline{\varphi}] \times [\underline{\kappa}, \overline{\kappa}]$.

2. **Financial contracting and investment**. Producers choose the optimal levels of process and quality innovations and sign a contract with an outside investor to cover the investment costs. Optimal prices are set.

3. **Moral hazard**. After financial contracting, the agent in the firm chooses to conduct the project diligently or to misbehave and reap a private benefit which is non-verifiable for external lenders.

4. **Production and profit realization**. Production and profits are realized and the loan is repaid to the lender.

Stages 2 and 3 introduce endogenous investment choices and financial frictions. Based on Holmstrom and Tirole (1997), we motivate credit constraints by a project choice which is non-verifiable for external investors and thus prone to moral hazard. The optimal contract between a firm and an outside investor specifies the loan size $d_l > 0$, at a gross interest rate $r > 1$, and the credit repayment k_l, whereas the index $l \in d, x$ denotes non-exporters (d) and exporters (x) respectively. We solve the model by backward induction. The next subsection describes optimal firm behavior after entry.

[7]See Kugler and Verhoogen (2012) or Johnson (2012), among others.

1.3.3 Optimal firm behavior

After entry, firms choose the optimal levels of process e_l and quality innovations q_l, and set prices at home and possibly in the foreign market. Exporters sell their product to consumers in an identical foreign country, but face higher fixed costs $f_x > f_d$, and iceberg-type transportation costs such that $\tau > 1$ units of a good have to be shipped for 1 unit to arrive. Whereas domestic and export prices of a firm differ because of transportation costs, we do not allow for market-specific investments. Hence, if a firm exports, the benefits of process and quality innovations are spread across sales in both destinations. Total sales of producers are defined as $s_l = p_l x_l + 1_{\{x_x^* > 0\}} p_x^* x_x^*$, whereas demand is given by equation (1.3) and the dummy variable $1_{\{x_x^* > 0\}}$ takes a value of 1 if the firm exports and is zero otherwise. Firms choose optimal investment levels and prices to maximize expected profits:

$$\underset{p_l, p_x^*, e_l, q_l}{max} \ \lambda \pi_l = \lambda \left[s_l - mc(q_l, e_l) \left(x_l + 1_{\{x_x^* > 0\}} \tau x_x^* \right) - k_l \right] - f_l. \tag{1.6}$$

Variable profits net of loan repayment k_l realize with success probability $0 < \lambda < 1$. Firms use labor input for fixed and variable production costs, but have to finance innovation outlays by external capital. This assumption can be motivated by a time lag between investment activity and profit realization. Depending on their export status $l \in d, x$, firms face the following constraints:

$$d_l \geq \frac{1}{\kappa} q_l^{\alpha} + \frac{1}{\varphi} e_l^{\beta}, \tag{1.7}$$

$$\lambda k_l \geq r d_l, \tag{1.8}$$

$$\pi_l \geq 0. \tag{1.9}$$

The budget constraint (1.7) states that the received credit amount has to be sufficiently high to cover endogenous investment costs. Participation constraints (1.8) and (1.9) ensure that external investors do not incur losses from lending and firms make at least zero profits. We assume perfect competition in the financial sector such that equation (1.8) holds with equality.

Based on Holmstrom and Tirole (1997), we motivate credit frictions by moral hazard. After financial contracting and loan provision, the success of the investment depends on a non-verifiable project choice within the firm. On the one hand, the agent can decide to behave diligently and conduct the project properly which implies that profits realize with high success probability λ. On the other hand, if the agent chooses to misbehave, the probability of success is lower $\lambda_b < \lambda$, but the borrower can reap a share of fixed investments as a non-verifiable private benefit $bf_l > 0$. The manager faces incentives to implement the project in a more pleasant way or pursue own advantages at the expense of investment success. Following Tirole (2006), the private benefit can be interpreted as a disutility of effort.[8] Hence, both investment and entrepreneurial effort are inputs in the production process. There are no information asymmetries with respect to firm characteristics, but the project choice is non-contractible for external investors which leads to moral hazard. Shirking can be ruled out if the following incentive compatibility constraint holds:

$$\lambda \pi_l \geq \lambda_b \pi_l + bf_l. \tag{1.10}$$

We assume that the success probability λ_b is sufficiently low such that the net present value of the marginal firm, which just meets incentive compatibility (1.10), is negative in case of shirking. Thus, the optimal financial contract has to satisfy incentive compatibility to rule out misbehavior and potential losses from lending. As long as the private benefit is positive, equation (1.10) is more restrictive than the zero-profit requirement (1.9). Hence, only firms that generate sufficiently high profits overcome moral hazard and have access to external finance. As private benefits are related to fixed costs, exporters face a trade-off between additional profits from selling abroad in case of diligent behavior and the prospect of higher perks in case of shirking. To describe the optimal behavior of firms, we proceed in two steps. First, conditional on access to finance, firms maximize expected profits (1.6) by taking into account constraints (1.7) and (1.8). Second, incentive compatibility (1.10) determines access to external capital and selection into exporting. Solving the firm's maximization problem leads to the following optimal choices of process and quality innovations:[9]

$$e_l(\varphi, \kappa) = \left(\frac{\lambda A_l}{r}\right)^{\frac{\alpha}{\gamma}} \left(\frac{1-\theta}{\alpha}\kappa\right)^{\frac{(\sigma-1)(1-\theta)}{\gamma}} \left(\frac{\varphi}{\beta}\right)^{\frac{\alpha+(1-\theta)(1-\sigma)}{\gamma}}, \tag{1.11}$$

$$q_l(\varphi, \kappa) = \left(\frac{\lambda A_l}{r}\right)^{\frac{\beta}{\gamma}} \left(\frac{1-\theta}{\alpha}\kappa\right)^{\frac{\beta+1-\sigma}{\gamma}} \left(\frac{\varphi}{\beta}\right)^{\frac{\sigma-1}{\gamma}}, \tag{1.12}$$

[8] See Tirole (2006), section 3.2, for a disussion of moral hazard in a simple model of credit rationing.

[9] See Appendix A.1 for a detailed derivation of firm's maximization problem.

whereby $\gamma \equiv \alpha\beta + (1-\sigma)\left[\alpha + (1-\theta)\beta\right]$, and $A_d \equiv XP^{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}$, $A_x \equiv (1+\tau^{1-\sigma})A_d$ are measures of market size for domestic sellers and exporters respectively. Consistent with theoretical and empirical work on investment activity in international trade, our model suggests a positive relationship between innovation and market size.[10] As exporters spread investment costs across both markets, they face larger incentives to engage in quality and process innovations, ($A_x > A_d$), whereas iceberg transportation costs τ and the borrowing rate r reduce investment activity. We assume that investment costs are sufficiently convex: $\alpha, \beta > (\sigma-1)(2-\theta)$, such that $\gamma > 0$. The convexity assumption implies that quality and process innovations are complements and increase in both capabilities φ and κ. A higher capability draw for one type of innovation has a direct positive impact on the corresponding investment level due to lower endogenous sunk costs, and additionally increases the marginal benefit of the other innovation type. This complementary structure relates to the literature on simultaneous process and product R&D choices and is driven by the fact that both types of innovation increase the price-adjusted quality, and hence the success of a firm in the market.[11] Consequently, producers will always engage in both types of innovation, whereas the relative investment in processes compared to quality improvements is given by:

$$\frac{e_l(\varphi,\kappa)}{q_l(\varphi,\kappa)} = \left(\frac{\lambda A_l}{r}\right)^{\frac{\alpha-\beta}{\gamma}} \left(\frac{1-\theta}{\alpha}\kappa\right)^{\frac{(\sigma-1)(2-\theta)-\beta}{\gamma}} \left(\frac{\varphi}{\beta}\right)^{\frac{\alpha+(2-\theta)(1-\sigma)}{\gamma}}. \tag{1.13}$$

The convexity assumption regarding endogenous sunk costs implies further that investments in process innovations relative to quality upgrades increase in the cost-based capability and decrease in the quality-based capability: $\frac{\partial\left(\frac{e}{q}\right)}{\partial\varphi} > 0$, $\frac{\partial\left(\frac{e}{q}\right)}{\partial\kappa} < 0$. Additionally, the relative investment increases in α and decreases in β as firms react to changes in the relative effectiveness of innovations. A higher sensitivity of marginal production costs with respect to quality (larger θ) reduces the marginal benefit of vertical product differentiation and increases the relative investment in processes. In the extreme case, if $\theta = 1$, higher quality leads to a one-to-one increase in marginal costs (1.5), such that marginal benefits of product upgrades and thus innovation choices (1.11) and (1.12) are driven down to zero.

[10] See Bustos (2011) as well as Kugler and Verhoogen (2012), among others.

[11] Theoretical papers discuss complementarities between product and process innovations under different modes of competition (Athey and Schmutzler, 1995; Lin and Saggi, 2002; Rosenkranz, 2003), and over the product life cycle (Klepper, 1996; Lambertini and Mantovani, 2010).

Analogous to standard models with monopolistic competition and CES demand structure, firms set the optimal price as a constant markup over marginal costs. In contrast to Melitz (2003), marginal production costs are endogenously determined by the two innovation choices, whereas p_l denotes domestic prices of firms with export status $l \in d, x$:

$$p_l(\varphi, \kappa) = \frac{\sigma}{\sigma - 1} \frac{q_l^{\theta}}{e_l} = \frac{\sigma}{\sigma - 1} \left(\frac{r}{\lambda A_l}\right)^{\frac{\alpha - \beta\theta}{\gamma}} \left(\frac{1 - \theta}{\alpha} \kappa\right)^{\frac{\beta\theta + 1 - \sigma}{\gamma}} \left(\frac{\beta}{\varphi}\right)^{\frac{\alpha - \sigma + 1}{\gamma}}, \tag{1.14}$$

and $p_x^*(\varphi, \kappa) = \tau p_x(\varphi, \kappa)$ stands for the export price of internationally active producers. The pricing rule captures two opposing effects of investment behavior. A higher level of process innovations enhances cost-based productivity, whereas quality innovations increase marginal costs according to equation (1.5). Consequently, the optimal price decreases in the cost-based capability φ, but increases in the quality-based capability κ.[12] Hence, the setup with two innovation choices captures both a negative relation between prices and firm size based on cost-based sorting à la Melitz (2003) and a positive correlation between prices and firm size as suggested by the quality and trade literature (e.g. Kugler and Verhoogen, 2012). The success of a producer in the market results from the ability to invest in processes as well as product quality at low costs. Therefore, we define firm's overall efficiency as a combination of both capabilities: $z = \varphi^{\alpha} \kappa^{\beta(1-\theta)}$. Figure 1.1 depicts an example for an iso-efficiency curve in the two-dimensional space, whereas the vertical axis shows the quality-based capability κ and the horizontal axis shows the cost-based capability φ. The curve represents a non-linear trade-off between the two attributes: $\frac{\partial \kappa}{\partial \varphi} < 0$ and $\frac{\partial^2 \kappa}{\partial \varphi^2} > 0$. If a firm possesses a low ability to invest in processes (low φ), it requires a relatively high quality-based capability κ to achieve the same overall efficiency level. Firms located along a particular iso-efficiency curve earn the same expected revenues and profits, since the latter can be expressed as monotone and increasing functions of efficiency z:

$$\lambda s_l(z) = \frac{\sigma}{\sigma - 1} (\lambda A_l)^{\frac{\alpha\beta}{\gamma}} \left(r^{-\alpha - \beta(1-\theta)} \beta^{-\alpha} \left(\frac{1 - \theta}{\alpha}\right)^{\beta(1-\theta)} z \right)^{\frac{\sigma - 1}{\gamma}}, \tag{1.15}$$

[12] Elasticities of prices with respect to capabilities are given by: $\frac{\partial p_l}{\partial \varphi} \frac{\varphi}{p_l} = \frac{\sigma - 1 - \alpha}{\gamma} < 0$ and $\frac{\partial p_l}{\partial \kappa} \frac{\kappa}{p_l} = \frac{\beta\theta - \sigma + 1}{\gamma} > 0$, if $\beta > \frac{\sigma - 1}{\theta}$. Note that this condition for the technology parameter β is more restrictive than the convexity assumption discussed earlier in this section.

$$\lambda\pi_l(z) = \frac{(\sigma-1)\,v}{\sigma}\lambda s_l(z) - f_l, \tag{1.16}$$

where $v = \frac{1}{\sigma-1} - \left(\frac{1}{\beta} + \frac{1-\theta}{\alpha}\right) > 0$. Comparable to single-attribute firm models, efficiency z is a one-dimensional measure of profits and firm size. However, producers with the same size or efficiency z choose different levels of quality and process innovations and thus set different prices, depending on their firm-specific capabilities. Revenues and profits depend positively on market size A_l, but negatively on the borrowing rate r and investment cost parameters α and β. Equations (1.11)-(1.16) characterize the optimal behavior of firms that have access to external finance. The next subsection takes into account incentive compatibility (1.10), which determines the selection of firms into exporting.

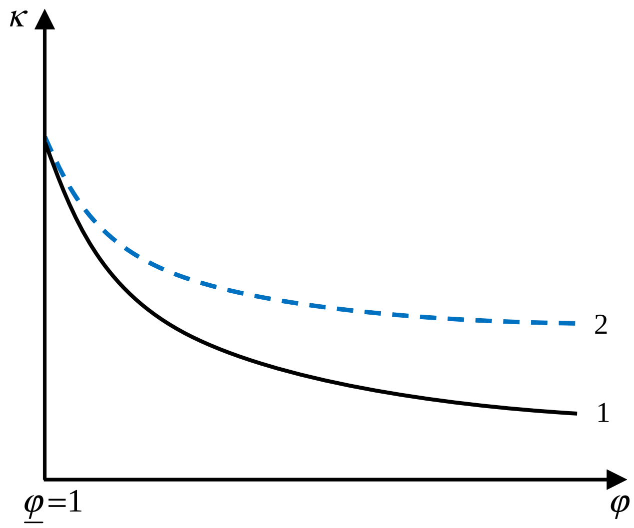

Figure 1.1: Iso-efficiency curve for low (1) and high (2) vertical differentiation

1.3.4 Selection of firms

Only firms that meet incentive compatibility (1.10) receive credit from outside investors. As profits (1.16) are a function of efficiency z, the binding financial constraint (1.10) determines a cutoff efficiency level that is necessary to obtain external finance:

$$z_l = \left(\frac{r}{\lambda}\right)^{\alpha+\beta(1-\theta)} \beta^{\alpha} \left(\frac{\alpha}{1-\theta}\right)^{\beta(1-\theta)} A_l^{\frac{-\alpha\beta}{\sigma-1}} \left(\frac{\Theta f_l}{v\lambda}\right)^{\frac{\gamma}{\sigma-1}}, \tag{1.17}$$

whereas $\Theta = 1 + \frac{\lambda b}{\lambda - \lambda_b}$ reflects agency costs from moral hazard. Independent of export status, this measure captures financial frictions and determines the difference between the zero-profit condition (1.9) and incentive compatibility (1.10):

$$\frac{z_{ICC}}{z_{ZPC}} = \Theta^{\frac{\gamma}{\sigma-1}}. \tag{1.18}$$

If the private benefit b is equal to zero, financial frictions disappear and incentive compatibility collapses to a zero-profit condition ($\Theta = 1$). Whenever the private benefit is positive ($\Theta > 1$), moral hazard prevents external financing of profitable investment projects as some lower efficiency firms satisfy the zero-profit condition (1.9), but not incentive compatibility (1.10). Thus, financial imperfections impede market access of small producers which is consistent with existing heterogeneous firm models that allow for credit constraints (e.g. Manova, 2013). Note that Holmstrom and Tirole (1997) consider differences in wealth, whereas in our model firm-specific innovation capabilities determine access to external capital. Hence, we neglect the role of internal liquidity to overcome credit frictions as analyzed by Chaney (2013). If fixed f_x and variable trade costs τ are sufficiently high, only the most capable firms select into exporting:

$$z_x > z_d \text{ if } \frac{f_x}{f_d}\left(1 + \tau^{1-\sigma}\right)^{\frac{-\alpha\beta}{\gamma}} > 1. \tag{1.19}$$

This condition differs from Melitz (2003) because exporters spread expenditures associated with endogenous investments across sales in both markets.[13]

Proposition 1.1 *If Condition (1.19) holds, the most efficient firms with $z \geq z_x$ export. Producers in the middle range of the efficiency distribution ($z_d \leq z < z_x$) sell only domestically, while the least efficient firms ($z < z_d$) have no access to external finance and exit.*

Graphically, equation (1.17) specifies the location of a marginal-access curve in the two-dimensional capability space (φ, κ). Figure 1.2 depicts the selection pattern of firms under Proposition 1.1, whereby the marginal-access curve for exporting lies above the one for domestic activity.[14] Marginal firms, characterized by cutoff efficiencies z_d and z_x, just meet incentive compatibility (1.10) and are indifferent between

[13]In Melitz (2003), a similar condition requires that $\frac{f_x}{f_d}\tau^{\sigma-1} > 1$.

[14]The two-dimensional selection pattern is closely related to Sutton (2007).

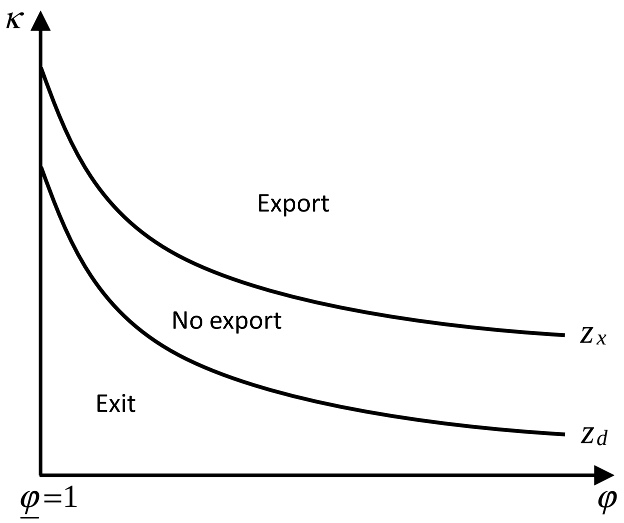

Figure 1.2: Selection pattern in open economy

diligent behavior and shirking, such that profits are equal to the probability-weighted private benefit: $\pi\left(z_l\right)=\frac{bf_l}{\lambda-\lambda_b}$. Sales and investment expenditures of marginal producers are independent of capabilities and depend on fixed parameters only:

$$s_l(z_l)=\frac{\sigma\Theta f_l}{(\sigma-1)\,v\lambda}, \tag{1.20}$$

$$\frac{1}{\varphi}e_l^{\beta}(z_l)=\frac{\Theta f_l}{cvr};\ \frac{1}{\kappa}q_l^{\alpha}\left(z_l\right)=\frac{(1-\theta)\,\Theta f_l}{\alpha vr}. \tag{1.21}$$

These expressions for marginal firms are obtained by combining optimal innovation choices (1.11) and (1.12) with the cutoff efficiency levels (1.17). An increase in the private benefit b aggravates moral hazard and requires a higher cutoff efficiency level (1.17) to meet incentive compatibility (1.10), resulting in exit of low capability firms. Graphically, marginal-access curves in Figure 1.2 shift upwards. Similar selection effects occur if fixed production costs go up. Furthermore, the cutoff level (1.17) increases in technology cost parameters α and β, and decreases in market size A_l. Whereas the private benefit imposes an access barrier to external finance and affects the extensive margin, a change in credit costs induces within-firm adjustments. The impact of credit conditions can be interpreted in a slightly different way: capital market imperfections impose minimum quality requirements. To see this, we follow Sutton (2012) and derive the quality-price ratio that reflects the effective competitiveness of a firm:[15]

$$\frac{q_l}{p_l} = \frac{\sigma - 1}{\sigma} \left(\left(\frac{\lambda A_l}{r} \right)^{\alpha + \beta(1-\theta)} \beta^{-\alpha} \left(\frac{1-\theta}{\alpha} \right)^{\beta(1-\theta)} z \right)^{\frac{1}{\gamma}}. \tag{1.22}$$

Like revenues and profits, the quality-price ratio is an increasing function of both innovation choices and thus of firm's efficiency z, as depicted in Figure 1.3. Whereas process innovations decrease prices for any given quality, product upgrades increase quality for any given price. Faced with higher borrowing rates, firms scale down both types of innovation resulting in a lower quality-price ratio. Graphically, within-firm adjustments correspond to a downward shift of the quality-price profile depicted in Figure 1.3 for two different borrowing rates: $r_1 < r_2$. While this effect negatively influences the intensive margin of international trade, credit frictions affect the extensive margin. The horizontal line represents a minimum quality requirement that is necessary to obtain external capital. This threshold is derived by inserting the cutoff efficiency level (1.17) in equation (1.22). An increase in the private benefit

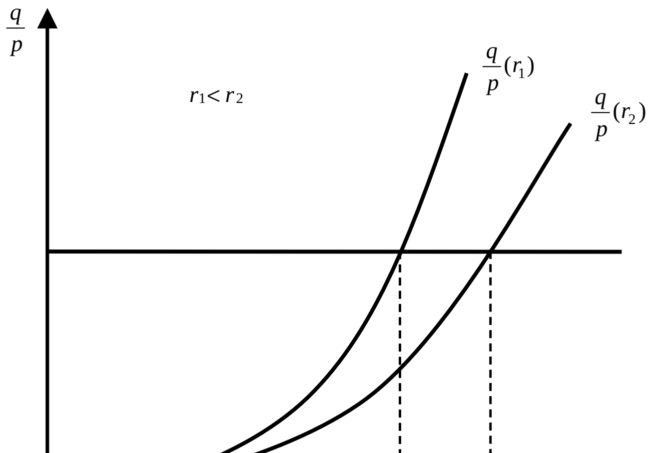

Figure 1.3: Financial frictions and quality sorting

raises the cutoff efficiency level and hence the minimum quality requirement reflected in an upward shift of the horizontal line in Figure 1.3, whereas within-firm adjustments and hence changes in the individual price-adjusted quality are not present.

[15]Compare Sutton (2012), chapter 1.6.

The remainder of the chapter discusses the implications of within-firm adjustments and selection effects in partial and general equilibrium. Consistent with empirical evidence, the following section shows that reoptimizations of innovation choices can explain positive as well as negative correlations of credit costs with export prices, depending on the scope for vertical product differentiation. In sections 1.5 and 1.6, we analyze the general equilibrium effects of credit tightening.

1.4 Quality and cost effects in partial equilibrium

This section analyzes how firms respond to changes of credit conditions in partial equilibrium, whereby the number of firms and the cutoff efficiency level remain unchanged. Hence, results of this analysis could be interpreted as short-term effects of credit tightening. Furthermore, the interest rate r is treated as exogenous, whereas section 1.5 takes into account general equilibrium effects and endogenizes the borrowing rate by capital market clearing. An increase in the borrowing rate r leads to negative effects on both process innovations (1.11) and quality investments (1.12):

$$\frac{\partial e_l(\varphi,\kappa)}{\partial r}\frac{r}{e_l(\varphi,\kappa)} = -\frac{\alpha}{\gamma} < 0 \ ; \quad \frac{\partial q_l(\varphi,\kappa)}{\partial r}\frac{r}{q_l(\varphi,\kappa)} = -\frac{\beta}{\gamma} < 0 \ . \tag{1.23}$$

A reduction in the success probability λ leads to the same within-firm adjustments as it increases the rate of return demanded by external investors. Reductions in both types of investment influence marginal costs (1.5) and hence optimal price setting in opposite ways. On the one hand, firms scale down process innovations resulting in lower production efficiency and increased marginal costs. As equation (1.14) shows, this cost effect pushes optimal prices up. On the other hand, producers reduce product investments which leads to an opposing quality effect and dampens prices. The relative importance of quality and cost effects depends on the scope for vertical product differentiation in the production sector.

The scope for vertical product differentiation. Following Sutton (2001) as well as Kugler and Verhoogen (2012), we define this measure as the ratio of expenditures for quality innovations relative to firm revenues:

$$\frac{\frac{1}{\kappa}q_l^{\alpha}(z)}{s_l(z)} = \frac{(\sigma-1)(1-\theta)}{\alpha\sigma r}. \tag{1.24}$$

As equation (1.24) shows, the scope for product differentiation is independent of firm-specific capabilities, but increases in the elasticity of substitution σ and decreases in the borrowing rate r. Furthermore, quality differentiation is lower if investment costs become more convex (higher α), and if the sensitivity of marginal costs to quality increases (higher θ). A similar measure expresses the scope for process innovations relative to firm size:

$$\frac{\frac{1}{\varphi}e_l^{\beta}(z)}{s_l(z)} = \frac{\sigma - 1}{\beta\sigma r}. \tag{1.25}$$

Increased product market competition (higher σ) has a positive effect on process intensity, whereas the borrowing rate r and the convexity of investment costs β lower innovation expenditures relative to firm revenues. The combination of equations (1.24) and (1.25) describes the relative scope for vertical product differentiation, compared to process innovations, as a constant ratio of technology parameters:

$$\frac{\frac{1}{\kappa}q_l^{\alpha}(z)}{\frac{1}{\varphi}e_l^{\beta}(z)} = \frac{(1-\theta)\beta}{\alpha}. \tag{1.26}$$

Increases in α and θ make quality innovations less effective and reduce the relative expenditures for this investment type. Conversely, the ratio increases in β, which changes investment in favor of product upgrades. Hence, expression (1.26) reflects the relative effectiveness of quality innovations compared to process innovations and is closely related to the estimation of quality ladders proposed by Khandelwal (2010). In sectors with higher relative effectiveness, firms engage more in vertical product differentiation resulting in a larger demand shifter q. Following Khandelwal (2010), a higher consumer's valuation for quality, conditional on prices, translates into larger market volumes and represents a proxy for a market's quality ladder. The relative scope for vertical product differentiation (1.26) determines how relative investment (1.13) and prices (1.14) respond to an increase in the borrowing rate:

$$\frac{\partial\left(\frac{e_l}{q_l}\right)}{\partial r}\frac{rq_l}{e_l} = \frac{\beta-\alpha}{\gamma}; \frac{\partial p_l}{\partial r}\frac{r}{p_l} = \frac{\alpha-\beta\theta}{\gamma}. \tag{1.27}$$

Proposition 1.2 *If the scope for vertical product differentiation is relatively high and hence $\alpha < \beta$, firms respond to higher credit costs by decreasing the (relative) investment in product quality, and set lower prices: $\frac{\partial\left(\frac{e_l}{q_l}\right)}{\partial r} > 0$, $\frac{\partial p_l}{\partial r} < 0$.*

Consistent with empirical evidence, our model rationalizes positive as well as negative relations of firm-level fob prices with credit costs, depending on the role of quality differentiation in a sector. Secchi et al. (2015) exploit Italian firm-level data and find that financially constrained exporters charge higher prices than unconstrained firms within the same product-destination market. This positive relationship between credit frictions and prices points to cost effects, but is reduced for product categories with high quality differentiation. Following Kugler and Verhoogen (2012), Secchi et al. (2015) use the ratio of advertising and R&D expenditures to total sales in U.S. industries as a proxy for vertical product differentiation. Hence, the measure is comparable to expression (1.24) in our theoretical model. Closely related, Fan et al. (2015) analyze Chinese firm-level data and find evidence for a negative relationship between credit frictions and prices. The authors rationalize this result by a partial equilibrium model based on Arkolakis (2010) and Manova (2013), and differentiate between exogenous and endogenous quality. Fan et al. (2015) show that constrained firms sell at higher prices when quality is exogenous, whereas the opposite holds in case of endogenous quality choice. In contrast, our model explains the prevalence of quality and cost effects when firms endogenously choose two innovation types that affect marginal production costs in opposite ways. Thus, we reconcile empirical evidence and stress the role of vertical product differentiation for counteracting cost and quality effects on prices.

Trade liberalization. Comparable to changes in credit costs, trade liberalization leads to opposing quality and costs effects on fob prices of exporters. A reduction in variable trade costs τ induces exporters to invest more, both in process and quality innovations, shown by the following elasticities:[16]

$$\frac{\partial e_x}{\partial \tau}\frac{\tau}{e_x} = \frac{\alpha\,(1-\sigma)}{\gamma}\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}} < 0 \;;\; \frac{\partial q_x}{\partial \tau}\frac{\tau}{q_x} = \frac{\beta\,(1-\sigma)}{\gamma}\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}} < 0. \tag{1.28}$$

Analogous to credit shocks, the relative scope for vertical product differentiation determines the adjustment of the relative investment and hence the direction of price changes:[17]

$$\frac{\partial\left(\frac{e_x}{q_x}\right)}{\partial \tau}\frac{\tau q_x}{e_x} = \frac{(\alpha-\beta)\,(1-\sigma)}{\gamma}\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}, \tag{1.29}$$

[16] The derivatives follow immediately from equations (1.11) and (1.12).

[17] Compare the expression for relative investment (1.13) and optimal price setting (1.14).

$$\frac{\partial p_x}{\partial \tau}\frac{\tau}{p_x} = \frac{(\alpha - \beta\theta)(\sigma - 1)}{\gamma}\frac{\tau^{1-\sigma}}{1 + \tau^{1-\sigma}}. \tag{1.30}$$

Proposition 1.3 *If the scope for vertical product differentiation is relatively high, such that $\alpha < \beta$, trade liberalization leads to an increase of the (relative) investment in product quality, and firms set higher fob prices: $\frac{\partial\left(\frac{e_x}{q_x}\right)}{\partial\tau} > 0$, $\frac{\partial p_x}{\partial \tau} < 0$.*

If the degree of vertical differentiation is high, product quality increases more than cost-based productivity leading to upward pressure on marginal costs and prices. Conversely, if the industry is characterized by low product differentiation, increases in process innovations and thus the cost reducing effect dominate and lead to negative price reactions. Consistent with these predictions, Fan et al. (2014) show for Chinese firm-level data that tariff reductions induce quality upgrading of exporters resulting in positive or negative price reactions, depending on whether the degree of vertical product differentiation is high or low. To rationalize this result, the authors extend a Melitz-type partial equilibrium model by endogenous quality choice. Faced with trade liberalization, firms readjust product quality by solving a trade-off between increases in demand due to higher quality and decreases in sales due to higher prices. In contrast, our model shows that trade and credit costs influence prices at the firm-level through endogenous adjustments of quality and process innovations.
In addition to this partial equilibrium scenario, we analyze the general equilibrium effects of credit tightening. Considering the selection of firms, the scope for vertical product differentiation does not only determine the direction of within-firm adjustments, but also influences the role of quality sorting and cost-based productivity sorting in our model with two sources of firm heterogeneity. Graphically, the slope of the marginal-access curve in the two-dimensional capability space is the negative inverse of measure (1.26): $\frac{d \ln \kappa}{d \ln \varphi} = -\frac{\alpha}{\beta(1-\theta)}$. Hence, sectors with higher quality differentiation are characterized by flatter marginal-access curves (see Figure 1.1) and a negative relationship between credit costs and prices. In this case, access to finance is mainly determined by a minimum requirement on the quality-based capability and our model is closely related to single-attribute frameworks that focus on quality sorting (e.g. Baldwin and Harrigan, 2011; Kugler and Verhoogen, 2012). Consistent with empirical evidence, prices and firm size are positively correlated if the scope for vertical product differentiation is high (e.g. Manova and Zhang, 2012). Larger firms with higher quality-based capability κ invest more in quality upgrades resulting in

higher prices: $\frac{\partial p_l}{\partial \kappa}\frac{\kappa}{p_l} = \frac{\beta\theta-\sigma+1}{\gamma} > 0$.[18] In contrast, if the scope for vertical differentiation is low, marginal-access curves become steeper and the model resembles a Melitz (2003) - type economy with cost-based sorting. In sectors with low quality differentiation, empirical studies point to a negative relation of firm size and productivity with unit values (Roberts and Supina, 1996; Foster et al., 2008). Accordingly, larger firms with higher cost-based capability φ invest more in process innovations that reduce marginal costs and prices: $\frac{\partial p_l}{\partial \varphi}\frac{\varphi}{p_l} = \frac{\sigma-1-\alpha}{\gamma} < 0$. In this case, financial shocks induce mainly cost effects resulting in a positive relationship between credit costs and optimal prices. To analyze the effects of credit tightening on aggregate export performance and firm selection, the next section presents the general equilibrium.

1.5 Equilibrium in the open economy

At the entry stage, firms draw both investment capabilities φ and κ from a joint probability distribution $h(\varphi,\kappa)$ with positive support over $[\underline{\varphi},\overline{\varphi}]\times[\underline{\kappa},\overline{\kappa}]$. As described in section 1.3, we summarize these two capabilities in a single measure of firm's efficiency: $z = \varphi^{\alpha}\kappa^{\beta(1-\theta)}$. The marginal-access cutoff levels (1.17) define regions in the two-dimensional capability space (φ,κ), as depicted in Figure 1.2:

$$\begin{aligned} D &= \left\{(\varphi,\kappa)\in[\underline{\varphi},\overline{\varphi}]\times[\underline{\kappa},\overline{\kappa}] : z \geq z_d\right\}, && (1.31)\\ D_d &= \left\{(\varphi,\kappa)\in[\underline{\varphi},\overline{\varphi}]\times[\underline{\kappa},\overline{\kappa}] : z_d \leq z < z_x\right\}, && (1.32)\\ D_x &= \left\{(\varphi,\kappa)\in[\underline{\varphi},\overline{\varphi}]\times[\underline{\kappa},\overline{\kappa}] : z \geq z_x\right\}, && (1.33)\end{aligned}$$

where D is the set of all active firms in equilibrium and D_l, with $l \in d,x$, denotes regions of non-exporters and exporters respectively. Ex-ante probabilities of being active in one particular region χ_l, as well as the probability of success χ_s, are defined as follows:

$$\chi_l = \int\int_{(\varphi,\kappa)\in D_l} h(\varphi,\kappa)d\varphi d\kappa;\ \ \chi_s = \int\int_{(\varphi,\kappa)\in D} h(\varphi,\kappa)d\varphi d\kappa, \qquad (1.34)$$

and the corresponding conditional probabilities are given by $\mu_s(\varphi,\kappa) = \frac{h(\varphi,\kappa)}{\chi_s}$, and $\mu_l(\varphi,\kappa) = \frac{h(\varphi,\kappa)}{\chi_l}$. For aggregation purposes we define the average efficiency within

[18] See the pricing rule (1.14) and Footnote 12.

the group of non-exporters and exporters:

$$\widetilde{z}_l^{\frac{\sigma-1}{\gamma}} = \iint\limits_{(\varphi,\kappa)\in D_l} z^{\frac{\sigma-1}{\gamma}}(\varphi,\kappa)\,\mu_l(\varphi,\kappa)d\varphi d\kappa. \tag{1.35}$$

Average revenues and expected profits by group can be written as:

$$\widetilde{s}_l = \iint\limits_{(\varphi,\kappa)\in D_l} s_l(\varphi,\kappa)\mu_s(\varphi,\kappa)d\varphi d\kappa, \tag{1.36}$$

$$E\pi_l = \iint\limits_{(\varphi,\kappa)\in D_l} \lambda\pi_l(\varphi,\kappa)\mu_s(\varphi,\kappa)d\varphi d\kappa. \tag{1.37}$$

Analogous to Melitz (2003), revenues of a particular firm with efficiency z can be expressed relative to the marginal domestic seller or exporter, characterized by the cutoff level z_l:

$$s_l(z) = \left(\frac{z}{z_l}\right)^{\frac{\sigma-1}{\gamma}} s_l(z_l). \tag{1.38}$$

As discussed in subsection 1.3.4, sales of marginal firms depend only on fixed parameters of the model. By taking into account expression (1.20) and the definition of average efficiency (1.35), we write expected sales and profits by group as follows:

$$\lambda\widetilde{s}_l = \frac{\sigma\Theta f_l}{(\sigma-1)\,v}\left(\frac{\widetilde{z}_l}{z_l}\right)^{\frac{\sigma-1}{\gamma}};\ E\pi_l = \frac{(\sigma-1)\,v}{\sigma}\lambda\widetilde{s}_l - f_l. \tag{1.39}$$

The equilibrium is determined by equation (1.39) and a free entry condition to ensure that fixed entry costs f_e are equal to expected profits before firms know their capability draws:

$$E\pi = \frac{\delta f_e}{\chi_s}, \tag{1.40}$$

whereas δ is the exogenous probability of a death shock. Total expected profits are the weighted sum of profits by group: $E\pi = \sum_l \psi_l E\pi_l$, and the share of producers in one group is defined as $\psi_l = \frac{\chi_l}{\chi_s}$. Equations (1.39) and (1.40) determine the minimum efficiency of marginal firms z_d that are just able to produce for the domestic market. The general equilibrium is characterized by two additional conditions. Labor market clearing pins down the number of active firms M in one country and capital market clearing determines the interest rate r. The labor demand of a firm consists of variable and fixed production costs and can be written as a function of sales:

$$mc_l(\varphi,\kappa)\left[x_l(\varphi,\kappa)+1_{\{x_x^*>0\}}\tau x_x^*(\varphi,\kappa)\right]+f_l=\frac{\sigma-1}{\sigma}s_l(z)+f_l. \tag{1.41}$$

Producers with higher efficiency z employ more labor due to increased investment expenditures and larger sales. In equilibrium, the inelastic labor supply L has to be equal to labor demands in the entry sector ($L_e = M_e f_e$) and of the two groups of active producers: $L = L_e + \sum_l L_l$. Analogous to Melitz (2003), aggregation of single labor requirements pins down the mass of active firms M in one country:

$$M=\frac{L}{\lambda\widetilde{s}\left[1-\frac{\sigma-1}{\sigma}\left(\frac{1}{\beta}+\frac{1-\theta}{\alpha}\right)\right]}, \tag{1.42}$$

where $\widetilde{s}=\sum_l \psi_l\widetilde{s}_l$ denotes average revenues in the total economy. This relationship is obtained by imposing aggregate stability such that the mass of successful entrants is equal to the mass of firms that are forced to exit due to the exogenous death shock: $\chi_s M_e = \delta M$. The aggregate demand for capital by group consists of investment expenditures for process and quality innovations:

$$M_l\iint\limits_{(\varphi,\kappa)\in D_l}\frac{1}{\varphi}e_l^{\beta}(\kappa,\varphi)\,\mu_l(\varphi,\kappa)d\varphi d\kappa=\frac{\sigma-1}{\beta\sigma r}M\lambda\widetilde{s}_l, \tag{1.43}$$

$$M_l\iint\limits_{(\varphi,\kappa)\in D_l}\frac{1}{\kappa}q_l^{a}(\varphi,\kappa)\,\mu_l(\varphi,\kappa)d\varphi d\kappa=\frac{(\sigma-1)(1-\theta)}{\alpha\sigma r}M\lambda\widetilde{s}_l. \tag{1.44}$$

More convex investment costs (higher α and β), as well as a higher borrowing rate r, scale down process and quality innovations which leads to lower capital demand. Aggregate investment expenditures for processes and quality upgrades are functions of average revenues and the number of firms in the market. The ratio of aggregate investment expenditures leads to the sectoral scope for vertical product differentiation (1.26) that is independent of firm capabilities, as discussed in section 1.4. Capital market clearing ensures that aggregate capital demand for both innovation types equals capital supply K:

$$K=\frac{\sigma-1}{\sigma r}\left(\frac{1-\theta}{\alpha}+\frac{1}{\beta}\right)M\lambda\widetilde{s}. \tag{1.45}$$

Combining the market clearing conditions for labor (1.42) and capital (1.45) uniquely determines the equilibrium interest rate:

$$r = \frac{\frac{\sigma-1}{\sigma}\left(\frac{1}{\beta}+\frac{1-\theta}{\alpha}\right)}{1-\frac{\sigma-1}{\sigma}\left(\frac{1}{\beta}+\frac{1-\theta}{\alpha}\right)}\frac{L}{K}. \tag{1.46}$$

The interest rate decreases in the investment cost parameters α, β and θ, as well as in capital supply K, and increases with product market competition captured by the elasticity of substitution σ. In the following two sections, we exploit general equilibrium properties of the model to derive aggregate effects and welfare implications of credit tightening.

1.6 Credit tightening in general equilibrium

In general equilibrium, we take into account that credit frictions change the number of active producers in the sector. To derive explicit solutions of aggregate variables, we assume that capabilities φ and κ are independently Pareto distributed with positive support over $[1, \overline{\varphi}] \times [1, \infty]$ and $\overline{\varphi} > 1$. The probability of drawing a particular combination of φ and κ is given by: $h(\varphi, \kappa) = h_\varphi(\varphi) h_\kappa(\kappa)$ with $h_\kappa(\kappa) = \xi \kappa^{-\xi-1}$ and $h_\varphi(\varphi) = \vartheta \frac{\varphi^{-\vartheta-1}}{1-\overline{\varphi}^{-\vartheta}}$, where ξ and ϑ are the shape parameters of the Pareto distributions.[19] As we consider two symmetric countries, our general equilibrium analysis neglects implications of bilateral differences in financial development or in credit conditions. In contrast, another strand of literature examines how national differences in financial characteristics influence cross-border trade and capital flows (see Antràs and Caballero, 2009; Furusawa and Yanagawa, 2010, among others). The next subsection shows how financial shocks affect optimal investment and pricing behavior in general equilibrium and compares the results to the partial equilibrium analysis in section 1.4. Subsection 1.6.2 discusses the welfare effects of credit tightening.

[19] For technical reasons, we assume that $\xi > \frac{\beta(1-\theta)(\sigma-1)}{\gamma}$ and $\vartheta > \frac{\alpha\xi}{\beta(1-\theta)}$. Appendix A.3 explicitly derives the cutoff efficiency z_d under the assumption of Pareto distributed capabilities.

Table 1.1: Effects of financial shocks in partial and general equilibrium

	Partial equilibrium				**General equilibrium**			
Financial shock	$r\uparrow$ / $\lambda\downarrow$		$b\uparrow$		$r\uparrow$		$\lambda\downarrow$ / $b\uparrow$	
Vertical differentiation	low	high	low	high	low	high	low	high
Process e / quality q	-		0		-		+	
Relative investment $\frac{e}{q}$	-	+	0		-	+	+	-
Price p	+	-	0		+	-	-	+

1.6.1 Effects on investment and price setting

Table 1.1 summarizes the optimal responses to financial shocks in partial and general equilibrium. The main result of this section is that stronger credit frictions (an increase in b or a decrease in λ) reduce the competitive pressure in general equilibrium and change or even reverse within-firm adjustments. In contrast, an increase in the interest rate does not reflect stronger credit frictions, but could be caused by a decrease in aggregate capital supply K, and has no effect on the extensive margin:[20]

$$\frac{\partial M}{\partial r}\frac{r}{M} = 0; \; \frac{\partial z_d}{\partial r}\frac{r}{z_d} = 0. \tag{1.47}$$

This result depends on the assumption that only endogenous investment costs have to be financed by external capital, whereas labor input is used for fixed production costs. As Table 1.1 shows, optimal firm responses to an increase in the borrowing rate r go into the same direction in partial and general equilibrium. If fixed costs have to be financed by external capital, exit of low efficiency firms would raise the cutoff efficiency. Consequently, increased competitive pressure would even amplify the responses in general equilibrium without changing the direction of the effects.[21]

Proposition 1.4 *An increase in the borrowing rate r has no effect on the extensive margin, whereas within-firm adjustments go into the same direction in partial and general equilibrium.*

In contrast to an increase in borrowing costs r, stronger credit frictions change the direction of optimal firm responses in general equilibrium. The private benefit b can be interpreted as an inverse measure of financial development which might be

[20] Compare the capital market clearing condition in general equilibrium (1.46).

[21] See Appendix A.5 for an extension of the model by external financing of fixed costs.

affected by countries' financial policies. Following Tirole (2006) and Antràs et al. (2009), this managerial benefit of shirking might be reduced by improved investor protection or stronger enforceability of financial contracts. An increase in the private benefit b enhances incentives of borrowers to misbehave such that external investors demand more pledgeable income to provide loans for investment. A decrease in the success probability of investment projects λ increases the rate of return required for investors to break even and aggravates moral hazard. Consequently, both shocks impose stronger restrictions on incentive compatibility (1.10), resulting in exit of low efficiency firms:[22]

$$\frac{\partial M}{\partial b}\frac{b}{M} = -\frac{\lambda b}{\Delta\lambda + \lambda b} < 0; \ \frac{\partial z_d}{\partial b}\frac{b}{z_d} > 0, \tag{1.48}$$

$$\frac{\partial M}{\partial \lambda}\frac{\lambda}{M} = \frac{\lambda b}{\Delta\lambda + \lambda b}\frac{\lambda_b}{\Delta\lambda} > 0; \ \frac{\partial z_d}{\partial \lambda}\frac{\lambda}{z_d} < 0. \tag{1.49}$$

whereas $\Delta\lambda = \lambda - \lambda_b$. Compared to partial equilibrium, the exit of low efficiency producers leads to additional firm adjustments in case of an increase in b and reverses the responses to a decrease in λ (see Table 1.1). This general equilibrium effect reduces the competitive pressure in the sector and induces still active suppliers to increase innovation activity. Intuitively, the negative effect of credit frictions on the extensive margin enhances the benefits of investments for existing firms. Thus, stronger credit frictions lead to an equilibrium with a lower number of producers that are larger on average. This effect is counteracted by an increase in the cutoff efficiency which reduces, but does not outweigh the positive response of innovation.

Proposition 1.5 *In general equilibrium, a higher private benefit b or a lower success probability λ reduces the number of active producers, raises the cutoff efficiency z_d, and increases innovation activity as well as firm size of existing suppliers.*
Proof. *See Appendix A.4.* ■

In contrast to partial equilibrium, stronger financial frictions lead to a reduction of prices in sectors with low quality differentiation. Thus, credit tightening intensifies quality-based sorting if the scope for vertical differentiation is high, and vice versa. The next subsection discusses the welfare consequences of financial shocks.

[22]See Appendix A.3 for an explicit derivation of the number of firms in one country.

1.6.2 Welfare analysis

Analogous to Melitz (2003), we derive welfare as a positive function of the cutoff efficiency level z_d:[23]

$$W = \frac{\sigma - 1}{\sigma} \left(\frac{1}{\beta}\right)^{\frac{1}{\beta}} \left(\frac{1-\theta}{\alpha}\right)^{\frac{1-\theta}{\alpha}} \left(\frac{1}{r}\right)^{\frac{\alpha+\beta(1-\theta)}{\alpha\beta}} \left(\frac{v}{\Theta f_d}\right)^{\frac{\gamma}{\alpha\beta(\sigma-1)}} \left(\frac{L}{1+v}\right)^{\frac{1}{\sigma-1}} z_d^{\frac{1}{\alpha\beta}}. \tag{1.50}$$

An increase in the borrowing rate r leads to negative effects on process and quality innovations (see section 1.4), resulting in welfare losses along the intensive margin:

$$\frac{\partial W}{\partial r}\frac{r}{W} = -\frac{\alpha + \beta\left(1-\theta\right)}{\alpha\beta} < 0. \tag{1.51}$$

Elasticity (1.51) shows that negative welfare effects become more pronounced with increasing quality differentiation (1.24) and process intensity (1.25), when technology parameters α, β and θ are low. Hence, an increase in credit costs leads to greater adjustments of innovation activity in sectors with high investment intensity. Consequently, consumers face a stronger decrease in price-adjusted quality resulting in larger welfare losses. As discussed in the previous subsection, stronger credit frictions cause negative effects on the extensive margin. The exit of least efficient firms leads to two opposing effects on welfare (1.50). On the one hand, welfare decreases due to a lower number of varieties. On the other hand, the average efficiency, and thus the average price-adjusted quality offered in the economy, increases ($\frac{\partial z_d}{\partial b} > 0, \frac{\partial z_d}{\partial \lambda} < 0$). The effects of credit tightening on welfare are given by:

$$\frac{\partial W}{\partial b}\frac{b}{W} = -\frac{1}{\alpha\beta}\left(\frac{\gamma}{\sigma-1}\frac{\lambda b}{\Delta\lambda + \lambda b} - \frac{\partial z_d}{\partial b}\frac{b}{z_d}\right), \tag{1.52}$$

$$\frac{\partial W}{\partial \lambda}\frac{\lambda}{W} = \frac{1}{\alpha\beta}\left(\frac{\gamma\lambda_b}{\Delta\lambda\left(\sigma-1\right)}\frac{\lambda b}{\Delta\lambda + \lambda b} + \frac{\partial z_d}{\partial \lambda}\frac{\lambda}{z_d}\right). \tag{1.53}$$

Proposition 1.6 *An increase in the borrowing rate r leads to negative effects on the intensive margin and welfare losses that are stronger in sectors with high investment intensity. A higher private benefit b or a lower success probability λ reduces welfare if the private benefit b is sufficiently high, whereas welfare losses are more pronounced in sectors with low investment intensity.*

Proof. *See Appendix A.4.* ■

[23] See Appendix A.2 for a derivation of the welfare function.

If financial development is low (captured by a high private benefit b), stronger credit frictions will lead to a large reduction in product variety that outweighs efficiency gains. Proposition 1.6 shows that the extent of welfare losses after credit tightening depends on the sectoral investment intensity. An increase in the borrowing rate leads to a larger reduction in welfare in sectors with high investment intensity due to stronger within-firm adjustments. In contrast, changes in the private benefit b and the success probability λ lead to a negative impact along the extensive margin, which affects sectors with low investment intensity more severely. The reason is that consumers in those sectors put more weight on the loss of variety compared to efficiency gains due to the exit of firms.

Figure 1.4 illustrates the welfare responses to an increase in the private benefit b, whereas Table 1.2 shows the chosen parameter values. Following Davis and Harrigan (2011), we set the elasticity of substitution σ equal to 2. Furthermore, we assume quadratic investment cost functions both for processes and quality, and choose a value of $\theta = 0.5$ for the sensitivity of marginal production costs with respect to quality. This parameter choice implies that the scope for vertical product differentiation in equation (1.24) is 0.125, which is very close to the R&D and advertising intensity in the most differentiated sectors as reported by Kugler and Verhoogen (2012).[24] The relative scope for vertical differentiation in equation (1.26) is 0.5. In Figure 1.4, we show the welfare response according to equation (1.52) for different values of investment cost parameters. If α or β increases, the scope for innovation is reduced and approaches 0.03, which is the mean of R&D and advertising intensity across all 4-digit U.S. industries reported by Kugler and Verhoogen (2012).

Furthermore, we set iceberg-transportation costs to $\tau = 1.9$, which is consistent with Anderson and van Wincoop (2003) and Bernard et al. (2007), whereas the domestic production costs f_d are normalized to one. To choose a value for fixed export costs f_x, we exploit that the share of exporters is determined by equation (A.11). Figure 1.4 shows welfare responses for high and low financial development (see upper part) and different values of the Pareto shape parameter ξ (lower part). A change in financial development, captured by the private benefit b, does not affect the share of exporters nor the scope for vertical differentiation. However, a larger Pareto shape parameter, and hence a higher dispersion of firm capabilities, reduces the fraction of exporters.

[24] See Table A3 in the Online Appendix of Kugler and Verhoogen (2012). R&D and advertising intensity is defined as ratio of R&D and advertising expenditures to total industry sales from the U.S. Federal Trade Commission (FTC) 1975 Line of Business Survey. Highest values for this ratio are reported for drugs and medicines (0.166), cosmetics (0.124), and spirits (0.121).

Table 1.2: Parameter values

Parameter	Description	Value
σ	Elasticity of substitution	2
α, β	Investment cost parameter	2
θ	Marginal cost parameter	0.5
ξ, ϑ	Pareto shape parameters	3 / 6
τ	Iceberg-transportation costs	1.9
f_x	Fixed trade costs	7
f_d	Fixed production costs	1
λ	Success probability diligent behavior	0.7
λ_b	Success probability shirking	0
b	Private benefit	5 / 10

In the first case, with $\xi = 3$, 46% of firms export. This fraction is reduced to 21% if $\xi = 6$, which is equal to the value found by Bernard et al. (2007) for U.S. firms.[25]
As shown in Proposition 1.6, Figure 1.4 depicts that negative responses of welfare to credit tightening are larger in sectors with low investment intensity. Further, the negative variety effect and welfare losses are more pronounced, if financial development is low (high private benefit), and if the Pareto shape parameter is large. Whenever the distribution of firms in the capability space is more dispersed, efficiency gains after firm exit will be lower, which results in stronger reactions of welfare.
Thus, the comparative static analysis shows that the effects of financial shocks within a sector depend on the investment intensity and the role of quality differentiation. Both in partial and general equilibrium, the relative scope for vertical differentiation (1.26) determines how optimal investment and pricing behavior are affected by credit conditions. Furthermore, aggregate effects of credit tightening depend on the sectoral investment intensity for quality (1.24) and processes (1.25). Interest rate shocks lead to adjustments along the intensive margin and especially hurt sectors with high investment intensity. Stronger credit frictions affect the extensive margin of international trade, whereas sectors with low investment intensity face larger welfare losses. Hence, this model contributes to the discussion how credit frictions affect the different margins of international trade (Berman and Héricourt, 2010; Minetti and Zhu, 2011; Muûls, 2015), by showing that the aggregate effects of financial shocks depend on the sectoral investment intensity.

[25] Note that the chosen values for the Pareto shape parameters have to satisfy the restrictions described in Appendix A3. Compare Footnote 19.

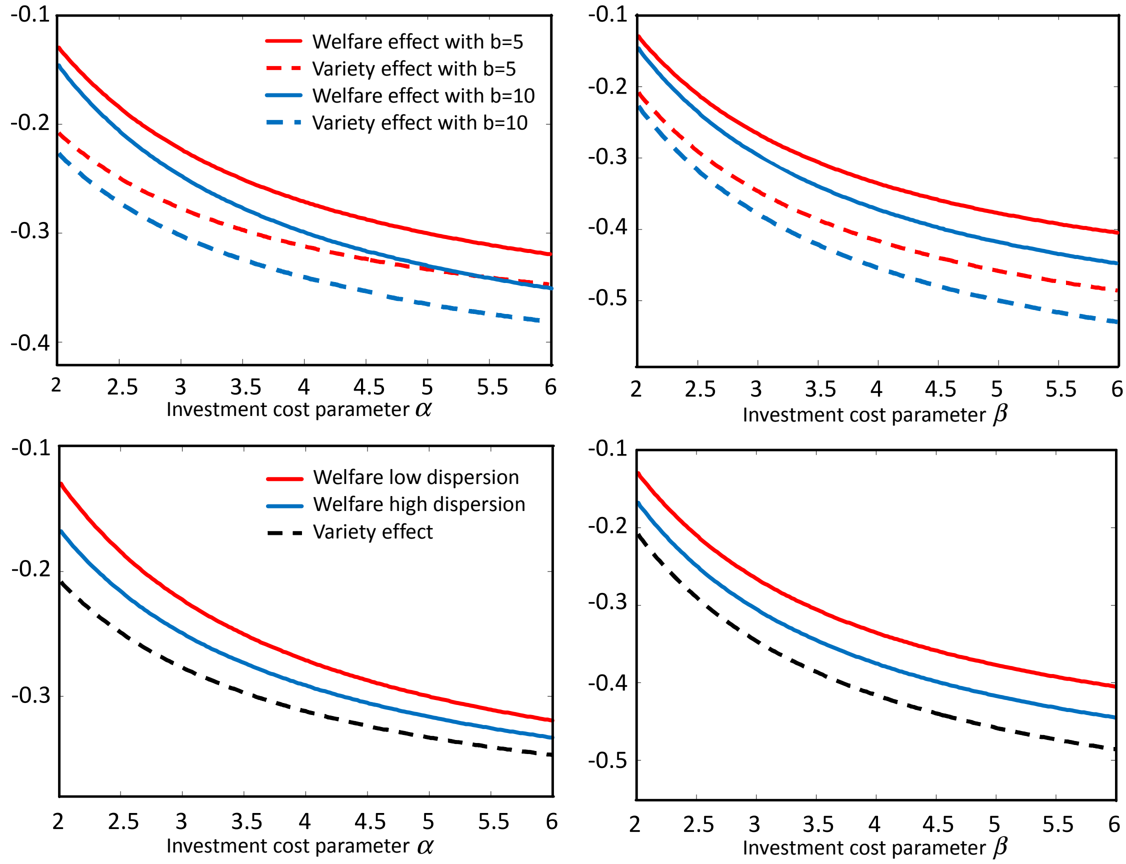

Figure 1.4: Welfare responses to credit tightening

1.7 Conclusion

This chapter has analyzed the effects of credit frictions on within-firm adjustments and selection into exporting in a two-dimensional heterogeneous firm model with endogenous innovation choices. Whereas existing trade models with financial frictions are mainly based on Melitz (2003), three elements are crucial for our theoretical analysis. First, we allow both for Melitz-type cost sorting and vertical product differentiation. As in single-attribute models, firms' competitiveness and hence profits are determined by a one-dimensional productivity measure. The latter can be separated along two dimensions: the cost-based and the quality-based capability of a producer. Second, we consider innovations in quality and processes associated with endogenous sunk costs that decrease in capabilities. Third, we assume that investment costs have to be financed by external capital and introduce credit constraints.

We show that the scope for vertical product differentiation in a sector determines how financial shocks affect investment and price setting. Consistent with empirical evidence, we rationalize positive as well as negative correlations of fob prices with credit frictions and variable trade costs. In addition, we distinguish the effects of financial frictions in partial and general equilibrium. In partial equilibrium, which could be interpreted as a short-term scenario, the number of suppliers is fixed and credit tightening leads to negative effects on investment. In general equilibrium, stronger credit frictions intensify quality-based sorting of firms, if the scope for vertical product differentiation is high. Credit tightening leads to firm exit, increased innovation activity among existing suppliers and welfare losses that are larger in sectors with low investment intensity.

Our theoretical analysis could be extended in several directions. First, we do not allow for market-specific investments. Both process innovations and quality upgrades are spread across domestic and foreign markets, whereas empirical evidence points to quality-based market segmentation of exporters (Bastos and Silva, 2010; Manova and Zhang, 2012; Flach, 2014). Second, we concentrate on moral hazard to introduce credit rationing. Empirical and theoretical literature suggests alternative channels through which financial market imperfections may influence export behavior, such as higher default risk, information asymmetries regarding firm attributes or imperfect financial contractibility (see Manova, 2013; Feenstra et al., 2014, among others). Third, suppliers rely on one source of external capital to finance total investment costs. This allows us to focus on within-firm adjustments, whereas selection effects between different sources of external finance might play an important role as well. Chapter 2 of this thesis introduces market-based and bank finance in a trade model with heterogeneous firms and shows how trade and financial shocks induce firms to switch the type of external debt. Lastly, whereas our analysis focuses on a CES demand structure, credit frictions may influence price-cost markups. Chapter 3 introduces credit frictions in a new trade model with linear demand.

Appendix A

Mathematical Appendix

A.1 Maximization problem of firm

This section derives the optimal investment and pricing behavior of a firm with export status $l \in d, x$, whereas $1_{\{x_x^* > 0\}}$ takes a value of one if the firm is an exporter and is zero otherwise. Firms maximize expected profits (1.6) which can be written as follows:

$$\lambda \pi_l = \lambda X P^\sigma q_l^{\sigma-1} \left[p_l^{1-\sigma} + 1_{\{x_x^*>0\}} \left(p_x^*\right)^{1-\sigma} - \frac{q_l^\theta}{e_l} \left(p_l^{-\sigma} + 1_{\{x_x^*>0\}} \tau \left(p_x^*\right)^{-\sigma} \right) \right] - \lambda k_l - f_l, \tag{A.1}$$

subject to the constraints (1.7), (1.8) and (1.10). The first order conditions for optimal domestic prices p_l and export prices p_x^*, as well as investment levels e_l and q_l, are given by:

$$(\lambda + \mu_3) X P^\sigma q_l^{\sigma-1} \left[(1-\sigma) p_l^{-\sigma} + \sigma p_l^{-\sigma-1} \frac{q_l^\theta}{e_l} \right] = 0, \tag{A.2}$$

$$(\lambda + \mu_3) X P^\sigma q_x^{\sigma-1} \left[(1-\sigma) \left(p_x^*\right)^{-\sigma} + \sigma \tau \left(p_x^*\right)^{-\sigma-1} \frac{q_x^\theta}{e_x} \right] = 0, \tag{A.3}$$

$$(\lambda + \mu_3) X P^\sigma \frac{q_l^{\theta+\sigma-1}}{e_l^2} \left(p_l^{-\sigma} + 1_{\{x_x^*>0\}} \tau \left(p_x^*\right)^{-\sigma} \right) - \mu_1 \frac{\beta}{\varphi} e_l^{\beta-1} = 0, \tag{A.4}$$

$$\begin{aligned} &(\lambda + \mu_3) X P^\sigma (\sigma - 1) q_l^{\sigma-2} \left(p_l^{1-\sigma} + 1_{\{x_x^*>0\}} \left(p_x^*\right)^{1-\sigma} \right) \\ &+ (\lambda + \mu_3) X P^\sigma \frac{(\theta + \sigma - 1) q_l^{\theta+\sigma-2}}{e_l} \left(p_l^{-\sigma} + 1_{\{x_x^*>0\}} \tau \left(p_x^*\right)^{-\sigma} \right) - \mu_1 \frac{\alpha}{\kappa} q_l^{\alpha-1} = 0. \end{aligned} \tag{A.5}$$

Optimality conditions with respect to credit amount d_l and loan repayment k_l are:

$$\mu_1 - r\mu_2 = 0, \tag{A.6}$$

$$-\lambda + \mu_2\lambda - \mu_3 = 0, \tag{A.7}$$

whereas μ_1, μ_2 and μ_3 are the Lagrange multipliers of the constraints (1.7), (1.8) and (1.10) respectively. Combining equations (A.6) and (A.7) leads to $\frac{\lambda+\mu_3}{\mu_1} = \frac{\lambda\mu_2}{\mu_1} = \frac{\lambda}{r}$, whereas $\mu_3 = 0$ if incentive compatibility is not binding. The optimal prices (1.14) follow immediately from equations (A.2) and (A.3). Combining the optimal pricing rules with the first-order conditions for quality (A.4) and process innovations (A.5), leads to:

$$e_l = \left(\frac{\lambda\varphi A_l}{\beta r}\right)^{\frac{1}{\beta+1-\sigma}} q_l^{\frac{(\sigma-1)(1-\theta)}{\beta+1-\sigma}}, \tag{A.8}$$

$$q_l = \left(\frac{\lambda(1-\theta)\kappa A_l}{\alpha r}\right)^{\frac{1}{\alpha+(1-\theta)(1-\sigma)}} e_l^{\frac{\sigma-1}{\alpha+(1-\theta)(1-\sigma)}}, \tag{A.9}$$

whereas the market size for domestic producers and exporters is defined as: $A_d = XP^\sigma\left(\frac{\sigma-1}{\sigma}\right)^\sigma$, $A_x = (1+\tau^{1-\sigma})A_d$. Equations (A.8) and (A.9) show the complementary structure of process and quality innovations, as discussed in subsection 1.3.3. Combining the two expressions leads to the optimal investment choices described by equations (1.11) and (1.12). By inserting the optimal investment levels into the first order conditions (A.2) and (A.3), one obtains the optimal price (1.14). Total sales of a firm with export status $l \in d, x$ are defined by $s_l(\varphi, \kappa) = XP^\sigma\left(\frac{q_l}{p_l}\right)^{\sigma-1} + 1_{\{x_x^*>0\}}XP^\sigma\left(\frac{q_x}{p_x^*}\right)^{\sigma-1}$, whereas $p_x^* = \tau p_x$. Inserting the optimal choices of quality innovation (1.12) and price setting (1.14) immediately leads to expression (1.15). The optimal loan repayment k_l follows from the constraints (1.7), as well as (1.8), and can be written as function of revenues:

$$\lambda k_l = \frac{\sigma-1}{\sigma}\lambda s_l(z)\left(\frac{1}{\beta}+\frac{1-\theta}{\alpha}\right). \tag{A.10}$$

A.2 Derivation of welfare

To derive the welfare function (1.50), we aggregate the price index (1.2) as follows:

$$\begin{aligned} P^{1-\sigma} &= M_d \iint_{(\varphi,\kappa)\in D_d} \left(\frac{q_d}{p_d}\right)^{\sigma-1} \mu_d(\varphi,\kappa) d\varphi d\kappa \\ &\quad + \left(1+\tau^{1-\sigma}\right) M_x \iint_{(\varphi,\kappa)\in D_x} \left(\frac{q_x}{p_x}\right)^{\sigma-1} \mu_x(\varphi,\kappa) d\varphi d\kappa. \end{aligned}$$

By using the expression for firm-specific quality-price ratios (1.22) and exploiting the labor market clearing condition (1.42), welfare can be written as:

$$\begin{aligned} W &= P^{-1} = \frac{\sigma-1}{\sigma}\beta^{-\frac{1}{\beta}}\left(\frac{1-\theta}{\alpha}\right)^{\frac{1-\theta}{\alpha}}\left(\frac{L}{r\left(1+v\right)}\right)^{\frac{\alpha+\beta(1-\theta)}{\alpha\beta}} \\ &\quad \left[M_d \widetilde{z}_d^{\frac{\sigma-1}{\gamma}} + \left(1+\tau^{1-\sigma}\right)^{\frac{\alpha\beta}{\gamma}} M_x \widetilde{z}_x^{\frac{\sigma-1}{\gamma}}\right]^{\frac{\gamma}{\alpha\beta(\sigma-1)}}. \end{aligned}$$

Analogous to Melitz (2003), we substitute for average efficiency $\widetilde{z}_l$ using the relationship $\frac{s_l(\widetilde{z}_l)}{s_l(z_l)} = \left(\frac{\widetilde{z}_l}{z_l}\right)^{\frac{\sigma-1}{\gamma}} = \frac{S_l}{M_l}\frac{(\sigma-1)v}{\sigma\left(\frac{1}{\lambda}+\frac{b}{\Delta\lambda}\right)f_l}$, and exploit that $\frac{z_x}{z_d} = \left(\frac{f_x}{f_d}\right)^{\frac{\gamma}{\sigma-1}}\left(1+\tau^{1-\sigma}\right)^{\frac{-\alpha\beta}{\sigma-1}}$. After some modifications, this allows to write welfare per worker as a function of the cutoff efficiency z_d, as specified in equation (1.50).

A.3 Solution with Pareto distributed capabilities

To obtain an explicit solution for the cutoff efficiency z_d, we assume that firm-specific capabilities φ and κ are independently Pareto distributed with positive support over $[1,\overline{\varphi}] \times [1,\infty]$, and $\overline{\varphi} > 1$. The probability of drawing a particular combination of φ and κ is then given by: $h\left(\varphi,\kappa\right) = h_\varphi(\varphi)h_\kappa(\kappa)$, with $h_\kappa(\kappa) = \xi\kappa^{-\xi-1}$ and $h_\varphi(\varphi) = \vartheta\frac{\varphi^{-\vartheta-1}}{1-\overline{\varphi}^{-\vartheta}}$, where ξ and ϑ are the shape parameters of the Pareto distributions. Probabilities of success χ_s and of belonging to the groups of non-exporters and exporters respectively χ_l, as defined by equation (1.34), can be expressed as functions of cutoff efficiency levels z_l, for $l \in d, x$:

$$\chi_s = \frac{1}{\Psi} z_d^{\frac{-\xi}{\beta(1-\theta)}}; \chi_d = \frac{1}{\Psi}\left(z_d^{\frac{-\xi}{\beta(1-\theta)}} - z_x^{\frac{-\xi}{\beta(1-\theta)}}\right); \chi_x = \frac{1}{\Psi} z_x^{\frac{-\xi}{\beta(1-\theta)}},$$

whereby $\Psi = \frac{\alpha\xi - \vartheta\beta(1-\theta)}{\vartheta\beta(1-\theta)} \frac{1-\overline{\varphi}^{-\vartheta}}{\overline{\varphi}^{\frac{\alpha\xi-\vartheta\beta(1-\theta)}{\beta(1-\theta)}}-1}$. The shares of exporters and non-exporters, $\psi_l = \frac{\chi_l}{\chi_s}$, are then given by:

$$\psi_x = \left(\frac{z_d}{z_x}\right)^{\frac{\xi}{\beta(1-\theta)}} ; \psi_d = 1 - \left(\frac{z_d}{z_x}\right)^{\frac{\xi}{\beta(1-\theta)}}, \tag{A.11}$$

with $\frac{z_d}{z_x} = \left(\frac{f_d}{f_x}\right)^{\frac{\gamma}{\sigma-1}} (1+\tau^{1-\sigma})^{\frac{\alpha\beta}{\sigma-1}}$. The components of expected profits in equation (1.39) can be expressed as:

$$\psi_d \left(\frac{\widetilde{z}_d}{z_d}\right)^{\frac{\sigma-1}{\gamma}} = \Omega \left(1 - \left(\frac{z_d}{z_x}\right)^{\frac{\xi\gamma-\beta(1-\theta)(\sigma-1)}{\gamma\beta(1-\theta)}}\right), \tag{A.12}$$

$$\psi_x \left(\frac{\widetilde{z}_x}{z_x}\right)^{\frac{\sigma-1}{\gamma}} = \Omega \left(\frac{z_d}{z_x}\right)^{\frac{\xi}{\beta(1-\theta)}}, \tag{A.13}$$

where $\Omega = \frac{\xi\gamma}{\xi\gamma-\beta(1-\theta)(\sigma-1)}$. The free entry condition (1.40) is an increasing function of the cutoff efficiency z_d:

$$E\pi = \delta f_E \Psi z_d^{\frac{\xi}{\beta(1-\theta)}}.$$

For technical reasons, we assume that the Pareto shape parameters are sufficiently large, $\xi > \frac{\beta(1-\theta)(\sigma-1)}{\gamma}$ and $\vartheta > \frac{\alpha\xi}{\beta(1-\theta)}$, such that $\Omega, \Psi > 0$. For the following analysis, we define a measure for average efficiency Δ_z, and the average fixed costs $\widetilde{f}$ in the economy:

$$\Delta_z = 1 + \psi_x \frac{f_x}{f_d} \frac{(1+\tau^{1-\sigma})^{\frac{\alpha\beta}{\gamma}} - 1}{(1+\tau^{1-\sigma})^{\frac{\alpha\beta}{\gamma}}} ; \widetilde{f} = \psi_d f_d + \psi_x f_x.$$

Combining expected profits and the free entry condition, leads to an explicit solution for the cutoff efficiency level z_d:

$$z_d = \left(\frac{E\pi}{\delta f_E \Psi}\right)^{\frac{\beta(1-\theta)}{\xi}}, \tag{A.14}$$

whereas expected profits can be written as: $E\pi = \Omega\Delta_z\Theta f_d - \widetilde{f}$.

Number of active firms As shown by equation (1.42), the number of active firms in one country is a function of labor supply L and average revenues (1.39). To solve for the number of firms explicitly, we use the expressions for expected efficiencies of non-exporters and exporters (A.12) and (A.13). With Pareto distributed capabilities, average revenues can be expressed as:

$$\lambda\widetilde{s} = \frac{\sigma\Omega\Delta_s\Theta f_d}{(\sigma-1)\,v},$$

with $\Delta_s = 1 + \psi_x \frac{f_x}{f_d} \frac{\left(1+\tau^{1-\sigma}\right)^{\frac{1}{\gamma}}-1}{\left(1+\tau^{1-\sigma}\right)^{\frac{1}{\gamma}}}$. The number of active firms in one country is:

$$M = \frac{(\sigma-1)\,vL}{\sigma\Omega\Delta_s\Theta f_d\left[1-\frac{\sigma-1}{\sigma}\left(\frac{1}{\beta}+\frac{1-\theta}{\alpha}\right)\right]}, \tag{A.15}$$

and the number of total varieties in one economy is defined as: $M_x = (1+\psi_x)\,M$.

A.4 Proofs

Proof of Proposition 1.5. The change of the number of firms with respect to the private benefit b and the success probability λ, as shown in equations (1.48) and (1.49) respectively, follows immediately from the derivative of equation (A.15). The derivatives of the cutoff efficiency z_d (A.14) are given by:

$$\frac{\partial z_d}{\partial b}\frac{b}{z_d} = \frac{\beta(1-\theta)}{\xi\Delta\lambda}\frac{\Omega\lambda b f_d\Delta_z}{E\pi} > 0, \tag{A.16}$$

$$\frac{\partial z_d}{\partial \lambda}\frac{\lambda}{z_d} = -\frac{\beta(1-\theta)}{\xi\Delta\lambda^2}\frac{\Omega\lambda\lambda_b b f_d\Delta_z}{E\pi} < 0. \tag{A.17}$$

The general equilibrium effects of credit tightening on investment and price setting can be derived from equations (1.11)-(1.14), by taking into account incentive compatibility (1.17) and the changes in the cutoff efficiency (A.16) and (A.17). The responses of process and quality innovations to an increase in the private benefit b are given by:

$$\frac{\partial e_l}{\partial b}\frac{b}{e_l} = \frac{1}{\beta}\frac{b\lambda}{b\lambda+\Delta\lambda}\left(1-\frac{\beta(1-\theta)\,(\sigma-1)}{\xi\gamma}\frac{E\pi+\tilde{f}}{E\pi}\right), \tag{A.18}$$

$$\frac{\partial q_l}{\partial b}\frac{b}{e_l} = \frac{1}{\alpha}\frac{b\lambda}{b\lambda+\Delta\lambda}\left(1-\frac{\beta(1-\theta)\,(\sigma-1)}{\xi\gamma}\frac{E\pi+\tilde{f}}{E\pi}\right). \tag{A.19}$$

The investment responses are positive as long as $\frac{\beta(1-\theta)(\sigma-1)}{\xi\gamma}\frac{E\pi+\tilde{f}}{E\pi} < 1$. Note that $\frac{\beta(1-\theta)(\sigma-1)}{\xi\gamma} < 1$ and $\frac{E\pi+\tilde{f}}{E\pi} > 1$, whereas $\frac{\partial\left(\frac{E\pi+\tilde{f}}{E\pi}\right)}{\partial b} < 0$. Hence, the general equilibrium response of innovations is positive whenever private benefits are sufficiently high. The derivatives of the relative investment and the optimal price are given by:

$$\frac{\partial\left(\frac{e_l}{q_l}\right)}{\partial b}\frac{bq_l}{e_l} = \frac{\alpha-\beta}{\alpha\beta}\frac{b\lambda}{b\lambda+\Delta\lambda}\left(1-\frac{\beta(1-\theta)(\sigma-1)}{\xi\gamma}\frac{E\pi+\tilde{f}}{E\pi}\right), \tag{A.20}$$

$$\frac{\partial p_l}{\partial b}\frac{b}{p_l} = \frac{\beta\theta-\alpha}{\alpha\beta}\frac{b\lambda}{b\lambda+\Delta\lambda}\left(1-\frac{\beta(1-\theta)(\sigma-1)}{\xi\gamma}\frac{E\pi+\tilde{f}}{E\pi}\right). \tag{A.21}$$

The responses of investment and price setting to a change in the success probability λ can be derived analogously.

Proof of Proposition 1.6. The welfare reaction in equation (1.52) is negative if $\frac{\gamma}{\sigma-1}\frac{\lambda b}{\Delta\lambda+\lambda b} > \frac{\partial z_d}{\partial b}\frac{b}{z_d}$, which leads to the following condition:

$$\frac{\partial W}{\partial b}\frac{b}{W} < 0 \text{ if } \frac{\beta(1-\theta)(\sigma-1)}{\xi\gamma}\frac{E\pi+\tilde{f}}{E\pi} < 1.$$

Note that this condition is satisfied whenever the private benefit b is sufficiently high, such that the negative variety effect outweighs efficiency gains after credit tightening. Analogously, the welfare reaction in equation (1.53) is positive if $\frac{\gamma\lambda_b}{\Delta\lambda(\sigma-1)}\frac{\lambda b}{\Delta\lambda+\lambda b} > -\frac{\partial z_d}{\partial\lambda}\frac{\lambda}{z_d}$, which leads to the following condition:

$$\frac{\partial W}{\partial\lambda}\frac{\lambda}{W} > 0 \text{ if } \frac{\xi\gamma}{\beta(1-\theta)(\sigma-1)}\frac{E\pi}{\lambda\left(E\pi+\tilde{f}\right)} > 1.$$

Thus, the welfare reaction is positive if financial frictions in terms of the private benefit b are sufficiently high. To show that the welfare loss of credit tightening is more pronounced in sectors with low investment intensity, the derivative (1.52) can be written as:

$$\frac{\partial W}{\partial b}\frac{b}{W} = -\frac{\lambda b}{\Delta\lambda+\lambda b}\left(\frac{\gamma}{(\sigma-1)\alpha\beta}-\frac{(1-\theta)}{\alpha\xi}\frac{E\pi+\widetilde{f}}{E\pi}\right).$$

Both the variety effect and the efficiency effect increase in investment cost parameter α: $\frac{\partial\left(\frac{\gamma}{(\sigma-1)\alpha\beta}\right)}{\partial\alpha} = \frac{(1-\theta)}{\alpha^2} > 0$, and $\frac{\partial\left(\frac{E\pi+\tilde{f}}{E\pi}\right)}{\partial\alpha} > 0$. Hence, we consider the limit case if

α approaches infinity. Note that $\lim_{\alpha\to\infty} \widetilde{f} = f_d$ and $\lim_{\alpha\to\infty} E\pi = f_d(\Theta - 1) > 0$. In the limit case, the variety effect converges to: $\lim_{\alpha\to\infty} \frac{\gamma}{\alpha\beta} = \frac{\beta+1-\sigma}{\beta} > 0$, whereas the efficiency effect disappears: $\lim_{\alpha\to\infty} \frac{(1-\theta)}{\alpha\xi} \frac{E\pi+\widetilde{f}}{E\pi} = 0$. Thus, welfare losses become larger in sectors with low quality differentiation due to the dominating variety effect. A similar argument holds for the investment cost parameter β as: $\frac{\partial\left(\frac{\gamma}{(\sigma-1)\alpha\beta}\right)}{\partial\beta} = \frac{1}{\beta^2} > 0$, and $\frac{\partial\left(\frac{E\pi+\tilde{f}}{E\pi}\right)}{\partial\beta} > 0$. In the limit case, for the variety effect it holds that: $\lim_{\beta\to\infty} \frac{\gamma}{\alpha\beta} = \frac{\alpha+(1-\sigma)(1-\theta)}{\alpha} > 0$. Note, however, that the efficiency effect does not disappear, but converges to a positive limit: $\lim_{\beta\to\infty} \frac{(1-\theta)}{\alpha\xi} \frac{E\pi+\widetilde{f}}{E\pi} > 0$.

A.5 Extension: external financing of fixed costs

If fixed costs have to be financed by external capital, the budget constraint (1.7) changes to $d_l \geq f_l + \frac{1}{\kappa} q_l^{\alpha} + \frac{1}{\varphi} e_l^{\beta}$, and the agency cost parameter can be written as $\Theta = r + \frac{\lambda b}{\lambda - \lambda_b}$ (compare subsection 1.3.4). In this case, an increase in the borrowing rate leads to an additional effect on the extensive margin without changing the direction of firm responses in general equilibrium. Compared to the results in the main text, there is still a negative response of process and quality innovations to an increase in the borrowing rate:

$$\begin{aligned}
\frac{\partial e_l}{\partial r}\frac{r}{e_l} &= -\frac{1}{\beta}\left(\frac{b\lambda}{b\lambda + r\Delta\lambda} + \frac{\sigma-1}{\gamma}\frac{\partial z_d}{\partial r}\frac{r}{z_d}\right) < 0, \\
\frac{\partial q_l}{\partial r}\frac{r}{e_l} &= -\frac{1}{\alpha}\left(\frac{b\lambda}{b\lambda + r\Delta\lambda} + \frac{\sigma-1}{\gamma}\frac{\partial z_d}{\partial r}\frac{r}{z_d}\right) < 0,
\end{aligned}$$

whereas the efficiency effect is given by:

$$\frac{\partial z_d}{\partial r}\frac{r}{z_d} = \frac{\beta(1-\theta)}{\xi}\frac{\Omega r f_d \Delta_z - r\widetilde{f}}{E\pi} > 0,$$

and expected average profits are defined as: $E\pi = \Omega\left(r + \frac{b\lambda}{\Delta\lambda}\right) f_d \Delta_z - r\widetilde{f}$.

Chapter 2

The Role of Financial Intermediation in International Trade

This chapter highlights that substitution between two types of finance represents an additional channel of adjustment to credit shocks and trade liberalization. Combining firm heterogeneity à la Melitz (2003) with credit frictions based on Holmstrom and Tirole (1997), there is selection of the largest firms into exporting and unmonitored finance, such as public debt or corporate bonds. Smaller producers serve only the domestic market and have to rely on more expensive financial intermediation. The model is consistent with empirical evidence that documents the important role of substitution effects between different sources of external credit. Producers respond to financial shocks by switching the type of finance. These selection effects lead to reallocations of market shares across firms and additional adjustments on the margins of international trade. Furthermore, the model highlights a new source of gains from trade liberalization: average productivity increases as falling trade costs allow some exporters to select into cheaper unmonitored finance.

This paper was awarded the "Best Paper Prize for Young Economists" at the Warsaw International Economic Meeting 2015. I am grateful to Carsten Eckel, Michael Irlacher, Monika Schnitzer, and Jens Wrona, as well as participants of the Fall 2015 Midwest International Trade Meetings at Pennsylvania State University, of the 17th Annual Conference of the European Trade Study Group in Paris, of the Warsaw International Economic Meeting 2015, of the Munich "IO and Trade seminar", of the 2nd MGSE Colloquium in Munich, and of the 17th Workshop "Internationale Wirtschaftsbeziehungen" in Goettingen for helpful comments and suggestions.

2.1 Introduction

Firms rely on outside investors to finance trade related production costs and up-front investments. Empirical evidence shows that credit constraints negatively affect both intensive and extensive margins of international trade (Berman and Héricourt, 2010; Minetti and Zhu, 2011; Manova, 2013; Muûls, 2015). To explain these effects, theoretical models combine firm-level heterogeneity à la Melitz (2003) with financial frictions (Chaney, 2013; Manova, 2013; Feenstra et al., 2014). These papers stress that credit constraints prevent smaller firms from exporting and restrict foreign sales below the optimal level. Trade models with firm heterogeneity and financial frictions typically rely on one source of external debt. The corporate finance literature, however, shows that firm size is an important determinant of access to different types of external credit. Large firms are more likely to use cheap finance provided with low-intensity monitoring, such as the issuance of public debt or corporate bonds.[1] Smaller producers suffer more from credit-rationing (Rajan and Zingales, 1995; Beck et al., 2006), and rely heavily on bank finance with intensive monitoring and higher borrowing rates (Cantillo and Wright, 2000; Denis and Mihov, 2003).[2]

This chapter develops an international trade model that accounts for the selection of producers into exporting and two types of finance. Combining productivity sorting à la Melitz (2003) with credit frictions based on Holmstrom and Tirole (1997), the largest firms export and use unmonitored finance. Smaller producers serve only the domestic market and have to rely on more expensive bank finance. Selection effects depend on trade costs, borrowing rates and access barriers to external funds due to credit frictions. This model highlights that producers respond to financial shocks and trade liberalization by switching the type of finance. Accounting for these selection effects is important for any assessment of welfare implications.

The main message of this chapter is that substitution between the two types of finance leads to a reallocation of market shares across producers and new effects on the margins of international trade. The model is consistent with empirical evidence that documents the important role of substitution effects. Credit tightening leads to large

[1] In the U.S., the percentage of long-term debt held in publicly traded instruments is 32% among larger firms and 14% for smaller producers (Cantillo and Wright, 2000). In Spanish non-financial companies, public debt amounts to 10% (de Miguel and Pindado, 2001), and among publicly traded U.S. firms, it represents almost 50% of new debt issues (Denis and Mihov, 2003).

[2] Empirical studies suggest additional firm characteristics that are positively related to direct lending with limited monitoring, such as project quality, profitability, collateral, age and credit reputation (see Cantillo and Wright, 2000; Denis and Mihov, 2003; Becker and Ivashina, 2014).

adverse impacts on small, bank-dependent firms, and induces selection into other types of external debt (Kashyap et al., 1993; Faulkender and Petersen, 2006; Leary, 2009). During the financial crisis of 2008-2009, producers responded to contraction in credit supply by switching to public bonds and trade credit.[3] Furthermore, the model highlights a new source of gains from trade: average productivity increases as falling trade costs allow some exporters to select into cheaper unmonitored finance. To analyze the role of these selection effects, this chapter extends a Melitz (2003)-type model by endogenous investments and credit frictions. Heterogeneous firms decide on innovations that reduce marginal production costs, but have to be financed externally. This assumption is based on a large literature that shows the important role of external finance for innovation activity (Hall and Lerner, 2010; Maskus et al., 2012; Gorodnichenko and Schnitzer, 2013). Credit frictions emerge from moral hazard based on Holmstrom and Tirole (1997). Following this, the success of investments depends on a managerial project choice which is non-verifiable for external lenders and thus prone to moral hazard. This agency problem reduces the pledgeability of firm profits and introduces access barriers to credit.

The key feature of the model is to allow for two types of external finance that differ in credit costs and accessibility. Passive lenders provide funds without monitoring, whereas financial intermediaries are able to imperfectly control the project choice within firms. On the one hand, access barriers to monitored funds are lower as financial intermediation alleviates moral hazard. On the other hand, monitoring is associated with additional costs, resulting in higher borrowing rates relative to unmonitored finance. This approach is consistent with empirical evidence that shows the important role of banks in reducing agency costs.[4] The selection mechanism stressed in this chapter is different from models with technology choice, in which the payment of additional fixed costs reduces marginal production costs (Lileeva and Trefler, 2010; Bustos, 2011). Unmonitored finance is associated with a lower borrowing rate, both for fixed and endogenous investments, but credit frictions impose an access barrier for smaller firms with low pledgeable income.[5]

The framework nests a model with one type of finance as a special case, which allows to disentangle direct effects of shocks from substitution effects. Thus, the

[3]See Adrian et al. (2012), Becker and Ivashina (2014), and Barraza et al. (2014) for evidence on substitution into public bonds among U.S. firms, as well as Iyer et al. (2014) for Portugal. Carbó-Valverde et al. (2012) and Coulibaly et al. (2013) document substitution into trade credit.

[4]See Gorton and Winton (2003) and Tirole (2006), chapter 2 for a review of related literature.

[5]See also the following discussion of related literature.

model features intra-industry reallocation and common gains from trade liberalization (Melitz, 2003), as well as negative effects of credit frictions as stressed in the existing literature (Manova, 2013; Muûls, 2015). However, new welfare implications arise because firms switch the type of finance. These additional selection effects change the degree of competition in general equilibrium and thus influence the margins of international trade. Compared to a model with only one type of credit, lower financial development leads to additional welfare losses because firms select into more expensive financial intermediation. While this shock aggravates moral hazard and increases access barriers to both types of finance, monitoring of intermediaries reduces the negative impact compared to unmonitored funds. Consequently, there is selection into financial intermediation and a reallocation of market shares away from firms that rely on passive investors. As now a larger fraction of producers faces higher borrowing rates, the competitive pressure in general equilibrium is reduced. This selection effect mitigates the negative reaction at the extensive margin, but amplifies welfare losses due to lower average productivity.
Likewise, additional gains from trade liberalization arise because of selection effects. Falling trade costs increase the pledgeable income of exporters and facilitate access to cheaper unmonitored funds. This leads to two new adjustments that further increase average productivity compared to a model with only one type of credit. First, some exporters gain access to cheaper unmonitored finance and reduce prices. Second, increased competitive pressure leads to even stronger exit of low productivity firms that rely on relatively expensive financial intermediation.

Related literature This chapter is related to three distinct strands of literature. First, the notion of capital market imperfections with two sources of external finance builds on Holmstrom and Tirole (1997), whereas financial intermediation alleviates credit frictions emerging from moral hazard. Alternative theories of banking stress advantages of financial intermediaries compared to direct lenders in presence of information asymmetries. Accordingly, banks may act as screeners regarding project choice ex ante (Diamond, 1991; Besanko and Kanatas, 1993), conduct costly monitoring in case of unknown output realizations ex-post (Diamond, 1984), or take the role of reorganizers with respect to ex-post bargaining (Rajan, 1992; Bolton and Scharfstein, 1996).
A second strand of literature analyzes the selection of heterogeneous firms in segmented capital markets. Russ and Valderrama (2012) introduce bond and bank

finance in a closed-economy version of Ghironi and Melitz (2005) and suggest a selection pattern that is consistent with this model. Large and more productive firms select into bond finance with higher fixed costs, but lower variable costs, whereas smaller producers rely on financial intermediation. Russ and Valderrama (2010) extend this framework to a small open economy. In both papers, financial choice is analogous to technology adoption in Bustos (2011). In contrast, the selection pattern of firms in this model is not only driven by profitability, but rather moral hazard introduces access barriers to external funds. Unmonitored finance is associated with lower borrowing costs, but smaller firms fail to overcome agency problems in presence of credit frictions. Financial intermediaries reduce access barriers to finance for low productivity firms, but charge higher interest rates both for fixed and endogenous investments. Egger and Keuschnigg (2015) analyze external financing of fixed R&D spending by venture capital and bank credit in a multicountry model of trade. The authors show the important role of venture capitalists in financing early-stage investments, especially for firms with little pledgeable earnings and high risk. A common feature to this chapter is that moral hazard based on Holmstrom and Tirole (1997) leads to credit frictions and monitoring facilitates access to finance. However, the focus of this model is quite different. Egger and Keuschnigg (2015) analyze the effects of financial frictions on a two-stage investment decision with heterogeneity in project quality and additional production risk. This chapter considers external financing of endogenous sunk costs for process innovations in a Melitz-type model with productivity differences, and shows how substitution effects between two types of finance change aggregate responses to financial shocks and trade liberalization.
Furthermore, Schmidt-Eisenlohr (2013) develops a model of payment contract choice in international trade and differentiates between exporter and importer finance, as well as bank finance, but abstracts from firm heterogeneity. Related papers are Eck et al. (2015), as well as Engemann et al. (2014), who show both theoretically and empirically the positive impact of trade credit on the probability to export, especially for lower productivity firms. The authors stress that supplier credits alleviate financial constraints due to information asymmetry and reduce uncertainty related to international transactions.
Third, this chapter is related to a growing literature that incorporates financial frictions in international trade models, but neglects different sources of external finance. Manova (2013) shows that credit constraints intensify the selection of the most productive firms into export markets. Feenstra et al. (2014) introduce financial

frictions, caused by information asymmetry between firms and a monopolistic bank, whereas the latter cannot observe the productivity of the former. Instead, I assume symmetric information regarding firm-specific productivity, but moral hazard introduces credit market imperfections. Felbermayr and Spiegel (2014) analyze the role of credit frictions in a dynamic model of trade and finance. Other papers extend the model of Melitz and Ottaviano (2008) with varying markups by credit constraints (Mayneris, 2011; Egger and Seidel, 2012; Peters and Schnitzer, 2015). Building on Holmstrom and Tirole (1997) as well, theoretical work analyzes the effects of credit frictions on industry agglomeration in a Krugman (1991) model (Ehrlich and Seidel, 2015) and on foreign direct investment (Antràs et al., 2009; Buch et al., 2010, 2014). The chapter is organized as follows. Section 2.2 presents the model setup and discusses the selection of producers into external finance and exporting. The following two sections analyze the effects of financial shocks in partial and general equilibrium. Section 2.5 presents effects of trade liberalization. Section 2.6 discusses assumptions and extensions of the theoretical framework, and finally, section 2.7 concludes.

2.2 Firm heterogeneity and access to credit

This section introduces credit frictions and endogenous innovations in a heterogeneous firm model à la Melitz (2003). Firms differ in marginal production costs, decide on the optimal level of productivity enhancing investments, and require external funds to cover fixed and endogenous sunk costs for innovation activity. This assumption can be motivated by a time lag between investment outlays and the realization of sales. Based on Holmstrom and Tirole (1997), credit frictions emerge from moral hazard regarding the project choice of managers within firms. The following subsection presents the demand side of the model. Subsection 2.2.2 introduces two types of outside lenders and discusses optimal firm behavior under credit constraints, and subsection 2.2.3 shows how producers select into external finance and exporting.

2.2.1 Demand side

There are two symmetric countries with population of size L, trading in horizontally differentiated varieties. Labor is the only factor of production and is immobile across countries.[6] A representative consumer in one country derives utility from

[6] Section 2.6 discusses how the model can be extended to capital as a second input factor.

the consumption of a continuum of varieties, indexed by $i \in \Omega$, according to the following CES function:

$$X = \left[\int_{i \in \Omega} x_i^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}, \tag{2.1}$$

whereas $\sigma > 1$ is the constant elasticity of substitution and Ω is the set of varieties. Demand for one particular variety i is given by:

$$x_i = X \left(\frac{p_i}{P} \right)^{-\sigma}, \tag{2.2}$$

and the aggregate price index is defined as follows:

$$P = \left[\int_{i \in \Omega} p_i^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}. \tag{2.3}$$

The next section describes the maximization problem of firms in the presence of credit constraints and two sources of external finance.

2.2.2 Optimal firm behavior under credit constraints

The productivity of a firm is determined by two components. As in Melitz (2003), each firm manufactures one horizontally differentiated variety i and draws a productivity parameter φ_i from a common probability distribution $g(\varphi)$.[7] Additionally, producers choose the optimal level of productivity enhancing investments e_i. Hence, marginal production costs are given by $mc_i(\varphi_i) = \frac{1}{\varphi_i e_i}$. Investments are associated with endogenous sunk costs that increase in the innovation level:

$$f(e) = \frac{1}{\alpha} e_i^{\alpha}, \text{ with } \alpha > \sigma - 1, \tag{2.4}$$

whereas α is a technology cost parameter that is the same across firms. Motivated by a time lag between investment outlays and profit realization, fixed and endogenous sunk costs associated with innovation activity have to be financed by external funds. Based on Holmstrom and Tirole (1997), credit frictions emerge from moral hazard between outside lenders and borrowing firms. There are two types of investors in the economy: passive lenders and financial intermediaries that are able to imperfectly monitor firms, denoted by the indices u and m in what follows. Each producer signs

[7] Section 2.4 presents the general equilibrium and assumes that productivity follows a Pareto distribution.

a credit contract with an outside lender, which defines the loan size $d_{jl} > 0$, at a gross interest rate $r_j > 1$, and the credit repayment k_{jl}, whereas $j \in m, u$ denotes the source of external finance and $l \in d, x$ is an index for the export status. The maximization problem of a producer can be described as follows, where asterisks stand for variables of export activity:[8]

$$
\begin{aligned}
\max_{p_{jl}, p^*_{jl}, e_{jl}} \lambda\pi_{jl} &= \lambda\left[s_{jl} - \frac{1}{\varphi e_{jl}}\left(x_{jl} + 1_{\{x^*>0\}}\tau x^*_{jx}\right) - k_{jl}\right] && (2.5)\\
s.t \qquad x_{jl} &= X\left(\frac{p_{jl}}{P}\right)^{-\sigma} \; ; \; x^*_{jl} = X\left(\frac{p^*_{jl}}{P}\right)^{-\sigma}, && (2.6)\\
d_{jl} &\geq f_l + \frac{1}{\alpha}e^{\alpha}_{jl} \, , && (2.7)\\
\lambda k_{jl} &\geq r_j d_{jl} \, , && (2.8)\\
\lambda\pi_{jl} &\geq 0. && (2.9)
\end{aligned}
$$

Depending on the source of external finance j and the export status l, firms maximize revenues net of variable production costs and loan repayment k_{jl}, whereas the variable $1_{\{x^*>0\}}$ takes a value of one if the firm exports and is zero otherwise. Total sales from domestic and international activity are defined as $s_{jl} = p_{jl}x_{jl} + 1_{\{x^*>0\}}p^*_{jl}x^*_{jl}$. Firms realize profits with success probability λ. The next subsection introduces moral hazard and shows that this success probability depends on a non-verifiable project choice of the firm. Exporting involves additional fixed costs ($f_x > f_d$) and iceberg-type transportation costs such that $\tau > 1$ units of a good have to be shipped for one unit to arrive. According to the budget constraint (2.7), the received credit amount has to cover fixed costs of production, as well as endogenous sunk costs for innovation. Internationally active firms have to raise additional external funds for fixed export costs. Investors only participate in a contract if expected loan repayments at least compensate for credit provision (2.8). Additionally, the firm will be active in the market if expected profits are non-negative (2.9). The solution to the firm's maximization problem provides the optimal investment level:[9]

$$
e_{jl}(\varphi) = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma}{\alpha-\sigma+1}} \left(\frac{\lambda A_l \varphi^{\sigma-1}}{r_j}\right)^{\frac{1}{\alpha-\sigma+1}} . \tag{2.10}
$$

[8]For notational simplicity I drop the firm's index i in what follows.

[9]See Appendix B.1 for a detailed derivation of the firm's maximization problem.

Equation (2.10) shows that process innovations decrease in probability-weighted borrowing costs $\frac{r_j}{\lambda}$, but increase in productivity φ and the market size, denoted by $A_d = XP^\sigma$ and $A_x = XP^\sigma \left(1 + \tau^{1-\sigma}\right)$ for domestic sellers and exporters respectively. Optimal prices are set as a constant markup over marginal production costs which decrease in exogenous productivity and endogenous innovation activity, whereas p^*_{jx} denotes the export price:

$$p_{jl}\left(\varphi\right) = \frac{\sigma}{\sigma - 1}\frac{1}{\varphi e_{jl}};\; p^*_{jx}\left(\varphi\right) = \tau p_{jx}\left(\varphi\right). \tag{2.11}$$

Firms that face higher borrowing costs choose lower investment levels and hence set higher prices resulting in lower expected profits:

$$\lambda\pi_{jl}(\varphi) = \frac{\alpha - \sigma + 1}{\alpha\sigma}\lambda s_{jl}\left(\varphi\right) - f_l r_j\ , \tag{2.12}$$

whereas sales can be expressed as follows:

$$s_{jl}(\varphi) = A_l^{\frac{\alpha}{\alpha-\sigma+1}}\left(\left(\frac{\sigma-1}{\sigma}\right)^{1+\alpha}\frac{\lambda\varphi^\alpha}{r_j}\right)^{\frac{\sigma-1}{\alpha-\sigma+1}}. \tag{2.13}$$

The borrowing rate will be higher for firms that rely on financial intermediation ($r_m > r_u$). The next subsection introduces moral hazard which motivates credit frictions and the difference in financing costs for unmonitored and monitored funds.

2.2.3 Moral hazard and selection of firms

Based on Holmstrom and Tirole (1997), financial imperfections originate from moral hazard within the firm. This leads to credit frictions and the selection of producers into two different types of external finance. Consider first the problem of firms that use unmonitored finance ($j = u$). After the credit contract has been signed and the loan has been provided to the firm, the success of investments depends on a project choice of the firm manager. This action is by assumption non-verifiable for external investors and thus prone to moral hazard. Following Holmstrom and Tirole (1997), the manager can decide to behave diligently or to misbehave resulting in high or low success probabilities: $\lambda > \lambda_b$. In case of shirking, the manager reaps a non-verifiable private benefit that is proportional to the fixed investment $bf_l > 0$. Thus, agents only behave diligently if the following incentive compatibility constraint is satisfied:

$$\lambda \pi_{ul}(\varphi) \geq \lambda_b \pi_{ul}(\varphi) + b f_l. \tag{2.14}$$

As profits increase in φ, high productivity firms have no incentive to shirk. However, managers of lower productivity firms might prefer to choose the bad project and reap private benefits if the expected profits of diligent behavior are not sufficiently high. The assumption that private benefits b are proportional to fixed costs introduces access barriers to external finance beyond profitability requirements.[10] Hence, exporters face a trade-off between additional profits from international activity in case of diligent behavior and the prospect of higher perks in case of misbehavior. Furthermore, I assume that the net present value of the marginal firm that just meets incentive compatibility (2.14) is negative in case of shirking. This assumption is satisfied whenever the success probability λ_b is sufficiently low.[11] In this case, investors have to ensure that a credit contract satisfies condition (2.14) to avoid losses from lending. As in Holmstrom and Tirole (1997), I introduce a second investor type that is able to imperfectly monitor firms, which reduces the private benefit to mb, where $0 < m < 1$. Thus, monitoring effort mitigates the problem of moral hazard, but comes at additional costs, $c_m > 1$, leading to a higher borrowing rate of financial intermediation: $r_m = c_m r_u > r_u$. Incentive compatibility in case of monitored finance is given by:

$$\lambda \pi_{ml}(\varphi) \geq \lambda_b \pi_{ml}(\varphi) + mb f_l. \tag{2.15}$$

Incentive compatibility conditions (2.14) and (2.15) are more restrictive than zero-profit requirements (2.9) as long as private benefits are positive, even after monitoring: $mb > 0$. Hence, the incentive constraints impose access barriers to unmonitored and monitored funds respectively, and describe the selection of firms into external finance. Since profits (2.12) are a function of productivity φ, the binding equations (2.14) and (2.15) determine minimum productivity levels that are necessary to obtain outside finance. Some low productivity firms meet the zero-profit condition (2.9) and hence would find it profitable to be active in the market. However, moral hazard prevents access to finance and a range of profitable projects is not conducted in the presence of credit frictions. Depending on export status and the type of finance,

[10] See Section 2.6 for a further discussion of the moral hazard approach and possible extensions.

[11] See Ehrlich and Seidel (2015) as well as Egger and Keuschnigg (2015) for a similar discussion of moral hazard with heterogeneous firms.

incentive compatibility (2.14) or (2.15) leads to the following cutoff productivities for access to external funds:

$$\varphi_{jl} = \left(\frac{\sigma}{\sigma-1}\right)^{\frac{1+\alpha}{\alpha}} \left(\frac{r_j}{\lambda}\right)^{\frac{1}{\alpha}} \left(\frac{\alpha\sigma\psi_j f_j}{\alpha-\sigma+1}\right)^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} A_l^{\frac{-1}{\sigma-1}}, \tag{2.16}$$

where $\psi_m = \frac{bm}{\Delta\lambda} + \frac{r_m}{\lambda}$ and $\psi_u = \frac{b}{\Delta\lambda} + \frac{r_u}{\lambda}$, with $\Delta\lambda = \lambda - \lambda_b$, are measures of access barriers to external finance that consist of probability-weighted borrowing costs and agency costs due to moral hazard. Consider first how exporters select into unmonitored and monitored finance ($l = x$). Comparing cutoff productivities for both types of funds (2.16) shows that the entry barrier to unmonitored lending is relatively higher if the following condition holds:

Condition 2.1 $\varphi_{ux} > \varphi_{mx}$ *if* $c_m^{\frac{\sigma-1}{\alpha-\sigma+1}} \frac{\psi_m}{\psi_u} < 1.$

Condition 2.1 compares the two sources of finance and is independent of export status. On the one hand, monitored lending reduces moral hazard and facilitates access to finance. The lower private benefit (mb) eases the restriction imposed by incentive compatibility (2.15). On the other hand, monitoring activity is associated with additional costs which reduces profits (2.12) and makes it more difficult to satisfy incentive compatibility compared to unmonitored finance. Condition 2.1 states that access to monitored finance is relatively easier if the benefit of financial intermediation (reduced moral hazard) outweighs additional borrowing costs.

Lemma 2.1 *If Condition 2.1 holds, the most productive exporters with $\varphi \geq \varphi_{ux}$ use unmonitored finance. International firms in the middle range of the distribution ($\varphi_{mx} \leq \varphi < \varphi_{ux}$) have to rely on more expensive financial intermediation, while lower productivity firms ($\varphi < \varphi_{mx}$) cannot raise external finance for export activity and sell only domestically.*

Figure 2.1 depicts the selection pattern of exporters if Condition 2.1 holds, whereas productivity φ is measured on the horizontal axis and profits are shown on the vertical axis. As financial intermediation is associated with higher interest rate payments for fixed costs and endogenous investments, the intercept as well as the slope of the profit line π_{mx} is lower compared to the use of unmonitored finance. Thus, in the absence of credit frictions, unmonitored finance is always preferred to the more expensive type of credit. However, moral hazard leads to credit rationing

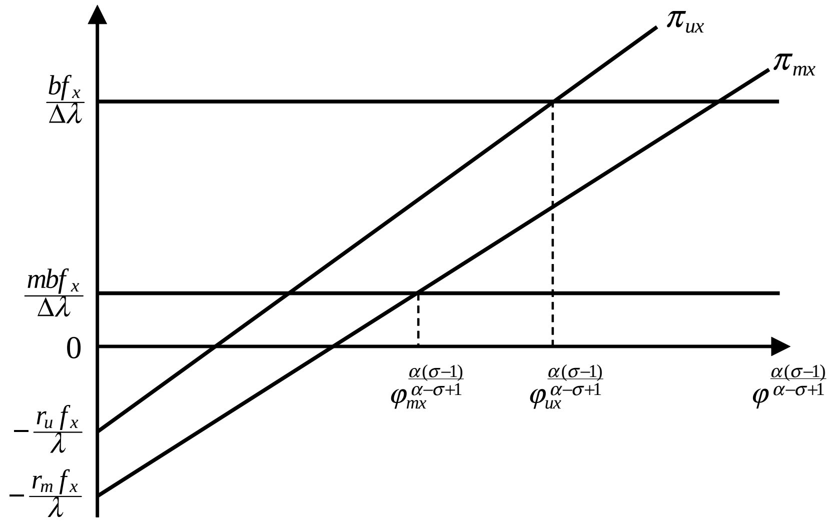

Figure 2.1: Selection of exporters into external finance

and the selection of firms into both types of finance. The access barriers to external funds are depicted as horizontal lines in Figure 2.1. Passive investors are only willing to provide loans to the most productive exporters with $\varphi \geq \varphi_{ux}$. Producers in the intermediate range of the distribution are not able to overcome moral hazard and rely on more costly financial intermediation with lower entry barrier.

Condition 2.1 is violated if monitoring effectiveness is very low or monitoring costs are prohibitively high. Lower monitoring effectiveness corresponds to an upward shift of the horizontal access line (see Figure 2.2), whereas higher monitoring costs are reflected by a lower intercept and a smaller slope of the profit line π_{mx} (see Figure 2.3). In both cases, financial intermediaries fail to facilitate access to external finance compared to passive lenders and no firm will choose the more expensive type of credit. In the following, I assume that Condition 2.1 is satisfied and hence both types of finance occur in equilibrium, as illustrated in Figure 2.1. Compared to previous international trade models with financial imperfections, credit tightening induces exporters to substitute between the two sources of external finance. The following section shows how exporters react to financial shocks in partial equilibrium.

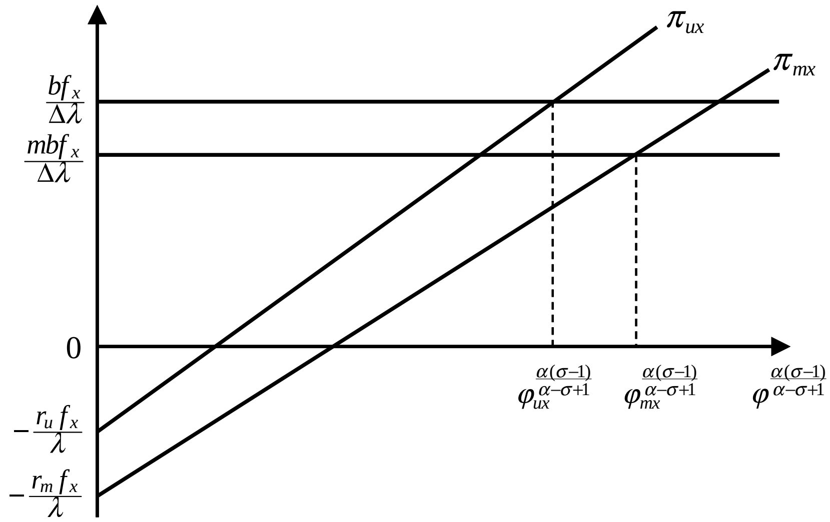

Figure 2.2: Selection pattern with low monitoring effectiveness

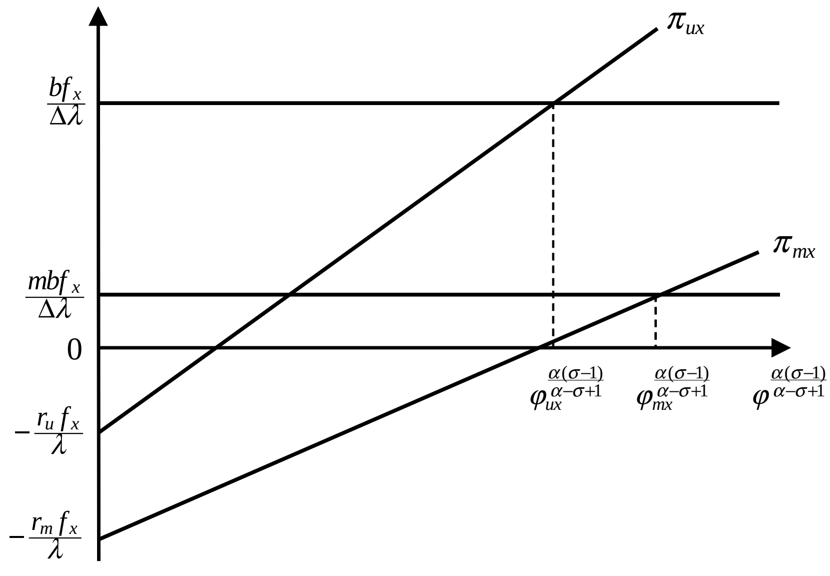

Figure 2.3: Selection pattern with high monitoring costs

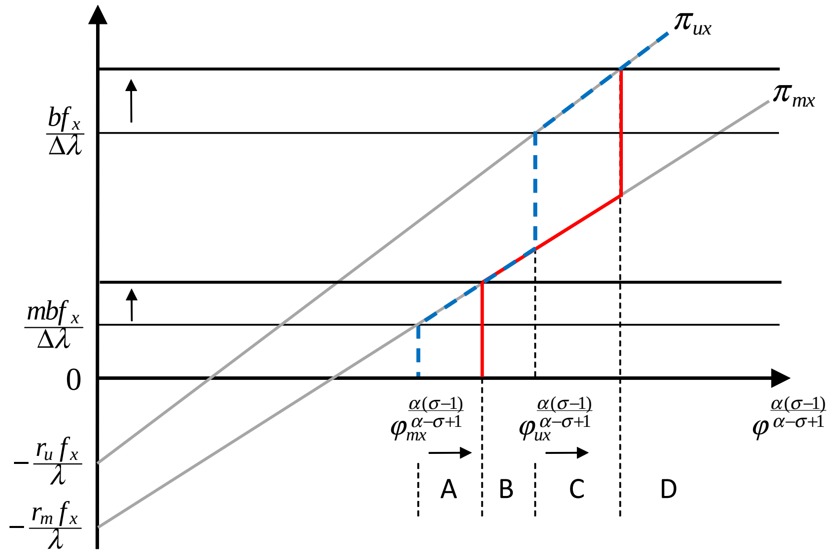

Figure 2.4: Increase in private benefit b

2.3 Credit tightening in partial equilibrium

This section analyzes how financial conditions affect optimal firm behavior and the selection pattern of producers. An increase in the private benefit b can be interpreted as a worsening of financial development. In this case, a larger incentive to misbehave weakens the enforcement of credit contracts and reduces the pledgeability of profits in conditions (2.14) and (2.15). Consequently, this shock raises the cutoff productivities for access to both types of external finance (2.16), and is illustrated by an upward shift of marginal-access lines in Figure 2.4. A decrease in monitoring effectiveness (larger m) aggravates access to financial intermediation. Hence, both shocks affect access barriers to external finance without changing innovation activity (2.10) and firm profits (2.12) in partial equilibrium.[12] Instead, if the borrowing rate r_u increases, profit lines in Figure 2.5 shift downwards and become flatter, as firms face higher costs for fixed and endogenous investments, and thus reduce innovation activity. Comparable to increases in b and m, this results in higher cutoff productivities.

Producers are affected very differently by worsening credit conditions, depending on their location along the productivity distribution. Firms in region A of Figures

[12]In general equilibrium, financial shocks change the competitive pressure and firm profits through the impact on the aggregate price. See section 2.4 for a discussion of general equilibrium effects.

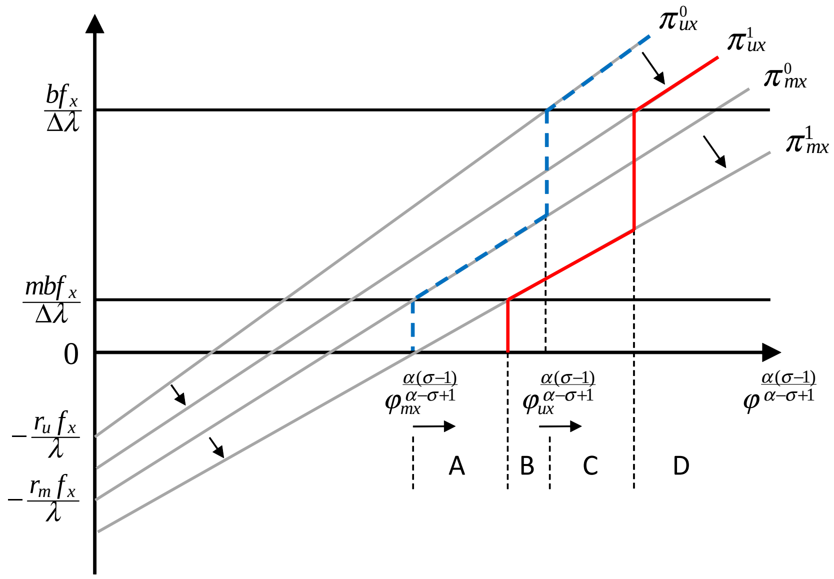

Figure 2.5: Increase in unmonitored interest rate r_u

2.4 and 2.5 stop exporting as they are not able to raise any funds for international activity after credit tightening. Firms in regions B and D change neither the export status nor the source of external finance, though face profit losses in case of higher borrowing costs. Exporters in region C, however, lose access to unmonitored finance and have to rely on more expensive monitored lending to cover fixed export and endogenous innovation costs. This substitution behavior leads to a direct negative effect on revenues and profits since switchers face larger interest rates and thus set higher prices. The following proposition summarizes the differential firm responses to credit tightening.

Proposition 2.1 *Increases in b and r_u lead to higher cutoff efficiencies φ_{jx}, such that least productive exporters quit international activity. Exporters in the middle range of the productivity distribution have to switch from unmonitored to monitored finance resulting in profit losses.*

So far, the discussion has focused on responses of exporters to credit tightening in partial equilibrium. In the open economy, firms select into the two types of external finance and choose their export status. Note that Condition 2.1 is independent of trade costs and has to hold for domestic sellers as well. Comparing the cutoff productivity for monitored finance and exporting φ_{mx} with the access barrier for non-exporters that use unmonitored finance φ_{ud}, leads to a second condition which determines the selection of firms:

Condition 2.2 $\varphi_{mx} > \varphi_{ud}$ *if* $c_m^{\frac{\sigma-1}{\alpha-\sigma+1}} \frac{\psi_m}{\psi_u} \frac{f_x}{f_d} (1+\tau^{1-\sigma})^{\frac{-\alpha}{\alpha-\sigma+1}} > 1$.

Depending on whether Condition 2.2 holds, I distinguish two selection cases that are summarized in the following Lemma.

Lemma 2.2 *If Conditions 2.1 and 2.2 hold, the selection of firms is described by the following sorting of cutoff productivities:* $\varphi_{md} < \varphi_{ud} < \varphi_{mx} < \varphi_{ux}$. *If Condition 2.2 does not hold, thresholds are ranked in the order:* $\varphi_{md} < \varphi_{mx} < \varphi_{ud} < \varphi_{ux}$.

In both cases, Condition 2.1 ensures that access to unmonitored finance is relatively more difficult both for international firms and domestic sellers. Hence, the most productive exporters have access to unmonitored finance, whereas the least productive firms sell only domestically and rely on financial intermediation. For given access barriers to external finance, Condition 2.2 is satisfied whenever trade costs are sufficiently high.[13] In this case, non-exporters select into both types of finance as well (see upper part of Figure 2.6). Lower trade costs decrease the cutoff productivities for international activity resulting in a larger fraction of exporters, whereas higher competitive pressure increases the minimum productivities required for domestic activity φ_{jd}. This reduces the share of non-exporters that use unmonitored finance. If trade costs are sufficiently low, Condition 2.2 is violated, such that access to unmonitored finance becomes more difficult for domestic sellers compared to exporting with the aid of financial intermediation. Under conditions derived below, this scenario with low trade costs implies that domestic firms lose access to unmonitored finance (see lower part of Figure 2.6). Lemma 2.2 describes only the feasible selection patterns based on the comparison of cutoff productivities (2.16). The next subsections derive conditions under which the selection cases with low and high trade costs, as depicted in Figure 2.6, are also optimal when taking into account profitability considerations of firms. Intuitively, these conditions ensure (i) that trade costs are sufficiently high and only the most productive firms are able to export, and (ii) that credit frictions are sufficiently strong, such that the selection of firms into exporting and external finance is influenced by moral hazard. Otherwise, profitability requirements might impose higher access barriers than financial frictions.

[13]Note that Condition 2.1 implies that: $c_m^{\frac{\sigma-1}{\alpha-\sigma+1}} \frac{\psi_m}{\psi_u} < 1$.

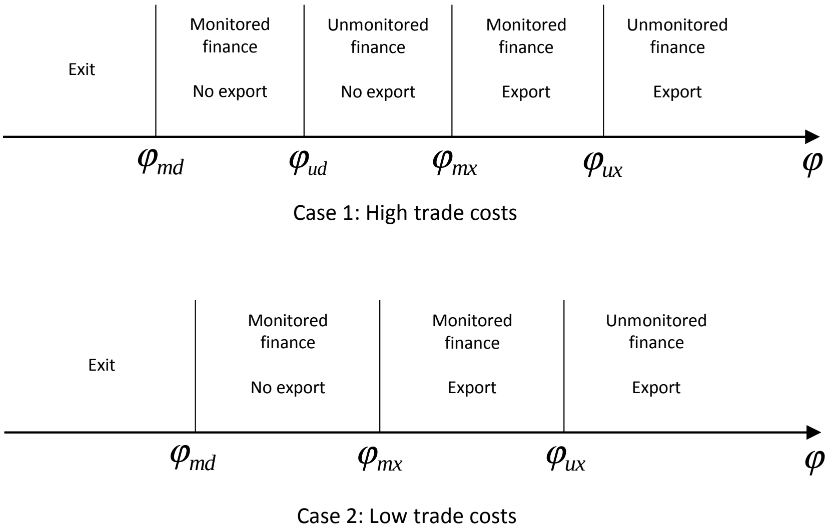

Figure 2.6: Selection into external finance and exporting

2.3.1 Selection case 1: high trade costs

If trade costs are relatively high such that Condition 2.2 is satisfied, firms can be divided into four groups. The most productive ones become exporters, whereas low productivity producers sell only in the domestic market. Among both groups, only the most productive firms obtain unmonitored finance. To ensure profitability, active firms located in one of the four regions compare the available financing and production choices. Firms with $\varphi_{md} \leq \varphi < \varphi_{ud}$ have only the possibility to sell in the domestic market by relying on financial intermediation. Profitability considerations of active producers in the remaining three groups are summarized by the following two Lemmas:

Lemma 2.3 $\pi_{ul}(\varphi) > \pi_{ml}(\varphi)$ *for* $l \in d, x$, *since* $r_m = c_m r_u > r_u$, *with* $c_m > 1$.

Lemma 2.4 $\pi_{mx}(\varphi) > \pi_{ud}(\varphi)$ *if* $s_{ud}(\varphi) > \frac{r_u}{\lambda}\frac{\sigma\alpha}{\alpha-\sigma+1}\frac{c_m f_x - f_d}{(1+\tau^{1-\sigma})^{\frac{\alpha}{\alpha-\sigma+1}} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} - 1}$.

According to Lemma 2.3, it is always optimal for producers with $\varphi_{ud} \leq \varphi < \varphi_{mx}$ and $\varphi \geq \varphi_{ux}$ to use unmonitored finance which implies lower interest rate payments. Firms with $\varphi_{mx} \leq \varphi < \varphi_{ux}$ face a trade-off between exporting by using monitored finance or selling only in the domestic market and obtaining unmonitored finance. On the one hand, exporting leads to additional profits. On the other hand, international activity is only possible with more costly financial intermediation. Productivities of firms within that group are not sufficient to satisfy incentive compatibility (2.14) and directly raise external funds for exports from passive investors. Lemma 2.4 determines a cutoff productivity at which additional export profits exactly offset higher financing costs. Comparing this profitability requirement with the cutoff productivity φ_{mx}, defined by equation (2.16), leads to the following condition:[14]

Condition 2.3 *Access to financial intermediation for exporters is more restrictive compared to profitability requirements, as described in Lemma 2.4, if*

$$\psi_m \geq \frac{r_u}{\lambda} \frac{c_m f_x - f_d}{f_x} \frac{\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}}{\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} - 1}.$$

Condition 2.3 compares the access barrier to monitored finance ψ_m with profitability requirements for marginal exporters. Larger fixed and variable trade costs, f_x and τ, as well as higher monitoring costs c_m, increase the right-hand side of Condition 2.3, as it becomes more difficult for lower productivity firms to earn positive profits in the foreign market. Condition 2.3 is satisfied whenever the remaining private benefit after monitoring mb, and thus the entry barrier to exporting with the aid of monitored finance ψ_m, is sufficiently high compared to profitability requirements. If Conditions 2.1-2.3 hold, the selection pattern depicted in the upper part of Figure 2.6 describes optimal firm behavior. In this case, moral hazard imposes stronger restrictions on firms than profitability. Hence, financial frictions hinder some marginal producers with productivity $\varphi < \varphi_{mx}$ to engage in international markets and conduct profitable investment projects. Conversely, all firms with productivity levels $\varphi \geq \varphi_{mx}$ find it optimal to become exporters, since profitability is ensured whenever external finance is accessible.

2.3.2 Selection case 2: low trade costs

If Condition 2.2 is not satisfied, the entry barrier to export markets under financial intermediation is relatively lower compared to the domestic sellers' access to unmonitored finance: $\varphi_{mx} < \varphi_{ud}$ (compare Lemma 2.2). As Condition 2.2 shows, this selection pattern becomes more likely if trade costs are low for given financial conditions. Analogous to Melitz (2003), Condition 2.4 ensures that fixed and variable trade costs are still sufficiently high such that only the most productive firms are able to export.[15]

[14] See Appendix B.4 for a derivation of Condition 2.3.

[15] Note that Condition 2.4 is always satisfied in selection case 1 due to Conditions 2.1 and 2.2.

Condition 2.4 $\varphi_{jx} > \varphi_{jd}$ *if* $t = \frac{f_x}{f_d}\left(1+\tau^{1-\sigma}\right)^{\frac{-\alpha}{\alpha-\sigma+1}} > 1$.

As in selection case 1, I still assume that Condition 2.3 is satisfied which implies that all firms with $\varphi \geq \varphi_{mx}$ find it optimal to become exporters and use funds from intermediaries. This condition is now less restrictive as trade costs are lower and thus profitability of export activity is easier to achieve compared to the access barrier ψ_m. Because of $\varphi_{mx} < \varphi_{ud}$, an important implication of this second selection pattern with low trade costs is that non-exporters will never use unmonitored finance. Firms with productivity $\varphi \geq \varphi_{ud}$ could decide to forego profits from foreign markets and use the cheaper type of finance. However, in case of low trade costs, this is never optimal for any firm that has access to external funds for international activity. This reasoning leads to the following selection pattern in equilibrium: $\varphi_{md} < \varphi_{mx} < \varphi_{ux}$, as depicted in the lower part of Figure 2.6. Compared to selection case 1, not only export status but also access to unmonitored finance is a monotone function of productivity and thus firm size. The following proposition summarizes the two selection cases.

Proposition 2.2 *If Conditions 2.1-2.3 hold, firms optimally select into exporting and external finance according to the following order:* $\varphi_{md} < \varphi_{ud} < \varphi_{mx} < \varphi_{ux}$. *If Conditions 2.1 and 2.3-2.4 are satisfied, the selection pattern is described by the following ranking:* $\varphi_{md} < \varphi_{mx} < \varphi_{ux}$.

In case of low trade costs, domestic sellers have no access to external funds without the aid of financial intermediaries and hence cannot react to credit tightening by switching the source of finance. In contrast, a scenario with high trade costs implies that substitution effects, as described above for exporters, occur among non-exporters as well. Based on this partial equilibrium analysis, the following section considers the effects of credit tightening in general equilibrium.

2.4 Credit tightening in general equilibrium

Compared to previous theoretical work, the partial equilibrium analysis in section 2.3 suggests substitution effects between two sources of finance as an additional channel through which credit tightening influences export behavior. The general equilibrium analysis in this section shows that financial shocks induce reallocations of market shares across groups of firms that use different types of external finance (subsection 2.4.2). These substitution effects change reactions along the extensive margin and welfare responses to credit tightening (subsection 2.4.3).

2.4.1 General equilibrium in the open economy

Free entry ensures that expected profits equal fixed entry costs, before potential producers know their productivity draw φ:

$$E\pi_k = \sum_j \sum_l E\pi_{jlk} = \frac{\delta f_e}{\chi_s}, \tag{2.17}$$

whereas $k \in 1, 2$ denotes the selection case and expected profits for each group with type of external finance j and export status l are given by:

$$E\pi_{jlk} = \int_{\varphi \in D_{jlk}} \lambda \pi_{jlk}(\varphi) \mu_s(\varphi) d\varphi. \tag{2.18}$$

After entry, firms draw productivity φ from a Pareto distribution with density function $g(\varphi) = \xi \varphi^{-\xi-1}$ and positive support over $[1, \infty]$, whereby ξ is the shape parameter of the Pareto distribution.[16] Probabilities of belonging to one of the four possible groups χ_{jl}, as well as the probability of survival χ_s, are defined as:

$$\chi_{jlk} = \int_{\varphi \in D_{jlk}} g(\varphi) d\varphi \;\; ; \;\; \chi_{sk} = \int_{\varphi \in D_k} g(\varphi) d\varphi, \tag{2.19}$$

where D_{jlk} denotes the set of active firms with type of external finance j and export status l, and D_k is the set of all active producers in the economy.[17] The corresponding conditional probabilities are given by $\mu_{sk}(\varphi) = \frac{g(\varphi)}{\chi_{sk}}$ and $\mu_{jlk}(\varphi) = \frac{g(\varphi)}{\chi_{jlk}}$. Combining equations (2.17) and (2.18) determines the cutoff productivity φ_{md}, at which firms are just able to produce for the domestic market by relying on monitored finance. Using the marginal-access condition (2.16), the remaining cutoff productivities can be expressed as functions of φ_{md} and exogenous parameters of the model:[18]

$$\frac{\varphi_{ud}}{\varphi_{md}} = \left(\frac{1}{c_m}\right)^{\frac{1}{\alpha}} \left(\frac{\psi_u}{\psi_m}\right)^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} ; \;\; \frac{\varphi_{mx}}{\varphi_{md}} = t^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} ; \;\; \frac{\varphi_{ux}}{\varphi_{md}} = \left(\frac{1}{c_m}\right)^{\frac{1}{\alpha}} \left(t\frac{\psi_u}{\psi_m}\right)^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} . \tag{2.20}$$

According to equation (2.20), the selection of firms depends on relative costs for external finance $\frac{\psi_u}{\psi_m}$ and trade costs $t = \frac{f_x}{f_d}\left(1 + \tau^{1-\sigma}\right)^{\frac{-\alpha}{\alpha-\sigma+1}}$. To analyze the importance of substitution effects in response to credit tightening, I define the share of firms with type of external finance j and export status l as γ_{jl}. For both selection cases,

[16] For technical reasons, I assume that $\xi > \frac{\alpha(\sigma-1)}{\alpha-\sigma+1}$. Appendix B.3 characterizes the equilibrium with Pareto distributed productivity.

[17] Appendix B.2 defines the regions of active firms for both selection cases.

[18] Note that in selection case 2, the cutoff φ_{ud} does not occur. See the discussion in section 2.3.2.

the fractions of exporters are given by:

$$\gamma_{mx} = \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{-\xi} - \left(\frac{\varphi_{ux}}{\varphi_{md}}\right)^{-\xi} ; \gamma_{ux} = \left(\frac{\varphi_{ux}}{\varphi_{md}}\right)^{-\xi} . \tag{2.21}$$

Like in standard trade models with heterogeneous firms, the share of exporters is solely determined by trade costs: $\gamma_x = \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{-\xi}$. Additionally, relative credit costs influence the selection of exporters into the two sources of external finance. In selection case 1, when trade costs are high, domestic sellers select into both types of external finance as well, such that $\sum_j \sum_l \gamma_{jl} = 1$, with:

$$\gamma_{md} = 1 - \left(\frac{\varphi_{ud}}{\varphi_{md}}\right)^{-\xi} ; \gamma_{ud} = \left(\frac{\varphi_{ud}}{\varphi_{md}}\right)^{-\xi} - \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{-\xi} , \tag{2.22}$$

whereas in case 2 domestic firms have only access to monitored finance:

$$\gamma_{md} = 1 - \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{-\xi} ; \gamma_{ud} = 0. \tag{2.23}$$

Furthermore, market shares are defined as the ratio of average revenues in one group relative to average revenues in the total economy: $\eta_{jlk} = \frac{\gamma_{jlk}\widetilde{s}_{jlk}}{\widetilde{s}_k}$, such that $\sum_j \sum_l \frac{\gamma_{jlk}\widetilde{s}_{jlk}}{\widetilde{s}_k} = 1$.[19] Each firm uses labor as single input factor for variable production costs as well as fixed and endogenous innovation costs. Total labor demand of one producer can be written as follows:

$$\frac{1}{\varphi e_{jl}} \left(x_{jl} + 1_{\{x^*>0\}} \tau x^*_{jx}\right) + k_{jl} = \frac{(\sigma - 1)(1 + \alpha)}{\sigma\alpha} s_{jl}(\varphi) + \frac{r_j}{\lambda} f_l. \tag{2.24}$$

In equilibrium, the inelastic labor supply L has to be equal to labor demands in the entry sector ($L_e = M_e f_e$) and in the four groups of active producers: $L = L_e + \sum_j \sum_l L_{jlk}$.[20] Additionally, the mass of successful entrants is equal to the mass of firms that are forced to exit due to an exogenous death shock: $\chi_s M_e = \delta M_k$. Analogous to Melitz (2003), labor market clearing pins down the mass of active firms M in the economy:

$$M_k = \frac{L}{\lambda \widetilde{s}_k} . \tag{2.25}$$

[19] The market shares η_{jl} are defined in Appendix B.3.

[20] In selection case 1, all four groups of firms are active. In case 2, domestic firms have no access to unmonitored finance and $L_{ud} = 0$. See section 2.3 for a detailed discussion of the two cases.

The borrowing rate is treated as exogenous. Section 2.6 introduces a capital market equilibrium which leads to an explicit solution for r_u. Average sales in equation (2.25) are defined as follows:

$$\widetilde{s}_k = \frac{\xi \alpha \sigma \psi_m f_d \Gamma_k}{\xi (\alpha - \sigma + 1) - \alpha (\sigma - 1)}. \tag{2.26}$$

The term Γ_k is a function of trade costs as well as financial conditions and captures the average productivity in the economy, dependent on the selection case:

$$\Gamma_1 = \Theta + \left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi} \left(\frac{f_x}{f_d}\Theta - t c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\right); \Gamma_2 = 1 + \left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi} \left(\frac{f_x}{f_d}\Theta - t\right), \tag{2.27}$$

whereas Θ is a measure for relative costs of external funds:

$$\Theta = 1 + \frac{\psi_u}{\psi_m} \left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi} \left(1 - c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\right), \tag{2.28}$$

which increases in effective costs for monitored finance, including borrowing rates and access barriers due to moral hazard. If there are no differences between the two sources of external finance, such that $m = c_m = 1$, the measure Θ equals one. Hence, this framework nests a model with financial frictions and one source of external finance as a special case, which will be discussed in more detail below.

2.4.2 Reallocation effects of credit tightening

The partial equilibrium analysis in section 2.3 has stressed two effects of credit tightening. Consistent with theoretical and empirical work on credit frictions and export behavior, worsening financial conditions increase access barriers to international markets. Furthermore, credit shocks change the ratio of access barriers $\frac{\psi_u}{\psi_m}$, and thus trigger substitution effects between the two sources of external finance, as shown by the following proposition.[21]

Proposition 2.3 *A higher private benefit b increases the fraction of firms that use monitored finance and raises their market share. In case 1, this selection effect is stronger for non-exporters:* $\frac{\partial \gamma_{md}}{\partial b} > \frac{\partial \gamma_{mx}}{\partial b} > 0$.
Proof. *See Appendix B.4.* ■

[21] Compare Proposition 2.1 for a summary of partial equilibrium effects of credit tightening. See Foley and Manova (2015) for a review of related theoretical and empirical literature.

A higher private benefit b increases the relative access barrier to unmonitored funds $\frac{\psi_u}{\psi_m}$, as it becomes relatively more difficult for firms using this type of finance to satisfy incentive compatibility. Producers that rely on financial intermediation are hit less, since monitoring attenuates aggravated moral hazard. In contrast, an increase in the borrowing rate r_u decreases the relative cost for unmonitored finance, as firms that rely on intermediaries are hurt relatively more due to additional monitoring costs. Consequently, relative access to unmonitored funds becomes easier and the share of firms using this type of finance increases (see Appendix B.4 for a formal proof). Proposition 2.3 shows that substitution effects are stronger for non-exporters if selection case 1 applies. Deteriorating financial conditions increase access barriers to finance and thus hurt low productivity firms most. In selection case 2, if trade costs are low, non-exporters have to rely on financial intermediation and cannot react to financial shocks by switching the source of external finance.

The model's predictions are consistent with empirical evidence documenting large adverse effects of credit tightening on small and bank-dependent firms, as well as substitution into alternative sources of external debt during the financial crisis of 2008-2009.[22] Credit tightening does not only affect the selection of firms into external funds and exporting, but induces reallocations of revenue-based market shares among producers that use different sources of finance. If the private benefit goes up, market shares of exporters that rely on financial intermediation increase.

Comparable to an increase in the borrowing rate r_u, a decrease in monitoring effectiveness (higher m) leads to a larger fraction of firms that use unmonitored finance and a reallocation of markets shares away from producers that rely on financial intermediation.[23] These reallocation effects change the degree of price competition in general equilibrium, which has important implications for reactions of aggregate variables to financial shocks. This will be discussed in the following subsection.

2.4.3 Aggregate effects of credit tightening

As shown in section 2.3, an increase in the private benefit aggravates moral hazard and leads to stronger credit frictions. Consequently, this shock reduces the number

[22] Compare the discussion in section 2.1.

[23] See the proof of Proposition 2.3 in Appendix B.4 for details.

of active firms (2.25), whereas $k \in 1, 2$ indicates the selection case:

$$\frac{\partial M_k}{\partial b}\frac{b}{M_k} = -\underbrace{\frac{mb}{\Delta\lambda\psi_m}}_{\text{Direct effect}} - \underbrace{\frac{\partial \Gamma_k}{\partial b}\frac{b}{\Gamma_k}}_{\text{Selection effect}} < 0. \tag{2.29}$$

Reactions along the extensive margin can be separated into two effects. The first term in equation (2.29) is independent of the selection case and captures the exit of lowest productivity firms that lose access to external finance after credit tightening (compare Proposition 2.1). The second term is a substitution effect that would not be present in a model with one source of external finance. Substitution effects lead to an additional channel of adjustment along the extensive margin. If the private benefit b increases, a larger fraction of firms has to rely on more expensive financial intermediation, which reduces the degree of price competition and attenuates exit of low productivity firms ($\frac{\partial \Gamma_k}{\partial b} < 0$). In contrast, substitution effects work in the opposite direction if the monitoring effectiveness decreases (higher m). An increase in m raises the share of firms that use unmonitored finance and leads to a reallocation of market shares away from producers relying on financial intermediation. This selection effect increases competition in general equilibrium, as a larger fraction of producers raises cheaper finance without monitoring, resulting in a lower average price and thus stronger firm exit. The same reasoning applies to an increase in the interest rate r_u.[24] To analyze the welfare effects of credit tightening, welfare can be expressed as a function of financial conditions and the cutoff productivity of the least productive domestic seller using financial intermediation φ_{mdk}:

$$W_k = P^{-1} = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{1+\alpha}{\alpha}} \left(\frac{\alpha-\sigma+1}{\alpha\sigma\psi_m f_d}\right)^{\frac{\alpha-\sigma+1}{(\sigma-1)\alpha}} \left(\frac{L}{\lambda}\right)^{\frac{1}{\sigma-1}} \left(\frac{r_m}{\lambda}\right)^{\frac{-1}{\alpha}} \varphi_{mdk} \,. \tag{2.30}$$

The derivative of equation (2.30) with respect to the private benefit b shows that credit tightening affects welfare through two channels:

$$\frac{\partial W_k}{\partial b}\frac{b}{W_k} = -\underbrace{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}\frac{mb}{\Delta\lambda\psi_m}}_{\text{Variety loss}} + \underbrace{\frac{\partial \varphi_{mdk}}{\partial b}\frac{b}{\varphi_{mdk}}}_{\text{Productivity gain}}. \tag{2.31}$$

As firms with lowest productivity and highest borrowing costs exit the market, consumers face a loss of product variety which is counteracted by a productivity gain.

[24]Compare Proposition 2.3 and see Appendix B.4 for details.

Compared to a model with one source of external finance, selection effects amplify negative welfare responses to credit tightening.

Proposition 2.4 *A higher private benefit reduces the number of active firms if the private benefit is sufficiently high, and leads to lower welfare if the effectiveness of monitoring is sufficiently low:* $\psi_m > \frac{r_u}{\lambda f_d} \frac{\widetilde{f}_k}{\Gamma_k}$. *Substitution into bank finance attenuates the negative effect on the extensive margin, but amplifies welfare losses.*
Proof. *See Appendix B.4.* ■

Selection into more expensive financial intermediation reduces average productivity and increases average fixed costs in the industry. This results in a lower productivity gain in equation (2.31) and thus higher welfare losses. In contrast, an increase in m leads to substitution into unmonitored lending, increases the exit of low productivity firms and reduces welfare losses compared to a situation with only one source of external finance. The same results apply to an increase in the borrowing rate r_u. The relative cost disadvantage of financial intermediation leads to substitution into unmonitored finance and intensifies negative reactions along the extensive margin resulting in additional productivity gains. An increase in credit costs affects welfare through three channels:

$$\frac{\partial W_k}{\partial r_u} \frac{r_u}{W_k} = -\underbrace{\frac{1}{\alpha}}_{\text{IM}} - \underbrace{\frac{\alpha - \sigma + 1}{\alpha (\sigma - 1)} \frac{r_m}{\lambda \psi_m}}_{\text{Variety loss}} + \underbrace{\frac{\partial \varphi_{mdk}}{\partial r_u} \frac{r_u}{\varphi_{mdk}}}_{\text{Productivity gain}} . \tag{2.32}$$

As producers scale down innovation activity and thus increase prices, a higher borrowing rate negatively affects the intensive margin (IM). If credit frictions in the financial intermediation sector are sufficiently high, the variety loss outweighs productivity gains and there is an additional negative reaction at the extensive margin.

Proposition 2.5 *An increase in the borrowing rate* r_u *negatively affects welfare through the intensive margin, as well as the extensive margin if monitoring effectiveness of financial intermediation is sufficiently low.*
Proof. *See Appendix B.4.* ■

Special case with one source of external finance If $c_m = m = 1$, there is no difference between monitored and unmonitored finance such that the relative access barrier to external funds is equal to one ($\frac{\psi_u}{\psi_m} = 1$) and from equation (2.20) follows that $\frac{\varphi_{ul}}{\varphi_{ml}} = 1$. Hence, the framework nests a heterogeneous firm model with financial frictions and one source of external finance. This special case allows to analyze the effect of financial intermediation on the number of active firms and welfare. The relative number of firms in selection case k compared to a scenario with only one type of external finance, denoted by the subscript o, can be expressed as follows:

$$\frac{M_k}{M_o} = \frac{\widetilde{s}_o}{\widetilde{s}_k} = \frac{\psi_u}{\psi_m}\frac{\Gamma_o}{\Gamma_k}. \tag{2.33}$$

The first term reflects the fact that financial intermediaries facilitate access to finance ($\psi_m < \psi_u$), which increases the number of available varieties in the economy. The second term captures that a higher number of producers increases the competitive pressure ($\Gamma_k > \Gamma_o$). Expression (2.33) monotonically increases in the private benefit b. Hence, stronger credit market imperfections enhance the benefit of financial intermediation in terms of larger product variety. Analogously, welfare relative to the case without financial intermediation is given by:

$$\frac{W_k}{W_o} = \left(\frac{\psi_u}{\psi_m}\right)^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} c_m^{-\frac{1}{\alpha}} \left(\frac{E\pi_k}{E\pi_o}\right)^{\frac{1}{\xi}}. \tag{2.34}$$

Compared to welfare without bank finance, the positive impact on product variety ($\frac{\psi_u}{\psi_m}$) is counteracted by a negative effect along the intensive margin as well as a productivity loss. Additional monitoring costs c_m reduce investments and hence increase prices resulting in lower welfare. As financial intermediaries enable lower productivity firms to enter, the average profits are reduced ($E\pi_k < E\pi_o$).

Proposition 2.6 *If credit frictions are sufficiently strong and monitoring effectiveness is high, financial intermediation increases product variety and welfare.*
Proof. *See Appendix B.4.* ■

From a policy perspective, the analysis shows that better access to financial intermediation leads to relatively larger product variety and potentially higher welfare, especially in industries with strong exposure to credit frictions. More effective intermediaries facilitate export activities of lower productivity firms. Furthermore, changes in credit conditions affect producers very differently depending on their productivity and the source of external finance. Policies that aim to ease access to external funds will induce reallocations of market shares across firms and thus generate losers and winners. These selection effects change the average productivity in the economy and welfare. Besides that, financial intermediation does also affect aggregate responses to trade liberalization.

2.5 Trade liberalization

This section shows that substitution between two types of external finance represents an additional channel how firms adjust to trade liberalization. I focus on a change in export fixed costs f_x, whereas analogous results can be derived for variable trade costs τ (see Appendix B.5). A reduction in trade costs decreases the cutoff productivities φ_{jx} and increases the share of exporters. Marginal firms with productivity slightly below φ_{mx} before trade liberalization start exporting. Additionally, exporters near but below the initial threshold φ_{ux} switch from financial intermediation to unmonitored finance resulting in lower borrowing costs (see Figure 2.6). In both selection cases, trade liberalization leads to a reallocation of market shares towards exporters:

$$\frac{\partial \eta_{x1}}{\partial f_x}\frac{f_x}{\eta_{x1}} = \frac{\alpha(\sigma-1)-\xi(\alpha-\sigma+1)}{\alpha(\sigma-1)}\frac{\Theta}{\Gamma_1} < 0, \tag{2.35}$$

$$\frac{\partial \eta_{x2}}{\partial f_x}\frac{f_x}{\eta_{x2}} = \frac{\alpha(\sigma-1)-\xi(\alpha-\sigma+1)}{\alpha(\sigma-1)\Gamma_2} < 0. \tag{2.36}$$

As in Melitz (2003), trade liberalization increases the cutoff productivity for domestic sales φ_{md}. Whereas market shares are reallocated towards exporters, low productivity firms have to exit:

$$\frac{\partial M_1}{\partial f_x}\frac{f_x}{M_1} = -\frac{\partial \eta_{x1}}{\partial f_x}\frac{f_x}{\eta_{x1}}\left[\Theta\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} - c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\right]\frac{t\gamma_x}{\Theta} > 0, \tag{2.37}$$

$$\frac{\partial M_2}{\partial f_x}\frac{f_x}{M_2} = -\frac{\partial \eta_{x2}}{\partial f_x}\frac{f_x}{\eta_{x2}}\left[\Theta\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} - 1\right]t\gamma_x > 0. \tag{2.38}$$

The reaction of domestic firms depends on the selection case. If trade costs are high (selection case 1), some non-exporters react to increased competitive pressure by switching from unmonitored to monitored finance. This substitution effect decreases the extent of price competition, as switchers face higher borrowing costs, which leads to a reduced reaction at the extensive margin. If trade costs are low, non-exporters cannot change the type of finance. Consequently, the comparison of equations (2.37) and (2.38) shows that exit pressure is more pronounced in selection case 2.

Higher monitoring costs c_m or a lower effectiveness of monitoring (higher m) increase the relative costs of financial intermediation compared to direct lending as captured by the term Θ. In this case, non-exporters are hurt more by increased competition after trade liberalization which leads to stronger exit. At the same time, the gain of market shares for exporters is attenuated when financial intermediation is less effective. This result is driven by two effects. First, additional profits are lower for new exporters that rely on monitored finance. Second, stronger exit of lower productivity firms increases the cutoff productivity and thus the competitive pressure in general equilibrium. Consequently, substitution effects influence the welfare gains from trade liberalization:

$$\frac{\partial W_k}{\partial f_x}\frac{f_x}{W_k} = -\frac{1}{\xi E \pi_k}\left[\frac{(\alpha - \sigma + 1)\,\lambda \widetilde{s}_k}{\alpha\sigma}\frac{\partial M_k}{\partial f_x}\frac{f_x}{M_k} + r_u f_x \frac{\partial \widetilde{f}_k}{\partial f_x}\right]. \tag{2.39}$$

Proposition 2.7 *Lower trade costs lead to a reallocation of market shares towards exporters and exit of low productivity firms. If monitoring effectiveness is sufficiently low, there are welfare gains from trade* $\left(\frac{\partial W_k}{\partial f_x}\frac{f_x}{W_k} < 0\right)$*, that increase in the relative cost for financial intermediation.*
Proof. *See Appendix B.4.* ■

Equation (2.39) and Proposition 2.7 show that welfare gains increase in credit frictions with respect to financial intermediation. Higher access barriers to external finance worsen the negative consequences of trade liberalization for lower productivity firms, but increase aggregate gains in terms of average productivity and welfare. Hence, a decrease in trade costs is more beneficial in the presence of stronger credit frictions. The comparative static analysis identifies substitution into financial intermediation as an additional channel how domestic firms react to increased competitive pressure induced by trade liberalization. A higher reliance on monitored finance reduces the negative responses along the extensive margin at the expense of welfare gains. Conversely, the absence of substitution possibilities among domestic sellers intensifies product churning, but at the same time increases welfare gains after trade liberalization. Hence, the introduction of two sources of external finance in the presence of credit frictions leads to two additional sources of gains from trade. First, some exporters obtain access to finance provided without monitoring resulting in a reduction of borrowing costs and prices. Second, stronger exit of lower productivity firms that rely on more expensive financial intermediation further increases average productivity in general equilibrium. The latter effect is attenuated if non-exporters are able to select into monitored finance in case of high trade costs.

2.6 Discussion and extensions

After presenting the effects of financial shocks and trade liberalization, this section discusses assumptions of the theoretical framework and analyzes possible extensions.

Moral hazard and external finance. Firms have to rely on external finance to cover fixed costs and endogenous investment outlays. The reactions of the intensive and extensive margins to an increase in the borrowing rate r_u depend crucially on this assumption. If external finance is needed for innovations only, access barriers are independent of borrowing rates: $\psi_m = \frac{bm}{\Delta\lambda} + \frac{1}{\lambda}$ and $\psi_u = \frac{b}{\Delta\lambda} + \frac{1}{\lambda}$ (compare subsection 2.2.3), and there will be no reaction along the extensive margin in equation (2.32). Instead, if only fixed costs have to be financed by investors, the influence of borrowing costs on the intensive margin disappears. Empirical evidence suggests that firms rely on external finance for fixed up-front costs and investments, especially in international trade.[25] One important feature of the theoretical framework is that borrowing costs for process innovations affect price setting and the intensive margin, without assuming external financing of variable production costs.

The assumption that private benefits are only related to fixed costs introduces credit frictions regarding the extensive margin. Moral hazard increases the access barriers to external finance and raises the cutoff productivities for domestic sales as well as exporting above the level of a zero-profit condition. The model does not allow that firms use a mix of both sources of credit. Instead, differences in private benefits as well as in borrowing costs lead to selection of firms into two types of external finance. Alternatively, the private benefit could be related to endogenous investment costs as well.[26] This assumption would lead to a negative effect of moral hazard on innovation choices and a direct impact on the intensive margin, but considerably complicates the analysis. The reason is that firms would additionally be divided into financially unconstrained and constrained ones besides the selection into two sources of external finance. By assuming only one type of lenders, the third chapter of this thesis introduces credit frictions and firm-specific moral hazard which leads

[25] See e.g. Manova (2013), Feenstra et al. (2014), as well as Muûls (2015), among others.

[26] Tirole (2006) discusses different specifications of moral hazard in corporate finance theory.

to an endogenous share of credit-rationed producers. This fraction is determined by the quality of financial institutions and industry characteristics such as the degree of product market competition.

Borrowing costs and capital market equilibrium. The model considers labor as single factor of production. Comparable to the general equilibrium in Melitz (2003), all resources for entry, production and investment are expressed in terms of labor. This implies that the borrowing rate r_u is exogenous. The framework could be easily extended by introducing capital as a second input factor for endogenous innovations. If labor is used for fixed and variable production costs, equation (2.25) can be rewritten as:

$$M_k = \frac{\alpha\sigma L}{\left[\sigma\left(\alpha-1\right)+1\right]\lambda\widetilde{s}_k}. \tag{2.40}$$

Additionally, fixed capital supply K has to be equal to aggregate investment outlays which leads to a further market clearing condition:

$$K = \lambda M_k \frac{\sigma-1}{\alpha\sigma}\frac{\sum_l \gamma_{mlk}\widetilde{s}_{mlk} + c_m \sum_l \gamma_{ulk}\widetilde{s}_{ulk}}{r_m}. \tag{2.41}$$

Combining equations (2.40) and (2.41) yields an explicit solution for the borrowing rate r_u:

$$r_u = \frac{L}{K}\frac{\sigma-1}{\sigma\left(\alpha-1\right)+1}\frac{\sum_l \gamma_{mlk}\widetilde{s}_{mlk} + c_m \sum_l \gamma_{ulk}\widetilde{s}_{ulk}}{c_m\widetilde{s}_k}. \tag{2.42}$$

If there is only one type of external capital ($c_m = m = 1$), borrowing costs depend on fixed parameters of the model and on relative capital supply $\frac{K}{L}$:

$$r_u = \frac{L}{K}\frac{\sigma-1}{\sigma\left(\alpha-1\right)+1}. \tag{2.43}$$

Equation (2.43) is closely related to the general equilibrium in Chapter 1 (compare section 1.5). The interest rate decreases in relative capital supply and increases with the elasticity of substitution σ. A larger convexity of investment costs α reduces capital demand and thus the borrowing rate. In a CES framework with one type of external finance, neither trade liberalization nor stronger credit frictions change the interest rate. This result is driven by two properties of the model. First, as in Melitz (2003), effects along the extensive margin are captured by labor market clearing. Second, the constant elasticity of substitution implies a constant marginal product of capital such that the effect of shocks on the intensive margin is fixed.

In contrast, Chapter 3 introduces a trade model with non-CES preferences, whereas the borrowing rate is endogenously determined by industry characteristics, and changes with trade liberalization. If there are two types of external finance, equation (2.42) reveals that capital costs are not merely pinned down by technology parameters and endowments.

Proposition 2.8 *The borrowing rate r_u decreases in the private b as well as in variable and fixed trade costs.*
Proof. *See Appendix B.4.* ■

Changes of the interest rate are caused by substitution effects between the two types of finance. If the private benefit increases, there is a reallocation of market shares away from the most successful firms with lowest borrowing costs. As producers select into more expensive monitored finance, average capital demand and thus the interest rate decreases ($\frac{\partial r_u}{\partial b} < 0$). Instead, a lower monitoring effectiveness (higher m) leads to more innovation and higher capital demand due to selection into unmonitored finance. With endogenous borrowing costs, the reaction of welfare to an increase in the private benefit is given by:

$$\frac{\partial W}{\partial b}\frac{b}{W} = -\underbrace{\frac{\alpha - \sigma + 1}{(\sigma - 1)\,\alpha}\frac{mb}{\Delta\lambda\psi_m}}_{\text{Variety loss}} + \underbrace{\frac{\partial \varphi_{md}}{\partial b}\frac{b}{\varphi_{md}}}_{\text{Productivity gain}} - \underbrace{\frac{1}{\alpha}\frac{\partial r_u}{\partial b}\frac{b}{r_u}}_{\text{Interest rate effect}}. \tag{2.44}$$

Compared to equation (2.31), stronger credit frictions lead to an additional adjustment along the intensive margin which counteracts substitution effects. Whereas selection into monitored finance causes a negative effect on welfare (compare Proposition 2.4), a decrease in borrowing costs enhances innovation activity of firms and tends to attenuate losses of credit tightening.
Analogous to financial shocks, trade liberalization changes the interest rate only through selection effects. As shown in section 2.5, lower trade costs lead to an additional welfare gain as marginal exporters switch from monitored to unmonitored finance. Facing lower borrowing costs, these firms increase capital demand which results in upward pressure on the borrowing rate. This induces a negative reaction along the intensive margin and reduces gains from trade.

Credit frictions and trade finance. The trade and finance literature discusses several reasons why exporters may be more exposed to credit frictions such as higher default risk, increased uncertainty in foreign markets or additional up-front costs.[27] This model could be extended in different ways to capture exporters' higher exposure to credit constraints. First, a higher uncertainty of investments in foreign markets could be modelled by a lower success probability λ for international firms. Second, a larger private benefit b would reflect a more difficult access to external finance. Third, it might be harder for financial intermediaries to control exporters' project choice if activity in foreign markets is associated with opaqueness of investments or weaker enforceability of financial contracts. This could be reflected by lower monitoring effectiveness m or higher borrowing costs c_m in case of exporting. These extensions imply that the share of exporters would not only depend on trade costs, but is affected by differences in financial conditions between domestic sellers and international firms (compare the discussion in section 2.4). Consequently, exporters would be hurt more by worsening financial conditions.

2.7 Conclusion

This chapter highlights that substitution effects between two types of external credit represent an additional channel how firms adjust to trade liberalization and financial shocks. Models that link firm heterogeneity à la Melitz (2003) to capital market imperfections explain negative effects of credit frictions on international trade. However, previous work mainly focuses on partial equilibrium analysis and considers only one type of external finance. The contribution of this chapter is to combine firm heterogeneity à la Melitz (2003) with financial frictions and two sources of external funds. Based on Holmstrom and Tirole (1997), moral hazard reduces the pledgeability of firm profits and aggravates access to credit. Passive lenders provide cheaper unmonitored finance, whereas financial intermediaries with monitoring ability reduce moral hazard and facilitate access to credit, but charge a higher interest rate.

The model adds a new dimension to the existing theoretical literature on heterogeneous firms in international trade. Besides the selection into exporting, productivity determines access to external finance. Consistent with empirical evidence, the most productive and largest firms export and use unmonitored finance, whereas low productivity firms sell only domestically and have to rely on more expensive financial intermediation. In addition to ex-ante differences in productivity, selection into ex-

[27] See Foley and Manova (2015) for a discussion of the trade and finance literature.

ternal finance introduces another source of firm heterogeneity. Larger producers that use unmonitored lending have a competitive advantage, compared to smaller producers that rely on intermediaries. The selection pattern of firms depends on trade costs, financial development and borrowing rates. This model shows that financial shocks and trade liberalization lead to heterogeneous firm responses, as well as new effects on the margins of international trade. Financial policies that aim to facilitate access to capital, change the relative costs for finance and thus lead to reallocations of market shares across producers with different source of external credit.

Besides that, the analysis highlights the importance of general equilibrium effects. The main idea is that financial shocks and trade liberalization induce firms to switch the type of finance, which influences price competition and thus aggregate responses in general equilibrium. In particular, stronger credit frictions lead to a larger share of producers that rely on more expensive financial intermediation and have to set higher prices. This selection effect reduces the competitive pressure in general equilibrium, forces less firms with low productivity to exit, but generates additional welfare losses. Furthermore, the model suggests a new source of gains from trade liberalization. Some exporters obtain access to cheaper unmonitored finance and reduce prices. Additionally, stronger exit of low productivity firms with high borrowing costs increases average productivity within an industry.

Appendix B

Mathematical Appendix

B.1 Maximization problem of firm

This section presents the maximization problem of a firm with export status $l \in d, x$ and external finance $j \in m, u$, whereas $1_{\{x^*>0\}}$ takes a value of one if the firm is an exporter and is zero otherwise. Firms maximize profits (2.5) subject to the constraints (2.6)-(2.9) and the corresponding incentive compatibility condition (2.14) for $j = u$ or (2.15) for $j = m$. First-order conditions for optimal prices at home p_{jl} and abroad p^*_{jx}, as well as investment e_{jl}, are:

$$XP^{\sigma}\left(\lambda+\mu_3\right)\left[(1-\sigma)p_{jl}^{-\sigma}+\frac{1}{\varphi e_{jl}}\sigma p_{jl}^{-\sigma-1}\right]=0, \tag{B.1}$$

$$XP^{\sigma}\left(\lambda+\mu_3\right)\left[(1-\sigma)\left(p^*_{jx}\right)^{-\sigma}+\frac{\tau}{\varphi e_{jx}}\sigma\left(p^*_{jx}\right)^{-\sigma-1}\right]=0, \tag{B.2}$$

$$\frac{\lambda+\mu_3}{\varphi e_{jl}^2}XP^{\sigma}\left[p_{jl}^{-\sigma}+1_{\{x^*>0\}}\tau\left(p^*_{jx}\right)^{-\sigma}\right]-\mu_1 e_{jl}^{\alpha-1}=0. \tag{B.3}$$

Optimality conditions with respect to credit amount d_{jl} and loan repayment k_{jl} are:

$$\mu_1 - r_j\mu_2 = 0, \tag{B.4}$$

$$-\lambda + \lambda\mu_2 - \mu_3 = 0, \tag{B.5}$$

where μ_1, μ_2 and μ_3 are the Lagrange multipliers of the constraints (2.7), (2.8) and (2.14) or (2.15) respectively. Optimal price setting (2.11) follows immediately from equations (B.1) and (B.2). Rearranging condition (B.3) leads to the optimal investment level e_{jl} as a function of prices:

$$e_{jl} = \left[\frac{\lambda + \mu_3}{\varphi \mu_1} X P^{\sigma} \left(p_{jl}^{-\sigma} + 1_{\{x^*>0\}} \tau \left(p_{jx}^* \right)^{-\sigma} \right) \right]^{\frac{1}{1+\alpha}}.$$

For unconstrained firms, $\mu_3 = 0$ and hence it follows from equations (B.4) and (B.5) that $\mu_1 = r_j > 1$ and $\mu_2 = 1$. If $\mu_3 > 0$, then $\frac{\lambda+\mu_3}{\mu_1} = \frac{\lambda}{r_u}$, such that optimal investment of constrained and unconstrained firms is expressed by equation (2.10). Profits (2.12) follow immediately from inserting investment (2.10) and prices (2.11) into the objective function (2.5) by taking into account constraints (2.7) and (2.8).

B.2 Regions of active firms in open economy

This section describes the regions of active firms for the two scenarios presented in section 2.3 of the main text. In both cases, the set of all active firms in equilibrium is characterized by:

$$D = \{\varphi \in [1, \infty] : \varphi \geq \varphi_{md}\}.$$

The regions of exporters using monitored and unmonitored finance are defined as:

$$D_{mx} = \{\varphi \in [1, \infty] : \varphi_{mx} \leq \varphi < \varphi_{ux}\},$$

$$D_{ux} = \{\varphi \in [1, \infty] : \varphi \geq \varphi_{ux}\}.$$

If case 1 occurs (see subsection 2.3.1), domestic firms select into two additional regions, depending on the type of external finance:

$$D_{md} = \{\varphi \in [1, \infty] : \varphi_{md} \leq \varphi < \varphi_{ud}\},$$

$$D_{ud} = \{\varphi \in [1, \infty] : \varphi_{ud} \leq \varphi < \varphi_{mx}\}.$$

In case 2 (see subsection 2.3.2), non-exporters have only access to monitored finance:

$$D_{md} = \{\varphi \in [1, \infty] : \varphi_{md} \leq \varphi < \varphi_{mx}\}.$$

B.3 Solution with Pareto distribution

As described in section 2.4, I assume that productivity φ is Pareto distributed to solve the model explicitly. Expected profits in equation (2.17) can be expressed as:

$$\begin{aligned} E\pi_k &= \lambda\psi_m f_d \left[\gamma_{mdk}\left(\frac{\widetilde{\varphi}_{mdk}}{\varphi_{mdk}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} + \gamma_{udk} c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\left(\frac{\widetilde{\varphi}_{udk}}{\varphi_{mdk}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}}\right] + \widetilde{f}_k \\ &\quad +\lambda\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}}\psi_m f_d\left[\gamma_{mx}\left(\frac{\widetilde{\varphi}_{mx}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} + \gamma_{ux} c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\left(\frac{\widetilde{\varphi}_{ux}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}}\right], \end{aligned} \tag{B.6}$$

whereas the index $k \in 1,2$ denotes the selection case, $\widetilde{\varphi}_{jlk}$ is the average productivity among producers with source of finance j and export status l, and average fixed costs are given by:

$$\widetilde{f}_k = \left(c_m\gamma_{mdk} + \gamma_{udk}\right) f_d + \left(c_m\gamma_{mx} + \gamma_{ux}\right) f_x.$$

For both selection cases, the components of exporters' expected profits in equation (B.6) are:

$$\gamma_{ux}\left(\frac{\widetilde{\varphi}_{ux}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} = \frac{-\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m} t\left(\frac{\varphi_{ux}}{\varphi_{md}}\right)^{-\xi},$$

$$\gamma_{mx}\left(\frac{\widetilde{\varphi}_{mx}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} = \frac{-\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)} t\left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{-\xi}\left[1 - c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\left(\frac{\varphi_{ud}}{\varphi_{md}}\right)^{-\xi}\right].$$

For technical reasons, it is assumed that the Pareto shape parameter is sufficiently high: $\xi > \frac{\alpha(\sigma-1)}{\alpha-\sigma+1}$, and hence $\frac{-\xi(\alpha-\sigma+1)}{\alpha(\sigma-1)-\xi(\alpha-\sigma+1)} > 0$. In selection case 1, the components for domestic firms are:

$$\gamma_{md}\left(\frac{\widetilde{\varphi}_{md}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} = \frac{-\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)}\left[1 - c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\left(\frac{\varphi_{ud}}{\varphi_{md}}\right)^{-\xi}\right],$$

$$\gamma_{ud}\left(\frac{\widetilde{\varphi}_{ud}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} = \frac{-\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)}\varphi_{md}^{\xi}\left(c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\varphi_{ud}^{-\xi} - t\varphi_{mx}^{-\xi}\right),$$

and in case 2, when trade costs are relatively low:

$$\gamma_{md}\left(\frac{\widetilde{\varphi}_{md}}{\varphi_{md}}\right)^{\frac{\alpha(\sigma-1)}{\alpha-\sigma+1}} = \frac{-\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)}\varphi_{md}^{\xi}\left(\varphi_{md}^{-\xi} - t\varphi_{mx}^{-\xi}\right).$$

The free entry condition (2.17) is an increasing function of the cutoff productivity level φ_{mdk}:

$$E\pi_k = \delta f_E \varphi_{mdk}^{\xi}.$$

Combining the free entry condition (2.17) and expected profits (2.18) leads to the following solution for the cutoff productivity φ_{md}:

$$\varphi_{mdk} = \left(\frac{1}{\delta f_E}\right)^{\frac{1}{\xi}} \left(\frac{\alpha-\sigma+1}{\alpha\sigma}\lambda\widetilde{s}_k - r_u\widetilde{f}_k\right)^{\frac{1}{\xi}}.$$

Market shares. Revenue-based market shares for exporters are defined as follows:

$$\eta_{mxk} = \frac{\gamma_{mx}\widetilde{s}_{mxk}}{\widetilde{s}_k} = \frac{f_x}{f_d}\left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi} \frac{1 - c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \frac{\psi_u}{\psi_m}\left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi}}{\Gamma_k},$$

$$\eta_{uxk} = \frac{\gamma_{ux}\widetilde{s}_{uxk}}{\widetilde{s}_k} = \frac{1}{\Gamma_k}\frac{f_x}{f_d}\frac{\psi_u}{\psi_m}\left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi}.$$

If trade costs are high (case 1), market shares for non-exporters can be expressed as:

$$\eta_{md1} = \frac{\gamma_{md1}\widetilde{s}_{md1}}{\widetilde{s}_1} = \frac{1 - c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \frac{\psi_u}{\psi_m}\left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi}}{\Gamma_1},$$

$$\eta_{ud1} = \frac{\gamma_{ud1}\widetilde{s}_{ud1}}{\widetilde{s}_1} = \frac{\frac{\psi_u}{\psi_m}\left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi} - t c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi}}{\Gamma_1},$$

and in case of low trade costs (selection pattern 2):

$$\eta_{md2} = \frac{\gamma_{md2}\widetilde{s}_{md2}}{\widetilde{s}_2} = \frac{1 - t\left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi}}{\Gamma_2},$$

whereas the measures Γ_k and Θ are defined in equations (2.27) and (2.28).

B.4 Proofs

Proof of Condition 2.3. The profitability condition for exporting with financial intermediation in Lemma 2.4 can be written as cutoff productivity:

$$\varphi \geq \left(\frac{\sigma}{\sigma-1}\right)^{\frac{1+\alpha}{\alpha}} \left(\frac{r_u}{\lambda}\right)^{\frac{1}{\sigma-1}} \left(\frac{\alpha\sigma}{\alpha-\sigma+1}\frac{c_m f_x - f_d}{(1+\tau^{1-\sigma})^{\frac{\alpha}{\alpha-\sigma+1}} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} - 1}\right)^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} A_d^{\frac{-1}{\sigma-1}}. \tag{B.7}$$

Comparing condition (B.7) with the cutoff productivity φ_{mx} in equation (2.16):

$$\varphi_{mx} = \left(\frac{\sigma}{\sigma-1}\right)^{\frac{1+\alpha}{\alpha}} \left(\frac{r_m}{\lambda}\right)^{\frac{1}{\alpha}} \left(\frac{\alpha\sigma\psi_m f_x}{\alpha-\sigma+1}\right)^{\frac{\alpha-\sigma+1}{\alpha(\sigma-1)}} A_x^{\frac{-1}{\sigma-1}}, \tag{B.8}$$

immediately leads to Condition 2.3. ■

Proof of Proposition 2.3. (i) A higher private benefit increases the relative cost for unmonitored finance:

$$\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} = \frac{r_u}{\lambda\Delta\lambda}\frac{c_m-m}{\psi_m^2} > 0 \text{ as } c_m > 1 > m.$$

For both selection cases, differentiating equation (2.21) with respect to b yields:

$$\frac{\partial\gamma_{mx}}{\partial b} = \frac{\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)}\left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi}\frac{\psi_m}{\psi_u}\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} > 0; \; \frac{\partial\gamma_{ux}}{\partial b} = -\frac{\partial\gamma_{mx}}{\partial b} < 0 \text{ as } \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} > 0.$$

For domestic firms, substitution effects are: $\frac{\partial\gamma_{md}}{\partial b} = \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{\xi}\frac{\partial\gamma_{mx}}{\partial b} > \frac{\partial\gamma_{mx}}{\partial b}$ in selection case 1, and $\frac{\partial\gamma_{md}}{\partial b} = 0$ in selection case 2. (ii) A lower monitoring effectiveness (an increase in m) and higher borrowing costs r_u reduce the relative access barrier to unmonitored finance:

$$\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial m} = -\frac{\psi_u}{\psi_m^2}\frac{b}{\Delta\lambda} < 0; \; \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial r_u} = \frac{b}{\lambda\Delta\lambda}\frac{m-c_m}{\psi_m^2} < 0 \text{ as } c_m > 1 > m.$$

For both selection cases, the shares of exporters (2.21) react as follows:

$$\frac{\partial\gamma_{mx}}{\partial m} = \frac{\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)}\left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi}\frac{\psi_m}{\psi_u}\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial m} < 0; \; \frac{\partial\gamma_{ux}}{\partial m} = -\frac{\partial\gamma_{mx}}{\partial m} > 0 \text{ as } \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial m} < 0;$$

$$\frac{\partial\gamma_{mx}}{\partial r_u} = \frac{\xi\left(\alpha-\sigma+1\right)}{\alpha\left(\sigma-1\right)}\left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi}\frac{\psi_m}{\psi_u}\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial r_u} < 0; \; \frac{\partial\gamma_{ux}}{\partial r_u} = -\frac{\partial\gamma_{mx}}{\partial r_u} > 0 \text{ as } \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial r_u} < 0.$$

In selection case 1, changes in shares of domestic sellers are given by:

$$\frac{\partial\gamma_{md}}{\partial m} = \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{\xi}\frac{\partial\gamma_{mx}}{\partial m} < 0; \; \frac{\partial\gamma_{md}}{\partial r_u} = \left(\frac{\varphi_{mx}}{\varphi_{md}}\right)^{\xi}\frac{\partial\gamma_{mx}}{\partial r_u} < 0,$$

whereas in selection case 2, there are no substitution effects among non-exporters:

$$\frac{\partial\gamma_{md}}{\partial m} = \frac{\partial\gamma_{md}}{\partial r_u} = 0.$$

For selection case 1, changes in b, m and r_u lead to reallocations of market shares according to the following derivatives:

$$\frac{\partial \eta_{md}}{\partial b} = \frac{\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi} \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} - \eta_{md}\frac{\partial \Gamma_1}{\partial b}}{\Gamma_1} > 0,$$

$$\frac{\partial \eta_{mx}}{\partial b} = \frac{\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \frac{f_x}{f_d} \left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi} \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} - \eta_{mx}\frac{\partial \Gamma_1}{\partial b}}{\Gamma_1} > 0,$$

$$\frac{\partial \eta_{md}}{\partial r_u} = \frac{\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi} \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial r_u} - \eta_{md}\frac{\partial \Gamma_1}{\partial r_u}}{\Gamma_1} < 0,$$

$$\frac{\partial \eta_{mx}}{\partial r_u} = \frac{\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \frac{f_x}{f_d} \left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi} \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial r_u} - \eta_{mx}\frac{\partial \Gamma_1}{\partial r_u}}{\Gamma_1} < 0,$$

$$\frac{\partial \eta_{md}}{\partial m} = \frac{\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi} \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial m} - \eta_{md}\frac{\partial \Gamma_1}{\partial m}}{\Gamma_1} < 0,$$

$$\frac{\partial \eta_{mx}}{\partial m} = \frac{\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)} c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \frac{f_x}{f_d} \left(\frac{\varphi_{md}}{\varphi_{ux}}\right)^{\xi} \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial m} - \eta_{mx}\frac{\partial \Gamma_1}{\partial m}}{\Gamma_1} < 0,$$

whereas $\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} > 0$, $\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial r_u}, \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial m} < 0$ and $\frac{\partial \Gamma_1}{\partial b} < 0$, $\frac{\partial \Gamma_1}{\partial r_u}, \frac{\partial \Gamma_1}{\partial m} > 0$. Analogous reactions of market shares can be derived for selection case 2. ∎

Proof of Proposition 2.4. The derivative (2.29) follows immediately from equation (2.25) by taking into account equation (2.26). Substitution effects subject to a change in the private benefit b, as stated in equation (2.29), are given by:

$$\frac{\partial \Gamma_1}{\partial b} = \frac{\partial \Theta}{\partial b}\left[1 + \left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi} \frac{f_x}{f_d}\right] < 0; \; \frac{\partial \Gamma_2}{\partial b} = \frac{\partial \Theta}{\partial b}\left(\frac{\varphi_{md}}{\varphi_{mx}}\right)^{\xi} \frac{f_x}{f_d} < 0,$$

whereas

$$\frac{\partial \Theta}{\partial b} = -\frac{\xi\left(\alpha-\sigma+1\right)-\alpha\left(\sigma-1\right)}{\alpha\left(\sigma-1\right)}\left(1-c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\right)\left(\frac{\varphi_{md}}{\varphi_{ud}}\right)^{\xi}\frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} < 0 \text{ as } \frac{\partial\left(\frac{\psi_u}{\psi_m}\right)}{\partial b} > 0.$$

The overall effect of an increase in b on the number of firms is negative as long as $-\frac{mb}{\Delta\lambda\psi_m} - \frac{\partial \Gamma_k}{\partial b}\frac{b}{\Gamma_k} < 0$, which leads to the following conditions in selection case 1:

$$\psi_u > \frac{\xi\left(\alpha-\sigma+1\right)-\alpha\left(\sigma-1\right)}{\alpha\left(\sigma-1\right)}\left(1-c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\right)\frac{r_u}{\lambda}\frac{c_m-m}{m}\left(\frac{f_d}{f_x}+\gamma_x\right)\eta_{ux1},$$

and in selection case 2:

$$\psi_u > \frac{\xi\left(\alpha-\sigma+1\right)-\alpha\left(\sigma-1\right)}{\alpha\left(\sigma-1\right)}\left(1-c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\right)\frac{r_u}{\lambda}\frac{c_m-m}{m}\eta_{ux2}.$$

Both conditions impose minimum requirements on the private benefit b, since the left-hand-side (ψ_u) increases in b, whereas the market shares η_{uxk} decrease in b. The productivity effect in equation (2.31) is given by:

$$\frac{\partial\varphi_{mdk}}{\partial b}\frac{b}{\varphi_{mdk}} = -\frac{1}{\xi E\pi_k}\left(\frac{\alpha-\sigma+1}{\alpha\sigma}\lambda\widetilde{s}_k\frac{\partial M_k}{\partial b}\frac{b}{M_k}+br_u\frac{\partial\widetilde{f}_k}{\partial b}\right), \tag{B.9}$$

whereas average fixed costs increase in the private benefit b: $\frac{\partial\widetilde{f}_k}{\partial b} > 0$. Inserting derivatives (B.9) and (2.29) into equation (2.31), and rearranging leads to:

$$\frac{\partial W_k}{\partial b}\frac{b}{W_k} = -\frac{\alpha-\sigma+1}{\alpha\sigma\xi E\pi_k}\left[\begin{array}{c}\left(\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha(\sigma-1)}\frac{mb}{\Delta\lambda\psi_m}-\frac{\partial\Gamma_k}{\partial b}\frac{b}{\Gamma_k}\right)\lambda\widetilde{s}_k\\ +r_u\widetilde{f}_k\left(\frac{\sigma\xi}{\sigma-1}\frac{mb}{\Delta\lambda\psi_m}+\frac{\alpha\sigma}{\alpha-\sigma+1}\frac{\partial\widetilde{f}_k}{\partial b}\frac{b}{\widetilde{f}_k}\right)\end{array}\right], \tag{B.10}$$

whereby the definition of average profits is exploited: $E\pi_k = \lambda\widetilde{s}_k\frac{\alpha-\sigma+1}{\alpha\sigma} - r_u\widetilde{f}_k$. Substitution effects decrease average productivity ($\frac{\partial\Gamma_k}{\partial b} < 0$) and increase average fixed costs ($\frac{\partial\widetilde{f}_k}{\partial b} > 0$), and thus, clearly amplify welfare losses of credit tightening. From the derivative (B.10) follows that a sufficient condition for a negative welfare response is given by: $\psi_m > \frac{r_u}{\lambda f_d}\frac{\widetilde{f}_k}{\Gamma_k}$. ■

A change in monitoring effectiveness m and an increase in borrowing costs r_u both lead to a clearly negative reaction along the extensive margin:

$$\frac{\partial M}{\partial m}\frac{m}{M} = -\frac{bm}{\Delta\lambda\psi_m}-\frac{\partial\Gamma_k}{\partial m}\frac{m}{\Gamma_k} < 0,\quad \frac{\partial M_k}{\partial r_u}\frac{r_u}{M_k} = -\frac{r_m}{\lambda\psi_m}-\frac{\partial\Gamma_k}{\partial r_u}\frac{r_u}{\Gamma_k} < 0. \tag{B.11}$$

as selection effects aggravate firm exit: $\frac{\partial\Gamma_k}{\partial m}, \frac{\partial\Gamma_k}{\partial r_u} > 0$. Comparable to equation (2.31), the effect of a change in monitoring effectiveness m on welfare can be written as:

$$\frac{\partial W}{\partial m}\frac{m}{W} = -\frac{\alpha-\sigma+1}{\left(\sigma-1\right)\alpha}\frac{mb}{\Delta\lambda\psi_m}+\frac{\partial\varphi_{md}}{\partial m}\frac{m}{\varphi_{md}}. \tag{B.12}$$

Analogous to the derivation for a change in the private benefit b, the welfare response is negative if the access barrier to monitored finance is sufficiently high, as the following conditions show for selection case 1:

$$\psi_m > \frac{r_u}{\lambda f_d}\frac{f_d c_m+\gamma_x\left(f_x c_m-f_d\right)}{1+\gamma_x t\left[\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}}-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\right]},$$

as well as for selection case 2:

$$\psi_m > \frac{r_u}{\lambda f_d} \frac{f_d c_m + \gamma_x (f_x - f_d c_m)}{1 + \gamma_x t \left[(1 + \tau^{1-\sigma})^{\frac{\alpha}{\alpha-\sigma+1}} - 1 \right]}.$$

Proof of Proposition 2.5. The effect of the interest rate r_u on cutoff productivity φ_{mdk} in equation (2.32) is given by:

$$\frac{\partial \varphi_{mdk}}{\partial r_u} \frac{r_u}{\varphi_{mdk}} = \frac{1}{\xi E \pi_k} \left(-\frac{\alpha - \sigma + 1}{\alpha\sigma} \lambda \widetilde{s}_k \frac{\partial M_k}{\partial r_u} \frac{r_u}{M_k} - r_u \widetilde{f}_k - r_u^2 \frac{\partial \widetilde{f}_k}{\partial r_k} \right), \tag{B.13}$$

whereas the reaction along the extensive margin is given in equation (B.11). Substitution into unmonitored finance increases within-industry productivity:

$$\frac{\partial \Gamma_1}{\partial r_u} = \frac{\partial \Theta}{\partial r_u} \left[1 + \left(\frac{\varphi_{md}}{\varphi_{mx}} \right)^{\xi} \frac{f_x}{f_d} \right] > 0; \ \frac{\partial \Gamma_2}{\partial r_u} = \frac{\partial \Theta}{\partial r_u} \left(\frac{\varphi_{md}}{\varphi_{mx}} \right)^{\xi} \frac{f_x}{f_d} > 0,$$

whereas for both selection cases it holds that:

$$\frac{\partial \Theta}{\partial r_u} = -\frac{\xi (\alpha - \sigma + 1) - \alpha (\sigma - 1)}{\alpha (\sigma - 1)} \left(1 - c_m^{\frac{1-\sigma}{\alpha-\sigma+1}} \right) \left(\frac{\varphi_{md}}{\varphi_{ud}} \right)^{\xi} \frac{\partial \left(\frac{\psi_u}{\psi_m} \right)}{\partial r_u} > 0,$$

as the relative access barrier to unmonitored finance decreases in r_u: $\frac{\partial \left(\frac{\psi_u}{\psi_m} \right)}{\partial r_u} < 0$. The effect on the extensive margin in equation (2.32) is negative if:

$$\begin{aligned} & \left[\frac{\xi (\alpha - \sigma + 1) - (\sigma - 1) \alpha}{(\sigma - 1) \alpha} \frac{c_m}{\lambda \psi_m} \Gamma_k - \frac{\partial \Gamma_k}{\partial r_u} \right] \frac{\xi (\alpha - \sigma + 1) \lambda \psi_m f_d}{\xi (\alpha - \sigma + 1) - \alpha (\sigma - 1)} \\ > \ & \widetilde{f}_k \left[\frac{\xi (\alpha - \sigma + 1) r_m - (\sigma - 1) \alpha \lambda \psi_m}{(\sigma - 1) \alpha \lambda \psi_m} - \frac{\partial \widetilde{f}_k}{\partial r_u} \frac{r_u}{\widetilde{f}_k} \right], \end{aligned}$$

whereas $\frac{\partial \widetilde{f}_1}{\partial r_u} < 0$. It can be easily shown that the left-hand side of this condition increases in m, whereas the right-hand side decreases in m. Hence, the reaction along the extensive margin is clearly negative as long as the monitoring effectiveness of financial intermediation is sufficiently low. ■

Proof of Proposition 2.6. Depending on the selection case $k \in 1, 2$, equation (2.33) can be rewritten by using the expressions for average revenues $\widetilde{s}_k$ in equation (2.26). If there is only one type of external finance, $\Theta = 1$ and $\Gamma = 1 + \left(\frac{\varphi_{md}}{\varphi_{mx}} \right)^{\xi} \left(\frac{f_x}{f_d} - t \right)$, as discussed in subsection 2.4.3. Exploiting this, product variety is larger ($\frac{M_k}{M_0} > 1$) if the following condition holds for selection case 1:

$$\frac{\psi_u}{\psi_m} > \frac{\Theta \left[1 + (1 + \tau^{1-\sigma})^{\frac{\alpha}{\alpha-\sigma+1}} t \gamma_x \right] - c_m^{\frac{\sigma-1}{\alpha-\sigma+1}} t \gamma_x}{1 + t \gamma_x \left[(1 + \tau^{1-\sigma})^{\frac{\alpha}{\alpha-\sigma+1}} - 1 \right]}.$$

A similar condition ensures variety gains in selection case 2:

$$\frac{\psi_u}{\psi_m} > \frac{1 + t\gamma_x \left[\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} \Theta - 1 \right]}{1 + t\gamma_x \left[\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} - 1 \right]}.$$

Note that for both cases, the left-hand side of the condition increases in b and decreases in m, whereas the opposite holds for the right-hand side. Hence, the conditions are satisfied whenever the extent of credit frictions, as well as monitoring effectiveness of financial intermediation, is sufficiently high. ■

Proof of Proposition 2.7. The market share of exporters is given by:

$$\eta_{xk} = \frac{\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} t\gamma_x}{\Gamma_k}. \tag{B.14}$$

Taking the derivative of equation (B.14) with respect to fixed trade costs leads to:

$$\frac{\partial \eta_{xk}}{\partial f_x}\frac{f_x}{\eta_{xk}} = \frac{\alpha(\sigma-1) - \xi(\alpha-\sigma+1)}{\alpha(\sigma-1)}\frac{\partial t}{\partial f_x}\frac{f_x}{t} - \frac{\partial \Gamma_k}{\partial f_x}\frac{f_x}{\Gamma_k},$$

whereas $\frac{\partial t}{\partial f_x} = \frac{\left(1+\tau^{1-\sigma}\right)^{\frac{-\alpha}{\alpha-\sigma+1}}}{f_d} > 0$, and the effects of trade costs on the measures of average productivity in the economy are given by:

$$\frac{\partial \Gamma_1}{\partial f_x} = \gamma_x \left[\Theta\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} - c_m^{\frac{\sigma-1}{\alpha-\sigma+1}} \right] \frac{\alpha(\sigma-1) - \xi(\alpha-\sigma+1)}{\alpha(\sigma-1)}\frac{\partial t}{\partial f_x} < 0, \tag{B.15}$$

$$\frac{\partial \Gamma_2}{\partial f_x} = \gamma_x \left[\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} \Theta - 1 \right] \frac{\alpha(\sigma-1) - \xi(\alpha-\sigma+1)}{\alpha(\sigma-1)}\frac{\partial t}{\partial f_x} < 0. \tag{B.16}$$

Inserting these expressions into the derivative of equation (B.14) and simplifying leads to equations (2.35) and (2.36). For both selection cases, the reaction of market shares decreases in Θ, and thus increases in the monitoring effectiveness of financial intermediation as $\frac{\partial \Theta}{\partial m} > 0$. Reactions of the extensive margin to trade costs follow immediately from the derivation of equation (2.25). Exit of firms is stronger if financial intermediation is less effective as:

$$\frac{\partial\left(\frac{\partial M_1}{\partial f_x}\frac{f_x}{M_1}\right)}{\partial \Theta} = \frac{\xi(\alpha-\sigma+1) - \alpha(\sigma-1)}{\alpha(\sigma-1)}\frac{t\gamma_x c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}}{\Gamma_1^2} > 0,$$

$$\frac{\partial\left(\frac{\partial M_2}{\partial f_x}\frac{f_x}{M_2}\right)}{\partial \Theta} = \frac{\xi(\alpha-\sigma+1) - \alpha(\sigma-1)}{\alpha(\sigma-1)}\frac{t\gamma_x \left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}}}{\Gamma_2^2} > 0.$$

The effects of fixed export costs f_x on average fixed costs for the two selection cases are given by:

$$\frac{\partial \widetilde{f}_1}{\partial f_x} = \frac{\left[\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)\right]\left(\gamma_{mx}c_m+\gamma_{ux}\right)+\xi\left(\alpha-\sigma+1\right)\frac{f_d}{f_x}\gamma_x}{\alpha\left(\sigma-1\right)}, \tag{B.17}$$

$$\frac{\partial \widetilde{f}_2}{\partial f_x} = \frac{\left[\alpha\left(\sigma-1\right)-\xi\left(\alpha-\sigma+1\right)\right]\left(\gamma_{mx}c_m+\gamma_{ux}\right)+\xi\left(\alpha-\sigma+1\right)\frac{f_d}{f_x}c_m\gamma_x}{\alpha\left(\sigma-1\right)}. \tag{B.18}$$

The welfare response in equation (2.39) is negative if the following condition holds:

$$-\frac{\xi\left(\alpha-\sigma+1\right)\lambda\psi_m f_d}{\xi\left(\alpha-\sigma+1\right)-\alpha\left(\sigma-1\right)}\frac{\partial\Gamma_k}{\partial f_x} > -r_u\frac{\partial\widetilde{f}_k}{\partial f_x}.$$

Exploiting equations (B.15) and (B.16), as well as the reactions of average fixed costs (B.17) and (B.18), leads to the following conditions for selection case 1:

$$\psi_m > \frac{r_u}{\lambda}\frac{\left[\xi\left(\alpha-\sigma+1\right)-\alpha\left(\sigma-1\right)\right]\left(\gamma_{mx}c_m+\gamma_{ux}\right)-\xi\left(\alpha-\sigma+1\right)\frac{f_d}{f_x}\gamma_x}{\xi\left(\alpha-\sigma+1\right)\gamma_x\left(\Theta-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\left(1+\tau^{1-\sigma}\right)^{\frac{-\alpha}{\alpha-\sigma+1}}\right)},$$

and correspondingly for selection case 2:

$$\psi_m > \frac{r_u}{\lambda}\frac{\left[\xi\left(\alpha-\sigma+1\right)-\alpha\left(\sigma-1\right)\right]\left(\gamma_{mx}c_m+\gamma_{ux}\right)-\xi\left(\alpha-\sigma+1\right)\frac{f_d}{f_x}c_m\gamma_x}{\xi\left(\alpha-\sigma+1\right)\gamma_x\left(\Theta-\left(1+\tau^{1-\sigma}\right)^{\frac{-\alpha}{\alpha-\sigma+1}}\right)}.$$

Note that $\frac{\partial\psi_m}{\partial m}$, $\frac{\partial\Theta}{\partial m} > 0$ and $\frac{\partial(\gamma_{mx}c_m+\gamma_{ux})}{\partial m} < 0$. Hence, the conditions are satisfied whenever the monitoring effectiveness is sufficiently low. ■

Proof of Proposition 2.8. By exploiting the properties of the model with a Pareto distributed productivity, as presented in Appendix B.3, the borrowing rate in equation (2.42) can be rewritten as follows for selection case 1:

$$r_{u1} = \frac{L}{c_m K}\frac{\sigma-1}{\sigma\left(\alpha-1\right)+1}\frac{\left(1+\frac{f_x\gamma_x}{f_d}\right)\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\alpha}{\alpha-\sigma+1}}-1\right)\right]-c_m^{\frac{\alpha}{\alpha-\sigma+1}}t\gamma_x}{\left(1+\frac{f_x\gamma_x}{f_d}\right)\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}-1\right)\right]-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}t\gamma_x}, \tag{B.19}$$

and in selection case 2:

$$r_{u2} = \frac{L}{c_m K}\frac{\sigma-1}{\sigma\left(\alpha-1\right)+1}\frac{1+\frac{f_x\gamma_x}{f_d}\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\alpha}{\alpha-\sigma+1}}-1\right)\right]-t\gamma_x}{1+\frac{f_x\gamma_x}{f_d}\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}-1\right)\right]-t\gamma_x}. \tag{B.20}$$

Taking the derivatives of equations (B.19) and (B.20) with respect to b leads to:

$$\frac{\partial r_{u1}}{\partial b}=\frac{(c_m-1)\,L}{c_mK}\frac{\sigma-1}{\sigma(\alpha-1)+1}\frac{\left(1+\frac{f_x\gamma_x}{f_d}\right)\frac{\partial\left(\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\right)}{\partial b}\left(1-t\gamma_x+\frac{f_x\gamma_x}{f_d}\right)}{\left[\left(1+\frac{f_x\gamma_x}{f_d}\right)\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}-1\right)\right]-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}t\gamma_x\right]^2}<0,$$

$$\frac{\partial r_{u2}}{\partial b}=\frac{(c_m-1)\,L}{c_mK}\frac{\sigma-1}{\sigma(\alpha-1)+1}\frac{\frac{f_x\gamma_x}{f_d}\frac{\partial\left(\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\right)}{\partial b}\left(1-t\gamma_x+\frac{f_x\gamma_x}{f_d}\right)}{\left[1+\frac{f_x\gamma_x}{f_d}\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}-1\right)\right]-t\gamma_x\right]^2}<0,$$

whereas $\frac{\partial\left(\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\right)}{\partial b}<0$ and $1-t\gamma_x>0$. Taking the derivative with respect to fixed trade costs f_x and simplifying yields:

$$\frac{\partial r_{u1}}{\partial f_x}=\frac{(c_m-1)\,L}{c_mK}\frac{\sigma-1}{\sigma(\alpha-1)+1}\frac{c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\left(\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}-1\right)\left[\left(1+\frac{f_x\gamma_x}{f_d}\right)\frac{\partial(t\gamma_x)}{\partial f_x}-t\gamma_x\frac{\partial\left(\frac{f_x\gamma_x}{f_d}\right)}{\partial f_x}\right]}{\left[\left(1+\frac{f_x\gamma_x}{f_d}\right)\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}-1\right)\right]-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}t\gamma_x\right]^2}<0,$$

$$\frac{\partial r_{u2}}{\partial f_x}=\frac{(c_m-1)\,L}{c_mK}\frac{\sigma-1}{\sigma(\alpha-1)+1}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\frac{\frac{\partial(t\gamma_x)}{\partial f_x}\frac{f_x\gamma_x}{f_d}+(1-t\gamma_x)\frac{\partial\left(\frac{f_x\gamma_x}{f_d}\right)}{\partial f_x}}{\left[1+\frac{f_x\gamma_x}{f_d}\left[1+c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}\left(c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}-1\right)\right]-t\gamma_x\right]^2}<0,$$

whereas $\left(1+\frac{f_x\gamma_x}{f_d}\right)\frac{\partial(t\gamma_x)}{\partial f_x}-t\gamma_x\frac{\partial\left(\frac{f_x\gamma_x}{f_d}\right)}{\partial f_x}<0$, and $\frac{\psi_u}{\psi_m}\frac{\gamma_{ux}}{\gamma_x}c_m^{\frac{1-\sigma}{\alpha-\sigma+1}}>1$ due to Condition 2.1. Changes with respect to variable trade costs τ can be derived analogously. ■

B.5 Effects of change in variable trade costs

This section presents comparative static results for a change in variable trade costs τ (compare section 2.5 on fixed trade costs). Market shares of exporters decrease in iceberg-trade costs τ:

$$\frac{\partial\eta_{x1}}{\partial\tau}\frac{\tau}{\eta_{x1}}=-\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\frac{\xi}{\Gamma_1}\left[\Theta\left(1-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}t\gamma_x\right)+t\gamma_xc_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\xi(\alpha-\sigma+1)}\right]<0,$$

$$\frac{\partial\eta_{x2}}{\partial\tau}\frac{\tau}{\eta_{x2}}=-\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\frac{\xi}{\Gamma_2}\left[1-t\gamma_x\frac{\alpha(\sigma-1)}{\xi(\alpha-\sigma+1)}\right]<0.$$

The reaction along the extensive margin is given by:

$$\frac{\partial M_1}{\partial\tau}\frac{\tau}{M_1}=\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\frac{t\gamma_x}{\Gamma_1}\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha-\sigma+1}\left[\frac{\xi\Theta(\alpha-\sigma+1)\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}}}{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}-c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\right]>0,$$

$$\frac{\partial M_2}{\partial \tau}\frac{\tau}{M_2} = \frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\frac{t\gamma_x}{\Gamma_2}\frac{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}{\alpha-\sigma+1}\left[\frac{\xi\Theta(\alpha-\sigma+1)\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}}}{\xi(\alpha-\sigma+1)-\alpha(\sigma-1)}-1\right] > 0.$$

The effect of τ on welfare can be derived as follows:

$$\frac{\partial W}{\partial \tau}\frac{\tau}{W} = -\frac{1}{\xi E\pi_k}\left[\frac{(\alpha-\sigma+1)\lambda\widetilde{s}_k}{\alpha\sigma}\frac{\partial M_k}{\partial \tau}\frac{\tau}{M_k} + \tau r_u\frac{\partial \widetilde{f}_k}{\partial \tau}\right],$$

whereas the effects on average fixed costs are:

$$\frac{\partial \widetilde{f}_1}{\partial \tau} = -\frac{\xi\tau^{-\sigma}\left[\gamma_{mx}(f_x c_m - f_d) + \gamma_{ux}(f_x - f_d)\right]}{1+\tau^{1-\sigma}} < 0,$$

$$\frac{\partial \widetilde{f}_2}{\partial \tau} = -\frac{\xi\tau^{-\sigma}\left[\gamma_{mx}c_m(f_x - f_d) + \gamma_{ux}(f_x - f_d c_m)\right]}{1+\tau^{1-\sigma}} < 0.$$

Analogous to a change in fixed export costs f_x (compare Proposition 2.7), the welfare response is negative ($\frac{\partial W}{\partial \tau}\frac{\tau}{W} < 0$) as long as the access barrier to monitored finance is sufficiently high in selection case 1:

$$\psi_m > \frac{r_u\left[(\gamma_{mx}c_m + \gamma_{ux})f_x - \gamma_x f_d\right]\left[\xi(\alpha-\sigma+1)-\alpha(\sigma-1)\right]}{\lambda f_d t\gamma_x\left[\xi(\alpha-\sigma+1)\left(\Theta\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} - c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\right) + c_m^{\frac{\sigma-1}{\alpha-\sigma+1}}\alpha(\sigma-1)\right]},$$

and in selection case 2:

$$\psi_m > \frac{r_u\left[(\gamma_{mx}c_m + \gamma_{ux})f_x - c_m f_d\gamma_x\right]\left[\xi(\alpha-\sigma+1)-\alpha(\sigma-1)\right]}{\lambda f_d t\gamma_x\left[\xi(\alpha-\sigma+1)\left(\Theta\left(1+\tau^{1-\sigma}\right)^{\frac{\alpha}{\alpha-\sigma+1}} - 1\right) + \alpha(\sigma-1)\right]}.$$

Chapter 3

Capital Market Imperfections and Trade Liberalization in General Equilibrium

This chapter develops a new international trade model with capital market imperfections and endogenous borrowing costs in general equilibrium. A key element of our model is that firm heterogeneity arises from the interaction of credit constraints at the firm level with financial frictions at the country level. Producers differ in pledgeability of sales which results in firm heterogeneity, if financial institutions are imperfect. We show that endogenous adjustments of capital costs represent a new channel that reduces common gains from globalization. Trade liberalization increases the borrowing rate, leads to a reallocation of market shares towards unconstrained producers and a larger fraction of credit-rationed firms. This increases the within-industry variance of sales and reduces welfare gains as consumers dislike price heterogeneity. Our theory is consistent with new empirical patterns from World Bank firm-level data. We highlight that credit frictions are positively related to the degree of product market competition, and to the variance of sales across firms.

This chapter is based on joint work with Michael Irlacher. We thank Daniel Baumgarten, Carsten Eckel, Lisandra Flach, Monika Schnitzer, and Jens Wrona, as well as participants of the Munich "IO and Trade seminar", of the 17th Workshop "Internationale Wirtschaftsbeziehungen" in Goettingen, of the 20th BGPE Research Workshop in Passau, and of the 17th Annual Conference of the European Trade Study Group in Paris for helpful comments and suggestions. Felix Roellig provided excellent research assistance.

3.1 Introduction

International activity of firms usually depends on access to external capital. Credit from outside investors is used to finance production costs, machinery, the purchase of material inputs, and up-front investments. Empirical studies show that access to external capital and financial development are important determinants of trade activity. Countries with better-developed financial systems export relatively more in industries with higher dependence on external finance and lower asset tangibility (Beck, 2003; Svaleryd and Vlachos, 2005; Manova, 2008, 2013). Existing theoretical work builds on the interaction of credit constraints at the industry or country level with ex-ante firm heterogeneity à la Melitz (2003), and shows negative effects of credit frictions on trade flows (Manova, 2013; Chaney, 2013).[1] These models typically focus on partial equilibrium and do not consider welfare implications.

The purpose of this chapter is to analyze the effects of globalization on firm performance and welfare, when producers differ in their exposure to financial frictions and borrowing costs are endogenous. A novel feature of this model is that firm heterogeneity results from the interaction between capital market imperfections at the country level and credit constraints at the firm level. Producers require external capital to cover production costs and differ in their incentive to divert external funds, while being homogenous in other respects. This firm-specific moral hazard problem reduces the pledgeability of sales and causes credit-rationing for some producers. Firm heterogeneity arises if financial institutions are imperfect, as only a fraction of firms can overcome credit frictions and behaves optimally. Producers with high incentives to misbehave face credit-rationing and have to restrict production. Hence, the share of financially constrained firms is endogenous in our model.

As a second departure from previous theoretical work, we explicitly model a capital market equilibrium which determines the interest rate.[2] We analyze the effects of globalization and show that adjustments of capital costs represent an additional channel which reduces common gains from trade. Trade liberalization increases the market size as well as competition through entry of foreign firms. A positive market size effect induces output expansion of all firms, raises capital demand, and thus leads to upward pressure on the interest rate. Higher borrowing costs, as well as stronger foreign competition, lead to a larger fraction of financially constrained

[1] See Foley and Manova (2015) for a review of the trade and finance literature.

[2] One exception is Foellmi and Oechslin (2010), which we discuss below.

producers. Hence, some initially unconstrained firms face credit-rationing and have to set higher prices. Furthermore, existing constrained producers are hurt more by higher capital costs, leading to a reallocation of profits towards unconstrained firms. These two adjustments increase the within-industry variance of prices in the economy. We consider the indirect utility associated with quadratic preferences as a welfare measure. As consumers dislike price heterogeneity, a higher within-industry variance represents a negative welfare channel of globalization.

To motivate our theoretical model, we exploit enterprise survey data from the World Bank and highlight three novel empirical patterns. First, we use the ratio of tangible assets over total assets as a proxy for access to external finance, and show that the majority of variation in this measure is across firms within industries rather than between industries. This pattern is consistent with empirical studies showing that financial health and access to external finance are important determinants of export and innovation activity, even after controlling for firm characteristics, such as size and productivity.[3] The high within-industry heterogeneity with respect to credit constraints motivates the analysis of firm-specific financial frictions in our theoretical model. Second, we show that in industries with a higher degree of competition, a larger fraction of firms is financially constrained. Third, more financially constrained industries and countries with lower financial development show a larger variance of firm sales and a higher share of credit-rationed producers.[4] All relationships hold after controlling for firm characteristics such as productivity or size.

Our theoretical model provides a rationale for these patterns. A higher degree of competition captures that consumers react more sensitive to price increases. This competition effect reduces firm sales and thus the pledgeable income, such that more producers become financially constrained. Lower financial development corresponds to weaker contract enforcement which results in stronger credit frictions. Hence, a higher fraction of producers faces financial constraints and firm-level differences in pledgeability translate into larger within-industry heterogeneity in sales.

This chapter contributes to the growing literature on capital market imperfections in international trade. Theoretical work introduces credit frictions in trade models with heterogeneous firms.[5] This strand of literature differs regarding (i) the usage of

[3]See Berman and Héricourt (2010), Minetti and Zhu (2011), Gorodnichenko and Schnitzer (2013), and Muûls (2015), among others.

[4]The link between credit frictions and international trade is particularly relevant in developing countries where the quality of financial institutions is low (Banerjee and Duflo, 2005, 2014).

[5]See e.g. Muûls (2008), Manova (2013), and Chaney (2013) for extensions of the Melitz (2003)

external funds (e.g. trade related fixed or variable costs), (ii) the theoretical motivation of financial constraints (e.g. moral hazard, imperfect contractibility, information asymmetry), and (iii) the underlying preference structure (e.g. CES vs. linear demand). To the best of our knowledge, this model is the first to introduce firm-specific credit frictions based on moral hazard, which leads to heterogeneity with respect to firm performance in the absence of ex-ante productivity or wealth differences. A related paper is Yeaple (2005), in which technology choice and different skill levels across workers generate firm heterogeneity among initially homogenous producers. In a dynamic model of trade and finance, Felbermayr and Spiegel (2014) introduce heterogeneity in default probabilities which results in firm-specific borrowing rates. Existing work analyzes the effects of credit frictions on product markets in general equilibrium without explicitly modelling capital markets. One exception is Foellmi and Oechslin (2010), who also consider an endogenous interest rate determined by capital market clearing. However, the focus of their approach is a different one. In a model with CES preferences and heterogeneity in wealth, they analyze the distributive impact of trade liberalization in less-developed countries. The authors show that globalization impedes access to external finance, especially for poor entrepreneurs, resulting in an increase of income inequality in the economy. In our setting with linear demand, we can disentangle the market size from the competition effect and separately analyze their impacts on equilibrium outcomes. In contrast to a model with CES preferences, markups are endogenous and thus affected by pro-competitive effects of globalization. The advantage of our framework is its high tractability, which allows us to explicitly solve for all endogenous variables, and to conduct comparative static analysis with respect to financial development and globalization. Furthermore, we derive welfare and show how capital market adjustments alter the gains from trade. Another paper that analyzes the welfare implications of credit frictions is Formai (2013). In a general equilibrium framework based on Melitz (2003), she shows how credit frictions distort the entry decision of producers, whereas trade liberalization can lead to negative welfare effects.

In our framework, the crucial mechanism in general equilibrium is the endogenous adjustment of the interest rate after globalization. Therefore, our analysis is related to models that study how credit frictions affect international capital and trade flows. In a Heckscher-Ohlin model with heterogeneous financial frictions across countries

model by financial frictions. Peters and Schnitzer (2015) introduce borrowing constraints in the framework of Melitz and Ottaviano (2008).

and sectors, Antràs and Caballero (2009) show that trade integration increases the interest rate in financially underdeveloped countries. Whereas this result is driven by specialization and across-sector reallocation of inputs, in our model interest rate adjustments after globalization lead to within-sector reallocation of market shares between constrained and unconstrained firms.

The chapter is structured as follows. The next section provides empirical motivation for our theoretical setup. Section 3.3 presents the theoretical model and discusses comparative statics in partial equilibrium. The following section introduces the capital market and discusses general equilibrium effects of globalization. Section 3.5 shows simulation results of the gains from globalization in both partial and general equilibrium. In section 3.6, we extend the model by free entry and show that the effects of globalization remain robust, and finally, section 3.7 concludes.

3.2 Empirical motivation

In this section, we present new empirical patterns by exploiting firm-level data from the World Bank. The empirical analysis is entirely descriptive and aims to motivate our theoretical framework. First, we show that a substantial fraction of the total variation in the exposure to financial constraints is across firms within industries rather than between industries. This pattern implies that credit frictions at the firm level are important, and that producers within the same industry face very different degrees of credit rationing. Second, a higher degree of product market competition is associated with a larger fraction of financially constrained firms. Third, more financially constrained industries and countries with lower financial development show a larger variance of firm sales and a higher share of credit-rationed producers. The first subsection describes the data set and the variables of interest. The second subsection presents empirical patterns that motivate our theoretical model.

3.2.1 Data description

We use cross-sectional firm-level data from the World Bank Enterprise Surveys (WBES).[6] Following existing empirical studies, the first part of the analysis uses the ratio of tangible assets over total assets (TOA) as a proxy for access to external finance. We measure tangible assets as land and buildings which reflects the avail-

[6]The database is available at http://www.enterprisesurveys.org.

ability of collateral and thus better access to credit.[7] We use this continuous proxy for credit access to investigate the variation in the exposure to financial constraints across firms within industries and between industries. Additionally, we are interested in the degree of product competition at the firm as well as the industry level. Therefore, we exploit a survey question which asks firms to assess the impact of a hypothetical price increase by 10% on demand for their main product. The answers are captured by a categorical variable, whereas a value of 1 reflects that consumers are insensitive to the price increase (low competition), and a value of 4 means that customers would stop buying (high competition). We use variation of this variable at the firm level and compute the industry mean. Furthermore, we compute the mean of tangible over total assets by industry and country, and relate it to the variance in log sales across firms. Variables are reported in local currency units, which we convert to 2005 U.S. dollars. For the first part of the empirical motivation, we exploit a cross-section of the period 2002-2005. As information on competition and tangible assets is not available for all countries, we restrict our analysis to a subsample. Table D.1 in the Data Appendix provides a description of all variables and Table D.2 shows summary statistics.

The second part of the empirical analysis further investigates the relationship between financial constraints and the variance of firm sales at the country level. Therefore, we exploit cross-section data for the years 2009 and 2013, which is available for a larger set of countries.[8] We use domestic credit to the private sector in percentage of GDP as a proxy for financial development and relate it to the within-country variance of firm sales, as well as to the share of financially constrained producers by country.[9] To obtain the latter measure, we consider a survey question which asks firms to state whether access to financing (including availability and costs) is an obstacle to the current operations of the establishment. The categorical variable ranges from 0 (no obstacle) to 4 (very severe obstacle).[10] We introduce a dummy

[7]Other studies that use similar proxies for access to external finance are Greenaway et al. (2007), Berman and Héricourt (2010), and Goerg and Spaliara (2013), among others. For a survey of empirical studies using firm-level data, see Wagner (2014). Results remain significant and robust if we include machinery and equipment in our proxy for tangible assets.

[8]See Table D.2 in the Empirical Appendix for summary statistics, as well as Tables D.4 and D.5 for summary statistics by country.

[9]The data on financial development is taken from the World Development Indicators of the World Bank.

[10]Gorodnichenko and Schnitzer (2013) use this self-reported information from the 2002 and 2005 Business Environment and Enterprise Performance Survey (BEEPS) for 27 transition countries to analyze the effect of credit constraints on innovation activity.

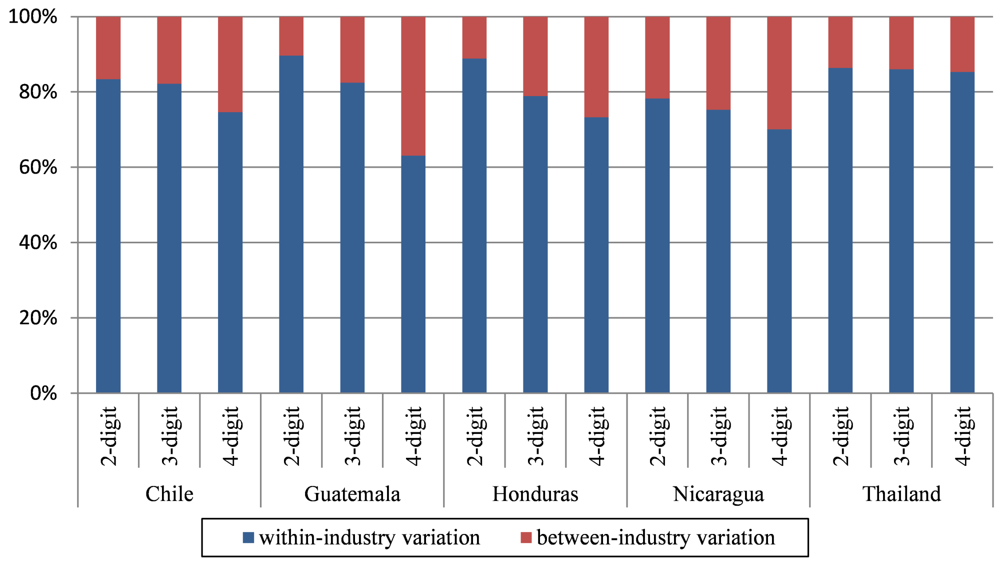

Figure 3.1: Within- and between-industry variation of tangible assets

variable for financially constrained producers which takes the value of 1 if firms perceive access to financing as a major or very severe obstacle (values 3 and 4 of the categorical variable). We take means by country as a measure for credit constraints.

3.2.2 Empirical results

The first pattern decomposes the total variation in the measure for credit access (tangible over total assets) into within- and between-industry variation. The literature on international trade stresses the importance of firm heterogeneity. Hence, one concern could be that the within-industry variation is mainly driven by differences in firm characteristics such as size or productivity. To address this, we include a set of firm-level controls related to productivity, size, legal status and ownership structure. Figure 3.1 shows results for five countries at three levels of industry aggregation and reveals that a substantial part of the variation is within industries. The observed pattern suggests that producers within the same industry are affected very differently by credit constraints, even after controlling for other firm characteristics.[11]

[11]The pattern holds for all countries with available data in our sample. Table D.3 in Data Appendix D.1 shows results for the full set of countries. See Table D.1 for a description of variables.

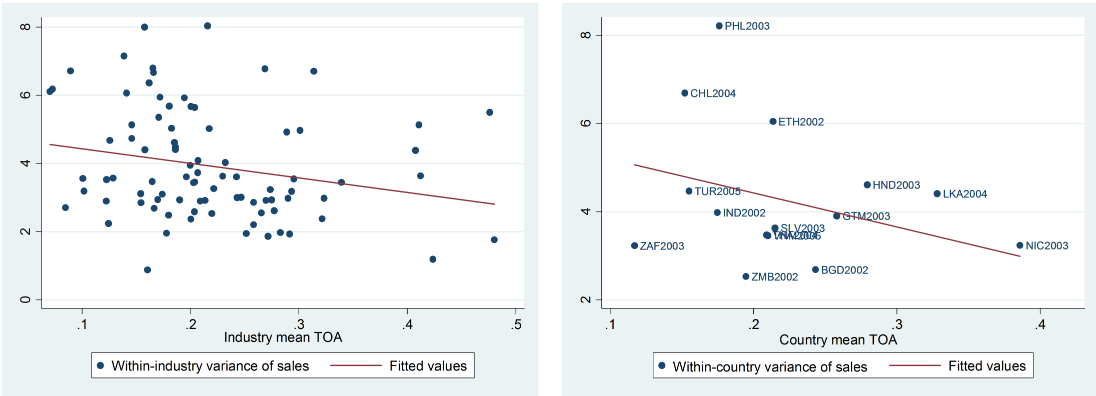

Figure 3.2: TOA and sales variance within-industry (left), within-country (right)

Empirical pattern 1 *The majority of variation in financial constraints is across firms within industries rather than between industries.*
In the following, we relate measures of credit constraints at the industry as well as the country level to the degree of competition and to the variance of sales. To motivate the main features of our theoretical model, we focus on simple pairwise correlations in the main text. Empirical studies show that larger and more productive firms are less credit-constrained. Hence, a major concern is that the correlations are driven by firm characteristics. We conduct a regression analysis in Appendix D.2 and show that our results are robust when we include firm- and industry controls.
Furthermore, we relate the degree of competition to credit constraints. Table 3.1 shows the correlations both at the firm and the industry level. Firms that report more price-sensitive consumers face stronger credit-rationing. The positive relationship holds at the industry level as well, whereas in industries with a higher degree of competition a larger fraction of producers is financially constrained.[12]

Empirical pattern 2 *Industries with a higher degree of product competition show a larger fraction of financially constrained firms.*
As a next step, we use the mean of the firm-level tangible assets over total assets ratio to compute a measure for credit access at the industry level. We relate this proxy to the within-industry variation of firm sales. The left panel of Figure 3.2 depicts within-industry variances of firm sales, whereas the right panel shows results at the

[12]Table D.6 in Appendix D.2 shows that the positive relationship between competition and credit constraints remains robust after controlling for firm characteristics, as well as year and country fixed effects.

Table 3.1: Correlation credit constraints and competition

Degree of competition	Access to finance	Share constrained firms
Firm level	0.0832***	
Industry level		0.0586**
Obs.	27,474	1,590

Notes: *** indicates 1%, and ** 5% significance.

country level. To compute the within-industry variances, we restrict our analysis to sectors with more than 25 firm observations. Figure 3.2 shows that industries with a higher ratio of tangible over total assets are characterized by a lower within-industry variance of sales. This relationship is significantly negative after controlling for year and country fixed effects, and firm characteristics (see Table D.7 in Appendix D.2).

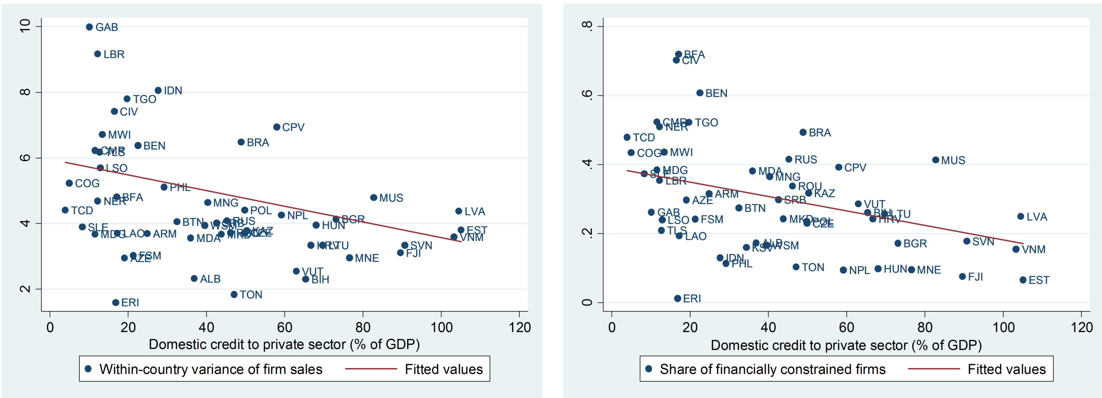

Figure 3.3: Financial development and within-country heterogeneity

We use more recent cross-section data of the WBES for the years 2009 and 2013, which is available for a larger set of countries, to investigate the relationship between financial development and firm heterogeneity at the country level. For the year 2009, the left panel of Figure 3.3 shows a significantly negative relationship between domestic credit provided to the private sector (in % of GDP) and the within-country variance of firm sales. Furthermore, the right panel depicts that higher financial development is associated with a lower share of financially constrained firms within a country. Table 3.2 summarizes the correlation coefficients for both years and further shows that the share of financially constrained producers is positively related to the variance of firm sales in a country.[13]

[13]Tables D.7 and D.8 in Appendix D.2 show that empirical pattern 3 still holds after controlling

Table 3.2: Correlation credit constraints and variance of firm sales

	Within-country variance sales		Share constrained firms	
	2009	2013	2009	2013
Private credit / GDP	-0.3884***	-0.4312***	-0.4683***	-0.2692*
Obs.	51	39	54	40
Share constrained firms	0.4539***	0.4051***		
Obs.	54	44		

Notes: *** indicates 1% significance, * 10% significance.

Empirical pattern 3 *More financially constrained industries and countries with lower financial development are characterized by a larger variance of firm sales, as well as a higher share of credit-rationed producers.*

Motivated by the first empirical pattern, the next section introduces a new international trade model with heterogeneity in credit frictions at the firm level. Our theoretical framework provides a rationale for empirical patterns 2 and 3. Furthermore, we analyze how globalization induces differential effects across firms within industries in the presence of credit frictions. The next section presents the setup of the theoretical model.

3.3 The model

This section develops a model of international trade with heterogeneity in credit frictions at the firm level. The world economy consists of k identical countries, each of which is populated by a number of L consumers and an exogenous mass of m producers. We motivate financial frictions by a simple moral hazard problem between borrowing firms and external investors. The following subsection presents the demand side of the model, whereas we assume a quadratic specification of preferences. Subsection 3.3.2 shows how firms behave in the presence of capital market imperfections depending on their exposure to financial frictions. The industry equilibrium, outlined in subsection 3.3.3, is determined by total industry output and an endogenous share of credit-rationed producers. In subsection 3.3.4, we analyze the effects of globalization and of an interest rate shock in partial equilibrium.

for firm characteristics and industry effects. For the year 2013, Figure D.1 in Data Appendix D.1 shows the relationship between financial development and within-country heterogeneity, whereas Figure D.2 relates the share of financially constrained firms to the within-country variance of sales.

3.3.1 Consumer side

The representative consumer's utility is defined over per variety consumption $q(i)$ and total consumption $Q \equiv \int_{i\in\Omega} q(i)di$, where the index i represents one variety and Ω is the set of horizontally differentiated products:

$$U = aQ - \frac{1}{2}b\left[(1-e)\int_{i\in\Omega} q(i)^2 di + eQ^2\right]. \tag{3.1}$$

The quadratic utility function depends on the non-negative preference parameters a, b and on an inverse measure of product differentiation e which lies between 0 and 1. Lower values of e imply that products are more differentiated and hence less substitutable. If $e = 1$, consumers have no taste for diversity in products and demand depends on aggregate output Q only. Thus, the parameter e determines the degree of product market competition and is closely related to the competition variable in our empirical motivation. Consumers maximize utility in equation (3.1) subject to the budget constraint $\int_{i\in\Omega} p(i)q(i)di \leq I$, where $p(i)$ denotes the price for variety i and I is individual income.[14] The maximization problem yields the linear inverse demand function:

$$\lambda p(i) = a - b\left[(1-e)q(i) + eQ\right], \tag{3.2}$$

where λ is the marginal utility of income, the Lagrange multiplier attached to the budget constraint. As firms are infinitesimally small in the economy, they take λ as given. In the following, we set the marginal utility of income as the numéraire equal to one.[15] To ensure market-clearing, total output of each firm equals the aggregate demand of all consumers in the world economy: $x(i) = kLq(i)$. Hence, the inverse world market demand is given by:

$$p(i) = a - b'\left[(1-e)x(i) + eX\right], \tag{3.3}$$

where a is the consumers' maximum willingness to pay and $b' \equiv \frac{b}{kL}$ is an inverse measure for the market size. Finally, $X \equiv \int_{i\in\Omega} x(i)\, di$ represents the total volume of varieties produced and consumed in the world economy.

[14] In general equilibrium, aggregate income consists of firm profits and factor income. We assume that capital is the only factor of production. Section 3.4 discusses the general equilibrium.

[15] Using the marginal utility of income as a numéraire ($\lambda = 1$) is standard in the literature of oligopoly in general equilibrium (GOLE). See Neary (2003) for further discussion.

3.3.2 Firm's maximization problem

The industry consists of an exogenous mass of m firms, each producing a horizontally differentiated variety i.[16] Firms receive revenues $p(i)x(i)$ and have to finance total variable production costs $cx(i)$ by external capital. There are no fixed costs of production. Motivated by empirical pattern 1, we assume that firms differ in their exposure to credit constraints. While producers are homogenous in marginal production costs c, the interaction of firm-level credit frictions and capital market imperfections creates firm heterogeneity. If financial institutions are imperfect, only a fraction of producers can overcome credit frictions, receives the required capital amount and is able to produce the optimal output. In contrast, firms with high exposure to credit constraints suffer from underprovision of external capital and cannot behave optimally. In equilibrium, the share of financially unconstrained firms is endogenously determined and affected by trade shocks. As we are interested in the effects of globalization on producers with different exposure to credit constraints, we do not consider endogenous entry and exit decisions. In the following, we describe the firm's maximization problem and introduce credit frictions at the firm as well as the country level.

The decision problem of a producer consists of two stages. At date $t = 0$, the firm borrows the credit amount $d(i)$ from an outside investor at the interest rate r. In partial equilibrium, the interest rate is treated as exogenous, whereas we endogenize it in general equilibrium as discussed in section 3.4. To motivate credit frictions at the firm level, we introduce a managerial action which is non-verifiable for outside investors and hence prone to moral hazard.[17] After credit provision, the manager of the firm can choose whether to use the external funds for production or divert the credit amount and invest it for own purposes. At date $t = 1$, production yields profits which consist of revenues net of loan repayment:

$$\pi(i) = p(i)x(i) - rd(i), \tag{3.4}$$

[16]In section 3.6, we endogenize the number of firms by allowing for free entry and show that the qualitative implications of our model remain robust.

[17]See Holmstrom and Tirole (1997) as well as Tirole (2006) for moral hazard in corporate finance. Related papers that introduce credit constraints motivated by moral hazard in a trade context are Ehrlich and Seidel (2015) and Egger and Keuschnigg (2015).

whereas the firm faces the following budget constraint:

$$d(i) \geq cx(i). \tag{3.5}$$

Alternatively, the manager can choose to divert the loan without using the provided capital in the production process. In this case, no revenues are realized and the loan cannot be repaid. Instead, the manager reaps a share $\beta(i)(1-\phi)$ of the credit amount $d(i)$ and invests it on the capital market at interest rate r. Hence, the non-verifiable private benefit from managerial misbehavior at date $t = 1$ is equal to $rd(i)\beta(i)(1-\phi)$. This private benefit consists of a country-specific and a firm-level component. We follow Antràs et al. (2009) and assume that private benefits are negatively related to the quality of financial institutions captured by the parameter $\phi \in [0, 1]$. Countries with better financial institutions (larger ϕ) tend to enforce laws that limit the ability of managers to divert funds or enjoy private benefits.[18]
In contrast to standard moral hazard approaches, we assume that producers are uniformly distributed at the unit interval and are heterogeneous in $\beta(i) \in [0, 1]$, which we denote the agency costs of a firm i. A higher $\beta(i)$ increases the private benefit and thus the incentive for managerial misbehavior. This assumption introduces heterogeneity in credit constraints at the firm level. The agency costs $\beta(i)$ can be interpreted in two ways. First, the parameter may capture differences in managerial incentives to divert external funds. This could be the case if managers attach different values to the misuse of loans. Second, a high $\beta(i)$ might reflect a larger scope for managerial misbehavior as investment projects are opaque or corporate control is weak. To prevent misbehavior of agents and thus losses from lending, investors have to ensure that the following incentive constraint holds:

$$\pi(i) \geq \beta(i)(1-\phi) rd(i). \tag{3.6}$$

At period $t = 1$, profits in case of production and loan repayment have to be (weakly) higher than private benefits in case of misbehavior. Rearranging equation (3.6) shows that moral hazard restricts the pledgeability of sales and thus the borrowing capacity:

$$d(i) \leq \frac{p(i)x(i)}{r[1+\beta(i)(1-\phi)]}. \tag{3.7}$$

[18]See Tirole (2006) as well as Antràs et al. (2009) for a similar notion of financial contract enforcement in models with moral hazard.

Firms with high agency costs $\beta(i)$ derive large private benefits from diverting the loan. Hence, investors restrict credit provision to prevent managerial misbehavior. If financial institutions are perfect ($\phi = 1$), managers have no incentives to misbehave and equation (3.6) collapses to a zero-profit condition. In this case, differences in agency costs $\beta(i)$ play no role and firms are homogenous. In contrast, if financial institutions are imperfect ($\phi < 1$), firm-specific moral hazard divides agents into two groups. First, producers with relatively low $\beta(i)$ choose the optimal output level as the financial constraint is not binding. Second, firms with higher agency costs face credit rationing and have to restrict production. To solve for outputs and prices, firms maximize profits (3.4), subject to the budget constraint (3.5) and the financial constraint (3.7).

Constrained firms For firms with high agency costs $\beta(i)$, the financial constraint is binding such that the constrained price equals effective marginal production costs:

$$p_C(\beta) = cr\left[1 + \beta(i)(1 - \phi)\right]. \tag{3.8}$$

Producing one unit of the good yields the price $p_C(\beta)$ which has to compensate for the marginal production costs cr and the opportunity costs of diligent behavior $cr\beta(i)(1 - \phi)$. The quantity offered by credit-rationed producers is given by:

$$x_C(\beta) = \frac{a - b'eX - cr\left[1 + \beta(i)(1 - \phi)\right]}{b'(1 - e)}. \tag{3.9}$$

More financially constrained firms with a higher value of $\beta(i)$ face larger opportunity costs of production and have to set higher prices, which results in lower outputs.

Unconstrained firms For unconstrained firms, the financial constraint is not binding such that optimal output is independent of $\beta(i)$:

$$x_U = \frac{a - b'eX - cr}{b'(2 - e)}. \tag{3.10}$$

By inserting equation (3.10) into the inverse demand function (3.3), we derive the optimal price of unconstrained firms:

$$p_U = \frac{a - b'eX + (1 - e)\,cr}{2 - e}. \tag{3.11}$$

In our model, the only source of firm heterogeneity occurs in β. As optimal output (3.10) and prices (3.11) do not depend on β, all unconstrained producers behave in the same way. It can be shown that unconstrained firms charge lower prices and offer larger quantities compared to credit-rationed producers.

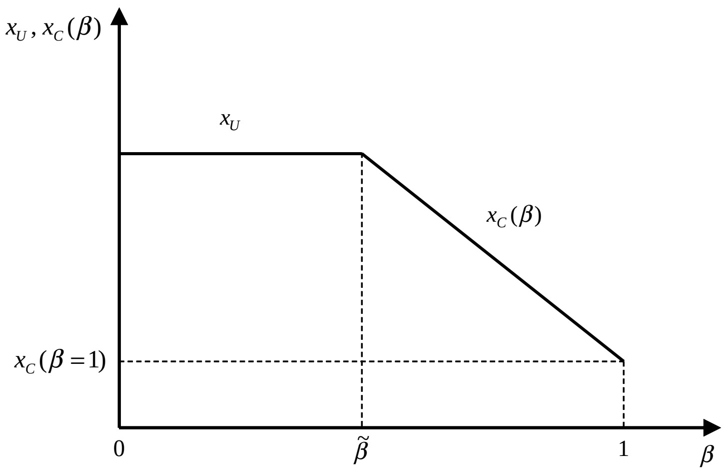

Figure 3.4: Output profile of constrained and unconstrained firms

3.3.3 Industry equilibrium

In equilibrium, we derive a critical value of agency costs $\widetilde{\beta}$ above which firms are financially constrained. We exploit that for the marginal unconstrained producer the financial constraint (3.6) is just binding and insert the optimal output from equation (3.10), which leads to:

$$\widetilde{\beta} = \frac{a - b'eX - cr}{(2-e)(1-\phi)\,cr}. \tag{3.12}$$

The share of financially constrained firms is given by $1-\widetilde{\beta}$, which corresponds to the fraction in empirical patterns 2 and 3. In a particular industry, a fraction $\widetilde{\beta}$ of firms is unconstrained and chooses the identical optimal output as shown in Figure 3.4. Following equation (3.9), output of constrained firms decreases in agency costs β. Consistent with our empirical motivation, the share of financially constrained producers depends negatively on financial development and positively on the degree of product market competition. We show that stronger competition (larger e) reduces the critical value $\widetilde{\beta}$, conditional on industry characteristics:

$$\frac{\partial\widetilde{\beta}}{\partial e} = \frac{a - cr - 2b'X}{(1-\phi)(2-e)^2 cr} < 0. \tag{3.13}$$

Proposition 3.1 *The share of financially unconstrained firms* $\widetilde{\beta}$ *decreases in the degree of product market competition* e.
Proof. *Equation (3.13) is negative if* $X > \frac{a-cr}{2b'}$. *Exploiting expression (3.10) and rearranging yields* $X > x_U$, *which is always satisfied.* ■

The negative relationship between $\widetilde{\beta}$ and e corresponds to our empirical motivation. The survey question exploited in empirical pattern 2 reflects the price sensitivity that a producer faces within an industry, which is captured by the parameter e in our model. A larger substitutability (higher e) increases the degree of competition as consumers react more sensitive to an increase in prices. This competition effect reduces firm sales and thus the pledgeable income, such that more producers become financially constrained. Consistent with empirical pattern 3, a higher quality of financial institutions ϕ reduces the fraction of credit-rationed producers. Furthermore, conditional on industry output X, the share of constrained firms increases in credit costs cr.
To arrive at an output profile as depicted in Figure 3.4, we impose two conditions. First, to ensure that both groups of firms occur, the threshold value $\widetilde{\beta}$ has to be smaller than one.

Condition 3.1 $\widetilde{\beta} < 1$ *if* $\frac{a-b'eX}{cr} < 1 + (1-\phi)(2-e)$

Second, the output of the firm with the highest agency costs, $\beta(i) = 1$, has to be positive. Otherwise it would not be active in the market.

Condition 3.2 $x_C(\beta = 1) > 0$ *if* $\frac{a-b'eX}{cr} > 2 - \phi$

Inserting Condition 3.2 in equation (3.12) leads to a lower limit value for the share of unconstrained firms $\widetilde{\beta}_l = \frac{1}{2-e}$. To determine the industry equilibrium, average output $\widetilde{x}$ in the economy can be expressed as:

$$\widetilde{x} = \int_0^{\widetilde{\beta}} x_U di + \int_{\widetilde{\beta}}^1 x_C(\beta)\, di. \tag{3.14}$$

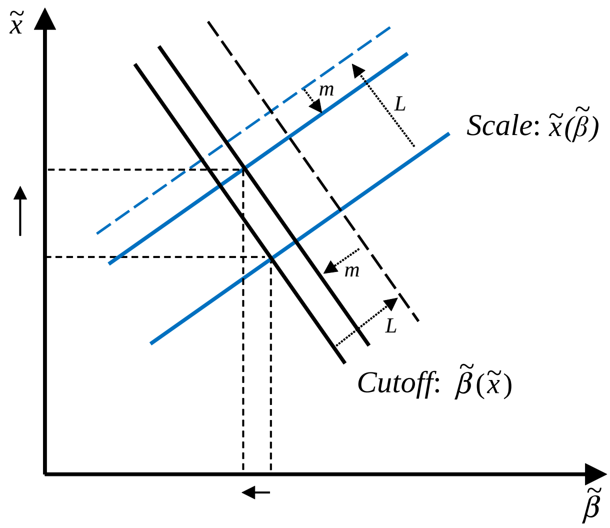

Figure 3.5: Industry equilibrium and trade liberalization

Inserting the outputs (3.9) and (3.10) in equation (3.14), and aggregating leads to:

$$\widetilde{x} = \frac{\left(2 - e - \widetilde{\beta}\right) a - \left[2 - e - \widetilde{\beta} + (2 - e)\left(1 - \widetilde{\beta}\right) \mu_c' (1 - \phi)\right] cr}{b' \left((2 - e)(1 - e) + \left(2 - e - \widetilde{\beta}\right) ekm\right)}, \tag{3.15}$$

with $\mu_c' \equiv \frac{1}{1-\widetilde{\beta}} \int_{\widetilde{\beta}}^{1} \beta(i)\, di$ being the average agency costs within the group of constrained producers. Figure 3.5 depicts the industry equilibrium. As the world economy consists of m producers in k countries, the aggregate output is given by $X = km\widetilde{x}$. Equations (3.12) and (3.15) represent two relationships between the endogenous variables $\widetilde{\beta}$ and $\widetilde{x}$. The curve $Cutoff$: $\widetilde{\beta}(\widetilde{x})$ illustrates equation (3.12) and determines the fraction of financially constrained firms dependent on average industry output. Intuitively, the negative slope captures the fact that higher industry scale increases competition and forces more firms into the constrained status. The curve $Scale$: $\widetilde{x}(\widetilde{\beta})$ is derived from equation (3.15) and reflects that with a higher critical value $\widetilde{\beta}$ more firms are unconstrained and thus choose optimal output levels. Hence, average industry scale increases. The intersection of the two curves in Figure 3.5 characterizes the industry equilibrium.

3.3.4 Comparative statics in partial equilibrium

The previous section has characterized the partial equilibrium in the economy. In a next step, we investigate how globalization and an exogenous change in the interest rate affect the industry. All results are derived by total differentiation of the two equilibrium conditions (3.12) and (3.15).[19] Furthermore, section 3.6 extends the model by free entry and endogenizes the number of producers.

Globalization Following Eckel and Neary (2010), we interpret globalization as an increase in the number of countries k in the integrated world economy. This shock affects optimal firm behavior through two channels. On the one hand, producers face a market size effect which corresponds to an increase in the number of consumers L. On the other hand, globalization is associated with stronger competition from foreign firms. This competition effect works like a rise in the number of producers m. To gain intuition for the effects of globalization, we analyze the two channels separately. From equation (3.3), we observe that a larger market rotates the inverse world demand outwards without affecting the intercept. Thus, firms face a larger demand and raise output levels resulting in a one-to-one increase in industry scale. This market size effect is counteracted but not outweighed by tougher competition. Consequently, globalization increases average industry scale:

$$\frac{d\ln\widetilde{x}}{d\ln k} = \underbrace{1}_{\text{Market size effect}} - \underbrace{\frac{\left(2-e-\widetilde{\beta}\right)ekm}{\left(2-e\right)\left(1-e\right)+\left(2-e-\widetilde{\beta}\right)ekm}}_{\text{Competition effect}} > 0. \tag{3.16}$$

The positive market size effect shifts the curve $Scale$: $\widetilde{x}(\widetilde{\beta})$ upwards and the curve $Cutoff$: $\widetilde{\beta}\left(\widetilde{x}\right)$ outwards in Figure 3.5. A larger market increases the pledgeable income and thus relaxes the financial constraint (3.7). As Figure 3.5 shows, the change in market size does not affect the share of credit-rationed producers in equilibrium. However, the competition effect leads to a partial backward shift of the two curves. A greater number of competitors producing at a larger average scale $\widetilde{x}$ aggravates

[19]See Appendix C.1 for a detailed derivation.

financial constraints and increases the share of credit-rationed firms:

$$\frac{d\ln\widetilde{\beta}}{d\ln k} = -\underbrace{\frac{(1-e)\,b'eX}{(1-\phi)\,cr\widetilde{\beta}\left[(2-e)\,(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]}}_{\text{Competition effect}} < 0. \tag{3.17}$$

Tougher competition reduces firm revenues and therefore pledgeable income as shown by equation (3.7). If goods are perfectly differentiated ($e = 0$), the competition effect disappears and globalization leads to a one-to-one increase in output without affecting the share of financially constrained producers.

Proposition 3.2 *In partial equilibrium, globalization increases industry scale as the positive market size effect dominates the counteracting competition effect. The latter raises the share of financially constrained producers (lower $\widetilde{\beta}$).*

Borrowing costs In this section, we analyze the effects of an exogenous change in the interest rate r. An increase in the borrowing costs reduces average industry scale $\widetilde{x}$ and forces more producers into the constrained status:

$$\frac{d\ln\widetilde{x}}{d\ln r} < 0\ ;\ \frac{d\ln\widetilde{\beta}}{d\ln r} < 0. \tag{3.18}$$

Proposition 3.3 *In partial equilibrium, an exogenous increase in the borrowing rate leads to a higher share of financially constrained firms and reduces industry scale.*
Proof. *See Appendix C.1.* ■

For both groups, an increase in the borrowing rate has a direct negative impact on firm outputs, whereby the effect is stronger for credit-rationed firms. By comparing equations (3.9) and (3.10), this can be explained by the agency problem, which leads to higher effective marginal production costs for financially constrained producers. Whereas credit-rationed agents experience strong contraction, total differentiation of equation (3.10) shows a counteracting competition effect for unconstrained firms:[20]

$$\frac{d\ln x_U}{d\ln r} = -\frac{cr}{b'\,(2-e)\,x_U}\left(1+\frac{eb'X}{cr}\underbrace{\frac{d\ln\widetilde{x}}{d\ln r}}_{(-)}\right) \lesseqgtr 0. \tag{3.19}$$

[20]See Appendix C.1 for an explicit derivation of the expression $\frac{d\ln\widetilde{x}}{d\ln r} < 0$.

Besides the direct negative impact of a higher interest rate, unconstrained producers optimally react to the reduction in industry scale by an increase of output. If varieties are perfectly differentiated ($e = 0$), the latter effect vanishes and unconstrained firms clearly reduce sales. However, the larger is the substitutability of goods, the more unconstrained firms benefit from reductions of rival firms' outputs.

3.4 General equilibrium

The partial equilibrium analysis is based on the assumption that the interest rate is exogenously given. This implies that capital supply is completely elastic. In the next subsection, we endogenize the interest rate by introducing a simple capital market with fixed supply. Our results can be interpreted as a short-run equilibrium as we abstract from endogenous entry and exit decisions of firms (see section 3.6 for an extension with free entry). Furthermore, we do not allow for adjustments of capital supply. After trade liberalization, the borrowing rate increases caused by higher capital demand. In the long-run, this effect might be counteracted by an increase in capital supply or capital market liberalization. In the following, we analyze how endogenous adjustments of borrowing costs affect the implications of globalization. Furthermore, we show the impact of financial development in general equilibrium.

3.4.1 Capital market clearing

Each firm has to cover variable production costs by external finance and hence demands $cx_j(i)$ units of capital, with $j \in C, U$. We assume that the economy is endowed with a fixed amount of capital K_S. In equilibrium, the inelastic supply of capital has to be equal to total capital demand K_D of m firms in a country:

$$K_S = K_D = cm \left(\int_0^{\widetilde{\beta}} x_U di + \int_{\widetilde{\beta}}^1 x_C(\beta)\, di \right) = cm\widetilde{x}. \tag{3.20}$$

By evaluating equilibrium condition (3.20), we explicitly solve for the interest rate:

$$r = \frac{\left(2 - e - \widetilde{\beta}\right) a - b' \left((2-e)(1-e) + \left(2 - e - \widetilde{\beta}\right) ekm \right) \frac{K_S}{cm}}{\left[2 - e - \widetilde{\beta} + (2-e)\left(1 - \widetilde{\beta}\right) \mu_c' (1-\phi) \right] c}. \tag{3.21}$$

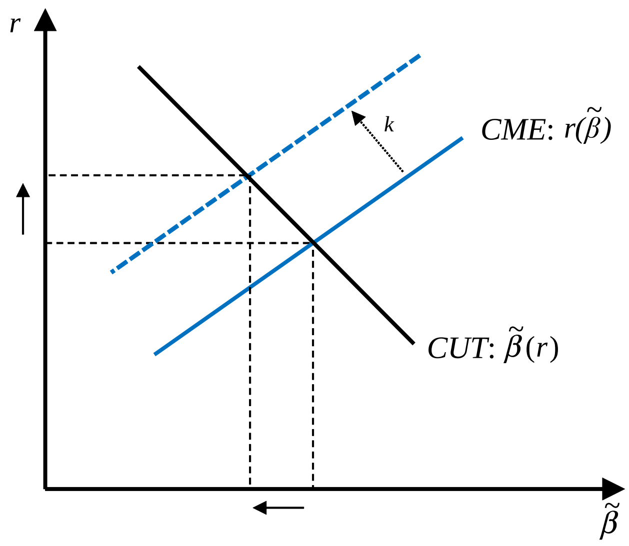

Figure 3.6: Globalization in general equilibrium

We add equation (3.20) to the system of equations from the partial equilibrium analysis (3.12) and (3.15). In general equilibrium, profits and capital income determine the aggregate income of consumers I. A rise in the interest rate r has no effect on aggregate income as the resulting increase in capital earnings is exactly offset by a decrease in firm profits.

3.4.2 Comparative statics in general equilibrium

We analyze the effects of globalization and changes in financial development in general equilibrium. As capital market clearing pins down average industry scale $\widetilde{x}$, we express our equilibrium by two equations in the endogenous variables r and $\widetilde{\beta}$. The curve CUT: $\widetilde{\beta}\,(r)$ in Figure 3.6 combines capital market clearing (3.20) with the financial condition (3.12). Intuitively, the curve is downward sloping as a higher interest rate increases the share of financially constrained firms and thus reduces the cutoff value $\widetilde{\beta}$. The curve CME: $r(\widetilde{\beta})$ is derived by inserting equation (3.20) into (3.15), and illustrates the relationship between r and $\widetilde{\beta}$, such that the capital market is in equilibrium. A higher share of unconstrained producers leads to an increase of average output and to higher capital demand. To ensure capital market clearing, the interest rate has to rise.[21]

[21]In section 3.6, we show that capital demand still increases after globalization with free entry.

Globalization In general equilibrium, the fixed capital amount determines average industry output. Therefore, in contrast to section 3.4, globalization (an increase in k) has no effect on industry scale:

$$\frac{d\ln\widetilde{x}}{d\ln k} = 0. \tag{3.22}$$

Globalization leads to an upward shift of the curve CME: $r(\widetilde{\beta})$ in Figure 3.6. For a given share of financially constrained firms, the dominating market size effect increases capital demand resulting in a higher interest rate:

$$\frac{d\ln r}{d\ln k} > 0. \tag{3.23}$$

This result is based on the assumption of fixed capital supply. An increase in the interest rate occurs as long as capital supply K_S is not completely elastic and trade liberalization is not accompanied by large capital inflows. The curve CUT: $\widetilde{\beta}\,(r)$ is unaffected, such that the new equilibrium is characterized by the intersection point with the new capital market clearing condition. Consequently, the share of financially constrained producers increases, as higher borrowing costs impose stronger restrictions on the financial constraint:

$$\frac{d\ln\widetilde{\beta}}{d\ln k} < 0. \tag{3.24}$$

Proposition 3.4 *In general equilibrium, globalization increases the interest rate and the share of financially constrained firms, but has no effect on industry scale.*
Proof. *See Appendix C.2.* ■

Comparing equations (3.17) and (3.24) shows that globalization leads to a stronger increase in the share of financially constrained producers in general equilibrium (see Appendix C.2 for a formal proof). This result is driven by the endogenous increase in borrowing costs which forces more firms into the constrained status. In contrast to partial equilibrium, the increase in the interest rate leads to different firm responses after globalization:

$$\frac{d\ln x_U}{d\ln k} = 1 - \frac{cr}{a - b'eX - cr}\frac{d\ln r}{d\ln k} > 0, \tag{3.25}$$

$$\frac{d\ln x_C(\beta)}{d\ln k} = 1 - \frac{[1+\beta(i)(1-\phi)]\,cr}{a - b'eX - cr[1+\beta(i)(1-\phi)]}\frac{d\ln r}{d\ln k} < 0. \tag{3.26}$$

The increase in the number of countries k affects optimal firm behavior in two opposing ways. As shown in partial equilibrium, the market size effect dominates the competition effect which induces firms to increase outputs. The endogenous adjustment of the interest rate in general equilibrium counteracts the positive impact of globalization. The latter effect especially hurts financially constrained producers with high agency costs $\beta(i)$, shown by the larger weight of the interest rate in equation (3.26) compared to unconstrained firms (3.25).

Proposition 3.5 *In general equilibrium, globalization leads to an output expansion among unconstrained firms, whereas financially constrained producers have to reduce output due to increased capital costs.*
Proof. *See Appendix C.2.* ■

The expansion among unconstrained firms is illustrated in Figure 3.7 by an upward shift of the output profile. In contrast, credit-rationed producers suffer from increased capital costs and decrease output depending on their agency costs. As the most constrained firm with $\beta = 1$ faces the strongest output reduction, the constrained output profile rotates clockwise. The slope is given by $-\frac{cr(1-\phi)}{b'(1-e)}$ (compare equation (3.9)), and increases in the interest rate and the market size. The differential responses across the two groups of producers increase the variance of output and prices within the industry. This result will be crucial for the welfare consequences which we discuss in more detail in section 3.5. As average industry scale is unaffected due to fixed capital supply, the output gain of unconstrained firms (region A in Figure 3.7) offsets the contraction of credit-rationed producers (region B).

Financial development An increase in ϕ reduces the incentives to reap private benefits and enhances the pledgeability of revenues. This shock can be interpreted as an improvement of financial contract enforcement. Comparable to trade liberalization, there is no effect on aggregate output due to fixed capital supply. However, an increase in ϕ relaxes the financial constraint (3.7) and increases the share of unconstrained producers in the economy:

$$\frac{d\ln\widetilde{\beta}}{d\ln\phi} > 0. \tag{3.27}$$

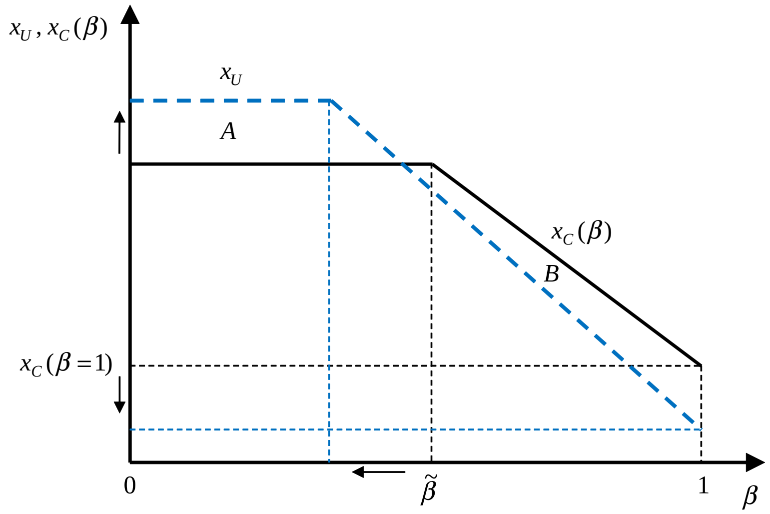

Figure 3.7: Output profiles and globalization

Furthermore, the increase in pledgeable income translates into higher capital demand and thus a higher borrowing rate:

$$\frac{d \ln r}{d \ln \phi} > 0. \tag{3.28}$$

Note that this result holds under the assumption of fixed capital supply. Hence, a higher quality of financial institutions only affects capital demand.[22]

Proposition 3.6 *In general equilibrium, higher financial development decreases the share of financially constrained firms.*
Proof. *See Appendix C.2.* ■

An improvement in the quality of financial institutions increases the borrowing capacity of credit-rationed firms. This direct positive effect is counteracted by an increase in capital costs. Whereas financially constrained firms expand output, unconstrained producers do not benefit from better financial development, but face a higher interest rate:

$$\frac{d \ln x_U}{d \ln \phi} = -\frac{cr}{(2-e)\, b' x_U} \frac{d \ln r}{d \ln \phi} < 0, \tag{3.29}$$

$$\frac{d \ln x_C}{d \ln \phi} = \frac{cr}{(1-e)\, b' x_C} \left[\phi \beta\,(i) - [1 + (1-\phi)\,\beta(i)] \frac{d \ln r}{d \ln \phi} \right] > 0. \tag{3.30}$$

[22] Appendix C.1 provides the effects of financial development in partial equilibrium which are not discussed in the main text.

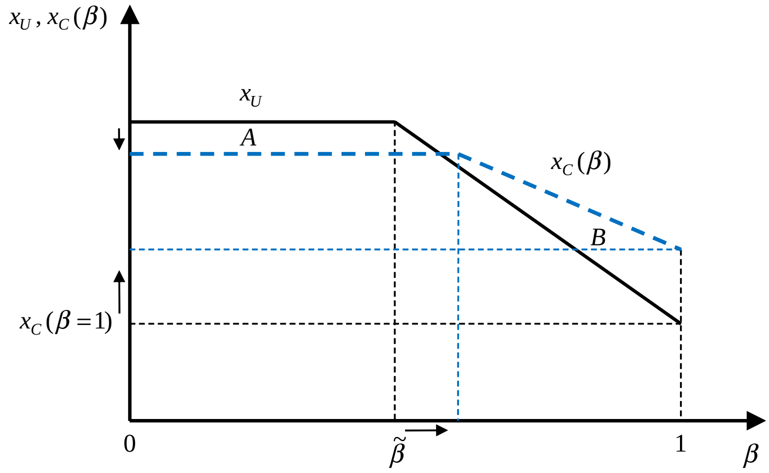

Figure 3.8: Output profiles and financial development

Consequently, an increase in financial development induces a reallocation of market shares towards credit-rationed producers. This effect can be seen graphically by a downward shift of the unconstrained output profile, as well as an outward rotation of the output line for constrained firms in Figure 3.8. Hence, higher financial development reduces the within-industry variance of sales, which provides a rationale for empirical pattern 3.

Proposition 3.7 *In general equilibrium, higher financial development reduces the variance of sales within an industry as financially constrained firms expand outputs at the expense of unconstrained producers.*
Proof. *See Appendix C.2.* ■

3.5 Welfare

This section analyzes how globalization affects welfare. In a first step, we derive a welfare measure for a representative consumer. We use the latter for a numerical simulation of the effects of trade liberalization on welfare.

3.5.1 Indirect utility

As an appropriate measure for welfare, we derive the indirect utility function for a representative consumer associated with the preference structure in equation (3.1).

As we choose the marginal utility of income as numéraire ($\lambda = 1$), indirect utility can be expressed as follows:

$$U = km\frac{a^2(1-e) + ekm\left(\overline{p}^U + \overline{p}^C\right)^2 - \left[1 + e\left(km-1\right)\right]\left(\gamma_c^2 + \gamma_u^2\right)}{2b(1-e)\left[1 + e\left(km-1\right)\right]}. \tag{3.31}$$

The welfare measure increases in the first moments of prices for unconstrained and constrained firms respectively, $\overline{p}_U = \int_0^{\widetilde{\beta}} p_U di$, $\overline{p}_C = \int_{\widetilde{\beta}}^1 p_C(\beta) di$, and decreases in the second moments of prices for both groups, $\gamma_U^2 = \int_0^{\widetilde{\beta}} \left(p_U\right)^2 di$ and $\gamma_C^2 = \int_{\widetilde{\beta}}^1 \left(p_C(\beta)\right)^2 di$. The structure of the utility function is comparable to welfare measures in general oligopolistic equilibrium models.[23] In these papers, welfare decreases in the variance of prices, which in our case would be defined as $\sigma_j^2 = \gamma_j^2 - \left(\overline{p}_j\right)^2$ for $j \in C, U$. Two important properties of the welfare function will be crucial for the subsequent analysis. Following from the preference structure in equation (3.1), consumers love variety and dislike heterogeneity in consumption levels and prices.

3.5.2 Welfare effects of trade liberalization

The aim of this section is to analyze the welfare implications of globalization. We simulate the responses of welfare (3.31) to globalization and compare results in partial and general equilibrium.[24] Similar to our previous analysis, we first consider only the market size effect of globalization (change in the number of consumers L). Subsequently, we take into account that trade liberalization increases competition and the number of varieties available to consumers (change in k).

Market size effect The market size effect reflects increased export opportunities after globalization. The left panel of Figure 3.9 shows that a larger market has no effect on welfare in partial equilibrium (PE), but leads to welfare losses in general equilibrium (GE). This difference is driven by the endogenous adjustment of the borrowing rate when the capital market equilibrium is taken into account.

As equation (3.31) shows, welfare depends on the first and second moments of prices for both groups. In partial equilibrium, an increase in the market size L leads to a proportional expansion of output among all firms without affecting optimal price setting and the share of unconstrained firms $\widetilde{\beta}$ (compare subsection 3.3.4).

[23] Compare e.g. Neary (2009), among others.

[24] We simulate the model in general equilibrium with MATLAB. The simulation code is available from the authors upon request.

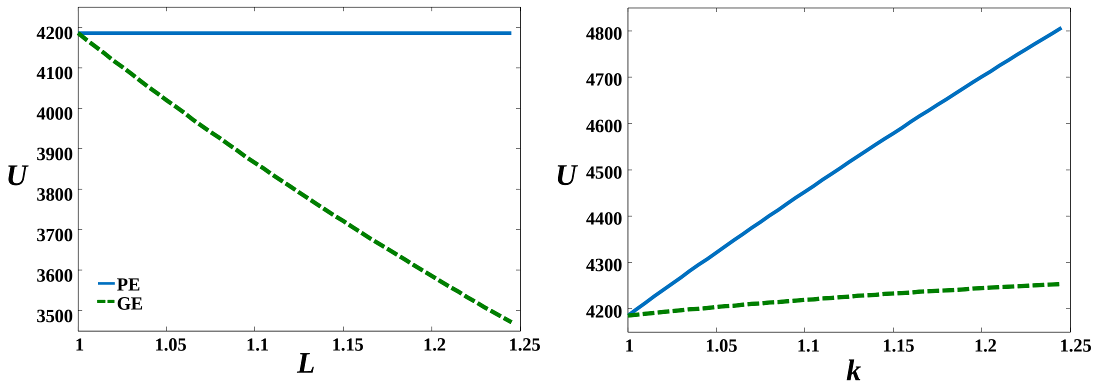

Figure 3.9: Welfare effects of market size (L) and globalization (k)

Thus, welfare does not respond to changes in the market size as the first and second moments of prices remain constant. In contrast, increased capital demand raises the interest rate in general equilibrium which leads to a higher variance of prices and thus to welfare losses. As discussed in subsection 3.4.2, higher borrowing costs increase the within-industry variance of prices in two ways. First, a larger fraction of firms becomes financially constrained (lower $\widetilde{\beta}$). Second, unconstrained producers expand output at the expense of credit-rationed firms.

Globalization By considering the effect of an increase in the number of countries k, we introduce two additional channels how globalization influences welfare (3.31). In contrast to the left graph, the right panel of Figure 3.9 shows that globalization leads to welfare gains both in partial and general equilibrium, resulting from (i) lower prices due to increased competition, and (ii) larger consumption variety. Importantly, the positive welfare effects are considerably lower in general equilibrium. The partial equilibrium analysis reflects well-known gains from trade through competition and larger variety. However, our model stresses an additional negative welfare channel of globalization driven by an increase in capital costs. Whereas unconstrained firms benefit from trade liberalization due to the positive market size effect, the higher interest rate especially hurts the most constrained producers (with high values of β). Compared to existing work, the negative welfare channel of a larger market is driven by two components of our model. First, the introduction of heterogeneity in financial frictions at the firm level induces endogenous selection of producers into unconstrained and constrained groups. Second, capital market clearing in general equilibrium determines the interest rate which increases with globalization. In the presence of firm-specific credit frictions and endogenous capital costs, trade liberalization leads to a larger variance of prices and reduces positive welfare effects. Table 3.3 shows outcomes of endogenous variables for different values of market size L and the number of countries k.

Table 3.3: Numerical simulation of trade liberalization

L	U_{PE}	U_{GE}	X_{PE}	X_{GE}	$\widetilde{\beta}_{PE}$	$\widetilde{\beta}_{GE}$	r_{PE}	r_{GE}
1	4185.43	4185.44	25.00	25.00	0.83	0.83	1.38	1.38
1.05	4185.43	4020.04	26.25	25.00	0.83	0.77	1.38	1.44
1.10	4185.43	3865.51	27.50	25.00	0.83	0.73	1.38	1.49
1.15	4185.43	3721.02	28.75	25.00	0.83	0.70	1.38	1.54
1.20	4185.43	3585.79	30.00	25.00	0.83	0.67	1.38	1.58
1.25	4185.43	3471.36	31.12	25.00	0.83	0.64	1.38	1.61
k	U_{PE}	U_{GE}	X_{PE}	X_{GE}	$\widetilde{\beta}_{PE}$	$\widetilde{\beta}_{GE}$	r_{PE}	r_{GE}
1	4185.43	4185.44	25.00	25.00	0.83	0.83	1.38	1.38
1.05	4321.50	4203.75	25.85	25.00	0.82	0.78	1.38	1.42
1.10	4452.66	4219.42	26.68	25.00	0.81	0.74	1.38	1.46
1.15	4579.11	4232.84	27.48	25.00	0.80	0.71	1.38	1.49
1.20	4701.08	4244.33	28.25	25.00	0.79	0.68	1.38	1.51
1.25	4807.18	4253.25	28.92	25.00	0.78	0.66	1.38	1.54

Notes: The table presents outcomes of endogenous variables for different values of L and k. The following parameter values are chosen: $a = 100$, $b = 1$, $m = 2$, $e = 0.3$, $c = 30$, $\phi = 0.25$, $K_S = 1500$.

Policy implications The negative welfare channel of globalization is especially relevant if financial development is low and credit frictions are significant. From a policy perspective, our model implies that trade liberalization should be accompanied by financial reforms that aim to mitigate negative effects. To do so, our theoretical framework suggests two potential policy measures: an improvement in the quality of financial institutions ϕ or an increase in capital supply K_S. Both measures reduce price heterogeneity and hence dampen potential welfare losses, but work through different channels. An increase in ϕ alleviates credit frictions and induces a reallocation of market shares towards financially constrained producers (subsection 3.4.2). As a second measure, globalization should be accompanied by an increase in capital supply K_S to weaken the increase in borrowing costs which benefits all firms.

3.6 Model extension with free entry

Our model abstracts from endogenous entry and exit decisions of firms. In this section, we allow for free entry, which endogenizes the number of firms m, and show that the implications of the model are robust to this extension. We introduce an entry stage, at which each firm pays a fixed cost f_E and draws a value for β, which is uniformly distributed along the unit interval. Hence, before producers know their agency costs, expected profits $E\pi$ have to be equal to the entry costs:

$$E\pi = \int_0^{\widetilde{\beta}} \pi_U di + \int_{\widetilde{\beta}}^{\widehat{\beta}} \pi_C(\beta) di = f_E, \tag{3.32}$$

whereas $\widehat{\beta}$ is the agency cost parameter of the most credit-rationed firm in the market. This marginal producer is determined by $x_C(\widehat{\beta}) = 0$. Evaluating equation (3.9) at $\widehat{\beta}$ yields:

$$\widehat{\beta} = \frac{a - b'ekm\widetilde{x} - cr}{(1-\phi)\, cr}. \tag{3.33}$$

Conditions (3.32) and (3.33) determine the cutoff value $\widehat{\beta}$ and the number of firms m. Comparing equations (3.12) and (3.33) leads to the following relationship between the share of unconstrained firms and the cutoff value: $\widetilde{\beta} = \frac{\widehat{\beta}}{2-e}$. By using this property and evaluating equation (3.32), the cutoff value can be expressed as follows:

$$\widehat{\beta}^3 = \frac{6b' f_E (2-e)^3 (1-e)}{\left[(1-\phi)\, cr\right]^2 \left[e^2 (6-e) + 5(2-3e)\right]}. \tag{3.34}$$

We analyze how globalization affects the economy with free entry and compare results to subsection 3.3.4. Analogous to equation (3.14), industry scale is now given by the average output of surviving firms:

$$\widetilde{x} = \frac{1}{\widehat{\beta}} \left[\int_0^{\widetilde{\beta}} x_U di + \int_{\widetilde{\beta}}^{\widehat{\beta}} x_C(\beta) di \right], \tag{3.35}$$

which can be expressed as a function of $\widehat{\beta}$:

$$\widetilde{x} = \frac{\widehat{\beta}\,(1-\phi)\, cr \left[e^2 + 3 - 4e\right]}{2b' (2-e)^2 (1-e)}. \tag{3.36}$$

Hence, our equilibrium with free entry consists of three equations with the unknowns $\widetilde{x}$, $\widehat{\beta}$, and m. As before, globalization is modelled by an increase in the number of countries k. Allowing for free entry leads to a new channel of adjustment compared to subsection 3.3.4. Foreign competition forces producers with high agency costs to exit the market which is captured by a decrease in the cutoff value $\widehat{\beta}$:

$$\frac{d\ln\widehat{\beta}}{d\ln k} < 0. \tag{3.37}$$

Furthermore, the number of firms reacts to globalization as follows:

$$\frac{d\ln m}{d\ln k} = -1 + \frac{a - cr}{3b'eX} \gtrless 0. \tag{3.38}$$

The net effect depends on the degree of competition. If the substitutability of products is high (large e), globalization reduces the number of domestic firms.

Proposition 3.8 *With free entry, globalization forces the most financially constrained producers to exit the market. The number of firms decreases if the degree of competition is sufficiently high.*
Proof. *See Appendix C.3.* ■

Comparable to Proposition 3.2, globalization leads to an increase in average industry scale and a higher share of financially constrained producers:

$$\frac{d\ln\widetilde{x}}{d\ln k} > 0, \ \frac{d\ln\widetilde{\beta}}{d\ln k} < 0. \tag{3.39}$$

Hence, the effects of globalization are robust to free entry. In section 3.4, we introduce a capital market equilibrium and show that globalization leads to a higher within-industry variance of firm sales and prices. This effect is driven by an increase in capital demand which raises the interest rate. To show that this channel of adjustment is still present, capital demand has to increase even with free entry. As the number of domestic firms could fall after globalization (see Proposition 3.8), the effect on aggregate capital demand $cm\widetilde{x}$ might be reversed. Solving for the number of firms from equation (3.33) and multiplying with equation (3.36), leads to total output of domestic producers:

$$m\widetilde{x} = \frac{\left[a - cr - \widehat{\beta}\,(1-\phi)\,cr\right] L}{be}. \tag{3.40}$$

This expression only depends on the cutoff value $\widehat{\beta}$ which decreases with globalization. Hence, aggregate capital demand is clearly increasing with free entry. This implies that the driving force behind the raise in the interest rate remains when the number of firms is endogenous.

3.7 Conclusion

This chapter has developed a new international trade model with firm-specific credit frictions and endogenous adjustments of capital costs in general equilibrium. A key element of our model is that firm heterogeneity results from the interaction of credit constraints at the firm level with capital market imperfections at the country level. Credit frictions arise from a simple moral hazard problem, whereas firms differ in their incentive to divert external funds. If financial institutions are imperfect, this agency problem reduces the pledgeability of sales and causes credit-rationing for some producers. Our model is consistent with new empirical patterns from the Enterprise Surveys data of the World Bank. We show that the majority of variation in financial constraints is across firms within an industry rather than between industries. This motivates the analysis of firm-specific financial frictions in our theoretical model. Furthermore, we highlight that credit frictions are positively related to the degree of product market competition, and to the variance of sales across firms. Our theoretical framework provides a rationale for these patterns.

We use this model to analyze the effects of globalization on firm performance and welfare. The main idea is that endogenous adjustments of capital costs represent an additional channel which reduces gains from trade. Trade liberalization increases the borrowing rate, induces a within-industry reallocation of profits towards unconstrained firms at the expense of financially constrained producers, and raises the share of credit-rationed producers. We show that these adjustments increase the variance of prices and reduce welfare.

From a policy perspective, our model implies that trade liberalization could lead to negative welfare effects and should be accompanied by financial reforms to counteract an increase in within-industry heterogeneity across firms. This implication is especially relevant in developing countries where credit frictions are significant and financial development is low.

Appendix C

Mathematical Appendix

C.1 Comparative statics in partial equilibrium

The partial equilibrium is characterized by two endogenous variables $\widetilde{\beta}$ and $\widetilde{x}$ in equations (3.12) and (3.15). Totally differentiating the two equilibrium conditions and writing the results in matrix notation yields:

$$\begin{bmatrix} (2-e)(1-e) + \left(2-e-\widetilde{\beta}\right) ekm & 0 \\ em & (1-\phi)(2-e)\,crL \end{bmatrix} \times \begin{bmatrix} b\widetilde{x} d\ln \widetilde{x} \\ \widetilde{\beta} d \ln \widetilde{\beta} \end{bmatrix} =$$

$$+ \begin{bmatrix} (2-e)(1-e) + \left(2-e-\widetilde{\beta}\right) ekm \\ em \end{bmatrix} \widetilde{x} bd\ln L + \begin{bmatrix} (2-e)\left(1-\widetilde{\beta}\right)\mu_c' k \\ \widetilde{\beta}(2-e) \end{bmatrix} crL\phi d\ln\phi$$

$$+ \begin{bmatrix} \widetilde{x}(2-e)(1-e)\,b \\ 0 \end{bmatrix} d\ln k - \begin{bmatrix} \left(2-e-\widetilde{\beta}\right) kb \\ b \end{bmatrix} em\widetilde{x} d\ln m$$

$$- \begin{bmatrix} \left(2-e-\widetilde{\beta}\right) k + (2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\,k \\ 1+\widetilde{\beta}(1-\phi)(2-e) \end{bmatrix} crLd\ln r.$$

The determinant of the coefficient matrix is given by:

$$\Delta = (1-\phi)(2-e)\,crL\left[(2-e)(1-e) + \left(2-e-\widetilde{\beta}\right) ekm\right] > 0.$$

In the following, we prove Proposition 3.3 in subsection 3.3.4, and show partial equilibrium results for a change in the financial development parameter ϕ.

Proposition 3.3 (Interest rate effect) In partial equilibrium, we analyze the effects of an exogenous change in the interest rate r. The effect on average industry scale $\widetilde{x}$ is given by:

$$\frac{d\ln\widetilde{x}}{d\ln r} = -\frac{\left[\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\right]cr}{\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]b'\widetilde{x}} < 0. \tag{C.1}$$

The effect on the cutoff $\widetilde{\beta}$ is given by:

$$\frac{d\ln\widetilde{\beta}}{d\ln r} = -\frac{1-e+(1-\phi)\left[(1-e)(2-e)\widetilde{\beta}+ekm\left((2-e)\widetilde{\beta}-\frac{1+\widetilde{\beta}^2}{2}\right)\right]}{(1-\phi)L\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]\widetilde{\beta}} < 0. \tag{C.2}$$

To derive the latter expression, note that $\left(1-\widetilde{\beta}\right)\mu_c' = \int_{\widetilde{\beta}}^1 \beta_i di = \frac{1-\widetilde{\beta}^2}{2}$.

Proof. To show that $\frac{d\ln\widetilde{\beta}}{d\ln r} < 0$, it is sufficient to prove that $(2-e)\widetilde{\beta}-\frac{1+\widetilde{\beta}^2}{2} > 0$. As the latter expression increases in $\widetilde{\beta}$, we insert the lowest possible cutoff value $\widetilde{\beta}_l = \frac{1}{2-e}$ (see Condition 3.2 in subsection 3.3.3), which leads to $\frac{(2-e)^2-1}{2(2-e)^2} > 0$. ■

Financial development For the sake of completeness, we present the results for an exogenous change in the parameter ϕ, which are not discussed in the main body of the chapter. The effect on average industry scale $\widetilde{x}$ is given by:

$$\frac{d\ln\widetilde{x}}{d\ln\phi} = \frac{(2-e)\left(1-\widetilde{\beta}\right)\mu_c' cr\phi}{\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]b'\widetilde{x}} > 0. \tag{C.3}$$

The solution for the effect on the cutoff value is:

$$\frac{d\ln\widetilde{\beta}}{d\ln\phi} = \frac{\phi}{1-\phi}\frac{(1-e)(2-e)\widetilde{\beta}+ekm\left((2-e)\widetilde{\beta}-\frac{1+\widetilde{\beta}^2}{2}\right)}{\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]\widetilde{\beta}} > 0, \tag{C.4}$$

whereby the proof of Proposition 3.3 ensures that $\frac{d\ln\widetilde{\beta}}{d\ln\phi} > 0$.

C.2 Comparative statics in general equilibrium

In general equilibrium, the three endogenous variables $\widetilde{\beta}$, $\widetilde{x}$, and r are determined in equations (3.12), (3.15), and (3.20). Totally differentiating these expressions results in the following matrix equation:

$$\begin{bmatrix} b\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right] & 0 & \left[2-e-\widetilde{\beta}+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\right]k \\ bem & (1-\phi)(2-e)crL & 1+\widetilde{\beta}(1-\phi)(2-e) \\ cm & 0 & 0 \end{bmatrix} \times$$

$$\begin{bmatrix} \widetilde{x}d\ln\widetilde{x} \\ \widetilde{\beta}d\ln\widetilde{\beta} \\ cLrd\ln r \end{bmatrix} = \begin{bmatrix} \widetilde{x}b(2-e)(1-e) \\ 0 \\ 0 \end{bmatrix} d\ln k + \begin{bmatrix} \left(1-\widetilde{\beta}\right)\mu_c'k \\ \widetilde{\beta} \\ 0 \end{bmatrix}(2-e)crL\phi d\ln\phi + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} K_s d\ln K_s,$$

whereas the determinant of the coefficient matrix is given by:

$$\Delta_{GE} = -(1-\phi)(2-e)\left[\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\right]rc^3L^2km < 0.$$

Proposition 3.4 (Globalization) In general equilibrium, a higher number of countries k increases the interest rate:

$$\frac{d\ln r}{d\ln k} = \frac{(2-e)(1-e)b'\widetilde{x}}{\left(2-e-\widetilde{\beta}\right)a-\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]b'\widetilde{x}} > 0. \qquad \text{(C.5)}$$

The effect of globalization on the cutoff level $\widetilde{\beta}$ is given by:

$$\frac{d\ln\widetilde{\beta}}{d\ln k} = -\frac{(1-e)\left[1+\widetilde{\beta}(1-\phi)(2-e)\right]b'\widetilde{x}}{(1-\phi)\left[\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\right]cr\widetilde{\beta}} < 0. \qquad \text{(C.6)}$$

Comparing the effects on $\widetilde{\beta}$ in partial (3.17) and general equilibrium (C.6), leads to:

$$\left|\frac{d\ln\widetilde{\beta}}{d\ln k}\right|_{GE} - \left|\frac{d\ln\widetilde{\beta}}{d\ln k}\right|_{PE} =$$

$$\frac{(2-e)\left[(1-e)\left[1+\widetilde{\beta}(1-\phi)(2-e)\right]+ekm(1-\phi)\left[\widetilde{\beta}(2-e)-\widetilde{\beta}^2-\frac{1-\widetilde{\beta}^2}{2}\right]\right]}{k\left[\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\right]\left[(2-e)(1-e)+\left(2-e-\widetilde{\beta}\right)ekm\right]} > 0,$$

whereas the proof in Proposition 3.3 ensures that the last term is positive.

Proposition 3.5 (Firm-level effects of globalization) Inserting the interest rate effect of globalization (C.5) into equations (3.25) and (3.26), leads to:

$$\frac{d\ln x_U}{d\ln k} = 1 - \frac{\widetilde{x}}{x_U} \frac{1-e}{2-e-\widetilde{\beta}+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)} > 0, \tag{C.7}$$

$$\frac{d\ln x_C(\beta)}{d\ln k} = 1 - \frac{\widetilde{x}}{x_C(\beta)} \frac{2-e+\beta(i)(1-\phi)(2-e)}{2-e-\widetilde{\beta}+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)} < 0. \tag{C.8}$$

As $x_U > \widetilde{x}$ and $\frac{1-e}{2-e-\widetilde{\beta}+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)} < 1$, the effect of globalization on unconstrained output (C.7) is clearly positive. For constrained firms, note that $x_C(\beta) < \widetilde{x}$.
Proof. A sufficient condition for a negative effect of globalization on constrained output is that the last fraction of expression (C.8) is larger than one. This is the case if $\beta(i) > \frac{1-\widetilde{\beta}^2}{2}$. Evaluating this condition for the marginal firm with $\beta(i) = \widetilde{\beta}$ and inserting the lower bound $\widetilde{\beta}_l$ leads to $\left(\frac{1}{2-e}\right)^2 + \frac{e}{2-e} > 0$. Thus, the effect of globalization is negative for all firms with $\beta(i) \geq \widetilde{\beta}$. ■

Proposition 3.6 (Financial development) The effect of financial development on the cutoff level $\widetilde{\beta}$ is positive, following the proof in Proposition 3.3:

$$\frac{d\ln\widetilde{\beta}}{d\ln\phi} = \frac{\phi\left[(2-e)\widetilde{\beta} - \frac{1+\widetilde{\beta}^2}{2}\right]}{(1-\phi)\left[\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)\right]\widetilde{\beta}} > 0. \tag{C.9}$$

The effect of a change in ϕ on the interest rate is given by:

$$\frac{d\ln r}{d\ln\phi} = \frac{(2-e)\left(1-\widetilde{\beta}\right)\mu_c'\phi}{\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)} > 0. \tag{C.10}$$

Proposition 3.7 (Firm-level effects of financial development) To show that the effect of financial development on constrained output (3.30) is unambiguously positive, we insert expression (C.10), resulting in:

$$\frac{d\ln x_C}{d\ln\phi} = \frac{cr\phi}{x_C b'(1-e)}\left[\frac{\left(2-e-\widetilde{\beta}\right)-(2-e)\left(1-\widetilde{\beta}\right)\mu_c'}{\left(2-e-\widetilde{\beta}\right)+(2-e)\left(1-\widetilde{\beta}\right)\mu_c'(1-\phi)}\right] > 0. \tag{C.11}$$

Proof. As the numerator of the term in brackets increases in $\widetilde{\beta}$, we insert the lower bound $\widetilde{\beta}_l = \frac{1}{2-e}$, which leads to $\frac{(2-e)^2-1}{2(2-e)} > 0$. ■

C.3 Comparative statics with free entry

This section presents comparative static results for a globalization shock (increase in number of countries k) in the case of free entry. The three endogenous variables m, $\widehat{\beta}$, and $\widetilde{x}$ are determined in equations (3.33), (3.34), and (3.36). We totally differentiate these expressions which leads to the following system of equations:

$$\begin{bmatrix} 2b'(2-e)^2(1-e) & -(1-\phi)cr\left(e^2+3-4e\right) & 0 \\ 0 & 3\left[(1-\phi)cr\right]^2\left[e^2(6-e)+5(2-3e)\right]\widehat{\beta}^2 & 0 \\ b'emk & (1-\phi)cr & b'ek\widetilde{x} \end{bmatrix}$$

$$\times \begin{bmatrix} \widetilde{x}d\ln\widetilde{x} \\ \widehat{\beta}d\ln\widehat{\beta} \\ md\ln m \end{bmatrix} = \begin{bmatrix} 2b'\widetilde{x}(2-e)^2(1-e) \\ -6b'f_E(2-e)^3(1-e) \\ 0 \end{bmatrix} d\ln k.$$

The determinant of the coefficient matrix is given by:

$$\Delta_{FE} = 6b'^2ek\widetilde{x}(2-e)^2(1-e)\left[(1-\phi)cr\right]^2\left[e^2(6-e)+5(2-3e)\right]\widehat{\beta}^2 > 0.$$

Proposition 3.8 The effect of globalization on the cutoff value $\widehat{\beta}$ can be written as follows:

$$\frac{d\ln\widehat{\beta}}{d\ln k} = -\frac{2b'f_E(2-e)^3(1-e)}{\left[(1-\phi)cr\right]^2\left[e^2(6-e)+5(2-3e)\right]\widehat{\beta}^3} < 0, \tag{C.12}$$

and the impact on the number of firms m is given by:

$$\frac{d\ln m}{d\ln k} = \frac{2f_E(2-e)^3(1-e)\left[3\widehat{\beta}(1-\phi)cr-2(a-cr)\right]}{\left[(1-\phi)cr\right]^2\left[e^2(6-e)+5(2-3e)\right]eX\widehat{\beta}^3} \lesseqgtr 0. \tag{C.13}$$

Combining expressions (3.33) and (3.34) with equation (C.13), leads to result (3.38) in Proposition 3.8. Furthermore, the impact of globalization on average industry scale is clearly positive:

$$\frac{d\ln\widetilde{x}}{d\ln k} = \frac{(2-e)\left(e^2+3-4e\right)f_E}{(1-\phi)cr\left[e^2(6-e)+5(2-3e)\right]\widetilde{x}\widehat{\beta}^2} > 0. \tag{C.14}$$

Appendix D

Empirical Appendix

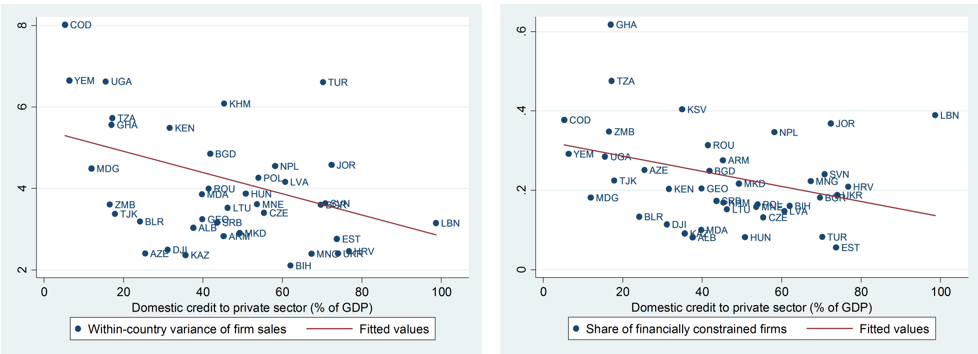

Figure D.1: Financial development and within-country heterogeneity, 2013

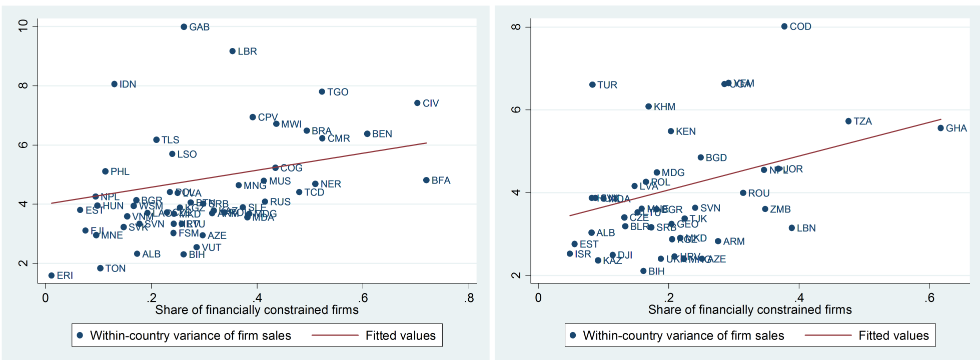

Figure D.2: Credit constraints and sales variance, 2009 (left) and 2013 (right)

D.1 Data Appendix

Table D.1: Description of variables

Variable	**Variable description**
Financial variables:	
TOA	Firm-level tangible assets / total assets, tangible assets=land and buildings
Access to finance	Access to finance is obstacle to business: 0=no obstacle, 1=minor obstacle, 2=moderate, 3=major, 4=very severe
Share constrained firms	Constrained=1 if firm answered Access to finance with 3 or 4.
Financial development	Domestic credit to private sector / GDP
Degree of competition	Expected effect of hypothetical 10% price increase of main product on demand: 1=no effect, 2=small decrease, 3=large decrease, 4=customers stop buying.
Firm-level controls:	
Size	Log number of workers
Labor productivity	Log sales / number of workers
Legal status	1=publicly listed, 2=private, 3=cooperative, 4=sole proprietorship, 5=partnership
Age	Number of years in business
Exporter	=1 if firm exports
Domestic private ownership	Percentage of firm owned by domestic private sector
Foreign private ownership	Percentage of firm owned by foreign private sector
Government ownership	Percentage of firm owned by government / state
Product innovation	=1 if firm developed a major new product line in last three years
Process innovation	=1 if firm introduced new production technology in last three years

Data source: WBES 2002-2005, 2009, 2013. Financial development: WDI World Bank. Variables reported in local currency units are converted to 2005 U.S. dollars. Database available at: http://www.enterprisesurveys.org.

Table D.2: Summary statistics

Variable	Obs.	Mean	Median	Std. Dev.	Min	Max
Cross-section 2002-2005						
Tangible over total assets	13,267	0.21	0.14	0.22	0	1
Share of constrained firms	69,377	0.21	0.18	0.19	0	1
Degree of competition	28,620	2.63	3.00	1.08	1	4
Log sales	13,175	14.05	13.77	2.89	-2.16	28.79
Cross-section 2009						
Constrained	18,911	0.30	0	0.46	0	1
Log sales	16,903	12.84	12.82	2.56	0.27	22.65
Cross-section 2013						
Constrained	21,067	0.24	0	0.42	0	1
Log sales	16,737	12.28	12.20	2.38	-0.81	28.35

Source: Authors' own computations from the WBES.

Table D.3: Within-industry and between-industry variation of TOA

		2-digit		3-digit		4-digit	
Country	Obs.	within	between	within	between	within	between
Chile	894	89.56	10.44	88.76	11.24	84.24	15.76
El Salvador	349	95.18	4.82	88.2	11.8	79.51	20.49
Guatemala	421	95.48	4.52	92.05	7.95	77.33	22.67
Honduras	401	90.86	9.14	81.63	18.37	76.45	23.55
Madagascar	123	91.46	8.54	80.64	19.36	78.11	21.89
South Africa	495	98.48	1.52	86.74	13.26	76.75	23.25
Thailand	718	93.14	6.86	92.37	7.63	91.26	8.74
Vietnam	1,048	98.52	1.48	97.92	2.08	83.68	16.32

Source: Authors' own computations from the WBES. Due to data availability, we restrict the analysis to a subsample of countries.

Table D.4: Summary statistics at the country level, cross-section 2013

			2013						
Country	Obs.	FinDev	Con.	Var.	Country	Obs.	FinDev	Con.	Var.
Albania	357	37.58	0.08	3.04	Kosovo	198	34.94	0.40	-
Armenia	359	45.18	0.28	2.83	Latvia	332	60.70	0.15	4.16
Azerbaijan	390	25.46	0.25	2.40	Lebanon	558	98.64	0.39	3.15
Bangladesh	1,437	41.79	0.25	4.85	Lithuania	263	46.22	0.15	3.52
Belarus	353	24.15	0.13	3.19	Madagascar	336	11.92	0.18	-
Bosnia and Herzegovina	360	62.01	0.16	2.11	Moldova	350	39.74	0.10	3.86
Bulgaria	287	69.64	0.18	3.60	Mongolia	359	67.28	0.22	2.39
Cambodia	467	45.33	0.17	6.08	Montenegro	145	53.61	0.16	-
Croatia	359	76.72	0.21	2.46	Nepal	482	58.11	0.35	4.55
Czech	250	55.36	0.13	3.40	Poland	534	53.93	0.17	4.26
DRC	511	5.24	0.38	8.02	Romania	532	41.41	0.31	3.99
Djibouti	263	31.09	0.11	-	Serbia	358	43.56	0.17	3.17
Estonia	270	73.70	0.06	2.76	Slovenia	270	70.79	0.24	3.63
FYROM	359	49.21	0.22	2.90	Tajikistan	348	17.86	0.23	3.37
Georgia	357	39.85	0.20	3.24	Tanzania	771	17.21	0.48	5.73
Ghana	711	16.99	0.62	5.57	Turkey	1,319	70.19	0.08	-
Hungary	306	50.76	0.08	3.87	Uganda	736	15.52	0.29	6.63
Jordan	573	72.33	0.37	4.57	Ukraine	983	73.96	0.19	2.40
Kazakhstan	570	35.58	0.09	2.36	Yemen	353	6.34	0.29	6.65
Kenya	767	31.63	0.20	5.48	Zambia	704	16.54	0.35	3.60
					Mean		45.51	0.22	3.90

Source: Authors' own computations from the WBES. FinDev: credit to private sector in % of GDP; Con.: share of financially constrained firms; Var.: within-country variance of firm sales.

Table D.5: Summary statistics at the country level, cross-section 2009

					2009				
Country	Obs.	FinDev	Con.	Var.	Country	Obs.	FinDev	Con.	Var.
Albania	52	36.92	0.17	2.32	Latvia	264	104.55	0.25	4.38
Armenia	371	24.86	0.32	3.69	Lesotho	146	12.84	0.24	5.69
Azerbaijan	360	19.07	0.30	2.95	Liberia	147	12.20	0.35	9.17
Benin	148	22.47	0.61	6.38	Lithuania	268	69.73	0.26	3.33
Bhutan	244	32.42	0.27	4.06	Madagascar	434	11.52	0.39	3.67
Bosnia and Herzegovina	360	65.37	0.26	2.30	Malawi	149	13.38	0.44	6.71
Brazil	1,783	48.87	0.49	6.48	Mauritius	397	82.74	0.41	4.78
Bulgaria	274	73.11	0.17	4.13	Micronesia	62	21.30	0.24	3.02
Burkina Faso	393	17.02	0.72	4.81	Moldova	346	36.00	0.38	3.56
Cameroon	361	11.48	0.52	6.23	Mongolia	345	40.30	0.37	4.64
CapeVerde	148	57.96	0.39	6.94	Montenegro	115	76.54	0.10	2.95
Chad	148	3.93	0.48	4.40	Nepal	486	59.18	0.10	4.26
Congo	122	4.92	0.43	5.23	Niger	147	12.20	0.51	4.69
Croatia	99	66.71	0.24	3.34	Philippines	1,280	29.16	0.11	5.11
Czech	244	49.86	0.23	3.72	Poland	429	49.75	0.24	4.40
Ivory Coast	512	16.43	0.70	7.41	Romania	497	46.15	0.34	3.71
Eritrea	172	16.77	0.01	1.59	Russia	976	45.26	0.42	4.09
Estonia	259	105.11	0.07	3.80	Samoa	108	39.53	0.17	3.94
FYROM	362	43.87	0.24	3.67	Serbia	382	42.55	0.30	4.01
Fiji	159	89.62	0.08	-	Sierra Leone	150	8.22	0.37	3.89
Gabon	172	10.12	0.26	9.99	Slovenia	276	90.69	0.18	3.33
Hungary	285	68.04	0.10	3.95	Timor-Leste	148	12.66	0.21	6.18
Indonesia	1,314	27.66	0.13	8.06	Togo	153	19.75	0.53	7.80
Kazakhstan	532	50.27	0.32	3.78	Tonga	145	47.09	0.10	1.84
Kosovo	176	34.34	0.16	-	Vanuatu	126	62.98	0.29	2.54
Laos	358	17.24	0.19	3.70	Vietnam	1,024	103.32	0.15	3.59
					Mean		41.02	0.29	4.67

Source: Authors' own computations from the WBES. FinDev: credit to private sector in % of GDP; Con.: share of financially constrained firms; Var.: within-country variance of firm sales.

D.2 Robustness checks for empirical patterns

This part shows that the empirical patterns presented in section 3.2 are robust to the inclusion of controls at the firm- as well as the industry level. Table D.1 describes the variables used in the empirical analysis. Empirical pattern 2 shows that industries with a higher degree of product competition are characterized by a larger fraction of financially constrained firms. We estimate the following equation:

$$Constrained_{ic} = \alpha + \beta Comp_{ic} + \gamma X_f + \upsilon_c + \upsilon_t + \varepsilon_{fic} \ , \tag{D.1}$$

whereas $Constrained_{ic}$ is the share of financially constrained firms within an industry i in country c. The variable $Comp_{ic}$ denotes the industry mean of the degree of competition (see Table D.1). We control for a set of firm characteristics X_f and include country fixed effects υ_c, as well as year dummies υ_t. Column (1) of Table D.6 shows results for this specification and highlights that the positive relationship between competition and the share of financially constrained firms is robust. As a further robustness check, we use the firm-level variable for access to external finance instead of the industry share in regression (D.1). Column (2) shows that credit-rationing is positively associated with competition. The advantage of the firm-level regression is that we further control for industry-fixed effects at the 4-digit level.
Empirical pattern 3 states that more financially constrained industries show a larger within-industry variance of sales. A major concern is that this relationship might be driven by firm heterogeneity with respect to productivity and size, or innovation activity. To address this issue, we run the following regression:

$$Variance_{ic} = \alpha + \beta TOA_{ic} + \gamma X_f + \upsilon_c + \upsilon_t + \varepsilon_{fic} \ , \tag{D.2}$$

whereas $Variance_{ic}$ is the within-industry variance of firm sales and TOA_{ic} denotes the industry-mean of tangible over total assets. Column (1) of Table D.7 shows the results. In columns (2)-(3), we replace the industry-mean TOA_{ic} with financial development at the country level for cross-sectional data in years 2009 and 2013. This specification allows us to include industry-fixed effects at the 4-digit level. Columns (4) and (5) show that the negative relationship between financial development and the variance of sales holds at the country level as well, when we use the within-country variance of sales as dependent variable.

In a last step, we do a similar exercise for the effect of financial development $FinDev_c$ on the share of credit-rationed producers, as shown by the following regression:

$$Constrained_{ic} = \alpha + \beta FinDev_c + \gamma X_f + \upsilon_i + \varepsilon_{fic} \ . \tag{D.3}$$

The first two columns of Table D.8 show the estimation results. Analogous to empirical pattern 2, we use the firm-level variable for access to external finance as dependent variable and show that the significantly negative relationship can be confirmed at the firm level (see columns 3 and 4).

Table D.6: Regression analysis credit constraints and degree of competition

	Share constrained	Access to finance
	(1)	(2)
Degree of competition	0.027***	0.060***
	(0.000)	(0.000)
Firm-level controls:		
Size	0.000	-0.023***
	(0.738)	(0.004)
Labor productivity	-0.005***	-0.023**
	(0.000)	(0.026)
Legal status	-0.001	0.003
	(0.277)	(0.779)
Age	0.000*	-0.003***
	(0.094)	(0.000)
Exporter	0.000	-0.004
	(0.912)	(0.896)
Domestic private ownership	0.000	0.000
	(0.235)	(0.736)
Foreign private ownership	0.000**	-0.005***
	(0.016)	(0.000)
Government ownership	0.000	-0.001
	(0.473)	(0.605)
Year fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
Industry fixed effects	No	Yes
Observations	17,792	15,350
R-squared	0.797	0.193

Note: Cross-section 2002-2005; industry fixed effects at 4-digit level.

Table D.7: Regression analysis credit constraints and variance of sales

	Within-industry variance sales			Within-country variance sales	
	(1)	(2)	(3)	(4)	(5)
Industry Mean TOA	-1.142***				
	(0.000)				
Financial development		-0.012***	-0.018***	-0.019***	-0.025***
		(0.000)	(0.000)	(0.000)	(0.000)
Firm-level controls:					
Size	-0.011	0.031**	0.071***	-0.024***	0.004
	(0.346)	(0.043)	(0.000)	(0.009)	(0.699)
Labor productivity	0.006	-0.090***	0.013	-0.121***	-0.021***
	(0.502)	(0.000)	(0.208)	(0.000)	(0.001)
Legal status	0.022**	0.042**	0.261***	0.063***	0.341***
	(0.037)	(0.027)	(0.000)	(0.000)	(0.000)
Age	0.000	0.058***	0.067***	0.020	0.065***
	(0.339)	(0.006)	(0.001)	(0.115)	(0.000)
Exporter	0.079**	-0.356***	0.183***	-0.273***	0.272***
	(0.015)	(0.000)	(0.000)	(0.000)	(0.000)
Domestic private ownership	0.006	-0.009***	-0.011***	-0.008***	-0.007***
	(0.103)	(0.000)	(0.000)	(0.000)	(0.000)
Foreign private ownership	0.007**	-0.007***	-0.010***	-0.008***	-0.008***
	(0.047)	(0.000)	(0.000)	(0.000)	(0.000)
Government ownership	0.006*	-0.015***	-0.014**	-0.017***	-0.013***
	(0.096)	(0.000)	(0.015)	(0.000)	(0.000)
Product innovation	0.010***				
	(0.000)				
Process innovation	0.036				
	(0.197)				
Year fixed effects	Yes	No	No	No	No
Country fixed effects	Yes	No	No	No	No
Industry fixed effects	No	Yes	Yes	Yes	Yes
Observations	5,108	14,703	14,481	14,942	14,634
R-squared	0.688	0.188	0.218	0.282	0.319

Column (1): 2002-05; (2) & (4): 2009; (3) & (5): 2013. Industry fixed effects at 4-digit level.

Table D.8: Regression analysis credit constraints and financial development

	Share constrained		Access to finance	
	2009	2013	2009	2013
Financial development	-0.002***	-0.001***	-0.008***	-0.005***
	(0.000)	(0.000)	(0.000)	(0.000)
Firm-level controls:				
Size	0.001	-0.005***	-0.032***	-0.056***
	(0.368)	(0.000)	(0.000)	(0.000)
Labor productivity	0.004***	-0.009***	-0.034***	-0.051***
	(0.000)	(0.000)	(0.000)	(0.000)
Legal status	-0.005***	0.039***	-0.028**	0.175***
	(0.001)	(0.000)	(0.013)	(0.000)
Age	-0.006***	0.002	-0.027**	0.003
	(0.001)	(0.163)	(0.031)	(0.814)
Exporter	-0.033***	-0.006	-0.050	-0.058*
	(0.000)	(0.126)	(0.135)	(0.062)
Domestic private ownership	-0.001***	0.000**	-0.003***	0.002**
	(0.000)	(0.011)	(0.000)	(0.032)
Foreign private ownership	-0.001	0.000***	-0.007***	0.000
	(0.000)	(0.001)	(0.000)	(0.912)
Government ownership	-0.001	0.000*	-0.001	0.001
	(0.002)	(0.073)	(0.679)	(0.565)
Industry fixed effects	Yes	Yes	Yes	Yes
Observations	14,935	14,630	14,555	14,474
R-squared	0.193	0.235	0.074	0.076

Note: Industry fixed effects at 4-digit level.

Conclusion

The question how financial frictions affect international trade has been analyzed at the country or industry level for a long time. In recent years, an increasing availability of micro datasets has shifted the perspective to the firm level. Empirical studies document the large heterogeneity of producers in terms of productivity, as well as financial characteristics, and find negative effects of credit constraints on firm-level exports and foreign market entry. This thesis is motivated by evidence on credit constraints and exports, and aims to contribute to the theoretical literature on financial frictions in international trade. It analyzes how firms react to financial shocks and trade liberalization in the presence of credit constraints, and shows how these adjustments change aggregate variables such as product variety, average productivity and welfare. The three chapters highlight new heterogeneous effects of credit constraints at the firm level. Chapter 1 combines financial frictions with the literature on quality in international trade. Firms require external credit for investments in processes and product quality. Consistent with empirical studies, the model explains both positive and negative correlations of prices with credit and trade costs, depending on the sectoral scope for vertical differentiation. Chapter 2 introduces two types of external finance and adds a new selection mechanism to the literature on firm heterogeneity in international trade. Besides the selection into exporting, productivity determines access to external finance. Only the most productive firms obtain unmonitored funds, such as corporate bonds, whereas low productivity firms have to rely on more expensive bank finance. Producers react to credit shocks and trade liberalization by switching the type of finance.

A common feature of the first two chapters is the interaction of firm heterogeneity with financial imperfections. Producers differ ex-ante in their capability to conduct innovations (Chapter 1) or in their productivity (Chapter 2), which both translates into heterogeneity in performance, such as sales and profits. The interaction of firm heterogeneity with credit frictions has two important implications. First, some firms with low capability or productivity face credit constraints as they cannot overcome financial imperfections. Second, financial shocks and trade liberalization will affect heterogeneous producers very differently. A new element in Chapter 3 is that heterogeneity arises from the interaction of credit constraints at the firm level and financial frictions at the country level, even in the absence of ex-ante differences in productivity or wealth. Producers differ in pledgeability of sales, which results in firm heterogeneity if financial institutions are imperfect.

Besides new heterogeneous effects on the firm level, the second common feature of all chapters is the analysis of general equilibrium effects. Whereas existing theoretical work mainly focuses on firm-level responses in partial equilibrium, this thesis shows how heterogenous reactions across producers affect aggregate variables. The main idea of the analysis is as follows: if producers respond differently to financial shocks, this changes price competition and the selection of firms in general equilibrium. To evaluate the welfare implications in the presence of credit frictions, it is crucial to account for these selection effects. In particular, Chapter 1 shows that credit frictions reduce the number of producers and thus the degree of competition for existing suppliers in general equilibrium. In contrast to partial equilibrium, the negative effect of credit frictions on the extensive margin leads to an equilibrium with larger firms and higher investment. The welfare losses of credit tightening depend on technology characteristics and are larger in sectors with low investment intensity. Chapter 2 identifies substitution effects as an additional channel of adjustment to credit tightening and trade liberalization. As some producers respond to shocks by switching the type of finance, price competition changes, which influences product variety and welfare. Chapter 3 shows that globalization raises the interest rate, leads to a reallocation of profits towards unconstrained firms and increases the share of credit-rationed producers. These effects increase the variance of prices and represent an additional negative welfare channel that reduces common gains from trade.

The analysis throughout this thesis aims to link heterogeneous effects of credit frictions at the firm level to aggregate implications for international trade. I hope that the chapters contribute to a better understanding of how firms react to financial and trade shocks in the presence of credit market imperfections. This thesis suggests that technological characteristics, the availability of different types of external finance, and adjustments of capital costs play an important role for evaluating welfare consequences. I hope that my dissertation contributes to the analysis of financial frictions in international trade, and motivates further research in this direction.

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9. Dezember 2015

Florian Unger