Information Technology, Competition and Trade:

Sourcing Decisions and Firm Adjustments in the Global Economy

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CHAPTER I

Preface

One of the most significant features of the global economy in the past half century is the tremendous growth in world trade. The key drivers behind this process constitute the international integration of product, capital and labor markets as well as revolutionary technological advances which contributed to a substantial reduction in the costs of transportation and communication. Accordingly, it has become feasible for firms to locate different stages of production in different countries in order to exploit locational advantages such as access to relatively cheap labor and proximity to markets. Production processes therefore increasingly involve global supply chains stretching across multiple countries with phases of production being located in those regions where they can be performed most efficiently. The emergence of global production networks has come along with the integration of low-wage countries into the world economy. Political reforms as well as the localisation of labor-intensive stages of production allowed developing countries to realize their comparative advantage in labor-intensive goods and spur industrial development and economic growth. Therefore, the most remarkable development in world trade in the past two decades has been the rapid growth of manufactured exports from low-wage economies. Consequently, the rise of low-wage countries in world trade, most notably led by China, has created an enormous global supply shock inducing a severe increase in the intensity of competition in global product markets. Understanding how firms react and adapt to this changing business environment is essential in order to evaluate the consequences of international trade in advanced economies.

This dissertation consists of three self-contained chapters which provide new insights into the organization of the global supply chain and into the adjustment of firms to international competition. In Chapter II, I first investigate how advances in information technology shape the patterns of global sourcing. Subsequently in chapter III, I research how international competition affects the composition of firm investments. Lastly, chapter IV studies the impact of import competition from low-wage countries on the pricing decisions of firms in an industrialized economy, namely Germany.

Chapter II investigates the impact of information technology on the organization of the global supply chain. Prior research suggests that international costs of knowledge transmission and communication have a substantial impact on the patterns of trade and foreign investment. Nevertheless, the effects of information technology have remained unexplored. In order to guide the empirical analysis, I develop a theoretical model which illustrates how information technology affects the decision of firms in the high-wage North whether to offshore production to a low-wage country in South. Offshoring to South results in costly communication reflected by the degree of contractual distortions between the Northern headquarter and its Southern supplier. More sophisticated information technology allows more efficient communication and thereby alleviates contractual frictions. The model provides several predictions about the impact of information technology on the organization of the global supply chain. First of all, complex industries for which the codification and verification of information is a much harder task are more likely to source intermediate inputs in countries with more efficient information technology infrastructure. Moreover, considering the mode of firm organization, more efficient information technology infrastructure is expected to increase the scale of arm's-length contracting with independent suppliers. These empirical predictions are tested and validated by using disaggregated industry-level data on the operations of US industries. Empirically I capture the location decision of multinationals with the number of imported intermediates and the mode of organization with the share of intra-firm trade. Product complexity is measured by means of the intensity in non-routine production activities by industry and the primary measure for the level of information technology infrastructure is the international internet bandwidth by country. The econometric analysis is in line with the empirical predictions. More efficient information technology raises the number of imported intermediates with the effect being stronger in more complex industries. Furthermore, the share of intra-firm imports is decreasing with the level of information technology. Again, the effect is more pronounced in more complex industries. Altogether, these findings are robust to the overall level of economic development as well as to well-known sources of comparative advantage and determinants of firm organization such as factor endowments, financial development and contract enforcement.

Chapter III is jointly co-authored with Jan Schymik and Jan Tscheke.[1] In this chapter we study how the exposure to international competition affects firm investments into durable and nondurable assets. While the economic literature has put forward several causes for short-term investment behavior related to uncertainty, investor pressures or agency problems, we argue that import competition incentivizes firms to shift investments from long-term assets towards short-lived assets. In order to understand how competition affects the investment decisions of firms, we develop a stylized framework incorporating the investment decision with respect to two types of investment: A short-term one and a long-term one. Our model implies that tougher competition, reflected by a reduction in the future price-cost margin, reduces the relative value of long-term investments and shifts investments towards short-term assets. In addition, we investigate how firm heterogeneity determines the relative size of the effect. The framework predicts larger firms to be less affected by competition and therefore to be less susceptible to reallocate investments towards the short-term. Based on our framework we derive a difference-in-differences estimation strategy in order to empirically test our predictions. We test this prediction using data on investment expenditures of listed US companies into seven different asset classes which we order according to their depreciation rates. Overall, our empirical results are consistent with the empirical predictions. Hence, import competition induces firms to shift the composition of investments towards short-term categories. In addition, this effect turns out to be less pronounced for larger firms. So as to provide further supportive evidence of a causal effect, we exploit the

[1]Jan Schymik is a post-doctoral researcher and Jan Tscheke is a PhD candidate at the Chair of International Economics at LMU Munich.

rise in Chinese imports to the US following China's WTO accession in 2001 as an alternative source of an exogenous competition shock. Overall, our results turn out to be robust to various alternative channels such as uncertainty, financial constraints and the evolution of sector specific attributes.

Finally in chapter IV, I study the impact of import competition from China on pricing decisions by firms in the German manufacturing sector. As the rapid rise of China in the world economy has coincided with a decline in manufacturing employment in many advanced economies, the real effects of import competition from low-wage countries on firms and workers at the micro-level have raised considerable interest among economists. The impact on prices is of particular importance. First of all from a microeconomic perspective, prices determine the allocative and distributive effects of globalization. From a macroeconomic perspective, the reaction of prices in response to increased import competition reflects changes in inflationary pressure which may have important consequences for the patterns of inflation. The chapter is based on unique survey data covering firms in the German manufacturing sector. This data provides detailed information about the timing and the direction of price changes at the product level. After controlling for other price determinants and taking endogeneity issues into consideration, a negative and significant causal impact on prices emerges. Subsequently, the chapter is extended in order to study how vertical differentiation at the sector level and capital intensity at the firm level affect individual price responses. As such, it is expected that firms in R&D intensive industries in which competition is played on non-price factors are less prone to lowering their prices in response to cheap Chinese imports. Furthermore, capital intensive firms are supposed to be less hit by low-wage country import competition as their products are supposed to be consistent with the comparative advantage of a relatively more capital abundant country like Germany. The econometric results are in line with these hypotheses and suggest that firms in more differentiated sectors and more capital intensive firms are less likely to engage in downward price adjustments in response to imports from China.

CHAPTER II

Information Technology and Global Sourcing

II.1 Introduction

The substantial growth in trade in intermediates throughout the last two decades is widely considered as a defining feature of the process of globalization. Trade in intermediates occurs both within and across the boundaries of the firm, as firms fragment production and organize their production activities on a global scale. As a result, countries do not specialize in the entire production of final goods but increasingly contribute to overall production by specializing in specific stages of the production process and providing partitions of value added. This trend in international vertical specialization and the rise of trade in intermediates has been subject to a considerable amount of research.[1] What lies behind this breaking up of the production process across borders is the reduction in the costs of offshoring due to revolutionary advances in information and communication technology. The continuous emergence of more efficient technologies of information transmission has enabled the expansion of multinational firms by codifying and communicating complex information in order to transfer technologies abroad. Nevertheless, international costs of communication still have a profound influence on the patterns of trade (see Fink, Illeana, and Neagu (2005)). As such,

[1] See Campa and Goldberg (1997), Feenstra (1998), Grossman and Rossi-Hansberg (2006), Hummels, Ishii, and Yi (2001) and Yeats (2001) amongst others.

evidence points out that foreign investment is sensitive to geographic distance and thereby responds strongly to the costs of international knowledge transfer when making location decisions (see Yeaple (2009) and Keller and Yeaple (2013)).[2] Yet, the forces unleashed by new information technologies and their impact on the patterns of global sourcing have not been studied so far.

This study examines the impact of the advances of information technology on the organization of the vertical supply chain. In order to guide empirics, the paper develops a partial equilibrium model describing the decision of firms located in the high-wage North, whether to offshore production to a low-wage country in the South. Offshoring to the South however gives rise to costly communication. The costs of information transmission are reflected by the amount of contractual distortions which arise when production is offshored. More efficient information technology reduces the costs of communication and thereby the degree of contractual incompleteness. The model illustrates how the propensity to relocate production to a specific destination country increases with its level of information technology infrastructure. Assuming that vertical integration is subject to lower costs of communication than arm's-length contracting, the model demonstrates how information technology increases the scale of contracting with indendent input suppliers and thus reduces the share of intra-firm trade. Since the transmission of complex information relies to a greater extent on successful codification, the effects of information technology are stronger in more complex industries characterized by a larger degree of contractual incompleteness. These empirical predictions are tested and validated using disaggregated trade data on the operations of US industries.

The model draws on the theory of the product cycle by Antràs (2005) and features a world of two countries, the high-wage North and the low-wage South. A headquarter firm located in North needs to decide whether to purchase intermediates from a Northern or Southern manufacturer in order to produce a final good. Whenever the headquarter firm engages in offshoring to South, communication costs arise which vary with the degree of complexity of the intermediate input and take the form of additional labor costs. Production processes

[2]While Yeaple (2009) finds total affiliate sales to decline with distance from the US headquarter, Keller and Yeaple (2013) explain this finding with increased costs at which heaquarter knowledge can be transferred to more distant affiliates.

comprising complex inputs are assumed to be more susceptible to effective communication. In order to illustrate the degree of complexity of the intermediate good, the paper introduces partially incomplete contracting on behalf of the manufacturing firm. Complex intermediates are characterized by a larger portion of complex tasks and activities that cannot be perfectly specified in a contract. Thus, more complex products and higher costs of communication are reflected by a greater degree of contractual distortions. More sophisticated information technology, represented by lower production costs in complex components, alleviates contractual frictions. As a result, more effective information technology increases incentives of firms to shift production to South in order to exploit lower wages. Overall, the model predicts industries to be more likely to import intermediates from countries with a higher level of information technology where the effect is supposed to be increasing in product complexity.

Next, the model deals with the impact of information technology on the organization of the multinational firm. Following the property-rights approach, asset ownership determines the bargaining power throughout ex-post renegotiation and determines the ex-ante incentives of each party to invest. Outsourcing provides the manufacturer with larger incentives to invest but is related to larger costs of communication than integration. When deciding about the optimal mode of organization, the headquarter firm therefore has to trade off the contractual distortions arising due to costly information transmission with outsourcing and the incentives provided to the manufacturing firm. More effective information technology reduces the scale of communication costs and increases the incentives to opt for independent subcontracting. Again, this effect is stronger for more complex inputs.

The model's predictions are tested in the empirical section of the paper. The main measure for the adoption of information technology is based on the international internet bandwidth by country.[3] Product complexity at the industry level is measured by making use of task level data. Production processes that require more complex and non-routine activities involve less codifiable information thereby implying higher costs of knowledge transmission. I therefore use data on the specific work activities in each industry in order to estimate

[3]More precisely, I use the international internet bandwidth (kbit/s) per internet user.

the intensity with which a sector employs non-routine tasks in the production process. Evidence of the impact of information technology on the geography of offshoring is based on the number of intermediate goods by industry that the US imports from South. In order to assess the impact on the mode of organization, I use data on the share of intra-firm imports as a fraction of total Southern imports to the US.[4] Since the empirical predictions relate to the interaction of information technology infrastructure and product complexity, the estimations follow a generalized difference-in-differences strategy including sector fixed effects as well as country-year-fixed effects. Identification is therefore with respect to within country variation across industries. This approach allows restricting the set of controls to variables which influence the level of information technology infrastructure as well as the intensity in non-routine tasks and might affect sourcing strategies of US firms. In line with the empirical prediction, the econometric analysis shows that the impact of information technology on the number of imported intermediates is increasing with product complexity. In addition, the share of intra-firm imports decreases with the level of information technology with the effect being strongest for more complex industries. Comparing two industries that differ in one standard deviation in terms of product complexity, a one standard deviation change in information technology yields a positive differential effect of $2,35\%$ in the number of imported intermediates and a negative differential effect of $1,11$ percentage points in the share of intra-firm trade. These results are robust to well known determinants of offshoring, multinational firm organization and the patterns of specialization. Amongst others, effects remain significant when controlling for factor endowments as well as for institutional determinants such as financial development or judicial quality. Moreover, results are robust to the inclusion of measures for overall economic development as well as trade openness. Additionally, several robustness checks are performed in order to validate the results. Results hold when using alternative measures of information technology adoption as well as when employing alternative estimation techniques. Besides, I replace my measure of product complexity with an alternative measure reflecting the intensity in routine tasks by industry. Consistent with the predictions, the coefficients point to a reverse pattern with the effect of information

[4] A country is defined as Southern if GDP per capita (at PPP) is lower than 50% of the US level in the year 2000.

technology decreasing in routine intensity.

The paper relates to several literatures. Firstly, the paper contributes to the literature on the costs of international knowledge transfer and the organization of knowledge in multinationals. Keller and Yeaple (2013) find large barriers for US multinationals to transferring knowledge from headquarter to affiliate. Similarly, Oldenski (2012b) finds US multinationals to be more likely to offshore production stages abroad the more intensively they employ routine tasks and the less intensively they are in communication. Moreover, Costinot, Oldenski, and Rauch (2011) identify the non-routine quality of production tasks as a source of contractual frictions between the multinational headquarter and its supplier. Their results show that intra-firm trade tends to be decreasing in more routine intensive industries. Antràs, Garicano, and Rossi-Hansberg (2006) study the organization of knowledge in cross-country teams and Antràs, Garicano, and Rossi-Hansberg (2008) consider the interaction of host country communication technology and human capital. Secondly, the paper relates to the literature on the determinants of global sourcing. Whereas previous literature concentrates on the impact of intellectual property rights (e.g. Ethier and Markusen (1996) and Javorcik (2004)), financial development (e.g. Carluccio and Fally (2012)), factor intensities (e.g. Antràs (2003)) and contract enforcement (e.g. Antràs and Helpman (2008) and Nunn and Trefler (2008, 2013)) I focus on the role of digitization in altering the global sourcing decisions of multinationals. Besides, the paper is based on a large literature which introduces the property-rights theory of the firm to international trade theory in order to study the organization of multinationals (e.g. Antràs and Helpman (2004) and Antràs (2005)).[5] Thirdly, several researchers have addressed the effect of the internet on trade flows. Freund and Weinhold (2002, 2004) assess the impact of the internet on international trade in services and goods. Higher internet penetration is associated with both, an increase in growth in services and bilateral goods trade. Ultimately, my paper is also related to the literature on the economic consequences of information and communication technology. Abramovsky and Griffith (2006) consider the role of information and communication technology in outsourcing and offshoring of business services. Bloom, Garicano, Sadun, and van Reenen (2014) deal

[5]See Antràs (2013) and Antràs and Yeaple (2015) for a survey about the literature on incomplete contracts and the organization of multinational firms.

with the differential impact of information and communication technology on the autonomy of employees within firms and Baker and Hubbard (2003, 2004) analyze the impact of the adoption of new information technologies on organizational changes in the trucking industry. This paper aims to contribute to these various strands of literature by studying how the advances in information technology affect the organization of the multinational firm along the global supply chain.

Section II.2 introduces a simple model of offshoring and the role of information technology. Section II.3 presents the data, the empirical strategy and the results of the econometric analysis. Section II.4 offers some concluding comments.

II.2 A Simple Model of Information Technology and Global Sourcing

II.2.1 Setup

Based on the theory of the product cycle by Antràs (2005), this section develops a simple partial equilibrium model in which contractual frictions illustrate how information technology determines the offshoring decisions of Northern firms and affects the international organization of production.

The world consists of two countries, North and South. Labor is the only factor of production in order to produce a single good y and cannot move across borders. The wage rate in the North is denoted by $w^N$and in the South by w^S. Throughout the model, wages in North are higher than in the South $w^N > w^S$.

II.2.1.1 Preferences

Consumer preferences are given by a standard CES utility over a range of final goods given by

$$U = \int_0^N \log \left[\int_0^{n_j} y_{j(i)}^{\alpha} di \right]^{\frac{1}{\alpha}} dj, \quad 0 < \alpha < 1. \tag{II.1}$$

Total consumption of variety i in industry j is given by $y_{j(i)}$. N is the number of industries in the economy and n_j is the number of varieties in industry j. Varieties enter the utility function symmetrically with an elasticity of substitution equal to $\epsilon = 1/(1-\alpha)$. The elasiticty between industries is one. Demand by the representative consumer for any variety $y_{j(i)}$ is therefore given by

$$y_{j(i)} = \lambda_j p_{j(i)}^{-1/(1-\alpha)}, \ \ \lambda_j = \frac{1}{N} \frac{E}{\int_0^{n_j} p_{j(i)}^{-\alpha/(1-\alpha)} di}, \tag{II.2}$$

where $p_{j(i)}$ is the price and λ_j is a function of total income and an aggregate price index taken as given by the consumer.

II.2.1.2 Production

Consider the production process of a final good i in industry j. Production of any final good $y_{j(i)}$ consists of two steps: It requires the provision of headquarter services such as engineering and marketing represented by a special and distinct high-tech input h, and it necessitates final assembly and production described by a special and distinct low-tech input m, provided by a manufacturing firm. It is assumed that the headquarter engages in a contract with an independent manufacturing firm. Output is produced using a Cobb-Douglas production function given by

$$y_{j(i)} = \left(\frac{h_{j(i)}}{1-z_j} \right)^{1-z_j} \left(\frac{\exp\left(\int_0^1 \log m_{j(i)} (s) \, ds \right)}{z_j} \right)^{z_j}, \ 0 \leq z_j \leq 1, \tag{II.3}$$

where the parameter z_j describes the output elasticity of the manufacturing process m of the final good. The relative intensity of manufacuring z_j can also be interpreted as the degree of standardization of the final good in industry j. The larger z_j, the less significant are headquarter activities such as engineering and other problem solving services and the more standardized the good is. Production of one unit of a high-tech input requires the employment of one unit of Northern labor. The South however, is much less efficient at producing the high-tech input. By assumption, the productivity advantage of the North is sufficiently high enough to ensure that headquarter services are always located in the North. Labor requirements for the production of one unit of low-tech input are assumed to be equal to 1 in both North and South. High- and low-tech input are relationship-specific and have to fit precisely the needs of its counterpart, otherwise no positive output can be produced.[6] In order to focus on the impact of information technology and communication costs on the provision of inputs, headquarter services h are not subject to costly transmission of information and fully non-contractible.

The specialized manufacturing input m is produced with a set of activites indexed by points on the interval $[0,1]$.[7] Activities related to input $m(s)$ in the range $[0,\mu_s]$ where $0 \leq \mu_s \leq 1$ are considered as basic tasks which are fully contractible. Activities in the fraction $(\mu_s, 1]$ represent complex tasks wich are non-contractible and due to a hold-up problem when investment costs are already sunk. Complex tasks may be either of good or bad quality which cannot be verified ex-ante. If they are of bad quality, total output of the final good y is zero. The nature of non-contractible activities is only resolved when investments are already made. If non-contractible investments are of bad quality, production costs can be neglected. Both inputs h and m can be freely traded and no transport costs accrue. Altogether, the parties engage in a partially incomplete contract leading to a two-sided hold-up problem. Thus they need to bargain about the joint surplus created by the relationship.[8]

In order to successfully implement final assembly of the final good engineered by the headquarter firm, both parties need to communicate. As a result communication costs $\Gamma > 1$ arise. So as to reflect the fact that international production sharing is associated with higher costs of communication than domestic fragmentation, it is assumed that communication costs only occur if the manufacturing firm is located in South. Communication costs Γ however are only related to the set of complex and non-contractible activities $(\mu_s, 1]$ on behalf of the manufacturer. Following Keller and Yeaple (2013) communication costs Γ take the form of additional labor requirements in Southern labor and are incurred by the Southern manufacturer. Higher costs of communication result in a less efficient production process associated with larger costs expressed as larger labor requirements. Most importantly, I as-

[6]An input designed to fit with a particular headquarter or manufacturing firm cannot be employed in the production of other varieties. Therefore, they are useless outside the relationship.

[7]See Antràs and Helpman (2008) and Acemoglu, Antràs, and Helpman (2007).

[8]By assuming that headquarter services h are fully non-contractible, it is implicitly assumed that the headquarter produces only complex activities.

sume that more sophisticated information technology reduces the costs of communication and coordination Γ.

Before a headquarter decides to produce a high-tech input it needs to decide whether to engage in a relationship with a manufacturing firm located in the North or to opt for an international fragmentation of the production process and contract with a manufacturing firm in the South. The timing of events characterizing the contract is the following: The headquarter first offers potential manufacturing firms a contract defining the manufacturer's required investment in contractible activities $\{m(s)\}_0^\mu$ and an upfront lump-sum transfer T.[9] Hence, the contract stipulates the investment levels for the contractible activities but does not specify the investment levels in the remaining $(1-\mu)$ non-contractible activities. The manufacturing firm may therefore choose to withhold its services in these activites from the headquarter firm. By assumption, there is a large pool of potential applicants, such that competition among them makes T adjust such that the final manufacturing firm exactly breaks even. The ex-ante outside option of manufacturing firms is normalized to zero in both countries. Subsequently, the manufacturer chooses its investment level in contractible activities and both, the headquarter and the manufacturer independently decide about their non-contractible investments h and $m(s)$ where $s \in (\mu, 1]$. Ultimately, the resulting output is sold, and the Nash bargaining leaves each party with one-half of the revenues (i.e. the quasi-rents).

By assumption, the setting is one of complete contracts if the manufacturing firm is located in the North.[10] However, the relationship turns into an partially incomplete contract in case of international fragmentation of production.[11] The headquarter decides whether to engage with a manufacturing firm in North or South by maximizing its ex-ante expected profits. Whenever manufacturing takes place in the South the two parties bargain over the surplus after inputs have been produced. Following Antràs (2005) the parties conduct ex

[9] The transfer T can be either positive or negative.

[10] Whenever the manufacturing stage is located in the North it is assumed that the headquarter firm can hire an outside party in order to enforce a quality-contingent contract which monitors the ex-ante investments in non-contractible investments h and $m(s)$ where $s \in (\mu, 1]$.

[11] If international production sharing occurs, no third party can observe whether the inputs provided are of good or bad quality and no quality-contingent contract can be written. Likewise, no outside party can control the size of ex ante investments of the manufacturing firm and no contracts can be written contingent on revenues earned when the final good is sold.

post symmetric Nash bargaining and equally share the rents created by the relationship. If the parties fail to agree on the bargaining outcome, both receive nothing.

Overall, costs of international fragmentation are incorporated by contractual frictions which mirror the imperfect transmission of information across borders. More efficient information technology reflected by lower costs of communication Γ reduces these distortions.

II.2.2 Partial Equilibrium

This section considers the choice of the final-good producer of variety i in industry j whether to source inputs from an independent supplier located in North or South. As noted earlier, wages in South are assumed to be lower than in the North $w^N > w^S$. However, whenever production occurs in South, contracts are partially incomplete and communication costs occur.

II.2.2.1 Production by a Manufacturing Firm in the North

If the headquarter decides to fragment production domestically and engage in a relationship with a Northern manufacturer, both parties can write a complete contract.[12] The contract stipulates production levels of headquarter and manufacturing services such that the headquarter's ex-ante profits are maximized. Considering the transfer T , the headquarter's profits are given by $\pi^N(z) = \lambda^{1-\alpha} \left({}^{h}/_{1-z}\right)^{\alpha(1-z)} \cdot \left({}^{m}/_{z}\right)^{\alpha z} - hw^N - mw^N$. Maximizing with respect to h and m results in ex-ante profits for the headquarter given by

$$\pi^N(z) = (1-\alpha)\lambda \left(\frac{w^N}{\alpha}\right)^{-\alpha/(1-\alpha)} . \tag{II.4}$$

II.2.2.2 Production by a Manufacturing Firm in the South

Whenever transaction occurs between a Northern headquarter and a manufacturer in the South, the contract stipulates the investment levels in contractible activities $m(s)$, $s \in [0, \mu]$, and the lump-sum transfer T. Overall, if non-contractible inputs are of good-quality, and

[12] Complete contracts are not subject to ex-post renegotiation since investment levels in headquarter h and complex manufacturing activities $m(s)$, $s \in (\mu, 1]$, are specified and can be controlled by a third party.

bargaining does not fail, revenues are given by $R = \lambda^{1-\alpha}\left(h/1-z\right)^{\alpha(1-z)} \cdot \left(m/z\right)^{\alpha z}$. Due to relationship-specificity, the inputs have no value outside the relationship and the outside option of every player is zero. Therefore, if bargainig fails, output is zero and so are revenues. Symmetric Nash bargaining gives each party its outside option plus one-half of the ex-post gains from the relationship (i.e. the difference between the sum of the player's payoff under trade and their sum under no trade). The payoffs of the headquarter firm and the manufacturer are therefore given by $0.5R$.[13] Since both parties do not capture the full surplus created by the relationship, this induces both parties to underinvest relative to a setting with Northern manufacturing and complete contracts. The game is solved by backwards induction. Rolling back in time, the headquarter and manufacturing firms first choose their investment levels in non-contractible activities. The firms' optimization problems are given by

$$\max_h \ 0.5\lambda^{1-\alpha}\left(\frac{h}{1-z}\right)^{(1-z)\alpha}\left(\frac{\exp\left(\int_0^1 \log m(s)ds\right)}{z}\right)^{z\alpha} - w^N h \tag{II.5}$$

$$\max_{\{m_s\}_\mu^1} 0.5\lambda^{1-\alpha}\left(\frac{h}{1-z}\right)^{(1-z)\alpha}\left(\frac{\exp(\int_0^1 \log m(s)ds)}{z}\right)^{z\alpha} - \Gamma w^S \int_\mu^1 m(s)ds, \tag{II.6}$$

subject to contractible investments $m(s)$, $s \in [0, \mu]$. The first order conditions can be simplified to describe the equilibrium investments

$$m(s) = \frac{z\alpha 0.5R}{w^S\Gamma}\ ,\ s \in (\mu, 1] \tag{II.7}$$

$$h = \frac{(1-z)\alpha 0.5R}{w^N}. \tag{II.8}$$

Obviously, larger costs of communication Γ create an additional distortion and reduce the amount of investment in complex activities of the manufacturing firm.

From there, the amount of revenues given contractible investment levels can be calculated and one can solve for investments in non-contractible activities on behalf of the headquarter

[13] Note that $0 + 0.5\,(R - 0 - 0) = 0.5R$.

h and the manufacturing firm $m(s)$ where $s \in (\mu, 1]$

$$m(s)^{1-\alpha(1-\mu z)} = \lambda^{1-\alpha} \alpha \xi_z^{\alpha} \left(\exp \left[\int_0^{\mu} \log m(s) ds \right] \right)^{\alpha z} \left(\frac{0.5(1-z)}{w^N} \right)^{\alpha(1-z)} \left(\frac{0.5z}{w^S \Gamma} \right)^{1-\alpha(1-z)} \tag{II.9}$$

$$h^{1-\alpha(1-\mu z)} = \lambda^{1-\alpha} \alpha \xi_z^{\alpha} \left(\exp \left[\int_0^{\mu} \log m(s) ds \right] \right)^{\alpha z} \left(\frac{0.5(1-z)}{w^N} \right)^{1-\alpha(1-\mu)z} \left(\frac{0.5z}{w^S \Gamma} \right)^{\alpha(1-\mu)z}. \tag{II.10}$$

Larger costs of communication Γ lower the investments in complex tasks of the manufacturing firm and reduce joint revenues. This gives rise to a negative feedback effect on headquarter activities which equally drop due to the presence of costly communication. The distortion created by costly information transmission declines with the range of basic activities μ and increases with the range of complex activities $(1-\mu)$. The contract offered by the headquarter needs to satisfy the manufacturer's participation constraint which is equal to

$$0.5R - w^S \int_0^{\mu} m(s) ds - w^S \Gamma \int_{\mu}^{1} m(s) ds + T \geq 0, \tag{II.11}$$

where non-contractible activities in the range $(1-\mu)$ are given by equation (II.9) and contractible investments h and $m(s)$, $s \in [0, \mu]$, are as specified in the contract. The headquarter in turn maximizes its payoff

$$0.5R - w^N h - T \ , \ s \in (\mu, 1]. \tag{II.12}$$

The transfer T is set such that the manufacturer exactly breaks even and its participation constraint is binding. For this reason, the optimization problem of the headquarter firm with respect to contractible manufacturing investments reduces to

$$\max_{\{m(s)\}_{\mu}^{1}} \pi = R - w^N h - w^S \int_0^{\mu} m(s)ds - w^S \Gamma \int_{\mu}^{1} m(s)ds. \qquad \text{(II.13)}$$

Combining this with non-contractible activities given in equation (II.9) and (II.10) one can solve for contractible investments on behalf of the manufacturing firm and derive profits. Profits of the headquarter are finally equal to

$$\pi^O = (1-\alpha)\lambda \left[\alpha^{\alpha} w_N^{-\alpha(1-z)} w_S^{-\alpha z} \Gamma^{-\alpha z(1-\mu)} \frac{0.5^{\alpha\theta} \left(1-\alpha 0.5\theta\right)^{(1-\alpha\theta)}}{\left(1-\alpha\theta\right)^{(1-\alpha\theta)}} \right]^{\frac{1}{1-\alpha}}, \qquad \text{(II.14)}$$

where $\theta = (1 - \mu z)$. Profits decline with less efficient information technology Γ. This effect is larger for more standardized production processes relying to a greater extent on efficient manufacturing and for intermediates containing a larger fraction of complex investments.

II.2.3 Information Technology and Offshoring

When deciding whether to produce in North or South, the headquarter firm has to trade off the benefits of free information transmission in North with the costly information transmission in South for a given wage differential between both regions. By comparing profits of Northern and Southern manufacturing it follows that the headquarter will decide to purchase the low-tech input in the South only if $\pi^S \geq \pi^N$ and $A(z, \mu, \Gamma) \leq \omega \equiv {}^{w^N}/_{w^S}$, where

$$\frac{w^N}{w^S} \geq \left(\frac{\left(1-\alpha\theta\right)^{(1-\alpha\theta)}}{0.5^{\alpha\theta} \left(1-\alpha 0.5\theta\right)^{(1-\alpha\theta)}} \right)^{\frac{1}{z}} \Gamma^{(1-\mu)} \equiv A(z, \mu, \Gamma). \qquad \text{(II.15)}$$

It can be shown that $A(z, \mu, \Gamma)$ is decreasing in the degree of standardization z with $\lim_{z\to 0} A(z, \mu, \Gamma) = +\infty$ and $A(1, \mu, \Gamma) > 1$. If wages in North are larger than in South $w^N > w^S$, a threshold level of standardization $\bar{z} \in (0, 1)$ arises: As long as $z < \bar{z} \equiv A^{-1}(\omega, \mu, \Gamma)$ final assembly is located in the North. If $z > \bar{z} \equiv A_O^{-1}(\omega, \mu, \Gamma)$ holds, final assembly takes place in the South. Hence, only when the final good is sufficiently standardized and the manufacturing stage sufficiently important in production, lower wages in the South are able to outweigh contractual frictions and communication costs.[14] Most importantly, the required wage differential $\omega \equiv \frac{w^N}{w^S}$ for a specific threshold level $\bar{z}$ of standardization increases with larger costs of communication Γ. This effect is stronger for final goods which exhibit a larger range of complex activities $m(s)$, $s \in (\mu, 1]$.

II.2.4 Information Technology and the Mode of Firm Organization

Given that the final good producer decides to produce in South, it may now integrate the manufacturing firm and engage in FDI. Consider the same setup as in the previous section. However, it is now assumed that communication costs do not arise in case of vertical integration whereas contracting with an independent manufacturer in South is subject to costly communication.[15] This assumption is meant to reflect that offshoring is connected with less efficient communication if the headquarter opts for outsourcing than in case of integration. This can be justified, as whenever production of intermediates occurs within the boundaries of the firm, the headquarter may fully exert control over the Southern manufacturer and thus align the modes of communication in North and South. It may for instance substitute managers in South by managers from North and improve the efficiency of knowledge transmission. Ownership dictates the residual rights of control over assets. As given in Antràs (2005), if the manager of the manufacturing plant refuses to trade after investments have been conducted, the headquarter manager may fire the manager in South and take possession of the amount of intermediates produced by the manufacturing plant. Failed bargaining is costly and firing the manufacturing manager is associated with a loss in the amount of the output produced equal to $(1-\delta)y$ with $\delta < 1$. The final good producer can then only generate sale revenues equal to $\delta^\alpha R$. This yields quasi rents given by $(1-\delta^\alpha)R$. Consequently, the headquarter firm chooses its optimal investment level with respect to anticipated revenues $0.5(1+\delta^\alpha)R$ whereas the manufacturing firm sets basic and complex investments with respect to $0.5(1-\delta^\alpha)R$. Accordingly, outsourcing provides the manufacturing firm with a larger share of the joint surplus ($0.5R > 0.5(1-\delta^\alpha)R$) for which reason it faces larger incen-

[14] Note that if wages were identical in North and South, manufacturing would always take place in North.

[15] See Defever and Toubal (2013) for recent research in international trade wich combines the incomplete contracting approach to the theory of the firm with similar key elements of the transaction cost approach by Williamson (1985).

tives to invest in the joint relationship than with integration. Therefore, ex ante efficiency requires to prefer outsourcing over integration whenever the manufacturing firm becomes relatively more important in the production process (i.e. z increases).[16] This however relates to additional distortions due to costly information transmission which in turn gives advantage to integration. Solving the game along the lines of section II.2.2 yields profits of the headquarter firm given by

$$\pi^{VI} = (1-\alpha)\,\lambda\left[\alpha^{\alpha} w_N^{-\alpha(1-z)} w_S^{-\alpha z}\frac{0.5^{\alpha\theta}\left(1-\delta^{\alpha}\right)^{\alpha(1-\mu)z}\left(1+\delta\right)^{\alpha(1-z)}\triangle^{(1-\alpha\theta)}}{\left(1-\alpha\theta\right)^{(1-\alpha\theta)}}\right]^{\frac{1}{1-\alpha}}, \qquad \text{(II.16)}$$

with $\triangle = \left[1-\alpha 0.5\left(\theta+\delta^{\alpha}\left(1-z\left(2-\mu\right)\right)\right)\right]$ and $\theta = (1-\mu z)$. Thus, the headquarter firm has to trade off the efficiency loss due to costly information transmission with the level of incentives provided to the manufacturing firm when choosing between integration and arm's-length contracting. The trade-off is governed by the relative importance of the manufacturing firm and the costs of information transmission. An increase in the relative importance of the manufacturer favors outsourcing whereas larger costs of information transmission promote integration. This effect is exacerbated by a wider range of complex activities. Considering the choice between offshoring via FDI and arm's-length contracting, it can be inferred that production of intermediates will take place in South within the boundaries of the firm whenever $\pi^{VI} > \pi^{O}$. This can also be written as

$$A^*(z,\mu,\Gamma) \equiv \left(\frac{\left(1-\delta^{\alpha}\right)^{\alpha z(1-\mu)}\left(1+\delta^{\alpha}\right)^{\alpha(1-z)}\triangle^{(1-\alpha\theta)}}{\left(1-\alpha 0.5\theta\right)^{(1-\alpha\theta)}}\right)^{\frac{1}{\alpha z}}\Gamma^{1-\mu} \geq 1. \qquad \text{(II.17)}$$

$A^*(z,\mu,\Gamma)$ is decreasing in the manufacturing intensity z with $\lim_{z\to 0} A^*(z,\mu,\Gamma) = +\infty$ and $A^*(1,\mu,\Gamma) > 1$ for all $z \in (0,1)$. Hence a cutoff $z^* \in (0,1)$ arises. Whenever $z < z^*$ the headquarter opts for integration. If the manufacturing firm is sufficiently important in the production process and $z > z^*$ the headquarter prefers outsourcing.

[16] The reverse pattern holds for the headquarter firm which faces a larger fraction of the joint surplus under integration compared to outsourcing $(0.5\left(1+\delta^{\alpha}\right)R > 0.5R)$. The headquarter firm therefore has larger incentives to invest if both parties integrate. Thus, ex ante efficiency implies that integration is preferred over outsourcing if the headquarter firm is relatively more important in the relationship (i.e. z is low).

II.2.5 Empirical Predictions

The impact of information technology in the partial equilibrium model has direct implications for the optimal sourcing strategies of industries. In the first instance firms offshore production in order to exploit differences in labor costs across countries. The model alludes that the overall pattern of offshoring might be affected by the necessity to transmit information between the headquarter in North and its manufacturing counterpart in South. Hence, by considering varying degrees of complexity across industries, the model illustrates how information technology leads to differential effects across industries which depend to a different extent on knowledge transmission.

Consider now the impact of information technology on the choice whether to source inputs in South in equation (II.15). Taking the derivatives of the log of the $A(z, \mu, \Gamma)$-curve with respect to communication costs Γ and the degree of complexity of the final good μ yields

$$\frac{\partial \ln A(z, \mu, \Gamma)}{\partial \Gamma} > 0 \ , \ \frac{\partial \ln A(z, \mu, \Gamma)}{\partial \Gamma \partial \mu} < 0. \qquad \text{(II.18)}$$

Hence, an increase in the costs of communication Γ shifts the $A(z, \mu, \Gamma)$-curve to the right as for any given relative wage $\frac{w^N}{w^S}$ industries shift production to the South only at a higher level of relative importance of the manufacturing firm z (i.e. a later stage of standardization). This effect is dampened, the larger the range of basic activities μ and the smaller the range of complex activities $(1 - \mu)$ in an industry. Overall, considering an increase in the costs of communication, the new equilibrium threshold level $\bar{z}$ at which offshoring occurs has increased. Considering the reverse case of more efficient information technology: A reduction in the cost of communication and coordination reduces the cutoff level $\bar{z}$ at which an industry offshores production to the South. More efficient information transmission alleviates contractual frictions in South and thereby permits international fragmentation of production at lower levels of manufacturing intensity z.[17] Figure A.1 depicts the impact of an increase in the efficiency of information technology $\Gamma' < \Gamma$ for a varying degree of product complexity

[17] An alternative interpretation would be that more efficient information technology allows for international fragmentation of production at an earlier stage of the life cycle of a product. Thus, advances in information technology shift comparative advantage in manufacturing from North to South and speed up the product cycle.

$\mu^{\circ} < \mu$ on the cutoff level $\overline{z}$ at which an industry starts to offshore production. A reduction in the costs of communication $\Gamma' < \Gamma$ shifts the $A(z, \mu, \Gamma)$-curve to the left and lowers the cutoff level $\bar{z}$. This effect however is stronger for the more complex industry characterized by a smaller fraction of contractible activities $\mu^{\circ} < \mu$. By emphasizing differences in complexity across industries and differences in information technology infrastructure across countries, the model can be used to derive a prediction about the geography of offshoring.

Prediction 1 *Industries are more likely to import inputs from a country with a higher level of information technology infrastructure. This effect is more pronounced for more complex industries.*

Turning towards the mode of firm organization, less sophisticated information technology increases the costs of outsourcing and favors vertical integration. Since costly communication applies only to the complex fraction of inputs, this effect drops with the level of basic activities μ and increases with the range of complex activities $(1 - \mu)$:

$$\frac{\partial \ln A^*(z, \mu, \Gamma)}{\partial \Gamma} > 0 \ , \quad \frac{\partial \ln A^*(z, \mu, \Gamma)}{\partial \Gamma \partial \mu} < 0. \tag{II.19}$$

Hence, the cutoff level of standardization z^* at which firms adapt their mode of organization increases and more firms purchase intermediate inputs within the boundaries of the firm. Figure A.2 displays the reverse case of an increase in the efficiency of information technology $\Gamma' < \Gamma$. More efficient information technology reduces the costs of outsourcing and shifts the $A^*(z, \mu, \Gamma)$-curve to the left. Thus, distortions created by information transmission are reduced for which reason outsourcing becomes the more viable mode of organization at even lower levels of importance of the manufacturing process z. Again, the effect is stronger for the more complex industry featuring a smaller fraction of contractible activities $\mu^{\circ} < \mu$ as a larger range of complex activities reinforces the distortions of costly communication. From there I can conclude:

Prediction 2 *Outsourcing is more likely to occur in countries with a higher level of information technology infrastructure. This effect is more pronounced for more complex industries.*

II.3 Empirical Evidence

This section first describes the data used to test the predictions of the model. Subsequently, I assess how information technology determines the geography of offshoring. Last, I estimate the impact of information technology on the sourcing mode. Several robustness checks are included within each of the empirical sections. Testing the empirical predictions requires in first instance data on North-South vertical offshoring, the degree of product complexity and the level of information technology.

II.3.1 Data Description

II.3.1.1 Global Sourcing

Estimations with respect to the geography of offshoring *(Prediction 1)* are based on trade data provided by the NBER.[18] This data provides a detailed documentation of the entire set of industries and countries exporting to the US up to the 10-digit level of the Harmonized System (HS). In order to focus on North-South trade and follow the setup of the model, I restrict the set of trading partners to countries located in the South, where I follow Romalis (2004) and define the South to be any country with per capita GDP (at PPP) lower than 50% of the US level in the year 2000. In addition, so as to measure vertical offshoring and trade in intermediates, I make use of the end-use classification established by the Bureau of Economic Analysis and drop all final goods and raw materials following Feenstra and Jensen (2012). The proxy variable to model the geography of offshoring is given by the number of intermediate goods per industry that a country exports to the US. This is because in the model *Prediction 1* and the geography of imports captures the extensive margin of offshoring. A good is defined as a 5-digit SITC category and an industry is classified by a 4-digit NAICS category.[19] The focus of the analysis is on the years 2002 - 2006.

[18]See Feenstra, Romalis, and Schott (2002).

[19]See Basco (2013) for recent research using a similar approach in order to quantify the number of imported goods by industry. In the econometric analysis industry fixed effects control for the fact that the number of goods may be varying in different industries.

Estimation of the impact of information technology on firm organization *(Prediction 2)* is based on related party trade data collected by the US Census Bureau. US cross-border shipments are required to report whether a transaction occurs between related parties such that the data covers almost the entire universe of related party shipments. The data reports both, the scale of related party (intra-firm) and non-related party (arm's-length) US imports. A related party transaction is defined as a transaction between two parties in which one owns at least 6% of the outstanding voting stock or shares of its counterpart. A shortcoming of the data is that it is not possible to infer whether the US importer is a US parent firm or a foreign-based affiliate. Nunn and Trefler (2013) investigate all headquarter-subsidiary pairs for global multinationals for which the headquarter firm or the subsidiary are from the US. They find that for a large range of countries the US can commonly be considered as the headquarter. Moreover, countries for which this turns out not to be the case are mostly developed countries. Therefore, once more I concentrate on North-South trade and drop all trading partners if per capita GDP (at PPP) is lower than 50% of the US level in the year 2000. I follow Nunn and Trefler (2008, 2013) and Bernard, Jensen, Redding, and Schott (2010) and compute the share of related party imports by industry and country to the US in order to measure the degree of vertical integration of the offshoring activities of an industry. Alternatively, for the purpose of further robustness tests, I construct a dummy variable which indicates whether the share of intra-firm trade is above the 90% percentile of the distribution. Estimation is again at the 4-digit NAICS level and for the years 2002 - 2006.

II.3.1.2 Country Variables

The level and efficiency of information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user derived from the ICT indicators database provided by the International Telecommunication Union (ITU). International internet bandwidth refers to the capacity that backbone operators provide to carry internet traffic. As such, the international bandwidth represents the maximum quantity of data transmission from a country to the rest of the world. An internet connection with a larger bandwidth can move a given amount of data much faster than an internet connection with a lower bandwidth.

Thus, countries with a higher international internet bandwidth (kbit/s) per internet user are characterized by a more efficient information technology infrastructure.[20] Table A.6 in the appendix presents the top and bottom 10 countries in information technology infrastructure in the data. In my robustness tests I also employ various alternative measures of information technology adoption. First of all, I rescale the level of international internet bandwidth (bit/s) with the population in order to account for country size. Moreover, I directly exploit the share of internet users per 100 people (ITU) as well as the number of secure internet servers per 1 million people (World Bank). While internet users provide extensive information about internet adoption in developing countries, secure servers protect data from unauthorized interception and reflect the security level of online transactions within the local information technology network.

I introduce several controls in order to take account of prior research on the determinants of offshoring. There is a considerable amount of research which studies the role of financial frictions on trade and investment. Carluccio and Fally (2012) study the impact of access to external finance on French multinationals and find evidence, that financial development provides comparative advantage in the supply of complex products and promotes arm's-length contracting relative to intra-firm imports. Similar evidence has been produced by Beck (2003) and Manova (2013) who demonstrate how financial frictions act as a source of comparative advantage and affect firms' export decisions at the micro-level. I follow the literature and concentrate on the share of financial resources provided to the private sector (i.e. loans, nonequity securities, trade credits) as a share of GDP. The variable is procured from the Global Financial Development Database provided by the World Bank.

Similarly, a related strand of literature emphasizes the quality of the contracting environment ('rule of law') as a further source of comparative advantage and determinant of multinationals' organization. Levchenko (2007) and Nunn (2007) find that the quality of a country's legal system provides comparative advantage in contract intensive industries. According to Antràs and Helpman (2008) judicial quality also affects the decision whether to integrate the foreign production facility. The measure for the rule of law is taken from Kauf-

[20]This approach is similar to Freund and Weinhold (2002, 2004) who use the number of top-level host domain names in order measure the adoption of information technology at the country level.

mann, Kraay, and Mastruzzi (2010). I also control for the level of intellectual property rights since firms might refrain from offshoring and outsourcing sensitive production processes in countries featuring little protection of intellectual property.[21] The index of patent protection is drawn from Ginarte and Park (1997, 2008).

Next, using data from Hall and Jones (1999) I take account of traditional trade theory and control for factor endowments as determinant of comparative advantage.[22] Moreover, in order to control for a country's degree of integration into global trade, I use the sum of imports and exports over GDP as measure of openness. Finally, the overall level of economic development is considered by the level of GDP per capita (at PPP). Both variables are drawn from the Word Development Indicators (World Bank).

II.3.1.3 Industry Variables

The measure for the costs of knowledge transmission and product complexity is based on task level data. Production processes that are based on more complicated activities (i.e. non-routine tasks) are subject to less codifiable information and exhibit higher costs of knowledge transmission between the headquarter and the manufacturing firm. Therefore, they rely to a larger extent on efficient information technology. In the model, more complex production processes being subject to more costly transmission of information, are reflected by non-contractible inputs. Information technology is supposed to ease knowledge transmission and to reduce the inefficiencies generated by contractual incompleteness. I follow the construction of task intensities by Oldenski (2012a,b). Raw data on tasks is taken from the Department of Labor's Occupational Information Network (O*NET) which comprises data on the importance of 277 worker and job characteristics in about 800 occupations. The O*NET data distinguishes between seven broad categories of worker and job characteristics given by abilities, interests, knowledge, skills, work activities, work context and work values. I follow Oldenski (2012a,b) and focus on work activities. So as to match the relevant task measures to the industry level trade data, I aggregate the raw O*NET scores up to the 4-digit NAICS level by combining them with employment data from the Occupational Employment Statis-

[21] See e.g. Ethier and Markusen (1996).
[22] See Romalis (2004) for recent evidence.

tics (OES) provided by the Bureau of Labor Statistics.[23] The importance of a task i in a sector s is given by

$$M_{is} = \sum_{o} \alpha_{so} \ell_{io}, \tag{II.20}$$

where o denotes occupations and α_{so} is the share of occupation o in an industry s. ℓ_{io} in turn measures the importance of task i in occupation o.[24] Summing over occupations for a given industry yields M_{is} which is an index for the unscaled importance score for a task i in industry s. Ultimately, each raw score is then divided by the sum of scores for each task. This results in an intensity measure for each task i in each industry s:

$$I_{is} = \frac{M_{is}}{\sum_i M_{is}}. \tag{II.21}$$

Since offshoring activities might likewise influence the task composition of industries, the measure is constructed for the year 2000 which precedes the panel data under investigation. Subsequently, I create a measure of complexity (i.e. non-routine intensity) by computing the average task intensity of 'analyzing data and information', 'developing objectives and strategies', 'interacting with computers', 'making decisions and solving problems', 'provide consultation and advice' and 'thinking creatively'. This procedure is akin to Oldenski (2012a,b). The basic idea is to capture tasks that are sufficiently complex such that they exhibit a low degree of codifiability and high costs of information transmission thereby making the use of information technology more valuable. In order to conduct further robustness checks I also construct a measure of routine intensity by building the average intensity of 'handling and moving objects', 'controlling machines and processes' and 'performing general physical activities'. Table A.7 in the appendix displays the correlations between the task intensities and the measures for complexity and routine intensity. As expected, the measures for routine intensive and non-routine intensive tasks are highly negatively correlated.

[23] The O*NET dataset and the occupational employment shares by the Bureau of Labor Statistics both use 6-digit Standard Occupational Classification (SOC) codes such that both datasources can be combined without concordance problems.

[24] ℓ_{io} is a $0-100$ score reported by O*NET in order to measure the importance of each task in each occupation. The data is derived from surveys of individuals in different occupations and normalized to a $0-100$ scale by the Bureau of Labor Statistics.

Moreover, I control for R&D intensity as additional proxy for product complexity. R&D intensity is given by R&D expenditures over sales and taken from Keller and Yeaple (2013). Additionally, I also employ a dummy variable indicating whether an industry represents a high-technology sector. The variable is derived from the Science and Engineering Indicators 2010 by the National Science Foundation and based on the intensity of high-technology employment within an industry. Furthermore, I include data on a sector's contract intensity as developed by Nunn (2007). The variable measures the importance of relationship-specific investments based on the proportion of inputs an industry processes which are not sold on markets or organized exchanges. Thus, an industry which uses a smaller fraction of inputs which are traded on markets exhibits a higher degree of relationship-specificity and is considered more contract intensive.[25]

Ultimately, I control for the skill and capital intensity of industries by using data from the NBER CES Manufacturing Industry Database. Skill intensity is defined as the share of non-production workers in total employment and capital intensity is measured as the capital stock per employee.

II.3.2 Information Technology and the Geography of Imports

II.3.2.1 Empirical Strategy and Results

Next, I turn towards the impact of information technology infrastructure on the location choice of Northern firms where to purchase intermediates in South. Following *Prediction 1*, industries are expected to prefer to source inputs from countries providing more sophisticated information technology infrastructure. This effect should increase with the level of product complexity. This implies a difference-in-differences approach.[26] The dependent variable is the number of goods imported to the US by a given industry from a specific country. For this reason I run a count data regression based on a negative binomial distribution. In contrast to the Poisson regression, the negative binomial regression allows for overdisper-

[25] I focus on the proportion of inputs of products that are not traded on organized exchanges (differentiated) but which might be reference priced based on the liberal classification of commodities into organized exchange, reference priced, and differentiated by Rauch (1999).

[26] This generalized difference-in-differences approach has been pioneered by Rajan and Zingales (1998).

sion and does not assume that the mean and variance coincide.[27] Moreover, I follow Allison and Waterman (2002) who recommend to estimate an unconditional negative binomial regression with dummy variables in order to take account of fixed effects.[28][29] This yields the following estimation equation

$$E\left[N_{cst}|\mathbf{X_{cst}}\right] = exp\left[\beta_1 \times complexity_s \times IT_{ct} + \mathbf{X'_{cst}}\gamma + \mu_s + \eta_{ct} + \varepsilon_{cst}\right]. \quad \text{(II.22)}$$

The number of goods N_{cst} imported from country c by industry s in year t is regressed on the interaction of sectoral product complexity $complexity_s$ and the level of information technology IT_{ct} reflected by the international internet bandwidth (kbit/s) per internet user in country c in year t. The focus of the empirical strategy is on the interaction terms. Therefore, I include country-year fixed effects η_{ct} that control for country characteristics in a given year that might affect sourcing activities by US industries. In addition, I also control for sector characteristics with sector fixed-effects μ_s. Hence, identification of the coefficient of interest β_1 is across industries and within countries for a given year. The fixed-effects capture the direct effects of the country and industry level variables for which reason the empirical strategy mainly requires to control for variables $\mathbf{X_{cst}}$ that might affect the level of international internet bandwidth (kbit/s) per internet user and that might likewise be correlated with the degree of complexity of industries. According to *Prediction 1*, if information technology influences the decision of firms where to source inputs, the number of imported goods should increase with the complexity of the industry. Thus, the coefficient of interest is expected to be positive. The regressions are based on standard erros which are clustered at the country level. Besides, taking logs on both sides of the estimation equation allows to interpret the coefficients as semi-elasticities.[30]

Table II.1 reports the estimation results. Column (1) presents the baseline equation: The

[27] The Poisson distribution can be considered as a particular case of the negative binomial distribution (see Cameron and Trivedi (2009), Ch. 20 for further explanation).

[28] Allison and Waterman (2002) find in their simulations that an unconditional negative binomial regression with dummy variables does not underestimate the standard errors and generate the "incidental parameters problem".

[29] This approach is similar to Carluccio and Fally (2012) who estimate the impact of financial development and product complexity on the number of multinationals which source intermediates from a specific country.

[30] Taking logs implies that the coefficients reflect the impact of the explanatory variables on the log of the expected number of imported goods.

	negative binomial regression				
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	**number of imported goods**				
$\text{complexity}_s * \text{IT}_{ct}$	0.0611***	0.0445**	0.0311*	0.0356**	0.0329**
	(0.0180)	(0.0175)	(0.0184)	(0.0144)	(0.0138)
$\text{R\&D int}_s * \text{fin devt}_{ct}$			-0.000211		
			(0.000835)		
$\text{high-tech}_s * \text{patent prot}_c$			0.137*		
			(0.0782)		
$\text{contract int}_s * \text{rule of law}_{ct}$			1.636**		
			(0.738)		
$\text{complexity}_s * \text{H/L}_c$				0.816*	
				(0.459)	
$\text{complexity}_s * \text{K/L}_c$				-0.00894	
				(0.0577)	
$\text{complexity}_s * \text{cgdp}_{ct}$					6.02e-06
					(7.00e-06)
$\text{complexity}_s * \text{openness}_{ct}$					0.00376***
					(0.000974)
$\text{skill int}_s * \text{H/L}_c$		1.122*	0.574	-0.584	0.442
		(0.642)	(0.809)	(1.190)	(0.733)
$\text{capital int}_s * \text{K/L}_c$		0.246	0.231	0.271	0.255
		(0.290)	(0.297)	(0.301)	(0.292)
alpha	0.0903	0.0877	0.0855	0.0877	0.0867
sector FE	yes	yes	yes	yes	yes
country-year FE	yes	yes	yes	yes	yes
Observations	10,014	9,573	9,276	9,573	9,556
log likelihood	-20,942	-20,128	-19,629	-20,119	-20,070
country clusters	86	76	68	76	76

Notes: Robust standard errors clustered by country. The dependent variable is the *number of imported goods*. The coefficient of interest is the interaction of complexity at the sector level $complexity_s$ and the level of information technology infrastructure at the country-year level IT_{ct}. Information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. Complexity is measured by the intensity in non-routine tasks by industry (see section II.3.1.3 for detailed explanations). For a definition of the covariates see Table A.10. *** p<0.01, ** p<0.05, * p<0.1

Table II.1: Prediction 1 - Impact of Information Technology and Complexity on the Geography of Imports international internet bandwith (kbit/s) per internet user is interacted with the measure of complexity which is given by the intensity in non-routine tasks by industry. Consistent with *Prediction 1*, the coefficient is positive and highly significant. Thus, firms relying to a larger extent on knowledge transmission are more likely to invest in countries with better information technology infrastructure. In the following regressions, I subsequently add several control variables which affect multinationals' sourcing decisions and might be correlated with both, the level of information technology as well as complexity. In column (2) I start with capital and skill endowments which are interacted with capital and skill intensity in order to control for Heckscher-Ohlin effects. This results in a drop in the size of the coefficient of interest which nevertheless remains highly significant. Consistent with traditional trade theory, the interaction of skill intensity and skill endowment is positive and significant. This however is not the case for the capital endowment and capital intensity interaction. Further control variables in column (3) include interactions of financial development and the protection of intellectual property rights with R&D intensity and the technology indicator while the rule of law is interacted with contract intensity. These interactions are included because several studies on institutions and trade have stressed the importance of financial development and judicial quality as sources of comparative advantage in R&D and contract intensive industries.[31] Moreover, prior research has emphasized the quality of intellectual property rights as determinant of FDI flows in industrial sectors being sensitive to the protection of intellectual property.[32] The coefficient of interest remains stable in size and significant. Overall, the control variables are in line with economic theory. The interactions of patent protection and the high-technology dummy as well as the interaction of the rule of law and contract intensity are both positive and significant. Hence, these results are in line with previous studies on institution driven comparative advantage. Information technology infrastructure however might be determined by both, a country's skill and capital endowment. In order to take account of this relationship I control for the interactions of skill as well as capital endowment and my measure for complexity in column (4). The coefficient of inter-

[31]See e.g. Beck (2003), Berkowitz, Moenius, and Pistor (2006), Nunn (2007), Levchenko (2007) and Carluccio and Fally (2012).

[32]See e.g. Javorcik (2004), Branstetter, Fisman, Foley, and Saggi (2011) and Bilir (2014).

est is stable in size and remains significant at the 5% level. The skill endowment interaction is likewise positive and significant, whereas this is not the case for the capital endowment interaction. Ultimately, I aim to control for the overall level of economic development and for a country's integration in the world economy. Therefore I include per capita GDP and openness and interact both measures with product complexity in column (5). The two variables are positively correlated with the international internet bandwidth (kbit/s) per internet user. The additional interaction term based on openness is positive and significant. Most importantly however, the main coefficient for information technology remains unaffected, robust and significant.[33]

The empirical strategy might nevertheless create doubts on the direction of causality. An argument that could be advanced is that US sourcing activities might trigger economic growth which might drive demand for more sophisticated information technology. Similarly, foreign firms might have an incentive to lobby for improvements in local information technology infrastructure. These effects might be systematically driven by complex industries which rely to a larger extent on efficient information transmission. Following this reasoning, the estimated coefficient of interest might therefore be subject to an upward bias induced by reverse causality. The sign of the coefficient would however still be correct and in line with the empirical prediction. Nevertheless, if demand for information technology adoption is independent from sector specific product complexity, these effects are captured by the country-year fixed effects and the coefficient of interest can be interpreted as causal.

Considering the size of the effect of information technology, I compare two industries that differ in one standard deviation in terms of complexity (i.e. intensity in non-routine tasks). Based on the coefficient in column (2), I then calculate the differential effect of a one standard deviation change in information technology (i.e. international internet bandwidth (kbit/s) per internet user) on the number of imported goods. This results in a differential effect of about 2,35%. This appears to be a noticeable effect, given that the effect of skill endowment with respect to industries that differ by one standard deviation in skill intensity

[33] Throughout all specifications, the estimated overdispersion parameter *alpha* is about 0.08 and the likelihood-ratio test for $alpha = 0$ is rejected. This implies that the variance of the residuals is larger than the mean and the residuals do not follow a Poisson distribution.

is about 3,02%.

II.3.2.2 Robustness

I perform different robustness checks to test the validity of the results. In Table A.1, I estimate the baseline specification with alternative OLS regressions where the dependent variable is the logarithm of the number of imported inputs. Additionally, standard errors are now two-way clustered at the country and sector level. Results indicate that the coefficient of interest remains unaffected. Finally, in order to check that results are not sensitive to outliers, I restrict the sample to the 75% percentile of the distribution of the number of imported goods. This amounts to restricting the maximum number of imported inputs to 6 imported goods. I obtain significant coefficients that are smaller than those in the full sample, reducing the concern of industry-country combinations importing a larger number of inputs driving the results (see Table A.2). Table A.3 presents various additional specifications based on the negative binomial regression. First of all, in columns (1) to (3) I control for the interaction of institutional determinants and the measure for complexity. The coefficient of interest remains positive and significant. Afterwards I substitute the complexity measure with routine intensity. Following *Prediction 1*, the number of imported goods increases with the level of information technology for more complex inputs. Consequently, the effect of information technology is expected to decrease for industries that are more basic in nature as they rely to a lesser extent on information transmission. The coefficients in columns (4) and (5) are both negative. However, only the former is statistically significant. Finally, throughout columns (6) to (7) I use alternative measures of information technology given by the international internet bandwidth (bit/s), the amount of internet users as well as the amount of secure internet servers relative to the population. The regressions yield a positive and significant coefficient of interest. Altogether, the results confirm that the country of origin's level of information technology is strongly correlated with the number of imported inputs in complex industries compared to basic industries.

II.3.3 Information Technology and the Mode of Organization

II.3.3.1 Empirical Strategy and Results

So far, I have tested *Prediction 1* by analyzing the impact of information technology and the complexity of traded intermediates on the number of imported inputs. I now turn towards *Prediction 2* and the effect of information technology on the optimal mode of organization. *Prediction 2* states that more efficient information technology should lead to a larger fraction of arm's-length contracting compared to FDI, with the effect being larger for more complex industries. The dependent variable is therefore now given by the share of intra-firm trade by industry and country in order to measure the optimal organizational mode of an industry. Again, the empirical strategy follows the difference-in-differences approach taken in the previous section. This allows once more to focus on the interaction terms and to control for all unobserved sector characteristics and country characteristics that vary across years by means of fixed effects. The estimation equation is now given by

$$IntraShare_{cst} = \beta_2 \times complexity_s \times IT_{ct} + \mathbf{X'_{cst}}\gamma + \mu_s + \eta_{ct} + \varepsilon_{cst}, \qquad \text{(II.23)}$$

where $IntraShare_{cst}$ reflects the share of intra-firm trade, $complexity_s$ denotes the measure of complexity (i.e. intensity in non-routine tasks) and IT_{ct} is the level of information technology represented by the international internet bandwidth (kbit/s) per internet user. In addition, the specification employs sector and country-year fixed effects μ_s and η_{ct} and controls for observable factors $\mathbf{X_{cst}}$ that might have an impact on information technology and product complexity as well as the share of intra-firm trade. Hence, identification is again based on variation across industries within countries for a given year. Following *Prediction 2*, the coefficient of interest β_2 is expected to be negative: Higher levels of information technology resolve contractual frictions in arm's-length relationships by reducing the inefficiencies due to imperfect knowledge transfer and raise the amount of market transactions. The effect is supposed to increase with the complexity of industries. All regressions are based on robust standard errors which are corrected for clusters by sector as well as by country-year combination.

	OLS				
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	**share of intra-firm trade**				
complexity$_s$ * IT$_{ct}$	-0.0205***	-0.0206***	-0.0167*	-0.0194***	-0.0245***
	(0.00705)	(0.00708)	(0.00842)	(0.00714)	(0.00819)
R&D int$_s$ * fin devt$_{ct}$		-0.000427*			
		(0.000220)			
high-tech$_s$ * patent prot$_c$			-0.0443		
			(0.0414)		
R&D int$_s$ * rule of law$_{ct}$			0.211***		
			(0.0330)		
contract int$_s$ * rule of law$_{ct}$			-0.226		
			(0.141)		
capital$_s$ * IT$_{ct}$				-0.0237	
				(0.0201)	
capital int$_s$ * rule of law$_{ct}$				0.370**	
				(0.165)	
complexity$_s$ * openness$_{ct}$					0.00107**
					(0.000416)
complexity$_s$ * cgdp$_{ct}$					2.40e-06
					(4.09e-06)
skill int$_s$ * H/L$_c$	0.121	0.129	0.190	0.104	-0.0589
	(0.165)	(0.166)	(0.234)	(0.163)	(0.194)
capital int$_s$ * K/L$_c$	-0.0165	-0.0168	-0.0417	-0.0232	-0.0178
	(0.0299)	(0.0302)	(0.0410)	(0.0268)	(0.0301)
sector FE	yes	yes	yes	yes	yes
country-year FE	yes	yes	yes	yes	yes
Observations	10,926	10,926	7,043	10,926	10,915
R-squared	0.286	0.287	0.320	0.287	0.289
sector clusters	85	85	85	85	85
country-year clusters	314	314	192	314	313

Notes: Robust standard errors two-way clustered by sector and country-year. The dependent variable is the *share of intra-firm trade*. The coefficient of interest is the interaction of complexity at the sector level $complexity_s$ and the level of information technology infrastructure at the country-year level IT_{ct}. Information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. Complexity is measured by the intensity in non-routine tasks by industry (see section II.3.1.3 for detailed explanations). For a definition of the covariates see Table A.10. *** p<0.01, ** p<0.05, * p<0.1

Table II.2: Prediction 2 - Impact of Information Technology and Complexity on the Sourcing Mode

Results are presented in Table II.2. As before, the coefficient of interest is the interaction of information technology and product complexity. The coefficient in column (1) is negative and significant. Moreover, the coefficient is robust to the inclusion of the full set of sector and country-year fixed effects as well as to controls for traditional determinants of comparative advantage given by the interaction of relative factor endowments and factor intensities. Hence, a higher level of information technology in the country of origin reduces the share of related party imports. The relationship is stronger in more complex industries relying to a larger extent on efficient codification and transmission of information. In column (2) I add the interaction of R&D intensity and financial development. The main coefficient of interest remains negative and significant. Besides, the additional control variable is negative and significant and in line with Carluccio and Fally (2012) who find that R&D intensive inputs are more likely to be traded intra-firm from countries with a lower level of financial development. Subsequently, I add controls for further institutional determinants in column (3) by including interactions of the technology indicator, R&D and contract intensity and the level of patent protection and the quality of the legal system. The enforcement of intellectual property rights might drive firms' decisions whether to outsource or integrate if they are subject to technological imitation. Next, firms' organizational decisions might be affected by the quality level of the judicial system. My coefficient of interest reduces in size and loses some of its statistical significance while the number of observations in the estimation drops considerably. Nevertheless, the coefficient remains negative and statistically different from zero in line with *Prediction 2*. The coefficients of patent protection and the interaction of contract intensity and the rule of law are insignificant. The interaction based on R&D intensity and the rule of law however is positive and significant which is in line with the idea of rule of law effects being larger in more contract dependent industries (see Antràs and Helpman (2008)). In column (4) I control for the interactions of capital intensity and information technology as well as the rule of law, respectively. Capital intensity is intended to reflect the headquarter intensity of the industry. The coefficient of interest is unaffected and stays negative and highly significant. This suggests, that the impact of information technology on the sourcing mode is not driven by the overall level of contract enforcement and further institutional determinants. In a final step, I add controls in order to account for the degree of openness of the country of origin and its level of economic development. My main coefficient of interest is again robust to the controls and shows up negative in line with *Prediction 2*.

As in section II.3.2.1 my estimation results might suffer from reverse causality. The share of goods purchased from integrated suppliers by multinational firms might systematically affect the level of information technology adoption where the effect might be induced by more complex industries that are more dependent on sophisticated information technology infrastructure. Nevertheless, it is a priori not clear by what mechanism this might take place for which reason the direction of the potential reverse causality bias is not obvious.

Based on the coefficient in column (1) and a comparison of two industries that differ in one standard deviation in their level of complexity, a one standard deviation increase in information technology creates a negative differential effect of about $1,11$ percentage points in the share of intra-firm trade.

II.3.3.2 Robustness

I engage in various robustness tests to evaluate the validity of the results (see Table A.4). First, I replace the sectoral degree of product complexity with routine intensity. More routine intensive industries are less dependent on efficient information transmission. In this regard, *Prediction 2* implies a positive coefficient of interest. Throughout columns (1) to (3) I control for Heckscher-Ohlin effects as well as institutional determinants. Across all specifications, the new coefficient of interest is positive and significant. Thus, information technology reduces the share of intra-firm trade with a less pronounced effect for routine intensive industries. In columns (4) and (5) I resort again to my main measure of complexity and control directly for the interaction of complexity and institutional determinants. Sign and significance of the main coefficient are unaffected. A possible problem of the estimations so far might be that the dependent variable is given by a share that is bounded between zero and one. Therefore, in column (6) the dependent variable is replaced with a dummy variable indicating whether the share of intra-firm trade is above the 90% percentile of the distribution in order to estimate a linear probability model. Again, the main result is stable showing a negative and significant coefficient of interest.[34]

II.4 Conclusion

This paper studies the impact of the advances in information technology on the global sourcing decisions of multinationals. While previous research has found large spatial barriers to knowledge transmission across borders, the impact of the digitization of the business world on the global supply chain has received only little attention.

In order to guide the empirical analysis, I provide a model based on the product cycle theory by Antràs (2005) which illustrates the impact of information technology on the geography of offshoring and the sourcing mode. More sophisticated information technology allows more efficient knowledge transmission between the headquarter firm in North and its supplier in South by alleviating contractual distortions. Overall, imperfect information transmission induces larger disruptions in the production process of more complex industries. This yields two predictions. Firstly, industries which are more intensive in complex and non-routine intensive activities are more likely to offshore parts of their production process to countries with high levels in information technology infrastructure. Secondly, information technology is expected to reduce the share of intra-firm trade with the effect being larger for more knowledge intensive industries. The paper provides empirical evidence in support of these hypotheses by combining data on the number of imported goods and the share of intra-firm imports with data on the international internet bandwidth by country and the intensity in non-routine production activities by industry. The measure of sectoral complexity and non-routine intensity is based on data at the occupational level. The empirical strategy concentrates on the identification of the interaction of information technology and product complexity which allows making use of a generalized difference-in-differences approach with fixed effects along the industry and country-year dimension. Econometric results are in line with the empirical predictions. US firms find it more profitable to offshore the production of complex intermediates to Southern countries with higher levels of information technol-

[34]Replacing the share of intra-firm trade in the baseline regression in Table II.2 with the integration indicator as dependent variable yields a negative and significant coefficient of interest throughout all specifications.

ogy infrastructure. In equal measure, information technology creates incentives to engage in arm's-length contracting with the relationship being stronger in more complex industries. Estimates suggest that a one standard deviation change in information technology yields a differential effect of about $2,35\%$ in the number of imported intermediates and a differential reduction of about 1.11 percentage points in the share of intra-firm trade when comparing two industries that differ by one standard deviation in terms of product complexity. The econometric estimates remain persistent in the presence of alternative determinants of the patterns of global sourcing and firm organization such as factor endowments, institutions and economic development.

Altogether, the paper highlights the effects of information technology adoption for the patterns of trade and the mode of firm organization along the global supply chain. Prior research has primarily hinted to the importance of skill endowments as well as contracting and financial institutions in shaping the location decisions of multinationals. Nevertheless, given that the development of human capital and trustworthy institutions takes a long time, the adoption of information technology might be a particularly viable economic policy for developing countries which lack these factors in order to attract knowledge intensive foreign investment and outsourcing.

A Appendix

A.1 Figures and Robustness

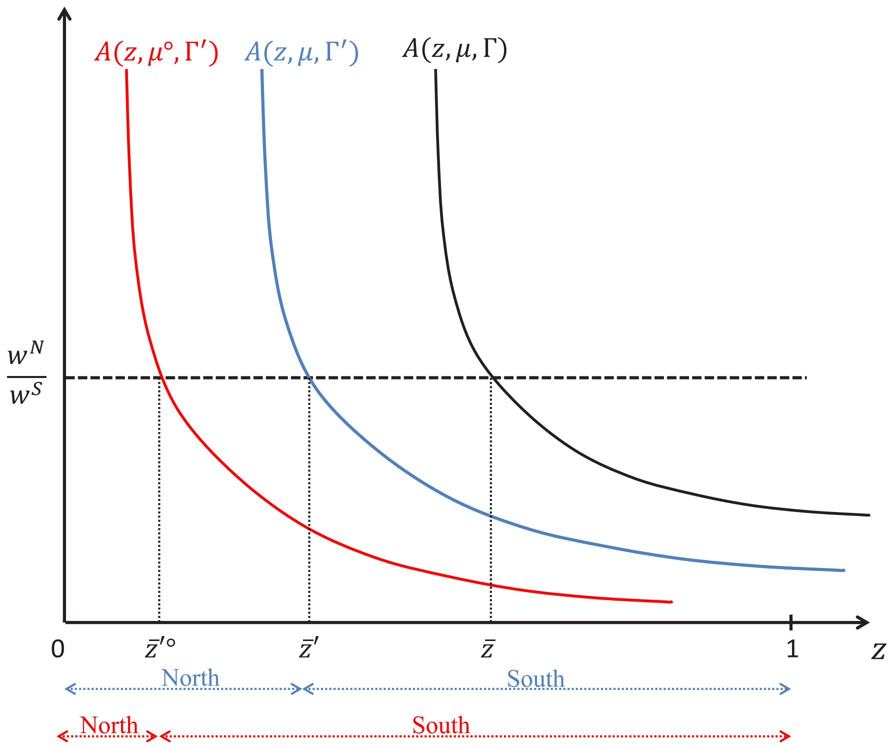


Figure A.1: The Impact of Information Technology on Offshoring

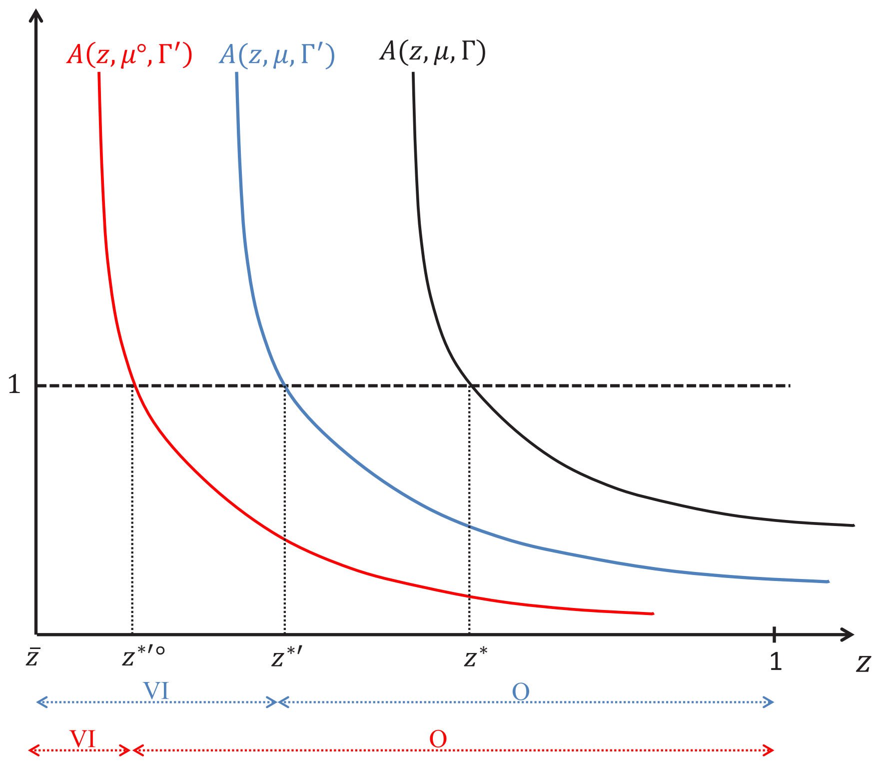


Figure A.2: The Impact of Information Technology on the Sourcing Mode

	OLS				
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	**log(number of imported goods)**				
$complexity_s$ * IT_{ct}	0.0615***	0.0550***	0.0414**	0.0401***	0.0361***
	(0.0167)	(0.0164)	(0.0173)	(0.0108)	(0.0126)
R&D int_s * fin $devt_{ct}$			0.000130		
			(0.000560)		
high-$tech_s$ * patent $prot_c$			0.125		
			(0.0935)		
contract int_s * rule of law_{ct}			2.013***		
			(0.692)		
$complexity_s$ * H/L_c				1.075**	
				(0.506)	
$complexity_s$ * K/L_c				0.00791	
				(0.0447)	
$complexity_s$ *$cgdp_{ct}$					1.57e-05
					(1.15e-05)
$complexity_s$ * $openness_{ct}$					0.00344***
					(0.00127)
skill int_s * H/L_c		0.264	-0.372	-2.171	-0.609
		(0.892)	(0.747)	(1.547)	(0.836)
capital int_s * K/L_c		0.421*	0.438**	0.452*	0.431*
		(0.232)	(0.211)	(0.234)	(0.229)
sector FE	yes	yes	yes	yes	yes
country-year FE	yes	yes	yes	yes	yes
Observations	10,007	9,566	9,270	9,566	9,549
R-squared	0.716	0.725	0.733	0.727	0.728
sector clusters	73	73	73	73	73
country clusters	85	75	67	75	75

Notes: Robust standard errors two-way clustered by sector and country. The dependent variable is the natural log of the *number of imported goods*. The coefficient of interest is the interaction of complexity at the sector level $complexity_s$ and the level of information technology infrastructure at the country-year level IT_{ct}. Information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. Complexity is measured by the intensity in non-routine tasks by industry (see section II.3.1.3 for detailed explanations). For a definition of the covariates see Table A.10. *** p<0.01, ** p<0.05, * p<0.1

Table A.1: Prediction 1 - Impact of Information Technology and Complexity on the Geography of Imports. Robustness Check 1 - OLS Regression

	OLS				
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	**log(number of imported goods)**				
$complexity_s * IT_{ct}$	0.0442***	0.0356***	0.0278**	0.0264**	0.0218*
	(0.0126)	(0.0132)	(0.0132)	(0.0110)	(0.0115)
$R\&D\ int_s * fin\ devt_{ct}$			0.000515		
			(0.000529)		
$high\text{-}tech_s * patent\ prot_c$			0.102		
			(0.0650)		
$contract\ int_s * rule\ of\ law_{ct}$			0.956**		
			(0.458)		
$complexity_s * H/L_c$				0.517	
				(0.370)	
$complexity_s * K/L_c$				0.0228	
				(0.0348)	
$complexity_s * cgdp_{ct}$					1.51e-05*
					(8.09e-06)
$complexity_s * openness_{ct}$					0.00158**
					(0.000726)
$skill\ int_s * H/L_c$		0.598	0.0384	-0.729	-0.0438
		(0.461)	(0.502)	(0.945)	(0.488)
$capital\ int_s * K/L_c$		0.122	0.118	0.135	0.128
		(0.0826)	(0.0776)	(0.0811)	(0.0796)
sector FE	yes	yes	yes	yes	yes
country-year FE	yes	yes	yes	yes	yes
Observations	7,582	7,185	6,891	7,185	7,168
R-squared	0.472	0.479	0.486	0.480	0.483
sector clusters	73	73	73	73	73
country clusters	85	75	67	75	75

Notes: Robust standard errors two-way clustered by sector and country. The dependent variable is the natural log of the *number of imported goods* which is restricted to the 75% percentile of the distribution (i.e. 6 imported goods). The coefficient of interest is the interaction of complexity at the sector level $complexity_s$ and the level of information technology infrastructure at the country-year level IT_{ct}. Information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. Complexity is measured by the intensity in non-routine tasks by industry (see section II.3.1.3 for detailed explanations). For a definition of the covariates see Table A.10. *** p<0.01, ** p<0.05, * p<0.1

Table A.2: Prediction 1 - Impact of Information Technology and Complexity on the Geography of Imports. Robustness Check 2 - Number of Imported Goods Restricted to the 75% Percentile. OLS Regression

	negative binomial regression							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	**number of imported goods**							
Measure of IT:	*bandwith per internet user*					*bandwidth per capita*	*internet users*	*secure servers*
complexity$_s$ * IT$_{ct}$	0.0469**	0.0316*	0.0333*			1.513***	0.00665**	0.00372***
	(0.0196)	(0.0169)	(0.0173)			(0.477)	(0.00321)	(0.000997)
routine int$_s$ * IT$_{ct}$				-0.0152**	-0.00688			
				(0.00599)	(0.00517)			
complexity$_s$ * fin devt$_{ct}$	0.00108							
	(0.00111)							
complexity$_s$ * patent prot$_c$		0.175**						
		(0.0839)						
complexity$_s$ * rule of law$_{ct}$			0.817**					
			(0.413)					
skill int$_s$ * H/L$_c$	0.961	0.784	0.585		1.348**	0.909	0.861	1.512**
	(0.733)	(0.797)	(0.791)		(0.645)	(0.702)	(0.720)	(0.620)
capital int$_s$ * K/L$_c$	0.247	0.236	0.249		0.239	0.248	0.258	0.191
	(0.290)	(0.292)	(0.292)		(0.290)	(0.292)	(0.272)	(0.293)
alpha	0.0877	0.0868	0.0874	0.0909	0.0880	0.0889	0.0890	0.0895
sector FE	yes	yes	yes	yes	yes	yes	yes	yes
country-year FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	9,565	9,284	9,573	10,014	9,573	9,644	10,056	7,852
log likelihood	-20,111	-19,668	-20,115	-20,954	-20,136	-20,276	-21,054	-16,630
country clusters	76	68	76	86	76	77	76	73

Notes: Robust standard errors clustered by country. The dependent variable is the *number of imported goods*. In columns (1) - (3) and (6) - (8) the coefficient of interest is the interaction of complexity at the sector level *complexity*$_s$ and the level of information technology infrastructure at the country-year level IT_{ct}. In columns (4) - (5) the coefficient of interest is based on routine intensity at the sector level *routine int*$_s$. Complexity and routine intensity are measured by the intensity in non-routine and routine tasks by industry (see section II.3.1.3 for detailed explanations). In columns (1) - (5) information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. In columns (6) - (9) the measure is replaced by the international internet bandwidth (kbit/s) per capita, the share of internet users per 100 people and the number of secure servers per 1 million people. For a definition of the covariates see Table A.10. *** p<0.01, ** p<0.05, * p<0.1

Table A.3: Prediction 1 - Impact of Information Technology and Complexity on the Geography of Imports. Robustness Check 3 - Routine Intensity, Institutions and Alternative Measures of Information Technology

	OLS					LPM
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	**share of intra-firm trade**					**integration**
routine int_s * IT_{ct}	0.00719***	0.00724***	0.00708**			
	(0.00242)	(0.00243)	(0.00292)			
$complexity_s$ * IT_{ct}				-0.0188***	-0.0181**	-0.0168**
				(0.00683)	(0.00846)	(0.00802)
R&D int_s * fin $devt_{ct}$		-0.000433*				
		(0.000220)				
$complexity_s$ * fin $devt_{ct}$				0.00107**		
				(0.000461)		
high-$tech_s$ * patent $prot_c$			-0.0420			
			(0.0415)			
$complexity_s$ * patent $prot_c$					-0.0864	
					(0.0565)	
R&D int_s * rule of law_{ct}			0.211***			
			(0.0339)			
contract int_s * rule of law_{ct}			-0.242*			
			(0.142)			
$complexity_s$ * rule of law_{ct}					0.389**	
					(0.150)	
skill int_s * H/L_c	0.129	0.138	0.221	-0.0104	0.0590	0.174
	(0.166)	(0.167)	(0.240)	(0.169)	(0.256)	(0.183)
capital int_s * K/L_c	-0.0122	-0.0124	-0.0371	-0.0172	-0.0446	0.00767
	(0.0297)	(0.0299)	(0.0407)	(0.0301)	(0.0398)	(0.0305)
sector FE	yes	yes	yes	yes	yes	yes
country-year FE	yes	yes	yes	yes	yes	yes
Observations	10,926	10,926	7,043	10,926	7,043	10,926
R-squared	0.286	0.287	0.320	0.288	0.321	0.148
sector clusters	85	85	85	85	85	85
country-year clusters	314	314	192	314	192	314

Notes: Robust standard errors two-way clustered by sector and country-year. In columns (1) - (5) the dependent variable is the *share of intra-firm trade*. In column (6) the dependent variable *integration* is a dummy variable indicating whether the share of intra-firm trade is above the 90%-percentile of the distribution. In columns (1) - (3) the coefficient of interest is the interaction of routine intensity at the sector level *routine* int_s and the level of information technology infrastructure at the country-year level IT_{ct}. In columns (4) - (6) the coefficient of interest is based on complexity at the sector level $complexity_s$. Complexity and routine intensiy are measured by the intensity in non-routine and routine tasks by industry (see section II.3.1.3 for detailed explanations). Information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. For a definition of the covariates see Table A.10. *** p<0.01, ** p<0.05, * p<0.1

Table A.4: Prediction 2 - The Impact of Information Technology and Complexity on the Sourcing Mode. Robustness Check: Routine Intensity, Institutions and Linear Probability Model

A.2 Data

Table A.5: List of Countries in the Data

Algeria	Czech Republic	Indonesia	Mozambique	South Africa
Bangladesh	Djibouti	Iran	Nepal	Sri Lanka
Barbados	Dominican Rep.	Iraq	Nicaragua	Suriname
Belize	Ecuador	Jamaica	Niger	Tanzania
Benin	Egypt	Jordan	Nigeria	Thailand
Bolivia	Ethiopia	Kenya	Pakistan	Togo
Brazil	Fiji	Korea (Rep. of)	Panama	Trinidad and Tobago
Bulgaria	Gabon	Lao P.D.R.	Paraguay	Tunisia
Burkina Faso	Gambia	Liberia	Peru	Turkey
Burundi	Ghana	Madagascar	Philippines	Uganda
Cameroon	Guatemala	Malawi	Poland	Uruguay
Chad	Guinea	Malaysia	Portugal	Venezuela
Chile	Guinea-Bissau	Mali	Romania	Yemen
China	Guyana	Mauritania	Rwanda	Zambia
Colombia	Haiti	Mauritius	Samoa	Zimbabwe
D.R. Congo	Honduras	Mexico	Senegal	
Costa Rica	Hungary	Mongolia	Seychelles	
Cote d'Ivoire	India	Morocco	Sierra Leone	

Table A.6: Top and Bottom 10 Countries in Information Technology Infrastructure

Top 10		Bottom 10	
country	IT	country	IT
Hungary	8.144	Guinea-Bissau	0.019
Czech Republic	8.045	Guinea	0.040
Jamaica	6.884	Congo D.R.	0.053
Djibouti	5.757	Zimbabwe	0.055
Portugal	3.918	Nigeria	0.068
Barbados	3.481	Chad	0.074
Panama	3.094	Zambia	0.085
Romania	2.819	Kenya	0.100
Chile	2.819	Pakistan	0.102
Colombia	2.787	Malawi	0.105

Notes: Information technology is given by the average *international internet bandwidth (kbit/s) per internet user* over the 2002 - 2006 period. Data is derived from the ICT indicators database by the International Telecommunication Union.

Table A.7: Correlations of Task Intensities

	analyze data	develop objectives	computers	solve problems	consultation	creativity	complexity	handle objects	control machines	physical activities	routine int
analyze data	1.00										
develop objectives	0.84	1.00									
	(0.00)										
computers	0.83	0.93	1.00								
	(0.00)	(0.00)									
solve problems	0.87	0.65	0.64	1.00							
	(0.00)	(0.00)	(0.00)								
consultation	0.82	0.93	0.96	0.67	1.00						
	(0.00)	(0.00)	(0.00)	(0.00)							
creativity	0.67	0.73	0.77	0.57	0.77	1.00					
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)						
complexity	0.91	0.95	0.97	0.77	0.97	0.84	1.00				
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)					
handle objects	-0.74	-0.88	-0.88	-0.57	-0.88	-0.61	-0.86	1.00			
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)				
control machines	-0.55	-0.84	-0.84	-0.36	-0.86	-0.61	-0.78	0.89	1.00		
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
physical activities	-0.80	-0.85	-0.89	-0.64	-0.88	-0.79	-0.91	0.88	0.77	1.00	
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)		
routine int	-0.74	-0.91	-0.92	-0.56	-0.92	-0.71	-0.90	0.98	0.93	0.94	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	

Notes: p-values in parentheses. For a detailed exposition of the construction of task intensities and measures of complexity and routine intensity see section II.3.1.3.

Table A.8: Top and and Bottom 10 Most and Least Complex Industries

Top 10 Most Complex Industries

NAICS 4-digit sector	description	complexity
3341	computer and peripheral equipment	2.901
3345	navigational, measuring, electromedical, and control instruments	2.850
3342	communications equipment	2.763
3364	aerospace product and parts	2.740
3344	semiconductor and other electronic component	2.676
3333	commercial and cervice industry machinery	2.583
3332	industrial machinery	2.581
3343	audio and video equipment	2.550
3254	pharmaceutical and medicine	2.520
3339	other general purpose machinery	2.472

Bottom 10 Least Complex Industrises

NAICS 4-digit sector	description	complexity
3116	animal slaughtering and processing	1.326
3273	cement and concrete product manufacturing	1.564
3211	sawmills and wood preservation	1.719
3115	dairy product manufacturing	1.733
3131	fiber, yarn, and thread mills	1.754
3114	fruit and vegetable preserving and specialty food manufacturing	1.767
3274	lime and gypsum product manufacturing	1.792
3222	converted paper product manufacturing	1.797
3122	tobacco manufacturing	1.807
3119	other food manufacturing	1.811

Notes: Complexity is measured by the intensity in non-routine tasks by industry. See section II.3.1.3 for detailed explanations on the construction of task intensities and the measure for complexity.

Table A.9: Summary Statistics

variable	**observations**	**mean**	**min**	**max**	**std. dev.**
global sourcing					
number of imported goods$_{cst}$	10682	6.123104	1	213	12.28056
log(number of imported goods)$_{cst}$	10682	1.097822	0	5.361292	1.067945
share of intra-firm trade$_{cst}$	11902	0.2746167	0.0000196	0.9997116	0.2813905
integration indicator$_{cst}$	11902	0.0999832	0	1	0.2999902
country level					
int'l internet bandwidth (kbit/s) per internet user$_{ct}$	391	1.071124	0.0023679	12.48208	1.732975
int'l internet bandwidth (bit/s) per capita$_{ct}$	402	0.0175254	4.50E-06	0.4671284	0.0496992
share of internet users per 100 people$_{ct}$	420	9.057331	0.0310112	78.1	12.69666
secure servers per 1 million people$_{ct}$	291	17.15283	0.0071846	520.0945	55.04144
financial development$_{ct}$	427	32.90474	0.7735366	163.369	31.35263
rule of law$_{ct}$	433	0.4154873	0.118	0.79	0.1442786
openness$_{ct}$	427	77.23927	21.67383	290.4993	39.01523
per capita gdp$_{ct}$	433	6208.162	405.4827	27044.03	5544.011
patent protection$_{c}$	74	3.124324	1.78	4.54	0.7115526
H/L$_{c}$	77	0.482419	0.07236	1.127	0.2397439
K/L$_{c}$	77	8.663346	5.76262	10.66226	1.362734
sector level					
complexity$_{s}$	73	2.09736	1.32669	2.901543	0.3050399
routine int$_{s}$	73	4.500416	2.254529	6.621832	0.836662
R&D int$_{s}$	73	0.0588022	0	2.665776	0.312024
high-tech$_{s}$	73	0.260274	0	1	0.4418206
contract intensity$_{s}$	73	0.8546387	0.0959204	0.9995984	0.1862124
skill int$_{s}$	73	0.2799016	0.0969529	0.6265237	0.1124233
capital int$_{s}$	73	0.140219	0.0155472	0.8833231	0.1412792

Table A.10: Variable Descriptions and Data Sources

variables	**descriptions and sources**
number of imported goods$_{cst}$	Number of 5-digit SITC products by 4-digit NAICS industry which are imported to the US. Raw materials and final goods are dropped according to the end-use classification following Feenstra and Jensen (2012). The sample is based on countries that exhibit per capita GDP (at PPP) of less than 50% of the US level in the year 2000. Data is derived from the *NBER trade database*.
log(number of imported goods)$_{cst}$	Natural logarithm of the number of 5-digit SITC products by 4-digit NAICS industry which are imported to the US. See above for further explanations.
share of intra-firm trade$_{cst}$	Share of related party transactions in both related and non-related party transactions of US imports at the 4-digit NAICS level. A related party transaction is defined as a transaction between two parties in which one owns at least 6% of the outstanding voting stock or shares of its counterpart. The sample is based on countries that exhibit per capita GDP (at PPP) of less than 50% of the US level in the year 2000. Data is from the *US Census Bureau*. For a discussion of the data see section II.3.1.1.
integration$_{cst}$	Dummy variable that indicates whether the share of intra-firm trade is above the 90% percentile of the distribution. See above for further explanations.
IT$_{ct}$	Information technology infrastructure is measured by the international internet bandwidth (kbit/s) per internet user. Alternative measures are the international internet bandwith (bit/s) per capita, the share of internet users per 100 people and the number of secure servers per 1 million people. Data for the first three measures is from the *ICT indicators database* by the *International Telecommunications Union (ITU)*. Data on secure servers is from the *World Development Indicators (World Bank)*.
financial development$_{ct}$	Domestic credit to the private sector by banks and other financial institutions as a share of GDP. Data is from the *Global Financial Development Database (World Bank)*.
rule of law$_{ct}$	Index of the quality of contract enforcement, the protection of property rights, the police, and the courts as well as the likelihood of crime and violence. Data is from the *Worldwide Governance Indicators 2013*.
openness$_{ct}$	Ratio of the sum of imports and exports over GDP taken from the *World Development Indicators (World Bank)*.
per capita gdp$_{ct}$	GDP per capita at PPP and current international Dollar taken from the *World Development Indicators (World Bank)*.
patent protection$_{c}$	Index of the protection of patent rights developed by Ginarte and Park (1997, 2008) for the year 2005.
H/L$_{c}$	Natural logarithm of human capital augmented labor relative to total labor which is based on estimations of the returns to schooling by Hall and Jones (1999) .
K/L$_{c}$	Natural logarithm of physical capital relative to total labor. See Hall and Jones (1999) for more detailed explanations.
complexity$_{s}$	Reflects the intensity in non-routine tasks by industry. Task intensities are contructed based on worker and job characteristics provided by the *Department of Labor's Occupational Information Network (O*NET)* for about 800 occupations. The task measures are aggregated to the 4-digit NAICS industry level by weighting them with employment shares from the *Occupational Employment Statistics (OES)* by the *Bureau of Labor Statistics*. Data is for the year 2000. *complexity*$_{s}$ is the average of selected tasks representing non-routine activities. See section II.3.1.3 for a detailed explanation.
routine intensity$_{s}$	Reflects the intensity in routine tasks by industry at the 4-digit NAICS level. Routine intensity is the average of selected tasks representing routine activities. See section II.3.1.3 and above for more detailed explanations.
R&D intensity$_{s}$	R&D expenditures over sales at the 4-digit NAICS level taken from Keller and Yeaple (2013). The measure is based on firm-level data from *COMPUSTAT*.
high-tech indicator$_{s}$	Dummy variable indicating whether a 4-digit NAICS sector represents a high-technology industry. Data is from the *Science and Engineering Indicators 2010* by the *National Science Foundation*. The classification is based on the intensity of high-technology empoyment within an industry. An industry is considered a high-technology industry if employment in technology-oriented occupations (scientific, engineering and technician occupations) accounts for a proportion of that industry's total employment that is more than twice the average for all industries.
contract intensity$_{s}$	Reflects the share of inputs that are relationship-specific. The measure is based on the proportion of inputs of products that are not traded on organized exchanges but which might be reference priced based on the liberal classification of commodities into organized exchange, reference priced, and differentiated by Rauch (1999). The data is aggregated to the 4-digit NAICS level by means of the BEA's input-output table on input use. See Nunn (2007) for a detailed exposition.
skill intensity$_{s}$	Share of non-production workers in total employment at the 4-digit NAICS level. Data is from the *NBER CES Manufacturing Industry Database*.
capital intensity$_{s}$	Capital stock per employee at the 4-digit NAICS level. Data is from the *NBER CES Manufacturing Industry Database*.

A.3 Theory

A.3.1 Profit Maximization with Manufacturing Firm in North

The headquarter firm's optimization problem is given by

$$\max_{h,m} \pi^N(z) = \lambda^{1-\alpha} \left(\frac{h}{1-z}\right)^{\alpha(1-z)} \left(\frac{m}{z}\right)^{\alpha z} - hw^N - mw^S. \tag{II.24}$$

From the first order conditions the optimal investment levels can be characterized by $\frac{h}{m} = \frac{1-z}{z}$. Plugging this back into the first order conditions, one can solve for the first best levels of investments in headquarter and manufacturing activities:

$$h = \left(\frac{\alpha\lambda}{w^N}\right)^{\frac{1}{1-\alpha}} (1-z) \tag{II.25}$$

$$m = \left(\frac{\alpha\lambda}{w^N}\right)^{\frac{1}{1-\alpha}} z. \tag{II.26}$$

Inserting the first best investment levels into the profit function given in equation (II.24) yields:

$$\pi^N = (1-\alpha)\,\lambda \left(\frac{w^N}{\alpha}\right)^{\frac{-\alpha}{1-\alpha}}. \tag{II.27}$$

A.3.2 Profit Maximization with Manufacturing Firm in South

Headquarter firm and manufacturing firm first choose their investment level in non-contractible activities h and $m(s)$, $s \in (\mu, 1]$:

Headquarter

$$\max_{h} \phi\lambda^{1-\alpha} \left(\frac{h}{1-z}\right)^{(1-z)\alpha} \left(\frac{\exp\left(\int_0^1 \log m(s)ds\right)}{z}\right)^{z\alpha} - w^N h \tag{II.28}$$

$$\frac{\partial}{\partial h} = (1-z)\alpha\phi h^{-1}\lambda^{1-\alpha}\left(\frac{h}{1-z}\right)^{(1-z)\alpha}\left(\frac{\exp\left(\int_0^1 \log m(s)ds\right)}{z}\right)^{z\alpha} - w^N = 0 \tag{II.29}$$

$$h = \frac{(1-z)\alpha\phi R}{w^N} \tag{II.30}$$

Manufacturer

$$\max_{\{m_s\}_\mu^1} (1-\phi)\lambda^{1-\alpha}\left(\frac{h}{1-z}\right)^{(1-z)\alpha}\left(\frac{\exp\left(\int_0^1 \log m(s)ds\right)}{z}\right)^{z\alpha} - \Gamma w^S \int_\mu^1 m(s)ds \tag{II.31}$$

$$\frac{\partial}{\partial m} = z\alpha(1-\phi)m(s)^{-1}\lambda^{1-\alpha}\left(\frac{h}{1-z}\right)^{(1-z)\alpha}\left(\frac{\exp\left(\int_0^1 \log m(s)ds\right)}{z}\right)^{z\alpha} - w^S\Gamma\ ,\ s \in (\mu, 1] \tag{II.32}$$

$$m(s) = \frac{z\alpha(1-\phi)R}{w^S\Gamma}\ ,\ s \in (\mu, 1]. \tag{II.33}$$

Plugging non-contractible headquarter and manufacturing activities into revenues R and solving for R yields:

$$R^{1-\alpha(1-\mu z)} = \lambda^{1-\alpha}\xi_z^\alpha\left(\frac{(1-z)\alpha\phi}{w^N}\right)^{(1-z)\alpha}\left(\exp\left[\int_0^\mu \log m(s)ds\right]\right)^{\alpha z}\left(\frac{(1-\phi)z\alpha}{w^S\Gamma}\right)^{(1-\mu)\alpha z}, \tag{II.34}$$

with $\xi_z^\alpha = (1-z)^{-(1-z)}z^{-z}$.

Solving for the level of non-contractible headquarter activities h:

Reinserting revenues R in the first order condition of headquarter acitivities gives

$$h^{1-\alpha(1-\mu z)} = \lambda^{1-\alpha}\alpha\zeta_z^{z\alpha}\left(\exp\left[\int_0^\mu \log m(s)ds\right]\right)^{\alpha z}\left(\frac{\phi(1-z)}{w^N}\right)^{1-\alpha(1-\mu)z}\left(\frac{(1-\phi)z}{w^S\Gamma}\right)^{\alpha(1-\mu)z}. \tag{II.35}$$

Solving for the level of non-contractible manufacturing activities m (s), s ∈ (¯, 1]:

Reinserting revenues R in the first order condition of manufacturing activities gives

$$m(s)^{1-\alpha(1-\mu z)} = \lambda^{1-\alpha}\alpha\zeta_z^{z\alpha}\left(\exp\left[\int_0^\mu \log m(s)ds\right]\right)^{\alpha z}\left(\frac{\phi(1-z)}{w^N}\right)^{\alpha(1-z)}\left(\frac{(1-\phi)z}{w^S\Gamma}\right)^{1-\alpha(1-z)}. \tag{II.36}$$

Solving for the level of contractible activities on behalf of the manufacturing firm:

The headquarter offers the manufacturing firm a contract that satisfies the participation constraint:

$$(1-\phi)R - w^S\int_0^\mu m(s)ds - w^S\Gamma\int_\mu^1 m(s)ds + T \geq 0. \tag{II.37}$$

The participation constraint is satisfied with equality and the final good producer chooses a contract that maximizes its payoff $\phi R - w^N h - T$:

$$\max_{\{m(s)\}_0^\mu} \pi = R - w^N h - w^S\int_0^\mu m(s)ds - w^S\Gamma\int_\mu^1 m(s)ds. \tag{II.38}$$

This can be rewritten as:

$$\max_{\{m(s)\}_0^\mu} \pi = R - w^N h - w^S\int_0^\mu m(s)ds - w^S\Gamma(1-\mu)m(s). \tag{II.39}$$

Plugging in the first order conditions characterizing non-contractible investments yields:

$$\max_{\{m(s)\}_0^{\mu}} \pi = [1-(1-z)\phi\alpha - z(1-\mu)(1-\phi)]\, R - w^S \int_0^{\mu} m(s)ds. \tag{II.40}$$

The first order condition of the profit maximization problem is given by:

$$\frac{\partial \pi}{\partial m(s)} = [1-(1-z)\phi\alpha - z(1-\mu)(1-\phi)]\, \frac{\partial R}{\partial m(s)} - w^S = 0\ ,\ s \in [0,\mu]\,, \tag{II.41}$$

where

$$\frac{\partial R}{\partial m(s)} = \frac{\alpha z}{1-\alpha(1-\mu z)} m(s)^{-1} R\ ,\ s \in [0,\mu]\,. \tag{II.42}$$

Contractible investments can then be expressed by:

$$m(s) = \frac{[1-\alpha\phi(1-z)-\alpha(1-\phi)(1-\mu)z]}{1-\alpha(1-\mu z)} \frac{\alpha z}{w^S} R. \tag{II.43}$$

Inserting revenues R from equation (II.34), solving for $m(s)$ with $s \in [0,\mu]$ and rearranging finally gives the level of contractible investments in manufacturing:

$$m(s) = \left\{ \frac{(1-\alpha\phi(1-z)-\alpha(1-\phi)(1-\mu)z}{1-\alpha(1-\mu z)} \right\}^{\frac{1-\alpha(1-\mu z)}{1-\alpha}} \left\{ \alpha\lambda^{1-\alpha}\xi_z^{\alpha} \left(\frac{\phi(1-z)}{w^N}\right)^{\alpha(1-z)} \left(\frac{(1-\phi)z}{w^S\Gamma}\right)^{\alpha(1-\mu)z} \right\}^{\frac{1}{1-\alpha}} \left(\frac{z}{w^S}\right)^{\frac{1-\alpha(1-\mu z)}{1-\alpha}}. \tag{II.44}$$

Solving for profits:

From equation (II.40) profits can be rewritten as

$$\pi = [1-(1-z)\phi\alpha - z\,(1-\mu)\,(1-\phi)]\, R - w^S \mu m(s)\ ,\ s \in [0,\mu]\,. \tag{II.45}$$

Plugging in contractible investments from equation (II.43):

$$\pi = (1-\alpha)\left(\frac{1-(1-z)\phi\alpha - z(1-\mu)(1-\phi)}{1-\alpha(1-\mu z)}\right)R. \tag{II.46}$$

Profits can now be derived by combining contractible investments from equation (II.44) with revenues R given by equation (II.34). Revenues R are then given by:

$$R = \lambda\alpha^{\frac{1}{1-\alpha}}(1-\phi)^{\frac{\alpha z(1-\mu)}{1-\alpha}}\phi^{\frac{\alpha(1-z)}{1-\alpha}}w_S^{\frac{-\alpha z(1-\mu)}{1-\alpha}}w_N^{\frac{-\alpha(1-z)}{1-\alpha}}\Gamma^{\frac{-\alpha z(1-\mu)}{1-\alpha}} \left[\frac{1-\alpha\phi(1-z)-\alpha(1-\mu)(1-\phi)z}{1-\alpha(1-\mu z)}\right]^{\left(\frac{\alpha(1-z)+\alpha z(1-\mu)}{(1-\alpha)(1-\alpha(1-\mu z))}\right)}. \tag{II.47}$$

Combining this with equation (II.46) and setting $\theta = (1-\mu z)$ finally yields:

$$\pi = (1-\alpha)\lambda\left[\alpha^{\alpha}w_N^{-\alpha(1-z)}w_S^{-\alpha z}\Gamma^{-\alpha z(1-\mu)} \frac{(1-\phi)^{\alpha(1-\mu)z}\phi^{\alpha(1-z)}\left(1-\alpha\phi(1-z)-\alpha(1-\mu)(1-\phi)z\right)^{(1-\alpha\theta)}}{(1-\alpha\theta)^{(1-\alpha\theta)}}\right]^{\frac{1}{1-\alpha}}. \tag{II.48}$$

Outsourcing:

- $\phi = 0.5$

$$\pi^{O} = (1-\alpha)\lambda\left[\alpha^{\alpha}w_N^{-\alpha(1-z)}w_S^{-\alpha z}\Gamma^{-\alpha z(1-\mu)}\frac{0.5^{\alpha\theta}\left(1-\alpha 0.5\theta\right)^{(1-\alpha\theta)}}{(1-\alpha\theta)^{(1-\alpha\theta)}}\right]^{\frac{1}{1-\alpha}}. \tag{II.49}$$

Vertical Integration:

- $\phi = 0.5\left(1+\delta^{\alpha}\right)$

$$\pi^{VI} = (1-\alpha)\,\lambda\left[\alpha^{\alpha}w_N^{-\alpha(1-z)}w_S^{-\alpha z}\frac{0.5^{\alpha\theta}\left(1-\delta^{\alpha}\right)^{\alpha(1-\mu)z}\left(1+\delta\right)^{\alpha(1-z)}\triangle^{(1-\alpha\theta)}}{(1-\alpha\theta)^{(1-\alpha\theta)}}\right]^{\frac{1}{1-\alpha}}, \tag{II.50}$$

with $\triangle = \left[1-\alpha 0.5\left(\theta+\delta^{\alpha}\left(1-z\left(2-\mu\right)\right)\right)\right]$.

A.3.3 Location Choice: The $A(z, \mu, \Gamma)$-curve

Comparing profits in North π^N and South π^S, production takes place in South if

$$\frac{\pi^N}{\pi^S} \leq 1, \tag{II.51}$$

which can be rearranged to get

$$\frac{w^N}{w^S} \geq \left(\frac{(1-\alpha\theta)^{(1-\alpha\theta)}}{0.5^{\alpha\theta}\,(1-\alpha 0.5\theta)^{(1-\alpha\theta)}} \right)^{\frac{1}{z}} \Gamma^{(1-\mu)} \equiv A(z,\mu,\Gamma). \tag{II.52}$$

$A(z, \mu, \Gamma)$ is a decreasing function of z since

$$\lim_{z\to 0} \left(\frac{(1-\alpha(1-\mu z)^{(1-\alpha(1-\mu z))}}{0.5^{\alpha(1-\mu z)}(1-\alpha 0.5\,(1-\mu z))^{(1-\alpha(1-\mu z))}} \right) = \frac{(1-\alpha)^{(1-\alpha)}}{0.5^{\alpha}\,(1-\alpha 0.5)^{(1-\alpha)}} > 1, \tag{II.53}$$

from where

$$\lim_{z\to 0} A(z,\mu,\Gamma) = +\infty, \tag{II.54}$$

follows. Moreover, note that

$$\begin{aligned} &\lim_{z\to 1} \left(\frac{(1-\alpha(1-\mu z)^{(1-\alpha(1-\mu z))}}{0.5^{\alpha(1-\mu z)}(1-\alpha 0.5\,(1-\mu z))^{(1-\alpha(1-\mu z))}} \right) \\ &= \frac{(1-\alpha\,(1-\mu))^{(1-\alpha(1-\mu))}}{0.5^{\alpha(1-\mu)}\,(1-\alpha 0.5\,(1-\mu))^{(1-\alpha(1-\mu))}} > 1 \end{aligned}, \tag{II.55}$$

for which reason

$$\lim_{z\to 1} A(z,\mu,\Gamma) = \left(\frac{(1-\alpha\,(1-\mu))^{(1-\alpha(1-\mu))}}{0.5^{\alpha(1-\mu)}\,(1-\alpha 0.5(1-\mu))^{(1-\alpha(1-\mu)}} \right) \Gamma^{1-\mu} > 1, \tag{II.56}$$

since $\Gamma > 1$. Most importantly, note that $f(b) = (1-ab)^{1-a}\, b^a$ is increasing in b for $b \in (0,1)$ and $a \in (0,1)$. Hence, the $A(z, \mu, \Gamma)$-curve is downwardsloaping. As long as the relative wage $\frac{w^N}{w^S}$ is large enough, a cutoff $\bar{z} \in (0,1)$ emerges such that for $z < \bar{z}$ profits with

Northern manufacturing are larger than profits with Southern manufacturing $\pi^N > \pi^S$. Thus, for any $z > \bar{z}$ manufacturing in South is more profitable $\pi^N < \pi^S$.

A.3.4 Mode of Organization: The $A^*(z, \mu, \Gamma)$-curve

Comparing profits with vertical integration and outsourcing, the headquarter firm opts for integration if

$$\frac{\pi^{VI}}{\pi^O} \geq 1, \tag{II.57}$$

which can be rearranged to obtain

$$A^*(z, \mu, \Gamma) \equiv \left(\frac{(1-\delta^\alpha)^{\alpha z(1-\mu)} (1+\delta^\alpha)^{\alpha(1-z)} \triangle^{(1-\alpha\theta)}}{(1-\alpha 0.5\theta)^{(1-\alpha\theta)}} \right)^{\frac{1}{\alpha z}} \Gamma^{1-\mu} \geq 1, \tag{II.58}$$

with $\triangle = [1 - \alpha 0.5 (\theta + \delta^\alpha (1 - z(2-\mu)))]$.

$A^\star(z, \mu, \Gamma)$ is a decreasing function of z since

$$\lim_{z\to 0} \frac{(1-\delta^\alpha)^{\alpha z(1-\mu)} (1+\delta^\alpha)^{\alpha(1-z)} [1-\alpha 0.5 (\theta + \delta^\alpha (1 - z(2-\mu)))]^{(1-\alpha\theta)}}{(1-\alpha 0.5\theta)^{(1-\alpha\theta)}} = \frac{(1+\delta^\alpha)^\alpha (1-\alpha 0.5 (1+\delta^\alpha))^{(1-\alpha)}}{(1-0.5\alpha)^{(1-\alpha)}} > 1, \tag{II.59}$$

which implies that

$$\lim_{z\to 0} A^*(z, \mu, \Gamma) = +\infty, \tag{II.60}$$

and

$$\lim_{z\to 1} \frac{(1-\delta^\alpha)^{\alpha z(1-\mu)} (1+\delta^\alpha)^{\alpha(1-z)} [1-\alpha 0.5 (\theta + \delta^\alpha (1 - z(2-\mu)))]^{(1-\alpha\theta)}}{(1-\alpha 0.5\theta)^{(1-\alpha\theta)}} = \frac{(1-\delta^\alpha)^{\alpha(1-\mu)} (1-\alpha 0.5 (1-\delta^\alpha)(1-\mu))^{(1-\alpha(1-\mu))}}{(1-\alpha 0.5 (1-\mu))^{(1-\alpha(1-\mu))}} < 1, \tag{II.61}$$

which implies that

$$\lim_{z\to 1} A^*(z,\mu,\Gamma) = \left(\frac{(1-\delta^{\alpha})^{\alpha(1-\mu)} \left(1-\alpha 0.5 \left(1-\delta^{\alpha}\right)(1-\mu)\right)^{(1-\alpha(1-\mu))}}{\left(1-\alpha 0.5 \left(1-\mu\right)\right)^{(1-\alpha(1-\mu))}} \right)^{\frac{1}{\alpha}} \Gamma^{1-\mu} < 1, \quad \text{(II.62)}$$

if Γ is not too large. Again, note that this is because $f(b) = (1-ab)^{1-a}\, b^{a}$ is increasing in b for $b \in (0,1)$ and $a \in (0,1)$. Hence, $\exists\, z \in (0,1)$ such that $\pi^{O}(z^*) = \pi^{VI}(z^*)$.

CHAPTER III

Import Competition and the Composition of Firm Investments

III.1 Introduction

Firms invest in expectation of some future benefits. A vigorous policy debate is in progress over the origins and consequences of short-term corporate behavior: when firms in the economy face short-term incentives and do not invest sufficiently long-term, into assets that pay off in distant future, this can be impedimental for economic growth. The literature has identified that credit crunches, uncertainty, investor pressures or agency problems can be causal for short-term investment behavior (see Aghion, Angeletos, Banerjee, and Manova (2010), Garicano and Steinwender (2016), Terry (2015), Garicano and Rayo (2016) and Bénabou and Tirole (2016)). In this paper, we put forward another reason for corporate short-termism: we argue that foreign competition can induce firms to distort investments away from assets that payoff in distant future towards short-term assets.

Falling trade barriers leading to a dramatic rise in international trade flows is a defining feature of the past century. The associated increase in competitive pressure from abroad can threaten domestic firms. When competition lowers future price-cost margins and thereby reduces the quasi-rents from durable investments, import competition might discourage long-

This chapter is joint work with Jan Schymik and Jan Tscheke.

term firm investments.

In this paper, we study how trade shocks affect the composition of firm investments with respect to durable and nondurable assets. We think that this investment composition matters due to three reasons. First, when firms do not sufficiently consider the long-term perspective when facing investment decisions but strongly react to short-term pressures, they might not fully exploit their growth potential in the long-run.[1] Second, when the amount of investment into nondurable assets increases, firms need to refinance more frequently as their assets deplete earlier. As a result, financing costs of firms increase. Third, changes in the investment composition due to trade shocks potentially affects the firm size distribution when investment responses are heterogeneous.

To guide our empirical analysis, we provide a simple model. We consider a firm in a two-period economy which engages in two types of investment: a short-term one and a long-term one. While short-term investments reduce production costs today and yield an immediate payoff, investments into more durable assets reduce future production costs and therefore pay off at a later point in time. When tougher competition from abroad reduces future price-cost margins, firms are incentivized to shift their investment expenditures towards nondurable investments. Furthermore, we show that firm heterogeneity matters for the relative size of this effect. Although tougher foreign competition shifts the composition of investments towards nondurable assets on average, larger firms are expected to respond less to competition shocks since they have more market power.

To estimate the effect of foreign competition on the investment composition inside firms, we use our model to derive a within-firm difference-in-differences estimator. Our model predicts that within a firm in a given year, tougher foreign competition should lead to a *relatively* larger reduction in long-term investments vis-à-vis short-term investments. We

[1] Hillary Clinton's US presidential election campaign is a prominent example for this policy debate about short-term corporate behavior. Creating stronger incentives for firms to plan for the long-run is part of the program of the Democratic Party for the upcoming legislative period: *"We need an economy where companies plan for the long run [...] - leading to higher productivity, better service, and larger profits."*, Hillary Clinton, 2016. Part of this debate also comes from business experts themselves. For example, Larry Fink, the CEO of the investment firm BlackRock stated: *"Over the past several years, I have written to the CEOs of leading companies urging resistance to the powerful forces of short-termism afflicting corporate behavior. Reducing these pressures and working instead to invest in long-term growth remains an issue of paramount importance for BlackRock's clients, most of whom are saving for retirement and other long-term goals, as well as for the entire global economy."*

use data for the population of stock listed manufacturing firms in the US between 1995 and 2009 to test this prediction. Using data on listed firms has two major advantages for our empirical analysis. First, listed firms disclose investment expenditures across different asset categories which differ in their durability. Similar to Garicano and Steinwender (2016), we exploit variation in durability across asset groups to distinguish between short- and long-term investments.[2] Second, we can use the volatility of each firms' stock returns within a given year to control for variation in the level of uncertainty that firms face.

With the data at hand, we estimate how changes in the sectoral degree of foreign competition lead to a shift of firms' investment composition. We find that between 1995 and 2009, firms became on average more short-term oriented when the level of sectoral import competition increased. Specifically, our estimates suggest that the average increase in import competition by 60% during our sample period has reduced the lifespan of firm assets by 72 days on average, which corresponds to 4.6% of the average asset lifespan. Presuming a refinancing rate of 3%, this would impose an additional cost of 6$ for each 1000$ invested.

We find this result to be robust to controlling for several alternative channels that could counteract our results. First, trade liberalization could be associated with a rise in perceived uncertainty. For firms that face a higher level of uncertainty, the real option value of future investment opportunities increases, leading to a postponement of long-term investments (see Bloom (2009), Handley and Limão (2015) and Novy and Taylor (2014)). We find that a higher level of trade-induced uncertainty cannot fully explain our effects, exploring variation in firm-level stock return volatility across time to control for changes in the level of uncertainty that firms face. Second, the level of import competition could be correlated with developments in the domestic industry. For example, if US industries become more productive over time, this might lead to relatively more long-term investments and a lower level of import competition. When we control for changes in total factor productivity, value added, capital- and skill-intensity of the US manufacturing industries our estimated effect is indeed smaller yet remains significant, both statistically and economically. Third, we find our re-

[2] Specifically, we consider seven investment categories which we group according to their durability by means of depreciation rates derived from accounting rules: Advertising expenditures, Computer expenditures, expenditures on R&D, expenditures on Transportation Equipment, expenditures on Machinery, expenditures on Buildings and expenditures on Land.

sults to be robust to controlling for financial frictions like credit constraints or the 2007-2009 financial crisis. Fourth, as our estimation is based on the within-firm responses across investment categories, we are able to take account for potential alternative firm-specific demand or technology shocks.

Additionally, we investigate the role of firm heterogeneity on investment responses. Our model suggests that a competition shock has a larger impact on profits of smaller, less productive firms since their residual demand is relatively more elastic than residual demand for larger firms. We find support for that prediction in our data. When comparing investment responses across the size distribution, we find that shifts in investments towards less durable assets as a response to foreign competition are more vigorous among smaller firms. Comparing a firm at the 10th percentile with a firm at the 90th percentile of the firm size distribution (in terms of assets), we find that the lifespan of assets decreases by about 15 days more in the small firm.

Lastly, we exploit the WTO accession of China in 2001 as a quasi-natural experiment to study how firms' investment composition changes in response to an exogenous increase in foreign competition. The increase in US imports from China was mainly due to changes in China's internal conditions rather than rising demand in the US. Furthermore, Autor, Dorn, and Hanson (2016) argue that China's comparative advantage in industrial goods resulted primarily in a large supply shock for manufacturing goods and a large demand shock for raw materials in the US. Since US imports from China vastly exceeded US exports to China, our identification strategy is likely capturing manufacturing import competition rather than export potential. We use the average effectively applied tariffs on imports from China over the years 1995 to 1999 as our treatment variable. Although tariff rates have already been reduced during the 1990s, the change in China's WTO membership status in 2001 led to a reduction in *expected* US imports tariffs on Chinese goods (see Pierce and Schott (2016)). In line with our model, we find that firms in industries with high pre-WTO tariffs shifted their investments towards less durable assets as a response to the rise in import competition from China. Our estimates suggest that between 1999 and 2003, firms with pre-WTO tariffs at the 25th percentile reduced the life span of investments by about 143 days more than a firm with pre-WTO tariffs at the 75th percentile.

This paper relates to studies that analyze how firms adjust their investment expenditures to international trade. Bloom, Draca, and Van Reenen (2016) examine the impact of Chinese import competition on within firm productivity changes and find that the absolute volume of innovation increases within the firms most affected by Chinese imports. Bustos (2011) and Lileeva and Trefler (2010) study how access to foreign markets can induce investments in technology upgrading. Both studies find that firms respond to better exporting opportunities with investments in productivity improvements. While these papers study the *absolute* level of firm investments in response to trade liberalization, our focus is on changes in the *composition* of investments within firms with respect to more or less durable assets.

Furthermore, the paper is also related to a nascent literature that studies the impact of international trade on corporate finance. Fresard (2010) finds that large corporate cash holdings lead to systematic future market share gains at the expense of industry rivals when an industry is hit by an import competition shock. Valta (2012) studies how the costs of bank credit respond to foreign competition and finds that firms face higher loan spreads when import competition toughens. Xu (2012) studies the financing response during periods of higher competition and finds that firms reduce their leverage by issuing equity and selling assets to repay debt when experiencing increases in import competition. While previous studies show that credit constraints determine firms' opportunities to participate in exporting (see e.g. Manova (2013), Foley and Manova (2015)), our paper studies the impact of foreign competition on the composition of firm investments which affects demand for credit itself.

The remainder of the paper is structured as follows. Section III.2 presents the theoretical framework, section III.3 describes the data, identification and the empirical results. Finally, section III.4 concludes.

III.2 Theoretical Framework

To understand the impact of competition on firms' investment behavior, we lay out a framework which incorporates the inter-temporal investment decision of a firm with respect to short- and long-term investments. The main goal of the section is to guide our empirical work.

III.2.1 Demand and Industry Structure

We consider an economy that exists for two time periods $t \in \{0, 1\}$. During each period t the economy is composed of L_t consumers which derive their demand from a linear-quadratic utility function following Melitz and Ottaviano (2008). As a result, firms face a linear demand

$$q_{it} = A_t - \frac{L_t}{\gamma} p_{it}, \tag{III.1}$$

where the intercept is given by $A_t \equiv \frac{\alpha L_t}{\eta N_t + \gamma} + \frac{\eta N_t}{\eta N_t + \gamma} \frac{L_t}{\gamma} \bar{p}_t$. The degree of product differentiation is described by γ, N_t reflects the number of consumed varieties and $\bar{p}_{it} = (1/N_t) \int_{i \in \Omega_t} p_{it} di$ characterizes the average price level in the economy. Linear demand implies an upper price bound $p_t^{max} = \frac{\alpha\gamma}{\eta N_t + \gamma} + \frac{\eta N_t}{\eta N_t + \gamma} \bar{p}_t$ at which demand for a variety is driven to zero. This upper price bound p_t^{max} is an inverse measure of the toughness of competition. A larger degree of differentiation γ, a larger mass of competing varieties N_t or a lower average price level $\bar{p}_t$ all trigger a decline in the price bound p_t^{max} such that firms are forced to charge lower prices in order to generate positive demand for their product.[3] Firms face a larger price elasticity of demand if they set higher prices or if the intensity of competition in the economy increases.[4]

[3]The parameters α and η are both positive and determine the pattern of substitution between a numéraire good and the differentiated varieties. An increase in α and a decrease in η induce an upward shift in the consumption levels of the differentiated varieties relative to the numéraire. If $\gamma = 0$, the varieties are perfect substitutes and consumers only focus on the total level of consumption. A rise in γ however implies that the degree of differentiation augments and consumers care about the distribution of consumption levels across varieties.

[4]The price elasticity of demand is given by $\varepsilon_{it} \equiv |(\partial q_{it} / \partial p_{it}) (p_{it} / q_{it})| = [(p_t^{max} / p_{it}) - 1]^{-1}$. This stands in contrast to a CES demand where price elasticity is uniquely determined by the level of product differentiation γ.

III.2.2 Production and Investment Decision

Production in the differentiated goods sector occurs at constant returns to scale with marginal costs c^* representing the corresponding unit labor requirement. Most importantly, we assume that profit maximizing firms can opt for two types of investment in order to reduce their marginal costs of production c^*. Short-term investments k reduce the unit costs of production instantaneously to $c_0 = c^* - (c^*)^\theta k^{0.5}$ in period 0. Long-term investments z yield larger productivity gains which however only materialize during the subsequent period 1 and reduce the firm's unit production costs to $c_1 = c^* - \varphi (c^*)^\theta z^{0.5}$ with $\varphi > 1$.[5] Higher levels of investment relate to lower unit costs with decreasing returns to scale.[6] The magnitude of cost reductions however depends on firm productivity c^* and the parameter θ. With $\theta > 0$ a unit of investment reduces marginal costs to a larger extent for less productive firms whereas $\theta < 0$ implies that low cost firms are more efficient in cutting costs. For the sake of simplicity, we assume a unit of short-term investment k and long-term investment z are both equally costly and require r units of labor to finance the investment.

In both periods firms compete on a monopolistically competitive market and take the average price level $\bar{p}_t$ as well as the number of firms N_t as given. This yields profits given by

$$\pi (c_t) = \frac{L_t}{4\gamma} \left(c_t^D - c_t \right)^2 . \tag{III.2}$$

If a firm's unit costs are just as high such that it earns zero profits, it is indifferent about remaining in the industry. This firm is characterized by marginal costs of production c_t^D such that $p\left(c_t^D\right) = c_t^D = p_t^{max}$. Thus, c_t^D reflects the intensity of competition in the economy as the threshold incorporates the impact of both, the average price level and the number of firms. A reduction in c_t^D implies a rise in the toughness of competition, as firms need to exhibit lower costs of production in order to produce profitably. Moreover, c_t^D integrates the impact of competition on firms' prices, demand and profits. Intuitively, firms with lower

[5] The basic setup of the investment function is akin to Dhingra (2013).

[6] In order for the effective marginal costs c not to become negative, investments k and z are restricted by firm productivity c^*. This however is no critical assumption since our primary interest is in the composition and not in the absolute level of short- and long-term investments.

marginal costs charge lower prices for which reason they generate larger demand and earn higher profits. Beyond that, they face a lower price elasticity of demand which allows them to set higher markups of price over marginal costs. An increase in market size L_t raises profits whereas more intense competition, reflected by a reduction in c_t^D, decreases demand and squeezes markups implying that firms loose earnings.

Having explained the basic organization of production, we now turn towards firm investments and the choice between short- and long-term investments. Taking the size of the market L_t and the level of competition c_t^D as given, the firm optimizes profits discounted with a factor $\delta \in (0, 1)$ over time

$$\max_{k,z} \pi\left(c_0\right) + \left(1-\delta\right)\pi\left(c_1\right) - rk - rz. \tag{III.3}$$

Determining the first order conditions with respect to short- and long-term investments and solving for the optimal level of k and z yields

$$k^{0.5} = \left[\frac{4\gamma r}{L_0} - \left(c^*\right)^{2\theta}\right]^{-1}\left(c_0^D - c^*\right)\left(c^*\right)^{\theta} \tag{III.4}$$

$$z^{0.5} = \left[\frac{4\gamma r}{L_1\left(1-\delta\right)\varphi} - \varphi\left(c^*\right)^{2\theta}\right]^{-1}\left(c_1^D - c^*\right)\left(c^*\right)^{\theta}. \tag{III.5}$$

From equations (III.4) and (III.5) it becomes clear that stronger competition (smaller c^D) reduces the marginal return of investment and thus diminishes investment volumes. However, we are not interested in the effects on the investment *volume* of firms but want to study the *composition* of investments inside firms. Building ratios of equations (III.4) and (III.5) and taking logs finally leaves us with the following expression for the relative composition of short-term and long-term investments k and z:

$$\begin{aligned}&\ln\left(k\right) - \ln\left(z\right) = \\ &2\left\{\left[\ln\left(c_0^D - c^*\right) - \ln\left(c_1^D - c^*\right)\right] - \left[\ln\left(\tfrac{4\gamma r}{L_0} - \left(c^*\right)^{2\theta}\right) - \ln\left(\tfrac{4\gamma r}{L_1(1-\delta)\varphi} - \varphi\left(c^*\right)^{2\theta}\right)\right]\right\}.\end{aligned} \tag{III.6}$$

III.2.3 The Impact of Import Competition on Investment Composition

We now analyze the effect of import competition on the relative composition of short-term and long-term investments. An increase in competition $c_1^D < c_0^D$ reduces firms' profits in period 1 which in turn diminishes the value of long-term investments relative to short-term investments. As such, tougher competition in period 1 incentivizes firms to adjust their investment composition towards short-lived investments. Figure B.1 illustrates the effect. Firms choose the investment composition that equalizes the marginal return of short- and long-term investments.[7] The optimal composition of investments (k^*, z^*) is therefore given by the intersection of the marginal return of short- (MR_k) and long-term investments (MR_z). According to our model, an increase in the intensity of competition reduces the return of long-term investments for any level of z thereby shifting the MR_z-curve downwards (the red, dashed curve). A new intersection of both marginal return curves emerges giving rise to a larger fraction of short-term investments and a smaller fraction of long-term investments.

In order to identify the investment distortion created by international competition, we compare the investment composition of a firm affected by an increase in import competition (*open* economy) with the investment composition of a firm facing no increase in import competition (*closed* economy). If import competition increases between period 0 and period 1, relative investments $[\ln(k) - \ln(z)]^{open}$ are given by equation (III.6). If the economy however remains closed and $c_1^D = c_0^D$ it follows that

$$[\ln(k) - \ln(z)]^{closed} = -2\left\{\ln\left(\frac{4\gamma r}{L_0} - (c^*)^{2\theta}\right) - \ln\left(\frac{4\gamma r}{L_1(1-\delta)\varphi} - \varphi(c^*)^{2\theta}\right)\right\}. \quad \text{(III.7)}$$

Hence, in the closed economy relative investments are exclusively determined by market size in both time periods. Subtracting the investment composition in the closed economy case (equation (III.7)) from the investment composition in the open economy case (equation (III.6)) provides us with the following difference-in-differences equation identifying the shift in the relative composition of investments induced by import competition

[7] If a firm expected a larger return in one type of investment than in the other, the firm would invest more into that investment type. Since we assumed decreasing marginal returns, the firm would increase investments until marginal returns are equalized.

$$[\ln(k) - \ln(z)]^{open} - [\ln(k) - \ln(z)]^{closed} = \ln\left(c_0^D - c^*\right) - \ln\left(c_1^D - c^*\right). \tag{III.8}$$

Summing up, international competition from abroad entails tougher competition in period 1. This shrinks the effective market size and lowers firms' market power and profits such that the value of long-term investments relative to short-term investments is reduced. Thus, import competition incentivizes firms to shift their investment expenditure towards investments characterized by a shorter lifespan. Based on these theoretical considerations we derive the following testable result.

Prediction 1 *Import competition increases the amount of short-term relative to long-term investments.*

III.2.4 Heterogeneous Investment Responses across Firms

From our difference-in-differences equation (III.8) it becomes obvious that the size of the investment shift depends on a firm's productivity c^*. For less productive firms, the relative loss in profits in period 1 compared to period 0 is more pronounced than for firms with lower unit costs. Hence, while all firms loose profits and market power, the relative change in profits across time decreases with firm productivity. Accordingly, this leads to a smaller reduction in the marginal return of long-term investments MR_z relative to the marginal return of short-term investments MR_k for more productive firms. Thus, high-cost firms shift their composition of investments to a larger extent towards more short-lived investments. In our theoretical framework, more productive firms are characterized by larger sales and employment. Therefore, we employ different measures of firm size as empirical counterpart to firm productivity.[8]

[8] Based on survey data, Atkin, Chaudhry, Chaudhry, Khandelwal, and Verhoogen (2015) provide recent evidence for a positive relationship of the level of markups and firm size. They therefore consider firm size to be the best proxy for the productivity parameter in heterogeneous firm models based on Melitz (2003).

Prediction 2 *Import competition increases the amount of short-term relative to long-term investments less for larger firms.*

III.2.5 The Impact of Market Size on Investment Composition

Given that trade liberalization is typically associated with both, higher import competition and larger export markets, we also study what an increase in market size would imply for our difference-in-differences estimator. From equations (III.4) and (III.5) it becomes clear that a larger market size L_t generates additional demand such that the marginal return of short- and long-term investments increases resulting in a higher level of firm investments for a given level of c_t^D (for both types of investments).[9]

An increase in market size $L_1 > L_0$ in period 1 raises demand and profits and thus the relative value of long-term investments, such that firms become less short-term oriented. Hence, the market size effect works in the opposite direction to the competition effect. In Figure B.2, this is depicted by an upward shift of the MR_z-curve as the marginal return of long-term investments increases for any level of z. As a result, the new intersection of the marginal return of short- and long-term investments shifts to the left implying a reduction in the fraction of short-term investments while the fraction of long-term investments increases.[10] In the empirical analysis, we therefore also take account of this market size effect to control confounding effects.

[9] These effects of trade liberalization on the investment *volume* of firms have been studied empirically by Lileeva and Trefler (2010) and Bustos (2011).

[10] The magnitude of the effect depends again on firm productivity c^*. However, the role of productivity is ambiguous and depends on the sign of the parameter θ which determines the impact of firm productivity on the efficiency of investments. If $\theta > 0$, less productive firms are more efficient in cutting costs and thus they face relatively larger incentives to engage in long-term investments. If $\theta < 0$, high productive firms are more effective in lowering unit costs such that an increase in market size in period 1 creates larger incentives for high productive firms to shift investment expenditures towards long-term investments. As long as $\theta = 0$, firm productivity has no impact on the magnitude of cost reductions.

III.3 Empirical Analysis

III.3.1 Identification

Equation (III.8) serves as our theoretical guideline to set up the econometric estimation strategy in order to identify the effect of import competition on the composition of firm investments. Based on equation (III.8) we derive the following difference-in-differences specification where I_{isct} denotes investments by firm i in investment category c at time t

$$\ln(I_{isct}) = \beta_0 + \beta_1 \times \ln(ImpComp_{st}) \times \textit{Short-Term}_c + \mathbf{X}'_{\mathbf{isct}}\zeta + \lambda_c + \lambda_{it} + \varepsilon_{isct} \qquad \text{(III.9)}$$

where $ImpComp_{st}$ is our measure of import competition varying across industries s and years t and $\textit{Short-Term}_c$ reflects the duration of an investment category c. In order to distinguish between long- and short-term investments, we rank each firm's investments into different assets according to their time to payoff. We follow here the approach suggested by Garicano and Steinwender (2016) and exploit expenditures on Advertising, Computer Equipment, R&D, Transportation Equipment, Machinery Equipment as well as on Buildings and Land. In our specification, the rate of duration follows an ordering where a higher ranking implies a more short-lived investment category. Alternatively, we also use depreciation rates. $\mathbf{X}'_{\mathbf{isct}}$ is a vector of control variables. λ_c and λ_{it} are fixed effects for different investment types as well as for firm-year combinations in order to sweep out unobserved firm-specific factors that vary across time and affect the investment decisions of firms. Notably, this includes demand shocks, credit shocks or technology shocks as long as they do not affect short- and long-term investments differently. Identification is therefore based on variation across investment categories *within* a firm for a given year. Most importantly, in this specification β_1 identifies the distortion in the relative composition of firm investments created by import competition and reflected in our theoretical model in equation (III.8).[11] Altogether, following *Prediction 1*, if import competition leads firms to adjust their composition of investments towards short-term investment categories, the coefficient of interest is supposed to be positive

[11] $\beta_1 = [\ln(k) - \ln(z)]^{open} - [\ln(k) - \ln(z)]^{closed}$

$\beta_1 > 0$.

Transferring this approach to firm size and its impact on the effect of import competition on firm investments, we obtain a triple difference specification of the following form

$$\ln(I_{isct}) = \beta_0 + \beta_2 \times \ln(ImpComp_{st}) \times Short\text{-}Term_c \times Size_i + \mathbf{X}'_{\mathbf{isct}}\zeta + \lambda_c + \lambda_{it} + \varepsilon_{isct}. \quad \text{(III.10)}$$

The coefficient β_2 measures the distortion created by competition and its differential impact across the firm size distribution.[12] Again, the specification makes use of investment category as well as firm-year fixed effects such that identification rests upon variation across investment types within firm-year combinations. According to *Prediction 2* we expect import competition to have a more negative influence on short-term relative to long-term investments for larger firms. Thus, our coefficient of interest is expected to be negative ($\beta_2 < 0$) in order to be in line with the theoretical prediction.

As an additional step, we use China's accession to the WTO in 2001 in order to identify the effect of foreign competition on the investment composition of firms based on a similar difference-in-differences strategy. China's WTO accession marked an inflection point in the evolution of Chinese exports and gave rise to a dramatic increase in exports to the US. The econometric specification is given by

$$\ln(I_{isct}) = \beta_0 + \beta_3 \times Post2000_t \times Pre\text{-}WTO\text{-}Tariffs_s \times Short\text{-}Term_c + \mathbf{X}'_{\mathbf{isct}}\zeta + \lambda_c + \lambda_{it} + \varepsilon_{isct}. \quad \text{(III.11)}$$

$Post2000_t$ is a dummy variable equal to one for years within the panel which succeed China's WTO entry. $Pre\text{-}WTO\text{-}Tariffs_s$ represents the average US tariff level on Chinese imports by industry during the period preceding the accession. We expect firms in industries with larger average tariffs prior to China's WTO entry to be subject bigger increases in import competition thereafter. Again, we expect the coefficient of interest to be positive. By exploiting the competition effect triggered by China's WTO accession as a quasi-natural experiment, we aim to provide corroborative evidence of capturing a causal and economically significant

[12] $\beta_2 = \left\{[\ln(k) - \ln(z)]^{open} - [\ln(k) - \ln(z)]^{closed}\right\}_{c^{*\prime}} - \left\{[\ln(k) - \ln(z)]^{open} - [\ln(k) - \ln(z)]^{closed}\right\}_{c^*}$, $c^{*\prime} < c^*$

effect.

In all estimation equations the within-firm identification strategy allows for a clean identification of the effect of competition on investments as potential firm-specific demand and supply shocks that symmetrically affect investment categories are captured by the firm-year fixed effects. Therefore, the specification mainly requires to control for investment determinants that vary at the firm or sector level and differentially affect a firm's composition of short- and long-term investments.

III.3.2 Data

We employ data on the population of listed manufacturing firms in the US for the years 1995 - 2009. The firms in our sample are obtained from the CRSP database. We match all CUSIP identifiers in the CRSP database for firms with a primary US SIC industry code between 2000 and 3999 with firm-level information from the Compustat and the Worldscope databases. Overall, we end up with 4,428 stock market listed manufacturing firms in our sample.

Measuring Firm Investment and Size

We follow the approach suggested by Garicano and Steinwender (2016) and exploit expenditures on Advertising, Computer Equipment, R&D, Transportation Equipment, Machinery Equipment as well as on Buildings and Land. Garicano and Steinwender (2016) assign the following depreciation rates to these investments based on a survey of the accounting literature to proxy for $\textit{Short-Term}_c$:[13] 60% for Advertising, 30% for Computer Equipment, 20% for R&D, 16% for Transportation Equipment, 12% for Machinery, 3% for Buildings and 0% for Land. Besides using these explicit depreciation rates, we also employ a simple ranking that orders the investments from the most long-term one (Land with a durability rank of 1) to the most short-term one (Advertising with a durability rank of 7). Tables B.4 and B.5 in the data appendix provide detailed information on the investment data.

To explore the second empirical prediction, we use three different measures of firm size ($Size_i$): a firm's total assets, employment and sales. Since firm size responds endogenously

[13]Note that an investment's depreciation rate is the inverse of its time to payoff in years.

to the level of investments, we hold firm size constant throughout all our estimations and construct firm-specific averages over the years 1995 - 1999, winsorized at the top 1%.

Measuring Foreign Competition and Trade Exposure

We measure import competition at the sector level s for a given year t following Bernard, Jensen, and Schott (2006) by

$$ImpComp_{st} = \frac{Imp_{st}}{Prod_{st} + Imp_{st} - Exp_{st}}, \tag{III.12}$$

where Imp_{st} and Exp_{st} represent the value of total US imports and exports at the 3-digit US SIC level derived from UN Comtrade data. $Prod_{st}$ reflects the value of US domestic shipments at the 3-digit US SIC level taken from the NBER CES manufacturing database. Along the same lines we compute a sector's share of export in domestic consumption

$$ExpMarket_{st} = \frac{Exp_{st}}{Prod_{st} + Imp_{st} - Exp_{st}}. \tag{III.13}$$

Finally, the sectoral degree of openness is given by the ratio of the sum of total US imports and exports over domestic shipments:

$$Openness_{st} = \frac{Imp_{st} + Exp_{st}}{Prod_{st}}. \tag{III.14}$$

We implicitly assume that all firms within an industry are subject to the same level of foreign competition as well as export market exposure and openness. In order to measure the level of tariff protection prior to China's WTO entry, we average the effectively applied US tariff on Chinese imports at the 3-digit US SIC level over the years $1995 - 2000$. Data on tariffs are again taken from UN Comtrade.

Firm and Sector Level Controls

Two alternative channels that can have an impact on the investment composition at the firm-level are changes in financial constraints and changes in the degree of uncertainty faced by firms. To control for changes in financial constraints, we use firms' current ratio, external financial dependence as well as capital cost. Table B.5 provides a detailed definition of these variables. Since trade liberalization can also be associated with an increase in the degree of uncertainty perceived by firms, we use the annual standard deviation of daily stock returns to proxy for variation in uncertainty.

Moreover, firms' investment composition as well as the level of foreign competition might be affected by sector specific attributes. If import competition is primarily traced back to low-wage countries such as China, the factor proportions framework predicts firms in capital or skill intensive sectors to be relatively less affected than their counterparts in labor or low-skill intensive industries. Furthermore, trade exposure might be related to trends in technology adoption which alter the demand for skill and capital and determine sector specific productivity. We therefore use the capital stock per worker and the share of non-production worker wages in total compensation in order to control for capital and skill intensity at the sector level. Ultimately, we control for sector specific productivity and size by measures of total factor productivity and value added. The entire set of industry level controls is obtained from the NBER CES manufacturing database.

III.3.3 Baseline Results

Table III.1 presents our main results from estimating equation (III.9). In panel A we use the simple ordering as our measure of duration. The ordering of categories follows the ordering of depreciation rates and ranges from 1 (Land) to 7 (Advertising). Panel B repeats all specifications using absolute depreciation rates from the literature as a measure of duration. By offering two distinct measures we aim to ensure that our results do not hinge on specific assumptions regarding the duration of investments, except for a broad ordering. We will show that our story goes through irrespective of the measure chosen.

In discussing our results, we will focus on the sign of the interaction between import competition and duration in a log-log specification, allowing us to compare how long-term investments react *relative* to short-term investments (both measured in percentage terms), when sector level import competition is increasing by one percent. According to *Prediction*

1, if import competition induces firms to shift their investments towards less durable categories, we expect our coefficient of interest β_1 to be positive. This implies that higher import competition is associated on average with a *relative* shift of investments towards more short-term categories, i.e. categories with a higher rate of depreciation.

All specifications include our measure of interest, category fixed effects and firm-year fixed effects. We correct for two-way clustered standard errors. We cluster at the firm-level and additionally, we cluster at the industry-year level, as our measure of import competition is the same for all firms in a given industry and in a given year. The level of import competition is sector-year specific and thus absorbed by the fixed effects. Thus, we do not identify the average effect of import competition on investments. Similarly, due to the inclusion of category fixed effects, we do not identify the between-category difference in average investments. We include these fixed effects because they allow us to effectively control for alternative channels that otherwise would potentially be confounding our results.

For example, sectors and firms will be exposed to temporary shocks that, on average, will have an impact on investments. Think about a domestic demand shock that reduces the demand for durable consumer goods. Potentially, this demand shock will be correlated with our sectoral measure of import competition. In response to the shock, firms in the durable goods sector might reduce average investments. Because this decision is due to the demand shock and independent of investment durations, the relative composition of short and long-term investments *within* firms and industries would remain constant. Nevertheless, our coefficient of interest might falsely pick up the variation if the investment composition in the durable goods sector happens to be on average more long-term than in other sectors. The uniform investment reduction in the durable goods sector would then shift the *economy-wide* investment composition towards more short run investments. Consequently, we would find a positive coefficient on the durability interaction and wrongly conclude that import competition was causing firms to invest more short-term. The inclusion of firm-year fixed effects will account for these confounding effects at the firm or sectoral level, as long as the change in investments is uniform across the different types of investment.

The fixed effect specification implies that identification, as well as potential confounding

Table III.1: Import Competition and Investment Composition - Baseline Results

Dependent Variable: log(Investment)				
	(1)	(2)	(3)	(4)
Panel A: Measure of Depreciation: Ordering				
log(ImpComp) * Depreciation	0.0455***	0.0347***	0.0330***	0.0333***
	(0.00813)	(0.00886)	(0.00906)	(0.00903)
Panel B: Measure of Depreciation: Depreciation rate				
log(ImpComp) * Depreciation	0.143	0.252***	0.237**	0.248**
	(0.0901)	(0.0968)	(0.0994)	(0.0998)
Industry Controls * Depreciation	no	yes	yes	yes
sd(Stock Return) * Depreciation	no	no	yes	yes
Investment FE	yes	yes	yes	yes
Firm-Year FE	yes	yes	yes	yes
Observations	89,735	89,436	81,912	72,064
Firm Clusters	3,308	3,308	3,308	3,308
Industry-Year Clusters	2,163	2,163	2,163	2,163

Notes: Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). The ordering of categories resembles the ordering of depreciation rates. Investment expenses are either derived from balance sheet data on assets (Land, Buildings, Machines, Transportation and Computer) or taken from the income statement (R&D and Advertising). Import competition (ImpComp) are imports at the sectoral level, relative to domestic production plus imports minus exports. Industry controls contain controls for capital-intensity, skill-intensity, tfp and value added. Sd(stock return) is the standard deviation of daily stock returns in a given year. Standard errors are twoway cluster-robust at the firm and at the industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

effects, all hinge on factors that vary across firms, years and investment categories. In specification (1), only the interaction of import competition with duration fulfills this requirement. No other controls are included. The coefficient is positive as predicted for both measures of depreciation but significant only for the ordered measure.

The problem with specification (1) is that a lot of systematic variation across the three dimensions is now potentially projected on the import channel. Thus, other sectoral developments with a direct impact on investment composition might interfere with our results provided that they are correlated with import competition. We therefore add interactions of the depreciation measure with various sector-level controls in specification (2). Specifically, we interact depreciation with time-varying measures of capital intensity, skill intensity, tfp and value added. The import competition coefficient remains positive and now turns significant for both measures of depreciation.

In specification (3), we add an interaction with firm-level volatility of stock returns. This is supposed to disentangle the import competition effect proposed in the theoretical framework from other effects due to trade induced uncertainty. As our coefficient of interest remains significant, we conclude that import competition must have an impact on investment composition other than through market insecurity.

Specification (3) is our baseline regression. Consider the following example in order to understand the meaning of our coefficients: a higher level of import competition creates a wedge between investments into different investment categories. Suppose for example that the level of import competition increases by 10%. Then our coefficient in panel A implies that this wedge is equal to 0.33%. Thus, if an exemplary firm reduces its land investments (the most long-term category) by 10%, we would expect that firm to reduce its investments in buildings by 9.67%, its machinery investments by 9.34%, its transportation investments by 9.01%, its R&D investments by 8.68%, its computer investments by 8.35% and its advertising investments (the most short-term category) by 8.02%.

To evaluate the economic significance of our estimates, we invoke a simple thought experiment. We consider the average increase in import competition over the sample period 1995-2009, i.e. 60% over the 15-year period. Additionally, we assume that Land investments respond inelastically to an import competition shock.[14] Using the results from Table III.1, panel B, specification (3), we can then calculate the change in the average depreciation rate that results from the increase in import competition.[15] Our estimates suggest that the average increase in import competition by 60% during our sample period has reduced the lifespan of firm assets by 72 days on average, which corresponds to 4.6% of the average asset lifespan. Presuming a refinancing rate of 3%, this would impose an additional cost of 6$ for each 1000$ invested. Thus, import competition is associated with a significant shift towards relatively short-term investments.

In specification (4), we exclude the years 2008 and 2009 from our sample in order to assure that our effect is not picking up specifics of the financial crisis. Garicano and Steinwender (2016) show for Spanish manufacturing firms that the credit crisis in 2008 effectively worked like an additional tax rate on long-term investments. If import competition was increasing during the crisis, we would not be able to distinguish the two effects. Dropping the crisis years however does not alter our results significantly. If anything, the estimated effects become stronger, indicating that omitting to control for the crisis actually led us to slightly underestimate the effect of import competition.

III.3.4 Firm Heterogeneity

In our theoretical framework we show that the import competition effect on investment composition should be less pronounced for larger firms.

In Table III.2, we confront this prediction (*Prediction 2*) with the data, using a triple interaction with measures of firm size in order to see whether the effect of import competition on investment composition varies along the firm size distribution. We use total employment, net firm sales and total assets as measures of size. Adding the size interactions increases the coefficient on the original interaction (β_1) compared to the baseline. The interaction remains significant at the 1% level in all specifications. The triple interaction with size has the expected negative sign in all specifications, implying that the shift towards short-term in-

[14]When regressing import competition on Land investments and adding firm and year fixed effects, we find Land investments to be inelastic with respect to import competition.

[15]See the data appendix for details on this calculation.

Table III.2: Import Competition and Investment Composition - Heterogeneous Investment Responses Across Firms

Dependent Variable: log(Investment)				
			Measure of Size	
		Employment	**Sales**	**Assets**
	(1)	(2)	(3)	(4)
Panel A: Measure of Depreciation: Ordering				
log(ImpComp) * Depreciation	0.0330***	0.0396***	0.0403***	0.0401***
	(0.00906)	(0.0101)	(0.00985)	(0.00966)
log(ImpComp) * Depreciation * Size		-0.000599	-3.42e-06*	-3.32e-06***
		(0.000385)	(1.74e-06)	(1.22e-06)
Depreciation * Size		-0.000736	-3.00e-06	-4.83e-06
		(0.000950)	(3.97e-06)	(3.36e-06)
Panel B: Measure of Depreciation: Depreciation rate				
log(ImpComp) * Depreciation	0.237**	0.321***	0.335***	0.326***
	(0.0994)	(0.109)	(0.106)	(0.105)
log(ImpComp) * Depreciation * Size		-0.00647*	-3.86e-05**	-3.58e-05***
		(0.00371)	(1.85e-05)	(1.23e-05)
Depreciation * Sales		0.00421	2.51e-05	-2.82e-06
		(0.0102)	(4.54e-05)	(3.62e-05)
Industry Controls * Depreciation	yes	yes	yes	yes
sd(Stock Return) * Depreciation	yes	yes	yes	yes
Investment FE	yes	yes	yes	yes
Firm-Year FE	yes	yes	yes	yes
Observations	81,912	73,136	75,578	75,660
Firm Clusters	2,866	2,866	2,866	2,866
Industry-Year Clusters	2,381	2,381	2,381	2,381

Notes: Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). The ordering of categories resembles the ordering of depreciation rates. Investment expenses are either derived from balance sheet data on assets (Land, Buildings, Machines, Transportation and Computer) or taken from the income statement (R&D and Advertising). Import competition (ImpComp) are imports at the sectoral level, relative to domestic production plus imports minus exports. Measures of size are from Compustat and represent firm averages over the years 1995 to 1999. Industry controls contain controls for capital-intensity, skill-intensity, tfp and value added. Sd(stock return) is the standard deviation of daily stock returns in a given year. Standard errors are twoway cluster-robust at the firm and at the industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

vestments is less pronounced for larger firms. Statistically, the effect is significant at the 1% level for total assets, independent of the depreciation measure chosen. The effects are less significant for sales and employment and on average stronger when we use the depreciation rate as our measure of duration. Using assets as a measure of size, the coefficients for the depreciation rank imply that for any two neighboring investment categories, a 10% higher import competition is associated with a 0.4% higher decrease in the long-term investment compared to the neighboring shorter-term investment for the median firm. Using an analogous back-of-the-envelope calculation as in the baseline with respect to the estimates from panel B, we compare a firm at the 10th percentile with a firm at the 90th percentile of the firm size distribution (in terms of assets). We find that the lifespan of assets decreases by about 15 days more in the small firm.

III.3.5 Reordering and Omitting Investment Categories

In order to determine whether our results hinge on the assumed ordering of investment categories in terms of depreciation rates, we omit and regroup various categories for the ordered measure of depreciation in Table B.1.[16] Specification (1) repeats our baseline regression. In specification (2) we omit investments into R&D in order to see whether R&D expenses are driving our result. For example, a rise in import competition might lead firms to foster innovation by investing more heavily in research activities.[17] This decision is independent of the duration of R&D investments, but would still render our coefficient positive because R&D expenditures just happen to be classified as relatively short-term. The inclusion of category fixed effects does not help us against this type of disturbances, as the unobservable effect varies over time. Omitting R&D investments reduces the number of observations by more than a quarter and diminishes the size of our coefficient. But our results remain robust at the 5% level of significance, indicating that R&D is an important, but not the only driver of our results.

In specification (3) we further omit investments in Advertising. Because different from

[16] Specifications (1) to (4) are robust to using the depreciation rate instead.

[17] Bloom, Draca, and Van Reenen (2016) show that Chinese import competition increases technical change within firms, among other things, by increasing the amount of R&D.

the other categories, both R&D and Advertising expenses are taken from the income statements rather than being derived from asset data, one concern is that our results are due to these constructional differences. The results in specification (3) show that our results go through when restricting the sample to asset data. Specification (4) omits Transportation and Computer investments. Computer investments are reported only for the years 1999 and onwards and Transportation is reported very little over the full range of years. Accordingly, these two categories might not be very representative and specifically prone to be affected by outliers. But again, our results remain robust when estimating the equation for the remaining categories.

Because estimates of depreciation rates vary in the literature, we regroup assets that are close to each other into single categories in specifications (5) to (7). In specification (5), we assign the same rank to Land, Buildings and Machinery. R&D and Computer investments are grouped into another category. The coefficient almost doubles in size and remains highly significant. Adding Transportation to the group of long-term investments in specification (6) further increases the coefficient, confirming that switching from one rank to another now has a higher impact on investment duration. Because the depreciation rate of Transportation is relatively close also to R&D and Computer, specification (7) assigns it into one group with these categories. Again, our results are not significantly altered.

Finally, it could be that firms increase research expenditures in order to remain competitive in the future, rendering R&D effectively a long-term investment. Then our ranking of investment categories would be flawed. Specification (8) therefore ranks R&D as the most long-term investment. The effect vanishes and we conclude that our original ordering is more coherent, given that R&D investments are not the sole driver of our results.

III.3.6 Alternative Financial Channels

In Table B.2 we try to rule out some alternative stories that might affect our results. Garicano and Steinwender (2016) argue that credit shocks reduce the relative value of long-term investments because firms might have to liquidate before the payoff materializes. Since we want to identify a competition shock, we need to make sure that time varying financial characteristics are properly controlled for. In specifications (2) to (5) we therefore add interactions of the depreciation measure with measures of the current ratio, external dependence, capital cost and a financial crisis dummy. While some of these controls appear to have an effect on the investment composition, the results for our measure of import competition are not significantly altered. We therefore conclude that import competition is not just working through changes in firms' financial characteristics and probably better explained by changes in demand.

III.3.7 Differentiating between Import Competition and Market Access

In subsection III.2.5 in the theory, we argue that higher market access should have effects exactly opposed to the effects of import competition. Table B.3 addresses this point. Because better market access implies higher demand in the future, we would expect firms to shift investments towards this future market. Accordingly, the results for import competition documented so far are probably biased in the opposite direction.

Specification (2) shows that our assumptions regarding the market access effects are confirmed in the data. When regressing investments on the interaction of depreciation with export market size, our estimates suggest that firms are shifting investments towards long-term categories when faced with better export opportunities. The effects for exports are slightly larger than for imports and highly significant. In specification (3) we add the export market interaction to the baseline specification to see how our original results are affected. Stable signs indicate that the impact of both imports and exports remain as the theory would predict. The increase in size of our coefficient of interest shows that failing to control for export opportunities biases our coefficient on import competition in the opposite direction.[18] Given these findings, we consider our previous results to represent a conservative estimate of the actual effect. Finally, in specification (4) we use an openness measure that incorporates both import competition and export opportunities and find that mixing up the two effects conceals much of the impact trade has on investment composition. Because the coefficient remains positive and marginally significant for the ordering measure, we conclude that im-

[18] The same holds *vice versa* for export opportunities.

port competition might have slightly outweighed the effect of export opportunities for the firms in our sample.

III.3.8 The Impact of China's WTO Accession on the Composition of Firm Investments in the US

In order to substantiate our claim that it is the surge in imports that induces a reallocation of investments towards long-term investments, we will exploit a quasi-natural experiment based on the large competition effect caused by China's accession to the WTO in 2001. China's WTO accession is a useful experiment for mainly two reasons.

First, China's accession to the WTO, and the dramatic increase of exports to the world that followed thereafter,[19] was driven mostly by the change in China's internal conditions and not by the rising import demand of receiving countries. As Autor, Dorn, and Hanson (2013a) point out, this interpretation is corroborated by the fact that China had an average annual TFP growth in manufacturing of 8% during that time, compared to only 3.9% for the US. Autor, Dorn, and Hanson (2016) cite several studies indicating that the prospect of formal WTO accession was a major force stimulating the underlying restructuring of the manufacturing industry. The increasing privatization of public enterprises, the extension of trading rights for private firms, greater access to imported intermediates and a solidification of the MFN status, providing security to Chinese exporters, all helped to foster a new level of productivity growth after 2001. Thus, although China had already been granted most-favored nation status (MFN) during the 80s, the surge in exports significantly accelerated after 2001. This surge can be treated as mostly exogenous to dynamics in the US market which is crucial for identification.[20]

Second, Autor, Dorn, and Hanson (2016) argue that China's comparative advantage in industrial goods implies that China's growth resulted primarily in a large supply shock for manufacturing goods and a large demand shock for raw materials. Given that US imports

[19] Between 2000 and 2007, the low-income country share of US imports almost doubled from 15 to 28%, with China accounting for 89% of this growth. Compare Autor, Dorn, and Hanson (2013a). Additionally, see Figure B.6 in the data appendix for the average share of imports from China in total US imports for the industries in our sample.

[20] See Iacovone, Rauch, and Winters (2013a) for a similar argument.

from China vastly exceeded US exports to China, this suggests that our identification strategy is likely going to capture manufacturing import competition rather than export potential.[21]

While we argue that the results we are going to present in this section represent a causal effect of imports on the investment composition, we are aware that we cannot precisely determine the channel through which imports are affecting the investment choices of firms. Thus, while we claim that import competition is the driving force behind our results, part of the variation we are using might be due to a rise in imported intermediates rather than final goods. Yet, note that cheaper intermediates should have a positive effect on the future market potential of US firms. Thus, if the surge in US imports to China was driven by a surge in intermediate imports, if anything, it would make it more difficult for us to detect a shift towards short-term investments.

Technically, the approach we use is related to Guadalupe and Wulf (2010), as we also use the average pre-trade-agreement level of tariffs to identify the firms most affected by trade liberalization. Specifically, we use the US effectively applied import tariff *vis-à-vis* China, averaged over the years 1995 to 1999 and specific to firms within US SIC three digit industries.[22] As noted by Pierce and Schott (2016), the change in China's WTO membership status in 2001 had two effects: it ended the uncertainty associated with annual renewals of China's MFN status and it led to a substantial reduction in expected US imports tariffs on Chinese goods. It is the latter aspect that we will use for identification.[23] Accordingly, we look at the differential change in investment behavior before and after the Chinese WTO accession in 2001, where we make use of the fact that the threat of tariff reductions is larger in high-tariff industries. The coefficient of interest is the interaction of a post-2000 dummy with the pre-trade-agreement level of tariffs. In all specifications, we focus our sample on a sample period between 1999 and 2003, around China's WTO entry in 2001.

[21] Bloom, Draca, and Van Reenen (2016), Iacovone, Rauch, and Winters (2013a) and Utar (2014) also use the WTO accession of China as a natural experiment for an increase in import competition.

[22] The effectively applied tariff is defined as the lowest available tariff, given by preferential tariffs if existent and MFN tariffs otherwise.

[23] In fact, the average tariffs remained relatively stable after 2000. Nevertheless, for the years 1999 to 2003, we find that industries with pre-WTO accession tariff levels above the median experienced a 66% larger increase in Chinese import competition than industries with pre-WTO accession tariffs below the median.

Table III.3: Import Competition and Investment Composition - The Impact of China's WTO Accession

Dependent Variable: log(Investment)				
	(1)	(2)	(3)	(4)
Panel A: Measure of Depreciation: Duration rank				
Post2000 * Pre-WTO-Tariff * Depreciation	0.00636**	0.00550*	0.00539*	0.00430
	(0.00290)	(0.00301)	(0.00300)	(0.00313)
Post2000 * Depreciation	-0.0359***	-0.0241*	-0.0219	-0.0123
	(0.0134)	(0.0144)	(0.0139)	(0.0148)
Pre-WTO-Tariff * Depreciation	0.00489	0.00541	0.0181***	0.0184***
	(0.00344)	(0.00352)	(0.00371)	(0.00378)
Panel B: Measure of Depreciation: Depreciation rate				
Post2000 * Pre-WTO-Tariff * Depreciation	0.0642**	0.0548*	0.0549**	0.0447
	(0.0272)	(0.0282)	(0.0270)	(0.0282)
Post2000 * Depreciation	-0.642***	-0.577***	-0.500***	-0.376**
	(0.146)	(0.154)	(0.147)	(0.157)
Pre-WTO-Tariff * Depreciation	0.105***	0.104***	0.134***	0.155***
	(0.0327)	(0.0337)	(0.0351)	(0.0364)
Industry Controls * Depreciation	no	no	yes	yes
sd(Stock Return) * Depreciation	no	yes	no	yes
Investment FE	yes	yes	yes	yes
Firm-Year FE	yes	yes	yes	yes
Observations	30,949	27,804	30,517	27,428
Firm Clusters	2,379	2,379	2,379	2,379

Notes: Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). The ordering of categories resembles the ordering of depreciation rates. Investment expenses are either derived from balance sheet data on assets (Land, Buildings, Machines, Transportation and Computer) or taken from the income statement (R&D and Advertising). Sample period 1999-2003. Post2000 is an indicator that takes the value 1 if the year is 2001 or later. Pre-WTO-Tariff is the simple industry average (over the years 1995-2000) of the effectively applied tariff on US imports from China as reported in the WITS/Comtrade data base. Industry controls contain controls for capital-intensity, skill-intensity, tfp and value added. Sd(stock return) is the standard deviation of daily stock returns in a given year. Standard errors are twoway cluster-robust at the firm and at the industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table III.3 shows the results for the two measures of depreciation. Again, we allow errors to be clustered at the firm level and include category and firm-year fixed effects in all specifications. In specifications (1) to (4), we subsequently add the time varying sector-level and uncertainty controls interacted with our measure of duration. Adding all controls simultaneously leads to insignificant results, but the triple-interaction of interest is significant at the 5% or 10% level when restricting the controls to one set or the other. The coefficient of interest is positive in all specifications, implying that the WTO accession of China led to a higher decrease (or lower increase) in long-term investments, compared to short-term investments, and that this effect was more pronounced in sectors that had higher average tariffs during the second half of the 1990s.[24] Specifically, using the results from specification (3) in panel B, we find that for a firm at the 25th percentile of our tariff measure, the average investment duration increased in the years after 2001 by roughly 106 days more than for firms at the 75th percentile of the pre-2000 tariff distribution.

III.4 Conclusion

This paper examines how the exposure to foreign competition affects the composition of short-term relative to long-term investments within firms. In order to guide our empirical strategy, we develop a stylized framework which illustrates the investment decision of a representative firm with respect to short- and long-term investments. An increase in the toughness of competition reduces the relative value of long-term investments and induces firms to shift their investment composition towards short-term investments. The magnitude of this effect varies with firm size. We test these predictions based on the population of listed US manufacturing firms by using data on seven asset classes which we order according to their depreciation rates. Based on our framework, the empirical strategy employs a difference-in-differences estimator. This approach allows using firm-year fixed effects as well as investment category fixed effects in order to identify the effect of trade induced com-

[24]Note that the negative coefficient on the interaction of our measure of depreciation with the post-2000 dummy implies that on average firms with a zero tariff-level invested relatively more long-term after 2000. This is a materialization of the general trend towards more long-term investments over time which can be seen in Figures B.5 and B.4.

petition on the composition of investments within firms. The empirical results are in line with our predictions. Import competition shifts the composition of investments towards more short-lived categories and the effect depends on firm size. Our results are robust to the inclusion of controls that account for alternative channels at the firm and sector level such as various measures of financial constraints and factor intensities. In order to provide further supportive evidence of a causal effect, we exploit the rise in Chinese imports to the US due to China's accession to the WTO as quasi-natural experiment. Finally, we also explore the impact of exporting on the composition of investments. Our results suggest that exposure to export markets works in the opposite direction, and induces a reallocation towards long-term investments.

We believe that adjustments in the composition of investment have important economic implications. If trade induced competition incentivizes firms to disregard the long-term perspective this implies a loss in sustainability, higher financing costs as well as changes in the firm size distribution. This suggests new research directions. Future research might for example study how changes in the composition of investment relate to the welfare effects of globalization.

B Appendix

B.1 Figures and Robustness

Figure B.1: The Impact of Tougher Competition on the Composition of Investments

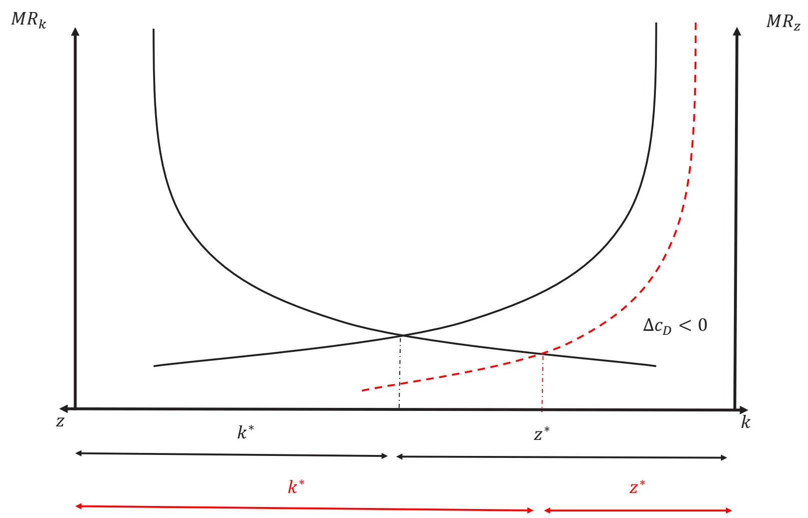


Figure B.2: The Impact of an Increase in Market Size on the Composition of Investments

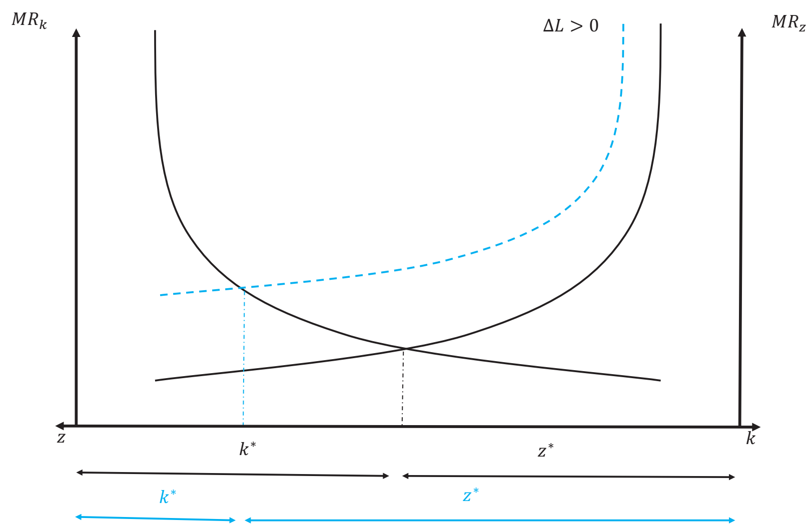


Table B.1: Altering Investment Categories

Dependent Variable: log(Investment)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Measure of Depreciation: Ordering								
log(ImpComp) * Depreciation	0.0330***	0.0194**	0.0236*	0.0334***	0.0634***	0.104***	0.0896***	-0.0133
	(0.00906)	(0.00918)	(0.0128)	(0.00935)	(0.0166)	(0.0281)	(0.0273)	(0.00870)
Industry Controls * Depreciation	yes	yes	yes	yes	yes	yes	yes	yes
sd(Stock Return) * Depreciation	yes	yes	yes	yes	yes	yes	yes	yes
Investment FE	yes	yes	yes	yes	yes	yes	yes	yes
Firm-Year FE	yes	yes	yes	yes	yes	yes	yes	yes
Excluded categories	none	R&D	R&D/ Advertising	Transportation/ Computer	none	none	none	none
Number of categories	7	6	5	5	4	3	3	7*
Observations	81,912	58,441	49,572	76,822	81,912	81,912	81,912	81,912
Firm Clusters	3,358	3,358	3,358	3,358	3,358	3,358	3,358	3,358
Industry-Year Clusters	2,441	2,441	2,441	2,441	2,441	2,441	2,441	2,441

Notes: Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). The ordering of categories resembles the ordering of depreciation rates in specification (1)-(4). Specification (5) groups Land, Buildings and Machinery into one category and R&D and Computer into another. Specification (6) additionally takes Transportation into the category with Land, Buildings and Machinery, while specification (7) takes it into the category with R&D and Computer. In specification (8), R&D is ordered as the most long-term investment. Investment expenses are either derived from balance sheet data on assets (Land, Buildings, Machines, Transportation and Computer) or taken from the income statement (R&D and Advertising). Import competition (ImpComp) are imports at the sectoral level, relative to domestic production plus imports minus exports. Industry controls contain controls for capital-intensity, skill-intensity, tfp and value added. Sd(stock return) is the standard deviation of daily stock returns in a given year. Standard errors are twoway cluster-robust at the firm and at the industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table B.2: Alternative Financial Channels

Dependent Variable: log(Investment)					
	(1)	(2)	(3)	(4)	(5)
Panel A: Measure of Depreciation: Ordering					
log(ImpComp) * Depreciation	0.0330***	0.0302***	0.0319***	0.0313***	0.0331***
	(0.00906)	(0.00904)	(0.00919)	(0.00912)	(0.00906)
Current Ratio * Depreciation		0.00963***			
		(0.00223)			
External Dependence * Depreciation			0.000198**		
			(9.86e-05)		
Capital Cost * Depreciation				-0.200***	
				(0.0233)	
Crisis * Depreciation					-0.00795
					(0.0187)
Panel B: Measure of Depreciation: Depreciation rate					
log(ImpComp) * Depreciation	0.237**	0.233**	0.229**	0.221**	0.241**
	(0.0994)	(0.0987)	(0.100)	(0.0989)	(0.0993)
Current Ratio * Depreciation		0.00579			
		(0.0247)			
External Dependence * Depreciation			0.00159*		
			(0.000821)		
Capital Cost * Depreciation				-2.116***	
				(0.290)	
Crisis * Depreciation					-0.260
					(0.209)
Industry Controls * Depreciation	yes	yes	yes	yes	yes
sd(Stock Return) * Depreciation	yes	yes	yes	yes	yes
Investment FE	yes	yes	yes	yes	yes
Firm-Year FE	yes	yes	yes	yes	yes
Observations	81,912	79,083	78,956	78,963	81,912
Firm Clusters	3,358	3,358	3,358	3,358	3,358
Industry-Year Clusters	2,441	2,441	2,441	2,441	2,441

Notes: Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). The ordering of categories resembles the ordering of depreciations rates. Investment expenses are either derived from balance sheet data on assets (Land, Buildings, Machines, Transportation and Computer) or taken from the income statement (R&D and Advertising). Import competition (ImpComp) are imports at the sectoral level, relative to domestic production plus imports minus exports. Financial controls are time varying at the firm level derived from Compustat: Current Ratio is the total of current assets over current liabilities, External Dependence is capital expenditure net of EBIT over total capital expenditure, Capital Cost is capital expenditure over total liabilities. Crisis is an indicator equal to 1 for the years 2007-2009. Industry controls contain controls for capital-intensity, skill-intensity, tfp and value added. Sd(stock return) is the standard deviation of daily stock returns in a given year. Standard errors are twoway cluster-robust at the firm and at the industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table B.3: Import Competition and Access to Foreign Markets

Dependent Variable: log(Investment)				
	(1)	(2)	(3)	(4)
Panel A: Measure of Depreciation: Ordering				
log(ImpComp) * Depreciation	0.0330***		0.0767***	
	(0.00906)		(0.0123)	
log(ExpMarket) * Depreciation		-0.0360***	-0.0814***	
		(0.00908)	(0.0118)	
log(Openness) * Depreciation				0.0146*
				(0.00763)
Panel B: Measure of Depreciation: Depreciation rate				
log(ImpComp) * Depreciation	0.237**		0.644***	
	(0.0994)		(0.126)	
log(ExpMarket) * Depreciation		-0.489***	-0.847***	
		(0.0994)	(0.117)	
log(Openness) * Depreciation				0.0894
				(0.0840)
Industry Controls * Depreciation	yes	yes	yes	yes
sd(Stock Return) * Depreciation	yes	yes	yes	yes
Investment FE	yes	yes	yes	yes
Firm-Year FE	yes	yes	yes	yes
Observations	81,912	81,912	81,912	81,912
Firm Clusters	3,358	3,358	3,358	3,358
Industry-Year Clusters	2,441	2,441	2,441	2,441

Notes: Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). The ordering of categories resembles the ordering of depreciation rates. Investment expenses are either derived from balance sheet data on assets (Land, Buildings, Machines, Transportation and Computer) or taken from the income statement (R&D and Advertising). Import competition (ImpComp) are imports at the sectoral level, relative to domestic production plus imports minus exports. Export market size (ExpMarket) are exports at the sectoral level, relative to domestic production plus imports minus exports. Openness is the sum of exports and imports at the sectoral level, relative to domestic production plus imports minus exports. Industry controls contain controls for capital-intensity, skill-intensity, tfp and value added. Sd(stock return) is the standard deviation of daily stock returns in a given year. Standard errors are twoway cluster-robust at the firm and at the industry-year level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

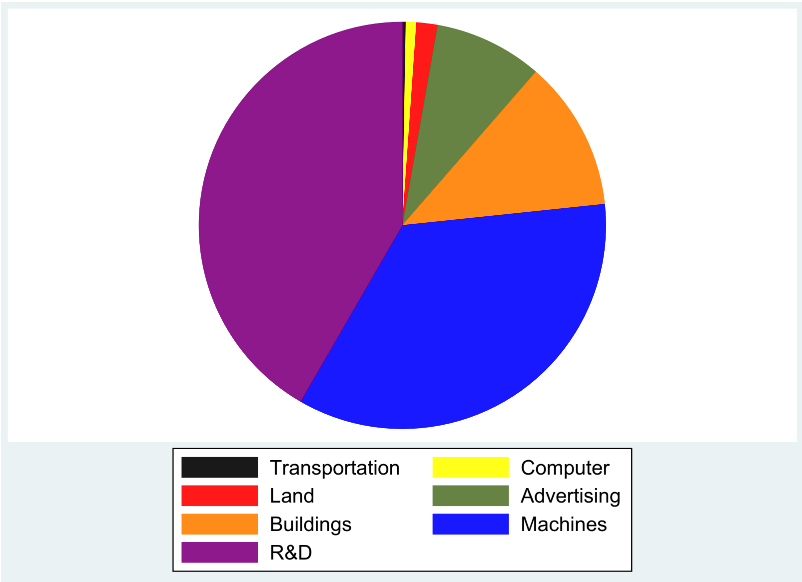
B.2 Data

Table B.4: Depreciation Rates of Investments

Firm Investment:	*Applied Depreciation Rate:*	*Duration Rank:*
advertising	60%	7
computer	30%	6
R&D	20%	5
transportation equipment	16%	4
machines	12%	3
buildings	3%	2
land	0%	1

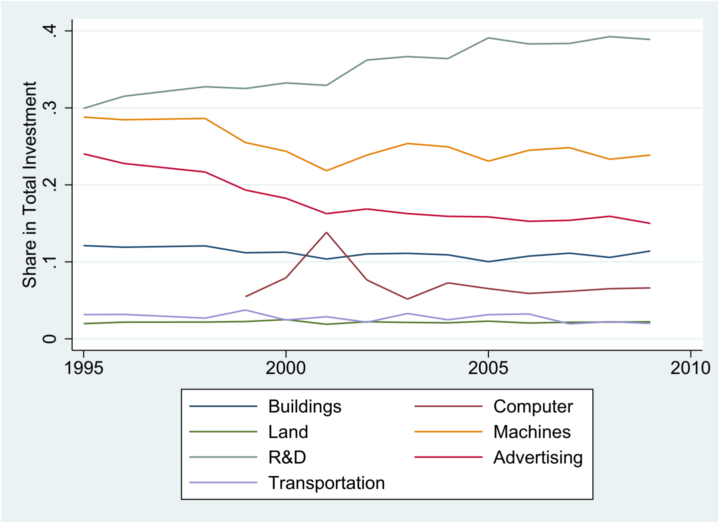
Notes: Applied depreciation rates are obtained from Garicano and Steinwender (2016) who derive the investment-specific depreciation rates from various sources of the accounting literature.

Figure B.3: Shares of Investment Categories in Total Investments



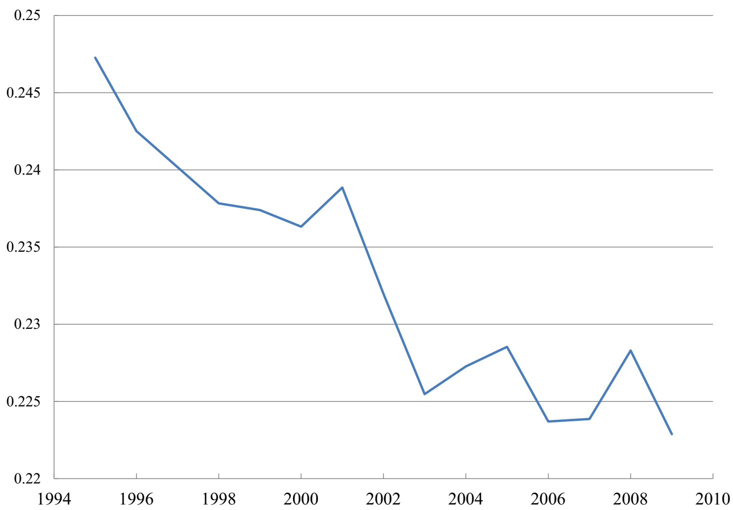
Notes: The figure shows the sample average composition of investment categories.

Figure B.4: Shares of Investment Categories over Time



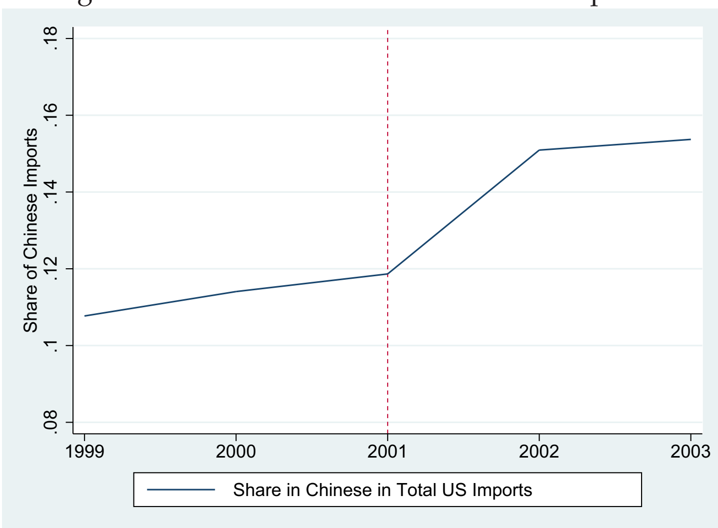
Notes: The figure shows the development of the composition of investment categories over time.

Figure B.5: Average Rate of Depreciation over Time



Notes: The figure shows the average depreciation rate over the years for the firms in our sample. The average is constructed by weighting each investment specific depreciation rate with its average investment share across all firms in a specific year. Investment categories and assumed depreciation rates: Land (0%), Buildings (3%), Machines (12%), Transportation (16%), R&D (20%) Computer (30%), Advertising (60%). See section B.3 in the appendix *(Calculation of the Marginal Effects)* for a detailed description on how the average depreciation rate is calculated.

Figure B.6: Share of Chinese in Total US Imports



Notes: The figure shows the average share of imports from China relative to total imports of the US for the US SIC 3-digit industries in our sample.

Table B.5: Variable Descriptions and Data Sources

variables	*descriptions*	*sources*
Firm Investments		
advertising_{it}	*advertising* represents the cost of advertising media (i.e., radio, television, and periodicals) and promotional expenses in millions USD; Compustat variable name: XAD	Compustat
computer_{it}	*computer software & equipment* (period t) - 0.95 × *computer software & equipment* (period $t-1$); *computer software & equipment* (gross property plant and equipment) represents computer equipment and the information a computer uses to perform tasks in millions USD	Worldscope
$\text{R\&D}_{it}$	*research & development expenses* (period t) represent all direct and indirect costs related to the creation and development of new processes, techniques, applications and products with commercial possibilities in millions USD	Worldscope
$\text{transportation equipment}_{it}$	*transportation equipment* (period t) - 0.95 × *transportation equipment* (period $t-1$); *transportation equipment* (gross property plant and equipment) represents the cars, ships, planes or any other type of transportation equipment in millions USD	Worldscope
machines_{it}	*machinery & equipment* (period t) - 0.95 × *machinery & equipment* (period $t-1$); *machinery & equipment* (gross property plant and equipment) represent the machines and machine parts needed by the company to produce its products in millions USD	Worldscope
buildings_{it}	*buildings* (period t) - 0.95 × *buildings* (period $t-1$); *buildings* (gross property plant and equipment) represent the architectural structure used in a business such as a factory, office complex or warehouse in millions USD	Worldscope
land_{it}	*land* (period t) - 0.95 × *land* (period $t-1$); *land* (gross property plant and equipment) represents the real estate without buildings held for productive use, is recorded at its purchase price plus any costs related to its purchase such as lawyer's fees, escrow fees, title and recording fees in millions USD	Worldscope
Firm Controls		
employment_{i}	average firm employment in thousands over the years 1995-1999, winsorized at the top 1%; Compustat variable name: EMP	Compustat
sales_{i}	average firm sales in millions USD over the years 1995-1999, winsorized at the top 1%; Compustat variable name: SALE	Compustat
assets_{i}	average firm assets in millions USD over the years 1995-1999, winsorized at the top 1%; Compustat variable name: AT	Compustat
$\text{current ratio}_{it}$	*current ratio* is an indication of a firm's market liquidity and ability to meet creditor's demands; defined as current assets divided by current liabilities during a given year t (banker's rule: >2 for creditworthiness); Compustat variable names: ACT/LCT	Compustat
$\text{external dependence}_{it}$	*external dependence* is the fraction of capital expenditures that are not financed by internal capital flows during a given year t; Compustat variable names: $(\text{CAPX} - \text{EBIT})/\text{CAPX}$	Compustat
capital cost_{it}	*capital cost* is defined as capital expenditures over liabilities during a given year t; Compustat variable names: CAPX/LT	Compustat
$\text{sd(stock return)}_{it}$	standard deviation of the daily firm stock returns (P_d/P_{d-1}) during a given year t	CRSP
Trade Variables		
$\text{import competition}_{st}$	*ImpComp* is defined as $ImpComp = imports^{World} / \left(domestic\ shipments + imports^{World} - exports^{World}\right)$; at the 3-digit US SIC level during a given year t	NBER CES data for vship, UN Comtrade for exports and imports
$\text{export market exposure}_{st}$	*ExpMarket* is defined as $ExpMarket = exports^{World} / \left(domestic\ shipments + imports^{World} - exports^{World}\right)$; at the 3-digit US SIC level during a given year t	NBER CES data for vship, UN Comtrade for exports and imports
openness_{st}	*Openness* is defined as $Openness = \left(exports^{World} + imports^{World}\right)/domestic\ shipments$; at the 3-digit US SIC level during a given year t	NBER CES data for vship, UN Comtrade for exports and imports
$\text{pre-WTO tariff}_{s}$	simple industry average tariff over the years 1995-2000 of the effectively applied US tariff on imports from China; at the 3-digit US SIC level	UN Comtrade
Industry Controls		
$\text{capital-intensity}_{st}$	total real capital stock in thousands USD per employee; at the 3-digit US SIC level during a given year t; NBER CES variable names: CAP/EMP	NBER CES data
$\text{skill-intensity}_{st}$	share of compensation for non-production workers in total compensation; at the 3-digit US SIC level during a given year t; NBER CES variable names: $(\text{PAY} - \text{PRODW})/\text{PAY}$	NBER CES data
tfp_{st}	5-factor NBER TFP index with base year 1995; $tfp_{'95}$ = 1	NBER CES data
value added_{st}	industry value added in millions USD; at the 3-digit US SIC level during a given year t; NBER CES variable names: VADD	NBER CES data
Other Controls		
economic crisis	is an indicator equal to 1 for the years 2007-2009	
post 2000	is an indicator equal to 1 for the years 2001-2003 and equal to 0 for the years 1999-2000	

B.3 Calculation of the Marginal Effects

For every firm in our sample, we calculate the sum of expenses in each year. Then we express the individual category investment as share of total firm investments for each year. Next, we use these shares to calculate the average investment share of each category across all firms and years in the sample. Because the resulting average shares do not add up to one, we re-weight the shares accordingly.[25] We use the resulting shares to construct an average depreciation rate, where we weight the category specific depreciation rates with the respective average share in investment. This way, we obtain an average sample depreciation rate of 23.1%, which implies that the average firm investment lasts 1579.8 days $[= (1/r) \times 365]$.

Now we consider an increase in import competition of 60%. This corresponds to the increase of the import competition variable in our estimation sample (from 22.4% in 1995 to 35.7% in 2009). We use the regression results to calculate the relative change in each category. Because we do not know the level effect of import competition on investments, we additionally need to assume the investment elasticity in one base category. Here, we use a 0% change in Land investments with respect to a trade shock (when regressing import competition on Land investments and adding firm and year fixed effects, we find Land investments to be inelastic with respect to import competition).

Applying the relative percentage changes in each category, we can then construct new after-trade-shock investment shares. As before, we use these shares to obtain the new average depreciation rate (23.28% for specification (3) in panel B of Table III.1). Investments now fully depreciate after 1507.8 days, implying that import competition has reduced the duration of investments by about 72 days on average.

Note that these results depend on the critical values chosen for the increase in import competition and the elasticity of Land investments with respect to import competition. Thus, letting the percentage change in Land vary from -10% to +10% (holding constant the increase in import competition at 60%) changes the reduction in days from -79 to -66.1.

[25] See Figures B.3 and B.4 for the average investment composition in our sample.

CHAPTER IV

Low-wage Country Import Competition and Firms' Pricing Strategy

IV.1 Introduction

Among the most significant aspects of globalization is the integration of low-wage economies into the world trading system. The dramatic rise in international trade between rich OECD countries and low-wage economies looms large as imports from low-wage countries constitute the fastest growing fraction of manufacturing imports in both the EU and the US. As a consequence, trade integration has led to an ever fiercer international competition to which firms are exposed. Low-wage country import competition has therefore been identified as a major threat for employment and wages in the manufacturing sector in industrialized countries, creating vigorous public debates about the benefits of globalization and its impact on developed countries. This has raised interest among economists how firms react and adapt to trade competition.

This paper investigates whether import competition from China affects the pricing decisions of German manufacturing firms by holding down prices and inflationary pressure. Using survey data, the paper tests whether increased import competition from China influences firms' pricing decisions by inducing a reduction in relative prices. From a microeconomic perspective the adjustment of prices is an essential component in modern theoretical models of international trade. Stronger trade competition squeezes markups and induces a reduction in prices and profits. Ultimately, the less efficient firms eventually exit the economy, thereby inducing a reshuffling of market shares. As the composition of firms in the industry changes, this gives rise to sectoral productivity gains. The effect of trade induced competition on prices thus appears as an important driver of industrial change. From a macroeconomic perspective, the topic relates to the impact of globalization on the pattern of inflation. Even though globalization has been a primary driver of economic growth, it has been accompanied by subdued patterns of inflation.[1] As a result, observers (e.g. Rogoff (2004) and Carney (2015)) have claimed that this effect might be traced back to international competition and a reduction in monopoly pricing power.

The paper is based on detailed survey data covering the German manufacturing sector from 1995 − 2012 and concentrates on the impact of import competition originating from China. Firms differ in their exposure to import competition due to their affiliation to different types of manufacturing industries. Product level data is at a monthly frequency and provides detailed information about the timing and the direction of price changes. In addition, the data provides an extensive insight to the evolution of a firm's demand, its overall state of business and its future expectations. This allows a clean separation of demand conditions and the Chinese supply shock in order to set the ground for the identification of the effect of import competition on firms' pricing decisions. Identification of the impact of low-wage country imports on prices needs to consider two major aspects of endogeneity. Firstly, import shares are endogenous to local demand conditions. Secondly, prices might have reverse feedback effects on low-wage country imports as the latter might target markets characterized by higher price levels so as to gain market shares by undercutting incumbents' prices. To estimate the causal effect of Chinese import competition on German firms' pricing decisions and rule out issues of reverse causality, the paper instruments for Chinese import competition using the level of lagged import tariffs to the European single market as well as the lagged level of the Chinese import penetration ratio. Thus, the aim is to isolate the component of China's exports that affects pricing decisions of German manufacturing firms and is explained by internal supply shocks in China.

[1] See e.g. Rogoff (2004), Borio and Filardo (2007) and Pain, Koske, and Sollie (2008).

In a second step, the paper extends its analysis in order to explore the heterogeneity of firms' pricing strategy in response to Chinese import competition along two dimensions. Firstly, it is analyzed whether the pro-competitive effects of Chinese imports are muted in more differentiated sectors. It is assumed that high-tech sectors characterized by larger R&D expenditures are less prone to price based competition as they offer a larger degree of vertical differentiation. As such, firms in R&D intensive sectors are expected to be more likely to successfully escape from low-wage country competition. Secondly, the paper examines the role of firm heterogeneity by concentrating on the effects of capital intensity. Drawing on the factor proportions framework, capital intensive firms are supposed to be less susceptible to low-wage country competition than their more labor intensive counterparts. This is because, to the extent that a firm's input intensity reflects its type of products, the products of capital intensive firms are expected to be consistent with comparative advantage of capital abundant Germany vis-à-vis labor abundant China.

The econometric evidence suggests a positive and significant causal impact of Chinese import competition on the probability of a price reduction. Thus, competitive pressure exerted by Chinese imports on average induces firms to lower their prices. Several alternative specifications and methodologies are applied in order to quantify the effect of imports on firms' pricing strategy and provide additional robustness tests. Results point out that a 1% increase in Chinese import competition may increase the probability of a price reduction by about 0.03 percentage points. This implies that throughout the $1995 - 2012$ period covered by my data, this amounts to a rise in the likelihood of a downward price adjustment of 23 percentage points. As firms rarely change their prices and the share of price reductions in the data is very small and accounts for only 8.38%, this appears to be a noticeable effect.

However, this effect turns out to vary substantially across sectors and firms. Firms in more vertically differentiated sectors are less likely to lower their prices. Hence, this evidence implies that price adjustments by firms in less vertically differentiated sectors where price competition is more prevalent tend to drive the aggregate price response. Similarly, the results stress the role of firm heterogeneity in capital intensity in determining the impact of low-wage country competition on firm performance. In line with trade theory, the evidence shows that the pro-competitive effects of imports are muted with respect to firms' capital intensity.

The question whether imports from low-wage countries affect prices in industrialized economies has already been subject to prior research. Only few papers however succeed in establishing a causal relationship between low-wage imports and prices.[2] Exceptions are Auer and Fischer (2010) and Auer, Degen, and Fischer (2013) who study the effect of low-wage country import competition on US and European inflationary pressure. Overall, they find industries more exposed to import competition to reduce output prices. Furthermore, Chen, Imbs, and Scott (2009) analyze the impact of trade openness on producer prices in seven EU manufacturing industries. Their findings suggest that international trade induces a pro-competitive effect which induces a temporary reduction in prices in the short run. Nevertheless, these studies are restricted to data at the industry level. To date, the only study which investigates the impact of low-wage country import competition using firm level price data has been recently provided by Bugamelli, Fabiani, and Sette (2015) for Italy.[3] Therefore, the aim of this paper is to add to the literature by investigating the impact of low-wage country import competition on pricing decisions at the firm-product level and by using unique survey data on pricing decisions in German manufacturing. Extending the literature to the firm level is important as estimation results at the industry level might be compounded by compositional effects. If low productivity firms characterized by higher output prices are not able to sustain the increased level of competition, they might exit the industry and thereby induce a reduction in the aggregate price level. In addition, these studies do not take account of sector and firm heterogeneity.

The effects of low-wage country imports on firms and workers in industrialized economies have raised considerable interest among researchers. Bernard, Jensen, and Schott (2006) analyze the impact of exposure to international trade with low-wage countries in the

[2] See e.g. Borio and Filardo (2007), Glatzer, Gnan, and Valderrama (2006), International Monetary Fund (2006) and Kamin, Marazzi, and Schindler (2006). Overall, the literature fails to take account of the endogeneity of low-wage country imports to changes in domestic demand. Thus, the literature is not able to separate domestic demand shocks from foreign supply shocks.

[3] While Auer, Degen, and Fischer (2013) do not find any significant price effect for Italy at the sector level, Bugamelli, Fabiani, and Sette (2015) find a significant effect in their study based on price data at the firm level. This corroborates the limits of studies based on price data at the industry level.

US and find a negative impact on plant survival and employment growth. In addition, firms respond to increased competition by adjusting their product mix. Mion and Zhu (2013) study the impact of imports from different origins on employment, market exit and skill upgrading in Belgian manufacturing. Chinese competition reduces firm employment and induces skill-upgrading while offshoring to China increases the probability of firm survival. Amiti and Khandelwal (2013) focus on the effect of import competition on product quality. Their findings show that tougher import competition spurs quality upgrading of products close to the world quality frontier and diminishes quality upgrading of products located far away from the technology frontier. Similarly, Bloom, Draca, and Van Reenen (2016) explore the impact of Chinese import competition on various measures of technology upgrading such as patents, IT adoption and productivity. They conclude that Chinese import competition has induced about 15% of European technology upgrading over the period 2000 – 2007. Autor, Dorn, and Hanson (2013b) and Autor, Dorn, Hanson, and Song (2014) assess the effect of Chinese import competition on US labor markets. Rising import competition relates to higher unemployment rates and reduced wages and earnings in labor markets that are more exposed to Chinese trade competition. Dauth, Findeisen, and Suedekum (2014) extend these studies to the German labor market. In equal measure, their results unveil that industries competing with imports from China and Eastern Europe are subject to job losses.

The rest of the paper is organized as follows. Section IV.2 discusses the theoretical and empirical background of Chinese imports, competition and prices in order to motivate the empirical analysis. Section IV.3 presents the data. Section IV.4 discusses the empirical strategy and provides the econometric estimates. Section IV.5 expands the inquiry to sector and firm heterogeneity and section IV.6 concludes.

IV.2 Theoretical and Empirical Background

In this section the theoretical background of trade, prices and competition is reviewed in order to consider how growth in German imports from China affects price setting.

Throughout the past two decades, China experienced spectacular economic growth and a surge in exports which is mainly traced back to its transition to a market oriented economy. The share of total German spending on Chinese manufacturing goods rose from roughly 3% in 1995 to about 10% in 2012. Similarly, China's share in world exports more than trippled over the same time period (see Figure IV.1). Obviously, China's trade shock offers the con-

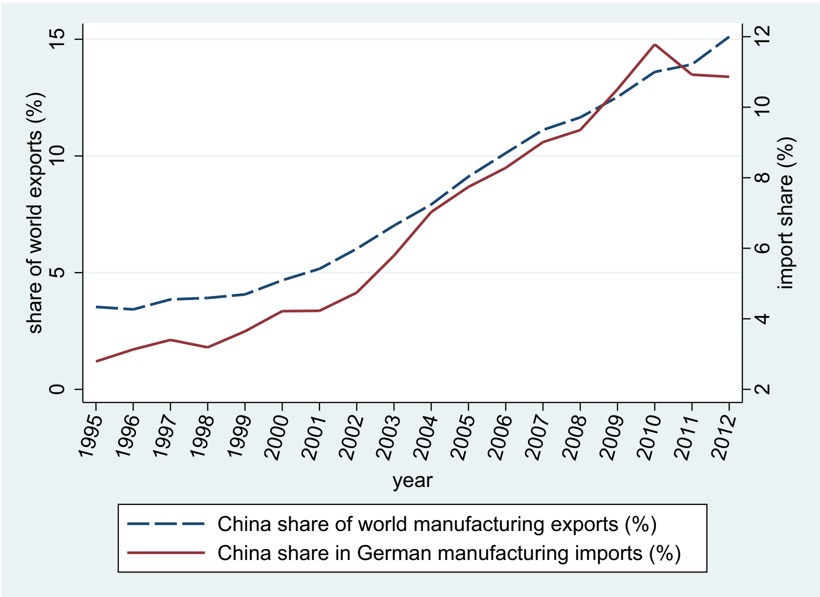


Figure IV.1: China's Share of World Manufacturing Exports and China's Share of Imports in German Manufacturing, 1995 - 2012

venience of being temporally well identified with an inflection point in 2001 when China joined the WTO and was granted most-favored nation status among the 153 WTO members. As such, China's export growth has been identified as a major source of disruption to the manufacturing sector in high-wage countries. Autor, Dorn, and Hanson (2013b) estimate that the rise of Chinese exports to the US explains about 21% of the aggregate decline in US manufacturing employment in the past 20 years. Besides, Schott (2008) documents the strong overlap in China's exports with products of industrialized high-income economies. Finally, with competitive pressure stemming from Chinese imports being mostly price based (cf. Schott (2008)), it appears particularly appealing to concentrate on import penetration from China, in order to gauge the impact of low-wage country competition on domestic firms' pricing decisions.

The negative impact of trade competition on prices is an inherent part of several seminal models of international trade based on monopolistic competition. Krugman (1979) provides a model of international trade, variable price elasticity of demand and pro-competitive effects in a model with symmetric firms. Opening up to trade increases the number of active firms and varieties in the market. As a result, consumption of each variety declines and the price elasticity of demand increases. Trade therefore yields a pro-competitive effect by reducing the markup of price over variable costs of production. Melitz and Ottaviano (2008) extend the Melitz (2003) model of heterogeneous firms and trade and develop a model with firm heterogeneity and endogenous toughness of competition and variable markups in a setting of monopolistic competition. Firms' markups and prices respond to the extent of trade integration as firms in more integrated markets exhibit lower markups due to tougher trade competition. Firms that do not break even exit the market. Consequently, competition induces a reallocation of market shares and resources which then increases average firm productivity as only the most productive firms are able to survive. The model by Melitz (2003) features no explicit pro-competitive effect since it is based on a CES demand function, sectoral productivity gains however lead to a reduction of the aggregate industry price index. By means of a different market structure, namely oligopolistic competition, Markusen (1981) highlights the pro-competitive effect from trade due to the reduction in market power of a domestic monopolist. Hence, the following testable hypothesis is considered.

Hypothesis 1 *Firms reduce their domestic sales prices with increasing industry exposure to imports from China.*

The theoretical and empirical background related to sector and firm heterogeneity is presented later on in section IV.5.

IV.3 Data Sources and Measurement

In this section details about the data are provided and the methodology used in order to construct the measure of Chinese import competition is set forth.

IV.3.1 Measuring Import Competition

Industry-level imports data comes from the Comext database provided by Eurostat. The database provides detailed data on merchandize trade conducted by the member countries of the EU and is compiled by Eurostat by using the official statistics from the member countries. I extract data on German manufacturing imports from China by 2-digit NACE rev. 1.1 industry for the period 1995–2012. Exposure to import competition faced by German manufacturing firms is measured as the share of imports from China in domestic consumption at the 2-digit NACE rev. 1.1 level following Bernard, Jensen, and Schott (2006). It is therefore assumed that firms within an industry experience a similar extent of competitive pressure on their final goods which can be proxied by the importance of imports within the respective sector. The measure is defined by

$$Import\ competition_{st}^{China} = \frac{Imp_{st}^{China}}{Prod_{st} + Imp_{st}^{World} - Exp_{st}^{World}}. \tag{IV.1}$$

The variable Imp_{st}^{China} denotes the value of imports from China from sector s in year t, whereas Imp_{st}^{World} and Exp_{st}^{World} represent German manufacturing imports and exports with respect to the entire universe of trading partners. The variable $Prod_{st}$ is German domestic production. Data on total imports and exports by industry as well as domestic production are taken from the PRODCOM database which is also constructed by Eurostat.

IV.3.2 Data on the Pricing Strategy of Firms

Data on firms' pricing strategy is based on the Ifo business tendency survey for German manufacturing firms collected by the Ifo Institute for Economic Research.[4] The Ifo business tendency survey is carried out on a monthly basis and concentrates on firm-specific appraisals and future expectations concerning the business as well as the market conditions. The data is at the product level. Moreover, since firms might respond to multiple questionnaires for different business units and product groups, the observation unit is a firm-product combination. Firms take part in the survey on a voluntary basis for which reason not ev-

[4] For more information on the survey data see Becker and Wohlrabe (2008) and Abberger, Hofmann, and Wohlrabe (2007).

ery firm responded every month yielding an unbalanced dataset. In order to obtain a more consistent sample, we drop firm-product observations for a given year if the product is covered less than 6 months. Finally, with my sample running from January 1995 to December 2012, this leaves us with 2539 firms and a total of 2829 firm-product combinations. Overall, the survey does not request firms to provide absolute or monetary figures for which reason the participating companies are mostly presented with binary or ordinally scaled response categories.

One of the survey questions relates to the pricing decision of the firm with respect to the domestic prices of sale versus the previous month. The answer is on an ordinal scale and firms indicate whether their domestic sales prices increased, remained unchanged or decreased. In the subsequent econometric analysis, the firms' pricing decision will be coded as as a binary response variable indicating whether a firm has decreased product prices or not. Alternatively, in order to test the robustness of the results, we also use an ordinal response variable signalling whether prices have been increased $(+1)$, remained unchanged (0) or decreased (-1). Figure C.1 depicts the evolution of the share of price increases per year as well as the annual inflation rate in the German manufacturing sector. Both variables follow a uniform path, suggesting that the pricing decisions by the sample of firms are highly representative for the German manufacturing sector as a whole. Overall in the entire sample, price reductions and price increases constitute a fraction of 8.38% and 10.17% respectively, whereas in 81.45% of all observations prices remained constant (see Table C.6). On average, firms change the price of a specific product about 2.17 times by year. In doing so, prices are reduced about 0.95 times and increased about 1.21 times per year on average (see Table C.7). [5]

Table C.5 displays the average share of price decreases in total price adjustments as well as the average degree of import competition in each 2-digit NACE rev. 1.1. industry before (1995 – 2000) and after China's accession to the WTO (2001 – 2007). The period 2008 - 2012 is dropped in order not to falsify the descriptive statistics with the impact of the economic recession due to the 2008 - 2009 financial crisis. Import competition from China increased in all

[5] Since firms may change product prices multiple times per year, we prefer to remain with the data at the monthly level and not to aggregate it to the year level.

manufacturing industries. The pattern of price reductions across industries nevertheless is less obvious. Computing a simple correlation between the average share of price reductions and the average change in import penetration yields a positive though slightly insignificant coefficient of 0.32. Restricting the set of industries to low-tech and medium low-tech sectors results in a large and highly significant correlation of 0.57 which drops again to 0.24 and turns insignificant once we concentrate on high-tech and medium high-tech sectors.[6] Altogether, this is consistent with the idea of Chinese imports exerting competitive pressure by selling at a discount and forcing firms in sectors which are less in line with German comparative advantage to cut prices.

IV.3.3 Firm and Product Level Controls

Measuring the impact of import competition on domestic sales prices requires data which allows to control for both, the costs of production and the demand and market situation of firms.

Data describing a firms' demand and market environment is again extracted from the Ifo business tendency survey at a monthly frequency. Amongst others, the survey provides detailed information about a firms' situation of demand. More precisely, firms specify whether their demand situation has improved, remained unchanged or deteriorated compared to the previous month. In addition, firms are requested to evaluate their current state of business. A firm may appraise its state of business as good, satisfactory or bad. Ultimately, the survey also includes questions on the expected future of the firm. As such, firms indicate whether their expectations for the next six months with respect to the economic development of their business situation are rather more favorable, about the same or rather more unfavorable. With respect to all three variables, the ordinal scale of the three response categories is coded as +1 (improvement/ good/ favorable), 0 (unchanged/ satisfactory/ same) and -1 (deterioration/ bad/ unfavorable).[7] Controlling for a firm's demand is fundamental in order to take

[6]The ranking of industries according to different technology intensities follows the Eurostat indicator on high-tech industries which classifies industries based on the share of R&D expenditures in value added.

[7]When a company assesses its current or future state of business, its response is likely to depend on the respective interpretation of the questionnaire. Questions related to the firm's business situation relate to the overall economic conditions with which the firm is confronted. It is the firm which is charged with choosing the

account for potential demand shocks such as the 2008 – 2009 financial crisis. Moreover, it allows to disentangle domestic demand shocks from the Chinese import shock as trade flows are endogenous to the development of local demand conditions: If firms in an industrial sector in Germany are subject to a positive demand shock, prices increase. This might in turn lead to a rise in low-wage country imports, as firms from low-wage countries might seek to expand their presence in the domestic market with cheap imports. In addition, the variable allows taking into account the impact of competition induced by the overall set of domestic and foreign competitors other than Chinese importers. In equal measure, controlling for the present state of business and future commercial expectations captures the economic performance of the firm. These two aspects are again affected by the competitive pressure the firm is facing and thereby reflect the market situation of a firm on its domestic product market in Germany. The survey also provides information about the export status of a product. Goods which are exported might suffer less from Chinese import competition as profit losses on the domestic market might be compensated by export revenues from foreign markets.

Furthermore, prior theoretical research suggests a relationship between the market power of a firm and its size. In the model by Melitz and Ottaviano (2008) larger firms exhibit lower unit costs and exhibit higher market power by charging larger markups. Atkin, Chaudhry, Chaudry, Khandelwal, and Verhoogen (2015) provide empirical evidence how markups systematically increase in firm size even in narrowly defined product categories. Firm size is primarily measured by the number of employees which is drawn from both, the Ifo business tendency survey and balance sheet data from the Amadeus and Hoppenstedt databases. In case that the balance sheet data does not provide the annual number of employees, we use employment numbers given by the survey data at the firm-product level which are then aggregated across months and business units at the firm-year level. In addition, so as to capture further alternative measures of firm size, we control for total fixed assets as well as operating revenues.

In order to account for the costs of production further variables at the firm level are used. The main data source is again annual balance sheet data taken from the Amadeus and Hop-

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fundamentals on which to make its appraisal (see Becker and Wohlrabe (2008)).

penstedt databases and matched with the Ifo survey data. Wages and salaries are measured by the amount of staff expenses and the proxy for a firm's input costs is given by the costs of materials. Labor costs are included in order to hold constant the impact of rising Chinese imports on wages and employment in import competing industries. Similarly, material costs intend to control for changes in the costs of inputs which might be affected by imports of cheaper Chinese intermediates as well as competitive pressure exerted by Chinese producers on the price level of intermediates.

Since a notable fraction of firms is not represented with balance sheet information, combining the survey data with the balance sheet data causes a large loss of observations. Nevertheless, the resulting panel still comprises about 1500 units of observation.

IV.4 Empirical Strategy

IV.4.1 Econometric Specification

This section examines the effects of Chinese imports on the pricing strategy of firms and presents the basic identification strategy and results. The aim of the empirical strategy is to isolate the effect of import competition from China. For that reason the empirical specification attempts to consider all major price determinants which might be related to low-wage country imports. The pricing strategy of a firm and product combination is a binary variable and reflects the decision to reduce the price with respect to the previous month or not. Hence, we fit a linear probability model (LPM) of the following form:

$$price\,reduction_{ismt} = \beta_1 \times \ln\left(ImpComp^{CN}_{st}\right) + \mathbf{X'_{ismt}}\gamma + \mu_i + \mu_s + \mu_m + \mu_t + \varepsilon_{ismt}. \quad \text{(IV.2)}$$

The pricing strategy of a firm with respect to a specific product i in month m within year t is regressed on its exposure to import competition at the sectoral level s from China and a set of control variables $\mathbf{X_{ismt}}$ as well as a set of fixed effects. Import competition is denoted by $ImpComp^{CN}_{st}$ and is given by the log of the measure developed in section IV.3.1. If, according to *Hypothesis 1*, the rise of Chinese import competition forces German manufacturing firms to reduce their domestic prices in order to remain on the market, the coefficient of $\ln\left(ImpComp_{st}^{CN}\right)$ is expected to be positive.

$\mathbf{X_{ismt}}$ is a vector containing controls at the product and firm level that account for further aspects that affect product level prices namely demand, market power and production costs.[8] These determinants are incorporated as they are potentially correlated with the degree of Chinese import competition. First of all, as noted earlier, the market environment might interact with the level of Chinese imports. Therefore the situation of demand, the state of business, commercial future expectations and export status are included. Market power reflected by firm size is considered by employing the number of employees, assets and revenues. Finally, labor costs and costs of inputs are included based on measures for staff expenses and material costs.

Lastly, μ_i is a set of fixed effects controlling for unobserved and time-invariant firm-product characteristics and μ_s are industry fixed effects that eliminate unobserved time-invariant factors that vary across sectors at the NACE rev. 1.1 4-digit level. Year fixed effects μ_t and month fixed effects μ_m are included to sweep out variation across time common to all firms and industries such as the business cycle, seasonal fluctuations and technology shocks. Standard errors are robust and two-way clustered at the firm-product level and at the 4-digit NACE rev. 1.1 sector level.

IV.4.2 Causality: Endogeneity and IV Strategy

The empirical model set forth above might suffer from an endogeneity problem even after inclusion of the range of different price determinants presented in section IV.3.3 and section IV.4.1. More precisely, price based Chinese importers might target specific sectors in which firms are less prone to decrease their prices so as to undercut the price level and gain market shares. Thus, the pricing strategy of firms could cause Chinese imports to be more present in certain industries. This causes the analysis to suffer from reverse causality and creates a correlation of Chinese import competition with the error term which is expected to provoke a downward bias of the OLS estimates. Similarly, an upwards bias could arise if firms in

[8]For the sake of simplicity a firm and firm-product combination are both denoted with the subscript *i*.

sectors that are not price competitive and less likely to reduce their price, engage in lobbying against Chinese imports. The time-invariant ability of firms and sectors to compete on prices is captured by fixed effects. Primarily however, so as to tackle this problem, I use most favored nation tariffs (MFN) applied to Chinese imports in the EU single market from the UN Comtrade database in order to instrument for import competition. The tariff measures are a weighted average of *ad valorem* tariffs for traded products (tariff lines) at the HS 8-digit level where more weight is given to products with larger import flows.[9] Subsequently, the data is concorded to the NACE rev. 1.1 classification and aggregated to the 2-digit level. Furthermore, the tariff measures are lagged by two years. Figure C.2 presents the correlation between the log of tariffs and the log of the import competition and Figure C.3 presents the development of the average most favored nation tariff rate and average import competition across all manufacturing industries for the period $1995 - 2012$. Both graphs exhibit the negative relationship which is employed in the first stage regressions. Clearly, tariffs are assumed to be exogenous to the pricing behavior of firms and hence permit identification of the impact of Chinese import competition on the pricing strategies in German manufacturing. This premise however could be violated if for example firms in price sensitive sectors are able to lobby for tariff protection from cheap low-wage country imports. In addition, I follow Bernard, Jensen, and Schott (2006) and employ the lag of Chinese import competition ln $\left(ImpComp^{CN}_{st-2}\right)$ as supplementary instrument based on the assumption that a firm's pricing strategy in the present has no impact on the rate of Chinese imports in the past.

IV.4.3 Baseline Results

This section presents the econometric results with respect to *Hypothesis 1* and equation (IV.2) and the fundamental question whether Chinese import competition involves firms in decreasing their prices. Table IV.1 presents the results of the OLS and the 2SLS estimations. As noted earlier, all regressions control for fixed effects along the firm-product, sector, month and year dimension.

The first column in Table IV.1 reports the coefficient from regressing the binary variable

[9] *Non ad valorem* tariffs have been transformed to *ad valorem equivalents* following the UNCTAD 1 method.

	LPM			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			**price reduction**			
$\log(\text{ImpComp China})_{st}$	0.0230***	0.0234***	0.0196*	0.0317***	0.0303**	0.0482**
	(0.00535)	(0.00549)	(0.0106)	(0.0109)	(0.0121)	(0.0235)
$\text{demand change}_{ismt}$		-0.0201***	-0.0168***		-0.0210***	-0.0183***
		(0.00328)	(0.00365)		(0.00339)	(0.00395)
$\text{state of business}_{ismt}$		-0.0581***	-0.0533***		-0.0579***	-0.0524***
		(0.00733)	(0.00670)		(0.00737)	(0.00676)
$\text{commercial expectations}_{ismt}$		-0.0296***	-0.0332***		-0.0294***	-0.0335***
		(0.00304)	(0.00474)		(0.00305)	(0.00475)
export_{ismt}		-0.00430	-0.0105		-0.00494	-0.0161
		(0.0119)	(0.0214)		(0.0126)	(0.0226)
$\log(\text{employment})_{ist}$		0.00240	-0.00311		0.00153	-0.00441
		(0.00496)	(0.00790)		(0.00493)	(0.00667)
$\log(\text{staff expenses})_{ist}$			-0.00800			-0.00460
			(0.00899)			(0.00885)
$\log(\text{cost of materials})_{ist}$			0.00632			0.00363
			(0.00650)			(0.00690)
$\log(\text{revenue})_{ist}$			-0.00116			-0.00384
			(0.00895)			(0.00920)
$\log(\text{assets})_{ist}$			0.0116*			0.0115*
			(0.00603)			(0.00626)
					2SLS first stage	
$\log(\text{ImpComp China})_{st\text{-}2}$				0.608***	0.608***	0.533***
				(-0.0308)	(-0.0309)	(-0.038)
$\log(\text{MFN tariff})_{st\text{-}2}$				-0.238***	-0.238***	-0.142***
				(-0.0612)	(-0.061)	(-0.0416)
Kleibergen-Papp Wald F stat				270.5	267.8	110.8
Hansen J statistic				1.829	2.671	1.353
p-value of Hansen J statistic				0.176	0.102	0.245
Observations	170,390	169,768	81,469	164,269	163,653	76,184
R-squared	0.256	0.279	0.286	0.261	0.283	0.295
firm-product clusters	2,829	2,828	1,504	2,798	2,797	1,476
industry clusters	212	212	190	211	211	189

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. The dependent variable *price reduction* is a binary variable indicating whether the domestic price of sale of a specific product has been reduced or not compared to the previous month. The coefficient of interest $log\,(ImpComp)_{st}$ is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. Instruments are the two-year lag of the log of Chinese import competition and of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table IV.1: Impact of Import Competition from China on Firms' Pricing Strategy: LPM and 2SLS Estimation indicating whether a firm has engaged in a price reduction on the log of import penetration. The coefficient is positive and highly significant suggesting a positive relationship between Chinese imports and the probability of lowering prices. As argued in section IV.4.2, the entry of Chinese importers on the German market might however depend on the pricing strategies by German manufacturing firms, as Chinese exporters might be attracted by sectors where firms are less price competitive. Following this line of reasoning, the specification might suffer from reverse causality and the coefficient of import competition is expected to be biased downwards. Considering the corresponding 2SLS estimation in column (4), the coefficient of interest is both positive and highly significant. Futhermore, the coefficient increases in size, hereby affirming the concern of reverse causality. Altogether these findings are in line with *Hypothesis 1* and suggest that firms on average reduce their domestic sales prices as response to low-wage country competition. Next, I add controls that capture a firm's market environment and size to the specification in column (2). More precisely, the change in demand with respect to the previous month, the assessment of the current state of business, commercial expectations as well as export status and firm employment are included. The coefficient of interest shows up positive and statistically significant and remains constant in size. Overall, the impact of the control variables appears to be reasonable and in line with expectations. An increase in demand, a favorable state of business as well as positive commercial expectations are negatively associated with a firm's likelihood of a price reduction. Export status and firm employment however are insignificant. Considering the estimation results of the 2SLS regression in column (5), the coefficient of interest is likewise positive and significant and points towards a stable positive impact of Chinese imports on price reductions even when taking into account reverse causality. Finally, column (3) controls for costs and further size measures at the firm level by employing staff expenses and costs of materials as well as total assets and revenues. Still, exposure to Chinese imports induces a reduction in a firm's domestic sales price according to both, the OLS estimates in column (3) and the 2SLS estimates in column (6), as the coefficient of interest is positive and significant. The OLS coefficient is stable in size whereas the 2SLS coefficient increases slightly compared to its counterparts in columns (4) and (5). While assets are positively related to a price reduction, the remaining firm level controls are insignificant. Furthermore, in each specification the instruments pass the tests of weak instrumentation (Kleibergen-Paap Wald F) and overidentification (Hansen J) as indicated by the test statistics at the bottom of Table IV.1. In addition, the sign of the instruments in the first stage regressions are consistent with expectations: The coefficients of lagged tariffs exhibit a negative sign and lagged import shares are positively related with the contemporaneous level of import competition.

In total, these results point towards a negative causal impact of competitive pressure exerted by Chinese imports on domestic sales prices. Given the coefficent in column (5), a 1% increase in import competition from China induces an increase in the probability of a price reduction by 0.03 percentage points. As my measure of import competition increased from 1.94% to 16.27% on average across all industries within the 1995-2012 period covered by my sample, this implies a rise in the likelihood of a price reduction of about 23 percentage points. Against the background that price reductions only account for 8.38% of the data, this seems to be a noticeable effect.

Adding balance sheet variables leads to a considerable drop in the number of observations. In order to investigate the impact of this change in sample size on the estimation results, I rerun my specifications with the sample fixed to firms providing balance sheet information. This entails a dataset which contains only about half of the original number of observations but which still counts about 1500 firm-products. Results are presented in Table IV.2. Columns (1) and (4) repeat the previous baseline regressions where controls for both demand and cost factors are included. Subsequently, controls are restricted to the demand and market conditions in columns (2) and (5) prior to focusing only on controls for production costs, assets and revenue in columns (3) and (6). The test statistics on the performance of the 2SLS estimations are always satisfied and the size of the coefficient of interest is constant throughout the set of OLS and 2SLS estimations. While the OLS coefficients are equal to the results when using the full sample in Table IV.1, this does nevertheless not hold for the 2SLS coefficients. Hence, whereas the change in sample size does not affect the size of the OLS coefficients, this seems to be slightly the case for the 2SLS estimates.

Chinese imports might exert a pro-competitive effect that leads to losses in market power

	LPM			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			**price reduction**			
log(ImpComp China)$_{st}$	0.0196*	0.0201*	0.0197*	0.0482**	0.0487**	0.0508**
	(0.0106)	(0.0108)	(0.0109)	(0.0235)	(0.0238)	(0.0248)
demand change$_{ismt}$	-0.0168***	-0.0168***		-0.0183***	-0.0183***	
	(0.00365)	(0.00367)		(0.00395)	(0.00397)	
state of business$_{ismt}$	-0.0533***	-0.0530***		-0.0524***	-0.0525***	
	(0.00670)	(0.00660)		(0.00676)	(0.00664)	
commercial expectations$_{ismt}$	-0.0332***	-0.0332***		-0.0335***	-0.0334***	
	(0.00474)	(0.00475)		(0.00475)	(0.00476)	
export$_{ismt}$	-0.0105	-0.0108		-0.0161	-0.0173	
	(0.0214)	(0.0213)		(0.0226)	(0.0227)	
log(employment)$_{ist}$	-0.00311	-0.00108	-0.000194	-0.00441	-0.00292	-0.000511
	(0.00790)	(0.00840)	(0.00803)	(0.00667)	(0.00692)	(0.00734)
log(staff expenses)$_{ist}$	-0.00800		-0.000828	-0.00460		0.00258
	(0.00899)		(0.00897)	(0.00885)		(0.00871)
log(cost of materials)$_{ist}$	0.00632		0.00485	0.00363		0.00134
	(0.00650)		(0.00729)	(0.00690)		(0.00800)
log(revenue)$_{ist}$	-0.00116		-0.0136	-0.00384		-0.0154*
	(0.00895)		(0.00850)	(0.00920)		(0.00869)
log(assets)$_{ist}$	0.0116*		0.0129**	0.0115*		0.0128**
	(0.00603)		(0.00597)	(0.00626)		(0.00617)
					2SLS first stage	
log(ImpComp China)$_{st-2}$				0.533***	0.534***	0.533***
				(0.0380)	(0.0384)	(0.0383)
log(MFN tariff)$_{st-2}$				-0.142***	-0.141***	-0.141***
				(0.0416)	(0.0421)	(0.0416)
Kleibergen-Papp Wald F stat				110.8	107.9	109.6
Hansen J statistic				1.353	1.408	0.970
p-value of Hansen J statistic				0.245	0.235	0.325
Observations	81,469	81,469	81,469	76,184	76,184	76,184
R-squared	0.286	0.286	0.267	0.295	0.295	0.275
firm-product clusters	1,504	1,504	1,504	1,476	1,476	1,476
industry clusters	190	190	190	189	189	189

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. The sample is restricted to firm-product observations that are matched with information from balance sheet databases. The dependent variable *price reduction* is a binary variable indicating whether the domestic price of sale of a specific product has been reduced or not compared to the previous month. The coefficient of interest $log\,(ImpComp)_{st}$ is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. Instruments are the two-year lag of the log of Chinese import competition and of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table IV.2: Impact of Import Competition from China on Firms' Pricing Strategy: LPM and 2SLS Estimation with Sample Restricted to Firms Represented with Balance Sheet Data on the domestic market which induces firms to reduce prices by squeezing their markups. Firms might nevertheless also adapt their production costs by engaging in innovations, by changing the composition and wages of the labor force or by adjusting the mix of intermediate inputs as well as products. Besides, a reduction in prices might be driven by outsourcing activities and access to cheap intermediates from China.[10] By improving the efficiency of production a firm might thus reduce its output price and keep the markup constant. A priori, it is not evident which underlying mechanism drives the adjustment of prices. Given that the specification takes account of staff expenses, input costs and different measures of firm size, a plausible reasoning however would be to assume that the negative impact of Chinese imports on prices reflects a competition effect that induces a reduction in markups. Next, I aim to investigate the robustness of the baseline results.

IV.4.4 Robustness

First of all, the rise of Chinese exports might reflect the increase in global trade throughout the last two decades. For this reason, I add a measure of import penetration by the rest of the world but other than China to my specification. The measure is constructed along the lines of section IV.3.1 by substituting Chinese imports with the difference of total world imports and Chinese imports. The estimation results are presented in Table C.1. The organization of the regressions follows the baseline specifications in section IV.4.3. Throughout all estimations, the coefficient of Chinese import competition remains positive and significant. Moreover, the coefficient is similar in size as in the baseline estimations in section IV.4.3. Import penetration induced by the rest of the world however appears insignificant in all specifications. Furthermore, note that while the 2SLS estimation in column (5) slightly fails the test of overidentification, specifications in columns (4) and (6) both satisfy the Hansen J test.

Since my panel includes the 2008 – 2009 financial crisis, my estimates might be con-

[10] Bloom, Draca, and Van Reenen (2016) provide evidence of increases in R&D expenditures, patent activity and TFP of European firms in response to Chinese import competition. Mion and Zhu (2013) find firms to reduce firm-employment growth and engage in skill-upgrading. Moreover they identify a positive impact of offshoring activities to China on a firm's survival probability. Bernard, Jensen, and Schott (2006) find evidence for firms adjusting their product mix in response to low-wage country competition by switching to industries that are less exposed. Similarly, according to Mayer, Melitz, and Ottaviano (2014) competition induces firms to drop badly performing products and reallocate resources towards the best performing core products.

founded by the dramatic price changes due to the economic recession (see Figure C.1). Therefore, I rerun my specifications after dropping the 2008 – 2009 period from the sample. Results displayed in Table C.2 suggest that sign, size and significance of the coefficient of interest once more remain unaffected.

The LPM offers the benefit of allowing to address issues of endogeneity conveniently by 2SLS estimation. The LPM however also features several shortcomings: Firstly, it might generate predictions for which the predicted probability is not bounded between zero and one. Secondly, it assumes that the probability of a price reduction depends linearly on the level of import penetration for all possible values. To deal with this concern, I estimate in a third step a Probit model based on dummy variables to capture fixed effects. Table C.3 presents the corresponding average marginal effects. Overall, the marginal effects of import competition from China are all similar in size to the LPM coefficients in Table IV.1 and Table IV.2. Hence, the choice of the LPM as main estimation method does not seem to primarily drive the results.

Lastly, I replace the binary variable indicating a price reduction with the ordinal response variable describing the direction of price changes. A price increase now takes the value of $+1$, a constant price is coded as 0 and a price reduction by -1. In order to be in line with *Hypothesis 1*, the coefficient of Chinese import competition is now supposed to be negative. Table C.4 presents the results. Regressing the direction of price changes on the import penetration measure yields negative and significant coefficients in both the OLS and 2SLS estimation. Hence, Chinese import competition again entails firms to lower prices. Beyond that, in the 2SLS estimation the coefficient increases once more in absolute size in line with the potential concern of reverse causality. Similar results appear when controlling for demand conditions and employment. Adding controls for staff expenses, input costs as well as assets and revenues however yields an insignificant coefficient of interest in the OLS estimation (column (3)) and the analogous 2SLS estimation (column (6)).

Overall, across all estimations the sign of the instruments in the first stage regressions is in line with expectations. While the lagged level of most favored nation tariffs is negatively related to my measure of import penetration, the level of lagged imports is positively related with the latter. In addition, the test statistics suggest that overidentifaction and weak identification are of no concern.

Summing up the robustness tests, the baseline estimations turn out to be valid in several alternative specifications thereby substantiating the main result.

IV.5 Sector and Firm Heterogeneity

The analysis is now extended in order to provide a more detailed understanding of the mechanisms and patterns of price responses to Chinese competitive pressure across firms and sectors. Additionally, this intends to increase the validity of the baseline results.

IV.5.1 Theoretical and Empirical Background

In focusing on sector heterogeneity my aim is to exploit information that indicates the extent to which competition in a given sector is based on prices. If products in a sector are homogenous, competition is supposed to be played on prices. Since in that case the sector's products compete closely with each other, cheap Chinese imports are expected to severely augment the toughness of competition in the market thereby forcing firms to cut prices in order to preserve market shares. If products are however vertically differentiated, German firms are expected to be less threatened by Chinese imports as competition is carried in the first instance with respect to product-specific attributes such as product quality and the degree of innovation. Khandelwal (2010) finds that heterogeneity across sectors in their scope for quality differentiation strongly determines the impact of low-wage country competition. In industries characterized by a large scope for quality differentiation, firms can readily escape competition through differentiating their product by upgrading quality. The opposite however arises in sectors with limited scope for differentiation where quality upgrading is no viable option. Hence, firms in these sectors are more strongly exposed to competition from low-wage countries. The degree of product differentiation and price based competition is measured by industry R&D intensity. As such, R&D expenditures are the main source of innovation for firms so as to differentiate their products. Beyond that, R&D intensive sectors are considered as skill-intensive as they occupy a large share of scientists and engineers. Following classical factor-proportions theory, countries that are abundant in skilled labor are supposed to exhibit comparative advantage in industries that intensively use a skilled labor force. China being abundant in low-skilled labor is by contrast supposed to possess comparative advantage in low-skill intensive industries. With China capturing larger shares in German imports in sectors that are intensive in low-skilled labor, the latter are most threatened by Chinese import competition compared to high-skill and R&D intensive sectors. Based on these considerations, the following hypothesis is derived.

Hypothesis 2 *The pro-competitive effect of Chinese imports on domestic sales prices is less pronounced in more vertically differentiated industries.*

Moreover, trade integration between a capital and skill rich developed country like Germany, and a labor abundant country such as China is expected to induce a reallocation of resources in both regions: Capital and skill intensive sectors in the developed country expand, whereas labor intensive sectors shrink. As developed countries specialize in high-skill intensive and vertically differentiated products and developing countries specialize in low-skill intensive and homogenous products, sectors in the developed country differ in their exposure to low-wage country import competition according to their equivalent sector specific attributes. Following Bernard, Jensen and Schott (2006), this reasoning can be extended to the firm level. Consequently, it is assumed that the input intensity of a firm displays the factor intensity of its product mix hereby revealing the firm's contestability to low-wage country imports. Hence, firms with relatively capital intensive production are assumed to produce capital intensive products. With the capital intensive sector expanding, capital intensive firms are therefore expected to feature a product mix which is more in line with comparative advantage and to be less affected by low-wage country imports.

Hypothesis 3 *The pro-competitive effect of Chinese imports on domestic sales prices is less pronounced for capital intensive firms.*

The following section presents the estimation strategy and results.

IV.5.2 Econometric Specification and Results

As argued before in section IV.5.1, the competitive pressure of Chinese imports is supposed to vary across sectors with different R&D intensity and firms with varying capital intensity. Accordingly, the regression equation is modified to take the following form

$$\begin{aligned} price\ reduction_{ismt} = \beta_1 \times \ln\left(ImpComp_{st}^{CN}\right) + \beta_2 \times \ln\left(ImpComp_{st}^{CN}\right) \times \Gamma \\ + \mathbf{X'_{ismt}}\gamma + \mu_i + \mu_s + \mu_m + \mu_t + \varepsilon_{ismt} \end{aligned}, \quad \text{(IV.3)}$$

where the variable Γ is either given by R&D intensity at the sector level s or capital intensity at the firm level i.

IV.5.2.1 Sector Heterogeneity: Vertical Differentiation

If more R&D intensive sectors entail a larger degree of product differentiation, they are subject to a lower extent of competitive pressure by Chinese imports. Thus, β_1 is expected to show a positive sign whereas β_2 is in contrast expected to show a negative sign in order to be consistent with *Hypothesis 2*. Sectoral R&D intensity is measured by the volume of R&D expenditures over the number of employees. Because I want the measure not to be affected by German firms' reactions to China's rise in world trade after its entry to the WTO in 2001, the measure is computed on the basis of US data and for the year 2000.[11] The data is at the 3-digit NACE rev. 1.1 level.[12] Subsequently an indicator is constructed according to which a sector is defined as R&D intensive if the ratio of R&D expenditures per employee is above the 75% percentile of the distribution.

Results are reported in Table IV.3. Column (1) displays the baseline specification with

[11]See Bloom, Draca, and Van Reenen (2016) for recent evidence how European firms increase R&D expenditures as response to import competition from China.

[12]The original US data is at the 3-digit NAICS 2002 level and mapped to the 3-digit NACE rev. 1.1 level by means of a NAICS 2002 - NACE rev. 1.1 correspondance (see Table C.9 for more details).

	LPM			2SLS		
	(1)	(2)	(3)	(1)	(2)	(3)
Dependent variable:			**price reduction**			
$\log(\text{ImpComp China})_{st}$	0.0233***	0.0239***	0.0223**	0.0310***	0.0294**	0.0504**
	(0.00545)	(0.00570)	(0.0105)	(0.0110)	(0.0122)	(0.0233)
$\log(\text{ImpComp China})_{st}$ * R&D int_s	-0.0134*	-0.0177**	-0.0176*	-0.0199*	-0.0247**	-0.0254**
	(0.00748)	(0.00733)	(0.00938)	(0.0108)	(0.00950)	(0.0116)
demand change_{ismt}		-0.0201***	-0.0168***		-0.0210***	-0.0183***
		(0.00329)	(0.00366)		(0.00340)	(0.00396)
state of business_{ismt}		-0.0580***	-0.0532***		-0.0578***	-0.0525***
		(0.00735)	(0.00672)		(0.00739)	(0.00678)
commercial $\text{expectations}_{ismt}$		-0.0296***	-0.0332***		-0.0294***	-0.0334***
		(0.00305)	(0.00475)		(0.00306)	(0.00476)
export_{ismt}		-0.00349	-0.00961		-0.00436	-0.0155
		(0.0119)	(0.0213)		(0.0126)	(0.0227)
$\log(\text{employment})_{ist}$		0.00261	-0.00279		0.00181	-0.00401
		(0.00495)	(0.00783)		(0.00495)	(0.00664)
$\log(\text{staff expenses})_{ist}$			-0.00788			-0.00454
			(0.00916)			(0.00907)
$\log(\text{cost of materials})_{ist}$			0.00605			0.00335
			(0.00642)			(0.00681)
$\log(\text{revenue})_{ist}$			-6.28e-05			-0.00252
			(0.00915)			(0.00947)
$\log(\text{assets})_{ist}$			0.0113*			0.0110*
			(0.00597)			(0.00618)
Kleibergen-Papp Wald F stat				90.10	89.23	66.88
Hansen J statistic				2.962	3.605	2.065
p-value of Hansen J statistic				0.227	0.165	0.356
Observations	169,813	169,193	81,288	163,712	163,098	76,023
R-squared	0.256	0.279	0.287	0.261	0.283	0.295
firm-product clusters	2816	2815	1496	2785	2784	1468
industry clusters	209	209	188	208	208	187

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. The dependent variable *price reduction* is a binary variable indicating whether the domestic price of sale of a specific product has been reduced or not compared to the previous month. The coefficient of interest is the interaction of R&D intensity $R\&D\ int_s$ and import competition from China $ImpComp\ China_{st}$. R&D intensity is a dummy variable equal to 1 if the level of R&D expenditures per employee is above the 75% percentile of the distribution. R&D intensity is measured at the 3-digit NACE rev 1.1 level and refers to US industries for the year 2000. Chinese import competition is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. Instrumentation is based on the two-year lag of the log of Chinese import competition and of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. First stage regressions are displayed in Table C.10. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table IV.3: Impact of Import Competition from China on Firms' Pricing Strategy: Sector Heterogeneity in R&D Intensity. LPM and 2SLS Estimation the measure of Chinese import competition and its interaction with the indicator for R&D intensity. Both coefficients, the effect of Chinese imports as well as the interaction term are statistically significant. However, while import competition is positively related to a price reduction, the interaction term is negative. The same outcome arises when moving towards the 2SLS estimation in column (4). Besides, the results remain robust after the inclusion of control variables reflecting the demand and market situation of a firm as well as its size in columns (2) and (5). Hence, these findings suggest that the negative impact of Chinese imports on domestic sales prices decreases with sectoral R&D intensity. Lastly, adding controls for staff expenses and input costs as well as revenues and assets in columns (3) and (6) still yields the same picture although the sample size is considerably reduced. Import competition from China exerts a positive and significant effect on the likelihood of a price reduction. The interaction term with R&D intensity however enters the equation significantly with a negative sign.[13]

Considering the order of magnitude of the effect of R&D intensity throughout all specifications, the positive impact of a 1% increase in import competition on the probability of a price reduction is less than half the size in the most R&D intensive sectors. Overall, the pattern of results is in line with *Hypothesis 2* and reveals that the competitive pressure from Chinese imports is softened in more differentiated sectors.

IV.5.2.2 Firm Heterogeneity: Capital Intensity

Following *Hypothesis 3*, Chinese imports exert less downward pressure on domestic sales prices if firms are capital intensive. Accordingly, so as to coincide with the hypothesis, the interaction must be negative. Capital at the firm level is calculated as the ratio of fixed assets and the number of employees. The ratio is built for all firms that provide balance sheet information on their assets within the $1995-2000$ period and subsequently averaged. This allows avoiding endogeneity issues due to firms' adjustment of production techniques after China's WTO accession in 2001. However, this occurs against the drawback of loosing a large amount of observations which ultimately leaves us with only 500 firm-product com-

[13] Results also hold when using a continuous measure of R&D intensity.

	LPM			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			**price reduction**			
$\log(\text{ImpComp China})_{st}$	0.0499*	0.0494*	0.0365*	0.0570	0.0572	0.0374
	(0.0298)	(0.0256)	(0.0190)	(0.0429)	(0.0396)	(0.0300)
$\log(\text{ImpComp China})_{st}$ * capital int_i	-0.0490**	-0.0517***	-0.0465***	-0.0540**	-0.0563***	-0.0484***
	(0.0195)	(0.0153)	(0.0123)	(0.0261)	(0.0184)	(0.0140)
demand change_{ismt}		-0.0121***	-0.0134***		-0.0143***	-0.0160***
		(0.00381)	(0.00384)		(0.00441)	(0.00450)
state of business_{ismt}		-0.0502***	-0.0481***		-0.0476***	-0.0454***
		(0.00835)	(0.00790)		(0.00813)	(0.00772)
commercial $\text{expectations}_{ismt}$		-0.0363***	-0.0341***		-0.0365***	-0.0347***
		(0.00679)	(0.00641)		(0.00684)	(0.00640)
export_{ismt}		-0.0433	-0.0147		-0.0571	-0.0272
		(0.0508)	(0.0281)		(0.0604)	(0.0302)
$\log(\text{employment})_{ist}$		0.000844	-0.00368		-0.00183	-0.00748
		(0.00864)	(0.00989)		(0.00829)	(0.00840)
$\log(\text{staff expenses})_{ist}$			-0.00879			-0.00618
			(0.00893)			(0.00845)
$\log(\text{cost of materials})_{ist}$			0.00730			0.00536
			(0.00643)			(0.00580)
$\log(\text{revenue})_{ist}$			0.00337			0.000309
			(0.0113)			(0.0114)
$\log(\text{assets})_{ist}$			0.00562			0.00467
			(0.00881)			(0.00922)
Kleibergen-Papp Wald F stat				88.97	83.36	55.99
Hansen J statistic				2.329	3.913	1.724
p-value of Hansen J statistic				0.312	0.141	0.422
Observations	46,707	46,585	40,526	40,742	40,625	35,305
R-squared	0.185	0.208	0.214	0.198	0.221	0.227
firm-product clusters	493	492	460	464	463	433
industry clusters	127	127	125	126	126	122

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. The dependent variable *price reduction* is a binary variable indicating whether the domestic price of sale of a specific product has been reduced or not compared to the previous month. The coefficient of interest is the interaction of capital intensity *capital* int_i and import competition from China $ImpComp\ China_{st}$. Capital intensity is a dummy variable equal to 1 if the average level of fixed assets per employee within the 1995 - 2000 period is above the 75% percentile of the distribution. Chinese import competition is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. Instrumentation is based on the two-year lag of the log of Chinese import competition and of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. First stage regressions are displayed in Table C.11. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table IV.4: Impact of Import Competition from China on Firms' Pricing Strategy: Firm Heterogeneity in Capital Intensity. LPM and 2SLS Estimation binations. Finally, a dummy variable is constructed which indicates a firm to be capital intensive if average assets per employee are above the 75% percentile of the distribution.

Regression results are displayed in Table IV.4. In the first column both coefficients are significant and consistent with expectations. Import competition from China is positively associated with price reductions. The impact however declines with firms' capital intensity. Turning towards the 2SLS estimation in column (4), the level effect of Chinese imports shows up statistically insignificant. Most importantly however, the interaction term remains negative and significant in line with *Hypothesis 3*. The same outcome appears in columns (2) and (5) when controlling for demand, state of business, expectations, export status and firm size. Futhermore, this pattern of results remains persistent even after extending the set of controls with costs of production, assets and revenues. Whereas the level effect of Chinese import competition loses its significance in the 2SLS estimation, the interaction term stays negative and highly significant.[14]

According to the estimated coefficients, the impact of a 1% increase in Chinese imports on prices is more than 0.04 percentage points smaller for capital intensive firms. Comparing this result with the baseline estimates in section IV.4.3 (see Table IV.1 and Table IV.2) this implies that the influence of Chinese import competition on prices is almost zero for the most capital intensive companies.

Altogether, results on sector and firm heterogeneity emphasize the importance of product differentiation and production technique in shaping the impact of foreign competition on firms' pricing decisions. Firms in more R&D intensive sectors and more capital intensive firms are less exposed to import competition and less likely to engage in price reductions.

IV.6 Conclusion

The paper investigates the impact of Chinese import competition on the pricing decisions of German firms in the manufacturing sector based on detailed survey data at the product level.

[14]In additional regressions not presented in the paper I employ sector-year fixed effects. This eliminates the level effect of import competition from China. Throughout all LPM and 2SLS specifications the interaction terms of import competition from China and capital intensity are significant, exhibit a negative sign and are similar in size compared to the results displayed in Table IV.4. Moreover, results also hold when using a continuous measure of capital intensity.

Examining the influence of foreign competition on prices is of great importance. Firstly, recent research in international trade has identified the adjustment of prices and markups as the fundamental trigger for a reallocation process of resources across firms that results in aggregate productivity and welfare gains. Secondly, this sheds light on the effect of imports from low-wage nations on prices and inflationary pressure in high-income countries.

A positive causal impact of Chinese import penetration on the likelihood of a price reduction is identified. According to the estimates, a 1% increase in import competition from China raises the probability of a price reduction by 0.03 percentage points. Against the background that firms only rarely adapt their product prices this is a non-negligible effect. Results are robust to controlling for the impact of import competition from countries other than China as well as to taking account of the 2008 – 2009 financial crisis and alternative estimation strategies.

Finally, the paper studies the differential impact of Chinese import competition across industries and firms. The analysis concentrates on two aspects put forward by the literature: Product differentiation and factor intensity. The results suggest that the exposure to Chinese competition declines with increasing R&D intensity at the sector level and capital intensity at the firm level.

Due to the qualitative nature of the survey data the analysis is restricted to analyzing the discrete decision of firms whether to adapt prices or not. Hence, no conclusions can be drawn on the size of price changes. Future research might aim to gather more informative data at the micro-level in order to separately estimate the impact of low-wage country competition on the size of price changes, the markup and unit costs. This might provide further valuable insights into how firms adapt their performance to international competition.

C Appendix

C.1 Robustness

	LPM			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			**price reduction**			
log(ImpComp China)$_{st}$	0.0229***	0.0234***	0.0203*	0.0316***	0.0303**	0.0483*
	(0.00544)	(0.00559)	(0.0110)	(0.0110)	(0.0121)	(0.0250)
log(ImpComp World)$_{st}$	-0.00777	-0.00500	-0.00479	-0.00778	-0.00438	-0.0145
	(0.00855)	(0.00815)	(0.0132)	(0.00971)	(0.00896)	(0.0157)
demand change$_{ismt}$		-0.0201***	-0.0168***		-0.0210***	-0.0182***
		(0.00328)	(0.00365)		(0.00340)	(0.00395)
state of business$_{ismt}$		-0.0581***	-0.0533***		-0.0579***	-0.0524***
		(0.00733)	(0.00670)		(0.00737)	(0.00678)
commercial expectations$_{ismt}$		-0.0296***	-0.0332***		-0.0294***	-0.0333***
		(0.00305)	(0.00472)		(0.00306)	(0.00473)
export$_{ismt}$		-0.00429	-0.0104		-0.00493	-0.0157
		(0.0119)	(0.0214)		(0.0125)	(0.0226)
log(employment)$_{ist}$		0.00242	-0.00299		0.00157	-0.00398
		(0.00497)	(0.00783)		(0.00494)	(0.00662)
log(staff expenses)$_{ist}$			-0.00813			-0.00489
			(0.00907)			(0.00887)
log(cost of materials)$_{ist}$			0.00633			0.00365
			(0.00650)			(0.00685)
log(revenue)$_{ist}$			-0.00114			-0.00381
			(0.00894)			(0.00919)
log(assets)$_{ist}$			0.0117*			0.0119*
			(0.00612)			(0.00643)
					2SLS first stage	
log(ImpComp China)$_{st-2}$				0.610***	0.610***	0.506***
				(0.0371)	(0.0372)	(0.0629)
log(MFN tariff)$_{st-2}$				-0.234***	-0.233***	-0.162***
				(0.0475)	(0.0474)	(0.0324)
Kleibergen-Papp Wald F stat				137.9	137.4	33.47
Hansen J statistic				2.115	2.933	1.663
p-value of Hansen J statistic				0.146	0.0868	0.197
Observations	170,390	169,768	81,469	164,269	163,653	76,184
R-squared	0.256	0.279	0.286	0.261	0.283	0.295
firm-product clusters	2829	2828	1504	2798	2797	1476
industry clusters	212	212	190	211	211	189

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. The dependent variable *price reduction* is a binary variable indicating whether the domestic price of sale of a specific product has been reduced or not compared to the previous month. The coefficient of interest $log\,(ImpComp)_{st}$ is the log of $Imports^{China}_{st} / \left(Production_{st} + Imports^{World}_{st} - Exports^{World}_{st}\right)$. Instruments are the two-year lag of the log of Chinese import competition and of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table C.1: Impact of Import Competition from China on Firms' Pricing Strategy. Robustness Check 1 - Import Competition from the Rest of the World

	LPM			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			**price reduction**			
$\log(\text{ImpComp China})_{st}$	0.0263***	0.0256***	0.0303**	0.0310***	0.0318**	0.0465**
	(0.00698)	(0.00716)	(0.0123)	(0.0118)	(0.0126)	(0.0187)
demand change_{ismt}		-0.0183***	-0.0159***		-0.0192***	-0.0176***
		(0.00335)	(0.00372)		(0.00345)	(0.00396)
state of business_{ismt}		-0.0549***	-0.0530***		-0.0545***	-0.0519***
		(0.00731)	(0.00727)		(0.00742)	(0.00739)
commercial $\text{expectations}_{ismt}$		-0.0319***	-0.0345***		-0.0318***	-0.0349***
		(0.00340)	(0.00529)		(0.00341)	(0.00533)
export_{ismt}		-0.00454	-0.0134		-0.00582	-0.0204
		(0.0105)	(0.0249)		(0.0112)	(0.0261)
$\log(\text{employment})_{ist}$		0.000472	-0.000310		-0.000798	-0.00215
		(0.00438)	(0.00795)		(0.00424)	(0.00689)
$\log(\text{staff expenses})_{ist}$			-0.00788			-0.00496
			(0.00911)			(0.00936)
$\log(\text{cost of materials})_{ist}$			0.00503			0.00267
			(0.00634)			(0.00636)
$\log(\text{revenue})_{ist}$			0.00197			-0.00133
			(0.00993)			(0.0102)
$\log(\text{assets})_{ist}$			0.0102			0.0103
			(0.00661)			(0.00688)
					2SLS first stage	
$\log(\text{ImpComp China})_{st-2}$				0.730***	0.730***	0.635***
				(0.0610)	(0.0611)	(0.0669)
$\log(\text{MFN tariff})_{st-2}$				-0.0872***	-0.0868***	-0.0822***
				(0.0193)	(0.0195)	(0.0173)
Kleibergen-Papp Wald F stat				624.9	617.9	155.8
Hansen J statistic				0.560	1.348	0.363
p-value of Hansen J statistic				0.454	0.246	0.547
Observations	142,390	141,880	70,157	136,269	135,765	64,872
R-squared	0.261	0.282	0.294	0.267	0.289	0.305
firm-product clusters	2,775	2,775	1,452	2,744	2,744	1,424
industry clusters	212	212	187	211	211	186

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. The financial crisis period 2008 - 2009 is excluded from the sample. The dependent variable *price reduction* is a binary variable indicating whether the domestic price of sale of a specific product has been reduced or not compared to the previous month. The coefficient of interest $log\,(ImpComp)_{st}$ is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. Instruments are the two-year lag of the log of Chinese import competition and of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table C.2: Impact of Import Competition from China on Firms' Pricing Strategy. Robustness Check 2 - 2008 - 2009 Crisis Period Excluded from the Sample

Probit - Average Marginal Effects

	(1)	(2)	(3)
Dependent variable:		**price reduction**	
$\log(\text{ImpComp China})_{st}$	0.0208***	0.0189***	0.0101**
	(0.00237)	(0.00228)	(0.00418)
demand change_{ismt}		-0.0257***	-0.0217***
		(0.00155)	(0.00232)
state of business_{ismt}		-0.0819***	-0.0775***
		(0.00173)	(0.00256)
commercial exp_{ismt}		-0.0356***	-0.0422***
		(0.00163)	(0.00245)
exporter_{ismt}		-0.00195	-0.00171
		(0.00572)	(0.0114)
$\log(\text{employment})_{ist}$		0.00361	-0.00350
		(0.00232)	(0.00479)
$\log(\text{staff expenses})_{ist}$			-0.00644
			(0.00872)
$\log(\text{cost of materials})_{ist}$			0.00990**
			(0.00468)
$\log(\text{operating revenue})_{ist}$			-0.00904
			(0.0113)
$\log(\text{assets})_{ist}$			0.0184***
			(0.00452)
Observations	108,881	108,374	49,432
log-likelihood	-31537	-29158	-13441
Pseudo R2	0.247	0.301	0.297

Notes: Average marginal effect with respect to a reduction of the domestic price of sale of a specific product compared to the previous month. The coefficient of interest $log\left(ImpComp\right)_{st}$ is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. For a definition of covariates see Table C.9. All specifications include firm, sector, and year dummy variables. *** p<0.01, ** p<0.05, * p<0.1

Table C.3: Impact of Import Competition from China on Firms' Pricing Strategy. Robustness Check 3 - Probit Estimation - Average Marginal Effects

	OLS			2SLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			**price direction**			
$\log(\text{ImpComp China})_{st}$	-0.0210***	-0.0216***	-0.00884	-0.0331**	-0.0307*	-0.0318
	(0.00681)	(0.00735)	(0.0104)	(0.0158)	(0.0166)	(0.0267)
$\text{demand change}_{ismt}$		0.0396***	0.0364***		0.0411***	0.0393***
		(0.00460)	(0.00597)		(0.00484)	(0.00655)
$\text{state of business}_{ismt}$		0.0940***	0.0898***		0.0931***	0.0871***
		(0.00883)	(0.00885)		(0.00857)	(0.00822)
$\text{commercial expectations}_{ismt}$		0.0453***	0.0488***		0.0446***	0.0478***
		(0.00436)	(0.00614)		(0.00438)	(0.00612)
export_{ismt}		0.0199	0.00564		0.0232	0.0231
		(0.0169)	(0.0307)		(0.0170)	(0.0320)
$\log(\text{employment})_{ist}$		-0.00120	0.00167		9.07e-06	0.00296
		(0.00684)	(0.0106)		(0.00695)	(0.00959)
$\log(\text{staff expenses})_{ist}$			0.00880			0.00574
			(0.0148)			(0.0147)
$\log(\text{cost of materials})_{ist}$			0.000196			0.00232
			(0.00906)			(0.00909)
$\log(\text{revenue})_{ist}$			-0.0182			-0.0152
			(0.0138)			(0.0134)
$\log(\text{assets})_{ist}$			-0.0101			-0.00866
			(0.00848)			(0.00909)
					2SLS first stage	
$\log(\text{ImpComp China})_{st-2}$				0.608***	0.608***	0.533***
				(0.0308)	(0.0309)	(0.0380)
$\log(\text{MFN tariff})_{st-2}$				-0.238***	-0.238***	-0.142***
				(0.0612)	(0.0610)	(0.0416)
Kleibergen-Papp Wald F stat				270.5	267.8	110.8
Hansen J statistic				0.0298	0.336	0.701
p-value of Hansen J statistic				0.863	0.562	0.402
Observations	170,390	169,768	81,469	164,269	163,653	76,184
R-squared	0.207	0.233	0.228	0.212	0.237	0.235
firm-product clusters	2,829	2,828	1,504	2,798	2,797	1,476
industry clusters	212	212	190	211	211	189

Notes: Robust standard errors clustered by firm-product. The dependent variable *price direction* is an ordinally scaled variable which indicates whether a product price has been increased $(+1)$, remained unchanged (0) or decreased (-1)compared to the previous month. The coefficient of interest $log\ (ImpComp)_{st}$ is the log of $Imports_{st}^{China} / \left(Production_{st} + Imports_{st}^{World} - Exports_{st}^{World}\right)$. The Instrument is the two-year lag of the log of most favored nation tariffs (MFN) on the European single market with respect to imports from China. For a definition of the covariates see Table C.9. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table C.4: Impact of Import Competition from China on Firms' Pricing Strategy. Robustness Check 4 - Direction of Price Change: OLS and 2SLS Estimation

C.2 Data

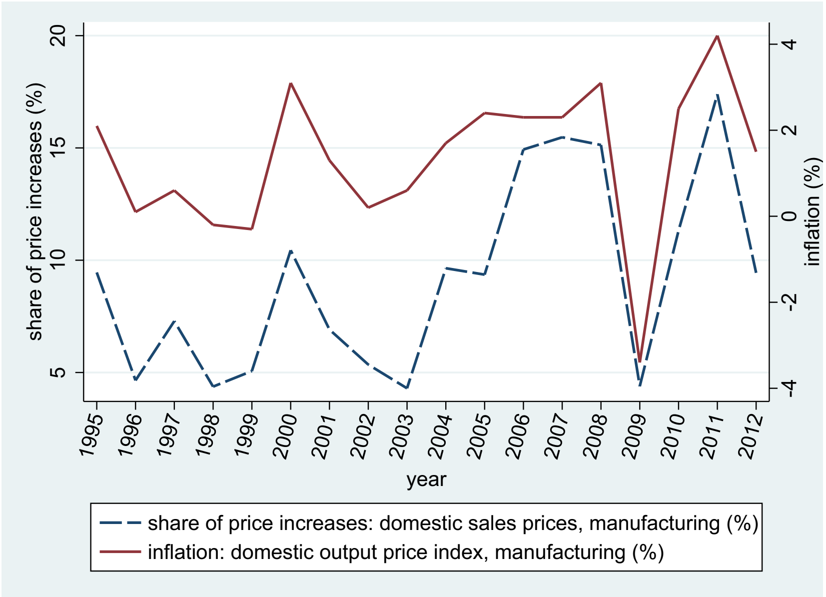

Figure C.1: Representativeness of the Data: Share of Increases in Domestic Sales Prices and Domestic Output Price Inflation in German Manufacturing, 1995 - 2012

		av. share price decreases			av. import competition			
industry description	nace rev. 1.1	95 - 00	01 - 07	Δ	95 - 00	01 - 07	Δ	technology
food products and beverages	15	0.335	0.456	0.120	0.003	0.005	0.001	low tech
tobacco products	16	0.000	0.000	0.000	0.000	0.000	0.000	low tech
textiles	17	0.366	0.667	0.301	0.039	0.095	0.056	low tech
wearing apparel; dressing and dyeing of fur	18	0.229	0.521	0.292	0.104	0.361	0.257	low tech
leather and leather products	19	0.000	0.520	0.520	0.113	0.202	0.089	low tech
wood and wood products	20	0.417	0.577	0.160	0.007	0.017	0.009	low tech
pulp, paper and paper products	21	0.419	0.477	0.058	0.001	0.002	0.001	low tech
publishing, printing and reproduction of recorded media	22	0.733	0.842	0.109	0.001	0.003	0.002	low tech
chemicals and chemical products	24	0.418	0.427	0.009	0.011	0.015	0.005	medium high tech
rubber and plastic products	25	0.524	0.425	-0.098	0.009	0.016	0.007	medium low tech
other non-metallic mineral products	26	0.445	0.362	-0.083	0.006	0.018	0.012	medium low tech
basic metals	27	0.511	0.533	0.022	0.009	0.008	0.000	medium low tech
fabricated metal products, except machinery and equipment	28	0.594	0.407	-0.186	0.011	0.020	0.009	medium low tech
machinery and equipment n.e.c.	29	0.281	0.356	0.075	0.011	0.030	0.019	medium high tech
office machinery and computers	30	0.875	0.958	0.083	0.049	0.316	0.267	high tech
electrical machinery and apparatus n.e.c.	31	0.795	0.483	-0.312	0.026	0.058	0.031	medium high tech
radio, television and communication equipment and apparatus	32	0.789	0.837	0.048	0.047	0.226	0.179	high tech
medical, precision and optical instruments, watches and clocks	33	0.253	0.481	0.228	0.034	0.056	0.022	high tech
motor vehicles, trailers and semi-trailers	34	0.308	0.297	-0.011	0.000	0.001	0.001	medium high tech
other transport equipment	35	0.750	0.435	-0.315	0.014	0.044	0.030	medium high tech
furniture; manufacturing n.e.c.	36	0.036	0.380	0.344	0.048	0.115	0.067	low tech

Notes: The average share of price decreases is the average share of downward price changes in all price adjustments for the periods 1995 - 2000 and 2001 - 2007 by 2-digit NACE rev. 1.1. industry; $av.share\ price\ decreases = \frac{1}{T}\sum_{t=1}^{T}\frac{\#price\ reduction_{st}}{\#price\ adjustment_{st}}$. Average import competition for each 2-digit NACE rev. 1.1. industry over the periods 1995 - 2000 and 2001 - 2007 ist given by $av.import\ competition = \frac{1}{T}\sum_{t=1}^{T} ImpComp_{st}^{CN}$. Later years are not considered in order to avoid the impact of the 2007 - 2009 financial crisis on price adjustments. The technology intensity indicator is given by Eurostat's indicators on high-tech industries.

Table C.5: Change in Average Import Competition and the Share of Price Decreases in Total Price Changes Before and After China's Accession to the WTO in 2001

price change	Freq.	Percent	Cum.
decrease	14,278	8.38	8.38
unchanged	138,798	81.45	89.83
increase	17,338	10.17	100
Total	170,414	100	

Table C.6: Fraction of Price Increases, Unchanged Prices and Price Decreases on the German Manufacturing Market Compared to the Previous Month

variable	mean	std. dev.	median	observations
price adjustment	2.168	2.878	1	9225
price increase	1.217	2.159	0	9225
price reduction	0.951	2.188	0	9225

Notes: In order to obtain consistent statistics, firm-product combinations that are covered less than 12 months for a given year have been dropped.

Table C.7: Summary Statistics on the Average Number of Annual Price Adjustments by Firm-Product Combination

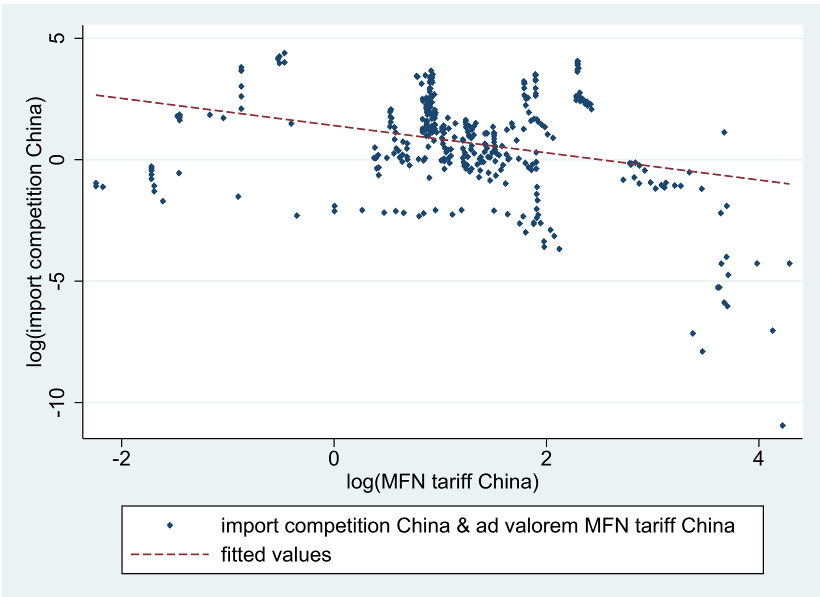

Figure C.2: China Import Competition in Germany and China Import Tariffs to the EU Single Market in the Manufacturing Sector

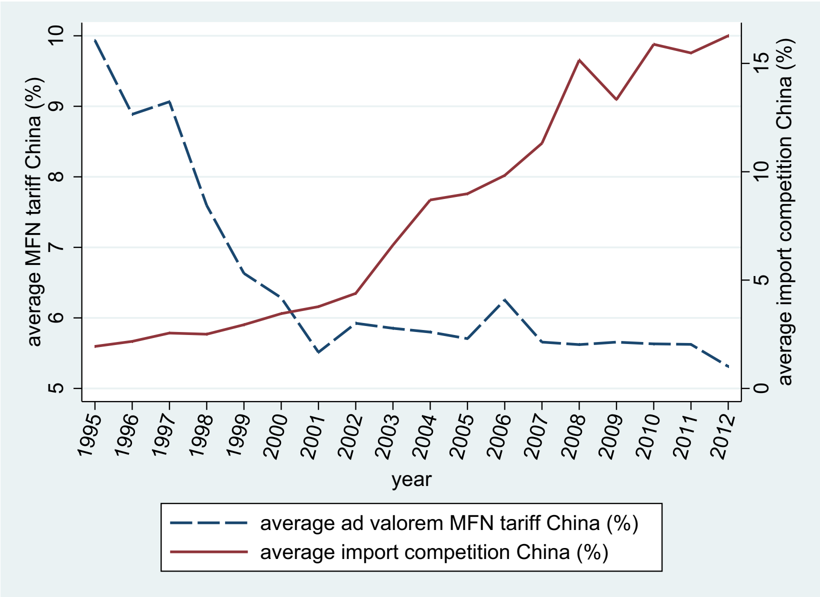

Figure C.3: Development of Average China Import Competition in the German Manufacturing Sector and Average MFN Tariff Rates to the EU Single Market, 1995 - 2012

Table C.8: Summary Statistics

variable	observations	mean	min	max	std. dev.
product level					
price reduction$_{ismt}$	170,390	0.083796	0	1	0.2770824
price direction$_{ismt}$	170,390	0.0179236	-1	1	0.4303434
demand change$_{ismt}$	170,296	-0.0113567	-1	1	0.6449138
state of business$_{ismt}$	170,334	0.0037749	-1	1	0.6793979
commercial exp$_{ismt}$	170,080	0.0040863	-1	1	0.6029215
exporter$_{ismt}$	170,220	0.8190753	0	1	0.3849569
firm level					
log(employment)$_{ist}$	14,103	5.191575			1.701462
employment$_{ist}$	14,103	1255.646			8934.349
log(staff expenses)$_{ist}$	8,739	16.40364			1.564354
staff expenses$_{ist}$	8,739	6.29e+07			3.37e+08
log(cost of materials)$_{ist}$	6,556	17.41348			1.788283
cost of materials$_{ist}$	6,556	2.56e+08			1.72e+09
log(revenue)$_{ist}$	10,270	17.47373			1.967104
revenue$_{ist}$	12,338	2.46e+08			1.84e+09
log(assets)$_{ist}$	11,160	15.53449			2.518364
assets$_{ist}$	11,231	1.18e+08			7.43e+08
average capital intensity$_{i}$	416	79169.24	0	1883034	166097
capital intensity indicator$_{i}$	416	0.2475962	0	1	0.4321356
sector level					
log(ImpComp China)$_{st}$	366	0.7682034	-7.894933	4.393843	1.976763
ImpComp China$_{st}$	366	0.0809884	3.73e-06	0.8095089	0.1344686
log(ImpComp China)$_{st-2}$	329	0.6024135	-7.894933	4.393843	2.015718
ImpComp China$_{st-2}$	329	7.140795	0.0003726	80.95089	12.44784
log(ImpComp World)$_{st}$	366	-0.6656394	-3.438418	1.763681	0.8241379
ImpComp World$_{st}$	366	0.6818717	0.0321155	5.83387	0.5158303
log(MFN tariff)$_{st-2}$	329	1.238816	-2.241961	4.287029	1.084997
MFN tariff$_{st-2}$	329	6.030615	0.10625	72.75	8.554935
average R&D intensity$_{s}$	88	5.370994	0.1790281	23.9309	5.435948
R&D intensity indicator$_{s}$	88	.25	0	1	.4354942

Notes: Minimum and maximum values of balance sheet variables are suppressed due to data protection.

Table C.9: Variable Descriptions and Data Sources

variables	**descriptions and sources**
price reduction$_{ismt}$ price direction$_{ismt}$	*price reduction* is a binary variable which indicates whether a firm has reduced the domestic price of sale of a specific product versus the previous month. *price direction* is an ordinal variable which indicates whether a firm has reduced the domestic price of sale of a specific product versus the previous month, remained the price unchanged or increased the price. The variable may take the values -1 (price decrease), 0 (price unchanged) or +1 (price increase). The variables are based on the *ifo business tendency survey* which asks participants whether domestic sales prices for a given product have increased, remained unchanged or decreased compared to the previous month.
demand change$_{ismt}$	*demand change* is an ordinal variable which indicates whether the situation of demand of a specific product versus the previous month has improved, remained unchanged or deteriorated. The variable may take the values -1 (deterioration), 0 (unchanged) or +1 (improved). The variable is based on the *ifo business tendency survey* which asks whether the demand situation (domestic and abroad) has improved, remained unchanged or deteriorated compared to the previous month.
state of business$_{ismt}$	*state of business* is an ordinal variable which indicates whether the current state of business of a specific product is evaluated as good, satisfactory or bad. The variable may take the values +1 (good), 0 (satisfactory) or -1 (bad). The variable is based on the *ifo business tendency* survey which asks participants whether the current state of business with respect to a given product is evaluated as good, satisfactory (or typical for the season) or bad.
commercial expectation$_{ismt}$	*commercial expectation* is an ordinal variable which indicates whether the business situation of a specific product during the next 6 months is considered as rather more favorable, about the same, or rather more unfavorable (after elimination of purely seasonal fluctuations). The variable may take the values +1 (favorable), 0 (same) or -1 (unfavorable). The variable is based on the *ifo business tendency survey* which asks participants to assess whether the business situation for a given product during the next 6 months with respect to economic development will be rather more favorable, about the same or rather more unfavorable.
exporter$_{ismt}$	Binary variable which indicates whether a product is exported or not. *Ifo business tendency survey*
employment$_{ist}$	Given by the number of employees at account date from the *Amadeus* and *Hoppenstedt* database. If no balance sheet data is available, employment in production by product line from the *ifo business tendency survey* is aggregated by products and business units and averaged across months to the firm-year level.
staff expenses$_{ist}$	Staff expenses taken from *Amadeus* and *Hoppenstedt* databases.
cost of materials$_{ist}$	Cost of materials taken from *Amadeus* and *Hoppenstedt* databases.
revenue$_{ist}$	Operating revenue taken from *Amadeus* and *Hoppenstedt* databases.
assets$_{ist}$	Fixed assets taken from *Amadeus* and *Hoppenstedt* databases.
capital intensity$_{i}$	Capital intensity is the ratio of tangible assets *(Amadeus & Hoppenstedt)* and employment *(Amadeus & ifo business tendency survey)*. Average capital intensity is computed for all firms that provide balance sheet data within the 1995 – 2000 period across years. A dummy variable is constructed that indicates whether average capital intensity of a firm is within the 75% percentile of the distribution.
import competition China$_{st}$	Ratio of German imports from China and the sum of German domestic production and total world imports minus total world exports. Imports from China are from the *Comext database (Eurostat)* and domestic production and world imports and exports are from the *PRODCOM database (Eurostat)*. The data is derived at the CPA 2002 6-digit level and aggregated to the NACE rev. 1.1 2-digit level.
import competition World$_{st}$	Ratio of total German imports minus imports from China and the sum of German domestic production and total world imports minus total world exports. Imports from China are from the *Comext database (Eurostat)* and domestic production and world imports and exports are from the *PRODCOM database (Eurostat)*. The data is derived at the CPA 2002 6-digit level and aggregated to the NACE rev. 1.1 2-digit level.
tariff$_{st}$	Data on most favored nation tariff rates (MFN) for Chinese imports to the European single market are from *UN Comtrade (World Bank)*. The data is derived at the HS combined 8-digit level and subsequently transposed to the NACE rev. 1.1 classification by building a HS combined – HS 2007 – CPA 2002 correspondence. Subsequently, the data is aggregated to the NACE rev. 1.1 2-digit level.
R&D intensity$_{s}$	R&D intensity is the ratio of R&D expenditures and the number of employees at the industry level. Data is for the year 2000. R&D expenditures are company and other non-federal funds for industrial R&D performance in the US and taken from the *National Science Foundation (Division of Science Resource Statistics)*. Employment is from the *NBER-CES manufacturing industry database*. The data is at the 3-digit NAICS 2002 level and mapped to the 3-digit NACE rev. 1.1 level by means of a NAICS 2002 – NACE rev. 1.1 correspondence. A dummy variable is constructed that indicates whether R&D intensity is within the 75% percentile of the distribution.

	OLS					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	**log(ImpComp^{CN})**	**log(ImpComp^{CN}) * R&D int**	**log(ImpComp^{CN})**	**log(ImpComp^{CN}) * R&D int**	**log(ImpComp^{CN})**	**log(ImpComp^{CN}) * R&D int**
log(ImpComp China)$_{st\text{-}2}$	0.608***	-0.0311**	0.608***	-0.0310**	0.531***	-0.0351**
	(0.0304)	(0.0146)	(0.0305)	(0.0146)	(0.0364)	(0.0157)
log(MFN tariff)$_{st\text{-}2}$	-0.238***	0.00230	-0.238***	0.00260	-0.141***	0.00364
	(0.0611)	(0.00312)	(0.0610)	(0.00320)	(0.0401)	(0.00437)
log(ImpComp China)$_{st\text{-}2}$ * R&D int$_s$	-0.00938	0.779***	-0.00962	0.779***	0.0157	0.788***
	(0.0792)	(0.0746)	(0.0790)	(0.0745)	(0.0949)	(0.0808)
log(MFN tariff)$_{st\text{-}2}$ * R&D int$_s$	0.0354	-0.225*	0.0345	-0.226*	-0.0520	-0.262*
	(0.138)	(0.134)	(0.138)	(0.134)	(0.175)	(0.155)
demand change$_{ismt}$			0.00287*	3.88e-05	0.00220	-7.76e-05
			(0.00158)	(0.000797)	(0.00173)	(0.000984)
state of business$_{ismt}$			0.00142	-0.00252	-0.00137	-0.00417*
			(0.00377)	(0.00193)	(0.00380)	(0.00242)
commercial expectations$_{ismt}$			0.00316	0.000344	0.00543*	0.00260
			(0.00283)	(0.00104)	(0.00299)	(0.00170)
export$_{ismt}$			-0.0151	-0.00107	0.00638	0.00517
			(0.0266)	(0.00342)	(0.0257)	(0.00512)
log(employment)$_{ist}$			0.00450	0.00487**	-0.0108	0.00634
			(0.00909)	(0.00219)	(0.0220)	(0.00764)
log(staff expenses)$_{ist}$					-0.0114	0.00372
					(0.0183)	(0.0133)
log(cost of materials)$_{ist}$					0.00515	-0.00248
					(0.00665)	(0.00405)
log(revenue)$_{ist}$					0.0103	0.0148
					(0.0128)	(0.00901)
log(assets)$_{ist}$					0.00488	0.000604
					(0.0140)	(0.00363)
Kleibergen-Papp Wald F stat	90.10	90.10	89.23	89.23	66.88	66.88
Hansen J statistic	2.962	2.962	3.605	3.605	2.065	2.065
p-value of Hansen J statistic	0.227	0.227	0.165	0.165	0.356	0.356
Observations	163,712	163,712	163,098	163,098	76,023	76,023
R-squared	0.964	0.981	0.964	0.981	0.976	0.983
firm-product clusters	2785	2785	2784	2784	1468	1468
industry clusters	208	208	208	208	187	187

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table C.10: Impact of Import Competition from China on Firms' Pricing Strategy: Sector Heterogeneity in R&D Intensity. First Stage Regressions

	OLS					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	**log(ImpComp ^{CN})**	**log(ImpComp ^{CN}) * capital int**	**log(ImpComp ^{CN})**	**log(ImpComp ^{CN}) * capital int**	**log(ImpComp ^{CN})**	**log(ImpComp ^{CN}) * capital int**
log(ImpComp China)$_{st-2}$	0.669***	-0.0495***	0.671***	-0.0497***	0.644***	-0.0613***
	(0.0370)	(0.0157)	(0.0384)	(0.0157)	(0.0444)	(0.0172)
log(MFN tariff)$_{st-2}$	-0.248**	0.0171***	-0.244**	0.0158***	-0.154**	0.0241**
	(0.108)	(0.00549)	(0.103)	(0.00575)	(0.0678)	(0.0105)
log(ImpComp China)$_{st-2}$ * capital int$_i$	0.0430	0.864***	0.0464	0.864***	0.0425	0.870***
	(0.0492)	(0.0457)	(0.0500)	(0.0463)	(0.0529)	(0.0480)
log(MFN tariff)$_{st-2}$ * capital int$_i$	0.132*	-0.167***	0.129*	-0.166***	0.0437	-0.171***
	(0.0693)	(0.0523)	(0.0656)	(0.0519)	(0.0430)	(0.0453)
demand change$_{ismt}$			-0.00168	0.000314	0.000230	0.00119
			(0.00238)	(0.00138)	(0.00260)	(0.00155)
state of business$_{ismt}$			0.00363	0.00121	0.000958	0.000775
			(0.00507)	(0.00374)	(0.00499)	(0.00386)
commercial expectations$_{ismt}$			0.00318	0.00331**	0.00259	0.00417**
			(0.00443)	(0.00167)	(0.00510)	(0.00202)
export$_{ismt}$			-0.0774	0.00802	0.0100	0.00627
			(0.0555)	(0.0191)	(0.0274)	(0.0206)
log(employment)$_{ist}$			0.00345	0.00423	-0.0212	-0.00174
			(0.0121)	(0.00493)	(0.0159)	(0.00905)
log(staff expenses)$_{ist}$					-0.00372	-0.00604
					(0.0237)	(0.00965)
log(cost of materials)$_{ist}$					-0.00277	-0.00541
					(0.00899)	(0.00454)
log(revenue)$_{ist}$					0.0193	0.0135
					(0.0184)	(0.00985)
log(assets)$_{ist}$					0.0230	0.0114
					(0.0182)	(0.00782)
Kleibergen-Papp Wald F stat	88.97	88.97	83.36	83.36	55.99	55.99
Hansen J statistic	2.329	2.329	3.913	3.913	1.724	1.724
p-value of Hansen J statistic	0.312	0.312	0.141	0.141	0.422	0.422
Observations	40,742	40,742	40,625	40,625	35,305	35,305
R-squared	0.978	0.962	0.978	0.962	0.980	0.963
firm-product clusters	464	464	463	463	433	433
industry clusters	126	126	126	126	122	122

Notes: Robust standard errors two-way clustered by firm-product and 4-digit NACE rev. 1.1 industry. All specifications include firm-product, sector, month and year fixed-effects. *** p<0.01, ** p<0.05, * p<0.1

Table C.11: Impact of Import Competition from China on Firms' Pricing Strategy: Sector Heterogeneity in R&D Intensity. First Stage Regressions

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Eidesstattliche Versicherung

Ich versichere hiermit eidesstattlich, dass ich die vorliegende Arbeit selbstständig und ohne fremde Hilfe verfasst habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sowie mir gegebene Anregungen sind als solche kenntlich gemacht.

Die Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht. Sofern ein Teil der Arbeit aus bereits veröffentlichten Papers besteht, habe ich dies ausdrücklich angegeben.

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