HETEROGENEOUS FIRMS, INFORMALITY AND TRADE LIBERALIZATION

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The dissertation explores the impact of trade liberalization on heterogeneous firms in the presence of informality. In the first paper, I investigate the role of the informal sector in the impact of trade liberalization on welfare, employment and wage inequality in a model of trade with heterogeneous firms. The findings suggest that trade liberalization reduces informal employment unambiguously. Contrary to the extant literature, however, its impact on welfare, total employment and wage inequality is country-specific. The second paper introduces product-level regulation as new driver of informality in a model of heterogeneous multi-product firms and endogenous product choice, where firms face regulation at both firm- and product-level and may comply with or evade either. The model suggests that firm-level regulation causes informality by deterring firm registration. However, product-level regulation has two effects: it directly drives product informality within the formal sector as evasion of product regulation and indirectly deters firms from registering. When considering product-revenue distribution, formal firms are less diversified than informal firms, which implies that the formalization of economies may entail welfare loses due to decreased product diversity. The third paper studies trade liberalization, informality and corruption. Informality is commonly seen as response to regulations and weak institutions. Yet, regulatory changes, such as trade liberalization, and institutions interact, rendering their joint effect on formality ambiguous. I therefore study the impact of trade liberalization on firm formality in a model of heterogeneous firms and endogenous corruption. The model suggests that a higher entry cost to the formal sector, entailing more corruption, and trade liberalization decrease formality. However, as trade liberalization reduces corruption, the formal sector is less responsive to trade in economies with higher entry cost, hampering the selection effect

of trade. An instrumental variable panel data analysis on Vietnamese SME surrounding Vietnam's WTO accession confirms the predictions.

BIOGRAPHICAL SKETCH

Dennis Becker received a Bachelor of Science in Agricultural Sciences with a major in Agricultural Economics from the University of Hohenheim in Stuttgart, Germany, in 2009. Starting in 2010, he spent six months as a research student at Kyushu University in Fukuoka, Japan and subsequently received a Master of Science in Agricultural Economics from the University of Hohenheim in Stuttgart, Germany, in 2011. Dennis joined the Charles H. Dyson School of Applied Economics and Management of Cornell University in Ithaca, NY, USA, in their doctoral program in August 2011.

To my family.

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CHAPTER 1

INTRODUCTION

Informality, defined as evasion of government regulation, is a global phenomenon with an estimated size of about 17% of the world's GDP and is particularly striking in the developing country context (Schneider et al., 2010). Its presence distorts the resource allocation process within economies, which can adversely affect welfare (La Porta and Shleifer, 2008; Hsieh and Klenow, 2009; D'Erasmo and Moscoso Boedo, 2012), and entails distributional consequences, such as wage inequality between informal and formal workers (Bargain and Kwenda, 2011; Günther and Launov, 2012).

At the firm-level, informality can be thought of as the result of entrepreneurs comparing the benefits and costs of formal and informal sector participation, that is the compliance and non-compliance with regulation, and firms only become informal if an entrepreneur finds it to be the most profitable choice (Perry et al., 2007). Accordingly, informality has been seen as a response to the institutional environment of the firm with weak institutions, plagued by red tape or corruption, that limit the benefit of regulation compliance and thus formal sector participation (de Soto, 1989; Djankov et al., 2002; Perry et al., 2007). However, by offering a different set of costs and benefits, informality also provides firms an option to cope with policy or regulatory changes that threaten their profitability in the formal sector (Mullainathan and Schnabl, 2010; Gajigo and Hallward-Driemeier, 2012).

Trade liberalization has been hailed as a classical means of generating economic growth and prosperity. The various gains from trade are long-standing results since Adam Smith and David Ricardo. Yet, the trade literature omits both the existence of informality and that international trade itself might affect the costs and benefits of formal sector participation. This is particularly obvious in the most recent trade models, starting with the seminal work of Melitz (2003). In these heterogeneous firm models the gains from trade arise as the

result of firm exit, firm selection into exporting as well as a subsequent resource reallocation from low- to high-productivity firms. Yet, the models ignore that firms can also select to become informal sector producers. The previous trade literature therefore omits a crucial piece of the puzzle in understanding trade liberalization in its impact on firms and thus aggregate outcomes, such as productivity, employment and wage inequality, particularly in the developing world.

This dissertation bridges the gap by providing insight into a world of heterogeneous firms upon trade liberalization and notably in the presence of informality. More specifically, each of the three papers of the dissertation sheds light on heterogeneous firms from a different angle to better understand informality as a response to trade liberalization and firms' institutional environment. The first paper in chapter 2 considers the role of the informal sector in the impact of trade liberalization on welfare, employment and wage inequality. The chapter puts considerably emphasis on the labor market, notably an imperfect one, and highlights the distributional consequences of trade that arise in a world with informality. As the least-productive formal firms cope with the impact of trade liberalization by informalizing, welfare, employment and wage inequality in the economy may increase or decrease, which stands in contrast to the predictions of the previous literature. The second paper in chapter 3 focuses on firms themselves and recognizes that they face a complex regulatory environment. Rather than merely non-compliance with a single regulation, in reality informality is a multi-dimensional concept that entails evasion of or compliance with several regulations. Specifically, in contrast to previous work focusing on firm-level regulations, I show the importance of product-level regulation as a driver of firm-level informality, informality within formal firms and firms' product diversification. Lastly, the third paper in chapter 4 sees heterogeneous firms in their institutional environment and recognizes that policy changes, such as trade liberalization, and institutions may interact. Using a heterogeneous firm trade model as well as a panel data analysis of Vietnamese small and medium-sized enterprises during Vietnam's WTO accession, I show that predominantly formal firms experience cor-

ruption as a cost of business, which makes formality less attractive for lower-productivity firms. Moreover, while low-productivity formal firms do use informality as a means of coping with the impact of trade liberalization, the responsiveness of the formal sector to trade liberalization is lower in more corrupt regions. This indicates that the presence of corruption hampers the selection of low-productivity firms out of the formal sector, a crucial mechanism through which trade liberalization increases welfare.

Therefore, by extending the previous trade literature to include informality, this dissertation demonstrates that informality plays a crucial role in the resource allocation process among firms and contributes to our understanding of the impact of trade liberalization on the entire economy.

CHAPTER 2

HETEROGENEOUS FIRMS AND INFORMALITY: THE EFFECTS OF TRADE LIBERALIZATION ON LABOR MARKETS

2.1 Introduction

Valued at about 17% of the world's GDP, the informal sector represents an important component of developing countries in particular (Schneider et al., 2010). In addition to its size, the ability to transition in and out of the informal sector has been shown to be a crucial coping mechanism allowing firms to weather adverse market conditions and thus could be important with regard to trade liberalization (Mullainathan and Schnabl, 2010; Gajigo and Hallward-Driemeier, 2012). That raises an important question, what is the role of the informal sector on the impact of trade liberalization in general equilibrium?

In the seminal heterogeneous firm trade model by Melitz (2003), trade liberalization induces firm selection on productivity into exporting and forces the least-productive firms to exit the market. The result is improved welfare and higher average productivity. Yet, empirical studies provide suggestive evidence that informality can act as a channel of distortion to the resource allocation process among firms (La Porta and Shleifer, 2008; Hsieh and Klenow, 2009; McCaig and Pavcnik, 2013). For instance, Nataraj (2011) shows that the productivity improvement as a result of the Indian trade liberalization in 1991 predominantly stems from the exit of the least-productive, informal firms. Additionally, the empirical evidence on the impact of trade on informal employment remains conflicting (Goldberg and Pavcnik, 2003; Fiess and Fugazza, 2012; Acosta and Montes-Rojas, 2014; McCaig and Pavcnik, 2014) and it is not clear what trade implies for wage inequality between informal and formal as well as among all workers. Thus, in this paper I address two important questions: First, what is the effect of trade liberalization on welfare in the presence of an informal sector? Second, how

does trade liberalization affect employment and wages in the presence of an informal sector?

To answer these questions, I develop a model that incorporates informality into a trade model with heterogeneous firms. The model consists of four crucial pieces. First, I define informality as firm-level non-compliance with registration (de Soto, 1989).[1] Second, firms are heterogeneous in productivity. Third, firms opt in or out of the informal sector according to profitability considerations. Informal sector participation is therefore an active entrepreneurial choice to maximize firm profits given the costs and benefits of informal and formal sector participation.[2] Fourth, labor markets are imperfect. Labor market frictions are caused by workers' fair wage expectations,[3] and informal workers are excluded from the formal labor market.[4] The pieces come together by introducing informality into the model of Egger and Kreickemeier (2009), which is a heterogeneous firm trade model à la Melitz (2003) with a fair wage specification along the lines of Akerlof and Yellen (1990).

The model delivers several predictions on the impact of trade liberalization in the presence of informality that correspond closely to the findings from empirical studies. First, higher-

[1]On a firm-level, informality is commonly defined as either registration non-compliance, tax evasion or both of these (e.g. Fajnzylber et al., 2011). My choice of definition is motivated by several empirical findings. de Paula and Scheinkman (2011) find that registration non-compliance and tax evasion are highly correlated. Exploring the impact of policies on the size of the informal sector, Ulyssea (2010) finds that the reduction of entry costs, rather than payroll taxes are effective in reducing the incidence of informality. Moreover, several studies find that high firm registration costs function as barriers to formality (Djankov et al., 2002; Auriol and Warlters, 2005; Antunes and de V. Cavalcanti, 2007). Importantly, in the most cases the registration costs are not an efficient transfer to the government, but rather red tape caused by bureaucratic hurdles and complex registration procedures (Djankov et al., 2002).

[2]Another common view sees informality as a last resort of business-owners waiting for formal employment. Bruhn (2013) provides evidence for the coexistence of both types of informal businesses. Given the firm-level focus, the model covers the entrepreneurial segment corresponding to the findings of e.g. La Porta and Shleifer (2008).

[3]Several empirical studies find wage curves, that is the negative relationship between regional unemployment and wages, for informal and formal salaried workers (Bucheli and González, 2007; Ramos et al., 2010; Baltagi et al., 2013), which is consistent with my model setup of the labor market frictions arising from fair wage preferences in both sectors (Blanchflower and Oswald, 1995).

[4]Alternatively, informal employment is seen as voluntary choice in the literature. While the mechanism driving informal employment is still disputed (see for example the review of the literature in Radchenko (2014)), current empirical evidence indicates a dual structure in the labor market, where a share of workers is excluded from formal employment and another share voluntarily chooses informal employment (Günther and Launov, 2012; Radchenko, 2014). Given that workers are salaried workers, the model corresponds to the exclusion view.

productivity firms are more likely to be formal, large, pay high wages and participate in international trade (Bernard and Jensen, 1999; Tybout, 2000; Perry et al., 2007), whereas lower-productivity firms are more likely to be informal, smaller, compensate workers with lower wages and earn less profits than their formal counterparts (La Porta and Shleifer, 2008; Dabla-Norris et al., 2008; McKenzie and Sakho, 2010; de Paula and Scheinkman, 2011).

Second, trade liberalization ambiguously affects formal sector employment and, consistent with Fiess and Fugazza (2012) and McCaig and Pavcnik (2014), leads to a decrease of informal sector employment. However, the effect of trade liberalization on total employment is ambiguous, corresponding to the conflicting findings of the empirical literature (Davidson and Matusz, 2009; Dutt et al., 2009; Felbermayr et al., 2011b; Menezes-Filho and Muendler, 2011). This result derives not just from export selection and firm exit, both well known from Melitz (2003), but a new adjustment mechanism - the informalization of firms. Intuitively, trade liberalization induces the selection of high-productivity formal firms into exporting and hiring more workers, while lower-productivity formal firms switch to informal production to remain profitable, and accordingly shed formal labor. Depending on the characteristics of the economy, such as firm registration costs, the additional hires by exporting firms may or may not compensate for the labor shedding in the formal sector. Furthermore, the lowest-productivity informal firms are forced to exit the market, resulting in a reduction in informal sector employment. The net effect on total employment is ambiguous.

Third, the effect of trade liberalization on aggregate output, and hence welfare, is ambiguous. Similar to the employment effect, the increase in aggregate output by shifting resources towards the highest-productivity exporting firms may or may not compensate for the loss in aggregate output due to the exit of the least-productive informal firms and the informalization of the least-productive formal firms. Therefore, the informal sector plays a role in the resource allocation process, found for example by Bruhn (2013), and trade liberalization can either increase aggregate output (McCaig and Pavcnik, 2013), and hence welfare,

or reduce it by affecting informal sector participation. This result is particularly interesting, as it stands in contrast to the clear increase in welfare predicted by Egger and Kreickemeier (2009) and commonly established in the theoretical literature on trade and heterogeneous firms.

Lastly, wage inequality is caused by a wage gap between informal and formal workers, a frequent result in the empirical literature (Bargain and Kwenda, 2011; de Paula and Scheinkman, 2011; Günther and Launov, 2012), and depends on employment in both sectors. Wage inequality between informal and formal workers increases through trade liberalization. Because of the reduction in informal sector employment and sector switching, the increase of the informal sector average wage is lower than the increase in formal sector average wage. Hence, the average wages of both sectors diverge and between-group wage inequality increases. Wage inequality among all employed workers is ambiguously affected through the above employment effect and depends on the proportion of formal sector firms prior to trade liberalization.

This paper contributes to the literature on trade models featuring heterogeneous firms, particularly the ones with labor market frictions, and models of the informal economy. There exist two groups of trade models with labor market frictions: In the first set of papers the labor market imperfections arise from a search-and-matching setup (Helpman and Itskhoki, 2010; Felbermayr et al., 2011a). The second group of models builds on fair wage specifications (Egger and Kreickemeier, 2009; Davis and Harrigan, 2011; Amiti and Davis, 2012). Further, Bustos (2011) considers a heterogeneous firm trade model with technology upgrading of exporters modeled in a fashion similar to formality in this model, albeit without labor market imperfections. These models readily address the impact of trade on labor markets and technology upgrading, and correspond to a wide range of empirical facts with regard to the formal economy. This paper takes these existing studies a step further to examine an informal sector.

Models of the informal economy have a long history. Fields (1975) uses a Harris-Todaro-type model to analyze unemployment, whereas Rauch (1991) provides a rationale for size-dualism with large formal and small informal firms. Loayza (1996) examines the interaction of tax evasion and public good congestion. Wage dualism between formal and informal workers is explained by Basu et al. (2011). Prado (2011) examines general equilibrium government decisions on regulation and enforcement in a heterogeneous firm model where informal firms evade taxes. Heid et al. (2013) construct a heterogeneous firm trade model with labor market frictions to analyze the rise of the maquiladora sector on employment, welfare and wage inequality in the presence of informality. The model, however, considers heterogeneous workers and a small open economy setting that features a fixed formality wage premium and no unemployment. Both Aleman-Castilla (2006) and Paz (2014) consider trade and informality from a labor market perspective by defining informality as payroll tax evasion, where Aleman-Castilla (2006) models a world without labor market frictions and full employment, and Paz (2014) features labor market imperfections, but only examines informal employment and average wages in a small open economy. Lastly, Fiess et al. (2010) take yet another direction by combining macroeconomic fluctuations and informal self-employment in a small open economy model.

Therefore, this is the first paper that presents a unified theory of the informal sector that accommodates four important points: i) heterogeneous firms ii) formal employment, informal employment and unemployment iii) endogenous wage dispersion in both formal and informal sector, which is particularly important given that for example in India 75% of all manufacturing workers are employed by informal firms (Hsieh and Klenow, 2014) iv) a large open economy setting. Further, by defining informality as firm registration non-compliance, the model complements the previous works that focus on the labor market and taxation perspectives of informality and rests on the parsimonious assumption that the only source of heterogeneity stems from firm productivity differences, yet captures a wide range of empirical findings.

I proceed as follows. Section 2.2 characterizes the closed economy specification of the model. Section 2.3 extends the model to an open economy and discusses the impact of trade liberalization. Section 2.4 concludes the paper.

2.2 The closed economy model

The economy consists of L units of labor, the only factor of production. There are two types of goods: a final output and intermediate goods. The final output is homogeneous and its market is in perfect competition. The intermediate goods are differentiated and produced under monopolistic competition by a mass of heterogeneous firms (Melitz, 2003).

2.2.1 The final output

The final output Y is an aggregate of all intermediate goods and is characterized by the following CES-production function (Blanchard and Giavazzi, 2003):[5]

$$Y = \left[M^{-(1-\rho)} \int_{v \in V} q(v)^{\rho} \mathrm{d}v \right]^{\frac{1}{\rho}}, 0 < \rho < 1. \tag{2.1}$$

Intermediate good varieties are indexed with v and V is the set representing the mass of available intermediate goods M. $q(v)$ and $p(v)$ are the quantity and the price of variety v. $\sigma \equiv \frac{1}{1-\rho}$ is the elasticity of substitution between the varieties of intermediate goods. The final output market is under perfect competition and the final output acts as numeraire. The

[5]This CES-specification ensures that the unemployment rate is independent of the size of the economy, as there is no evidence on the correlation between the two, and prevents an increase in aggregate output due to an increase in the number of input varieties. If, for example, equal amounts of every input $q(v) = \frac{q}{M}$ were to be used in the final good production process, the production function would imply $Y = q$. External scale effects are well understood from previous literature, e.g. Ethier (1982), and through the specification the focus lies purely on the selection effect of trade liberalization.

resulting CES-price index P is thus normalized to 1. The price index is described by

$$P = \left[M^{-1} \int_{v \in V} p(v)^{1-\sigma} \mathrm{d}v \right]^{\frac{1}{1-\sigma}}. \tag{2.2}$$

Through profit maximization of the producer of the final good, the demand for variety v of the intermediate good is

$$q(v) = \frac{Y}{M} p(v)^{-\sigma}. \tag{2.3}$$

2.2.2 The intermediate goods: Informal and formal sector

The intermediate goods are produced under monopolistic competition by firms in two sectors: an informal and a formal sector. Henceforth all informal sector variables feature subscript i and formal sector variables subscript f. The firms are heterogeneous in their productivity and every firm produces one unique variety of input for the final output production. Hence, M can interchangeably be used to account for the number of firms or total number of input varieties v. $M = M_i + M_f$ is the number of domestically active firms, which consists of all informal sector firms, M_i, and formal sector firms, M_f. Firms face fixed costs of production in terms of final output Y and variable costs that are directly related to the firm's productivity φ. Firm output is linear in labor input l and productivity φ, that is $q = \varphi l$. Firms with the same productivity behave in the same manner. Therefore, I henceforth index firms solely in terms of their productivity φ.

Firms voluntarily choose to become either informal or formal producers. Informal producers face fixed cost f_i and formal producers face f_f to start production. I assume $f_f > f_i$, as the formal fixed cost reflects complex firm registration and red tape (Djankov et al., 2002; Auriol and Warlters, 2005; Antunes and de V. Cavalcanti, 2007). As unregistered firms, informal firms are deprived of access to public goods and face a probability of detection

$\delta \in [0,1)$ by the authorities, which leads to the total loss of firm revenues.[6] The probability of audit and detection is a reflection of the institutional quality of the economy (Loayza, 1996; Dabla-Norris et al., 2008). As a result of formal sector participation, formal firms experience a productivity bonus $\lambda \in (0,1)$, which can be imagined as the result of access to public goods and rule of law (de Soto, 1989; La Porta and Shleifer, 2008; Dabla-Norris et al., 2008). Formal sector productivity is then described by $\frac{\varphi}{1-\lambda}$ and λ is assumed to be exogenously given.[7]

The profit maximizing price of both types of firms is a constant markup $\frac{1}{\rho}$ over marginal cost, where $w(\varphi)$ denotes the wage paid by a firm with productivity φ and ϵ is the effort level of workers.

$$p_i(\varphi) = \frac{w_i(\varphi)}{(1-\delta)\rho\varphi\epsilon} \text{ and } p_f(\varphi) = \frac{w_f(\varphi)}{\rho\frac{\varphi}{1-\lambda}\epsilon}. \tag{2.4}$$

In combination, demand for the individual input variety (2.3) and the profit-maximizing price (2.4) lead to the informal and formal revenues

$$r_i(\varphi) = \frac{Y}{M}\left(\frac{w_i(\varphi)}{(1-\delta)\rho\varphi\epsilon}\right)^{1-\sigma} \text{ and } r_f(\varphi) = \frac{Y}{M}\left(\frac{w_f(\varphi)}{\rho\frac{\varphi}{1-\lambda}\epsilon}\right)^{1-\sigma}, \tag{2.5}$$

and profits

$$\pi_i(\varphi) = (1-\delta)^{\sigma}\frac{Y}{\sigma M}\left(\frac{w_i(\varphi)}{\rho\varphi\epsilon}\right)^{1-\sigma} - f_i \text{ and } \pi_f(\varphi) = \frac{Y}{\sigma M}\left(\frac{w_f(\varphi)}{\rho\frac{\varphi}{1-\lambda}\epsilon}\right)^{1-\sigma} - f_f. \tag{2.6}$$

Besides firm productivity and fair wages, firm revenue depends on two factors. First, the number of firms operating in the domestic market M (and hence the number of varieties sold in the domestic market) influence the demand for each individual variety. A strong

[6] While occurring at the same time in the model, intuitively a firm has to first pay the fixed cost to start production and only then earns revenue. Government enforcement only comes into play once the entry costs are sunk and the firm is meanwhile generating revenue. Hence, enforcement leads to a loss of revenue independent of the fixed cost.

[7] The recent empirical work that examines the effect of formality on firm performance, controlling for firm characteristics and self-selection into the formal sector, finds a significant effect of formality, particularly of increasing firm profits (Fajnzylber et al., 2011; McKenzie and Sakho, 2010; Rand and Torm, 2012a). λ can be seen to capture this effect of formality on firm performance.

domestic competition (thus, a high M) reduces the demand for each variety and therefore the profitability of each firm's operation. Second, the demand for each firm's variety rises with the aggregate revenue in the economy (here Y, as P is normalized to 1).

2.2.3 The labor market and wage determination with informality

There are three groups of workers: informal workers L_i, formal workers L_f and unemployed workers L_u. Together they make up the total labor force in the economy $L \equiv L_i + L_f + L_u$. The informal sector employment share, formal sector employment share and share of unemployed workers are described by $E_i = (L_i/L)$, $E_f = (L_f/L)$ and $U = (L_u/L)$. $E \equiv E_i + E_f$ is the fraction of employed workers.

Workers are identical and have a preference for fair wages along the lines of Akerlof and Yellen (1990). As workers are identical, they are randomly selected by employers in the hiring process and can become either informal or formal salaried workers or remain unemployed. Therefore, I distinguish the informal sector average wage $\bar{w}_i$ from the formal sector average wage $\bar{w_f}$. The average wages are calculated as follows. The wage bill of the informal sector W_i, i.e. the sum of all wages $w_i(\varphi)$ paid in the informal sector, is divided by the amount of informal employment L_i. This provides the informal sector average wage $\bar{w}_i = (W_i/L_i)$. The calculation of the formal sector average wage follows the same procedure. To take the potential unemployment into account, the average wage income per worker in the economy $(E_i\bar{w}_i + E_f\bar{w}_f)$ consists of the two average wages weighted by the respective employment shares, that is:

$$E_i\bar{w}_i + E_f\bar{w}_f = \frac{W_i + W_f}{L}. \tag{2.7}$$

The reference wage of workers consists of two parts: a firm-internal and a firm-external factor (Howitt, 2002; Bewley, 2005; Danthine and Kurmann, 2007). The firm-internal com-

ponent captures the economic success of the firm as measured by the firm's productivity φ. When hired by a formal firm, workers are aware of the formal sector productivity bonus and take the firm's effective productivity $\frac{\varphi}{1-\lambda}$ into account. In line with Kreickemeier and Nelson (2006), the firm-external component relates to the labor market and is the outside option of workers. The external reference point is therefore described by the average wage income per worker $(E_i\bar{w}_i + E_f\bar{w}_f)$.

The workers' fairness consideration between firm-internal and -external reference points is a geometric average weighted by the fairness parameter $\theta \in (0,1)$. Through the firm-internal component that relates the wage to firm productivity, the fair wage setup induces heterogeneous wages among workers that are identical before the hiring process. The informal and formal reference wages take the following functional form:

$$\hat{w_i}(\varphi) = \varphi^{\theta}(E_i\bar{w}_i + E_f\bar{w}_f)^{1-\theta} \text{ and } \hat{w_f}(\varphi) = \left(\frac{\varphi}{1-\lambda}\right)^{\theta}(E_i\bar{w}_i + E_f\bar{w}_f)^{1-\theta}. \tag{2.8}$$

Workers exert effort level ϵ relative to what they perceive to be a fair wage $\hat{w}$. For $w(\varphi) \geq \hat{w}$ workers effort their maximum effort level $\epsilon = 1$, that is $\epsilon = \min\{w(\varphi)/\hat{w}, 1\}$. Additionally, I assume that worker effort level ϵ cannot be contracted and the only mechanism to induce effort is a wage offer. Therefore, outside workers are not able to underbid the wage of currently employed workers, all firms pay the firm-specific reference wage $\hat{w}$ and all employed workers exert effort $\epsilon = 1$.[8] This is supported by the experimental evidence of Fehr and Falk (1999), who show that worker effort level is positively related to their wage and that employers are not interested in wage underbidding by outside workers in a world of incomplete contracts. With all employed workers exerting full effort $\epsilon = 1$, I henceforth ignore ϵ.

The presence of two sectors leads to two crucial differences of this model's wages to

[8] If an outsider were to be hired for a lower wage, she would adjust her reference wage $\hat{w}$ and, given the wage below reference level, decrease her effort level accordingly. Therefore, in equilibrium wage underbidding is not attractive to firms.

the wage specification of Egger and Kreickemeier (2009). First, the firm-external reference point depends on both informal and formal sector wages. Due to the random selection of workers, both employment types are viable options for workers. Second, workers are aware of the productivity bonus that formal sector firms experience and adjust their firm-internal reference point accordingly.

2.2.4 The firm's decision to enter the informal or formal sector

A firm's decision to become informal or formal is established as follows. Before the start of operation, the firm pays a fixed cost f_e and draws a productivity φ, a mechanism explained in detail in subsection 2.2.6. A firm's productivity influences its variable costs but not the fixed cost it faces for entering either the informal or formal sector. Having full information over entry costs and productivity bonus accruing to formal production, firms choose the sector in which they can produce the most profitable or do not produce at all, that is $\max\{\pi_i(\varphi), \pi_f(\varphi), 0\}$. Corresponding to empirical evidence, I assume that informal firms are low-productivity and formal firms are high-productivity firms (La Porta and Shleifer, 2008; Dabla-Norris et al., 2008; de Paula and Scheinkman, 2011). That is $\varphi_f^* > \varphi_i^*$, where φ_i^* and φ_f^* are the cutoff productivity levels at which informal and formal firms start profitably operating. The relationship between the benefits and costs to achieve this sorting with $\xi \equiv (1-\sigma)(\theta-1)$ are summarized in Proposition 1:

Proposition 1. *If* $\frac{(1-\lambda)^{-\xi}}{(1-\delta)^{\sigma}} < \frac{f_f}{f_i}$, *then formal sector firms are higher-productivity firms than informal sector firms; that is* $\varphi_f^* > \varphi_i^*$.

The sorting of sectors along the productivity spectrum according to Proposition 1 can be seen in Figure 2.1. The drivers of this sorting are the formal sector productivity bonus λ, the sector entry costs f_i and f_f as well as the enforcement parameter δ that steer the profitability of production in both sectors. Intuitively, if the benefit of formality relative

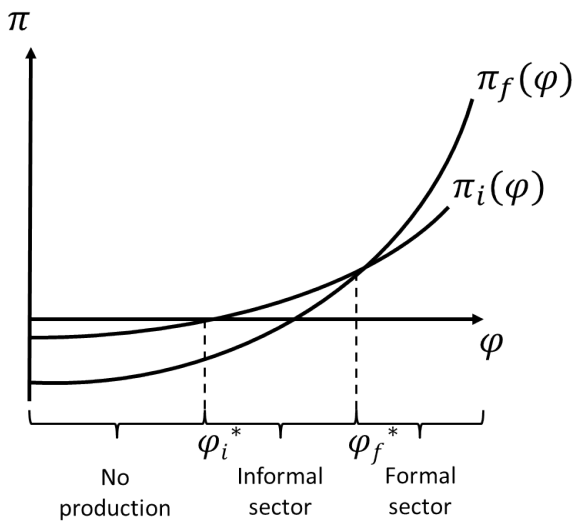

Figure 2.1: Sector sorting along the productivity spectrum according to Proposition 1.

to informality is less than the relative formal sector entry cost, then only high-productivity firms enter formal production and informal firms break even at a lower productivity level than formal firms do.[9] As both profit functions are monotonically increasing in productivity, a single-crossing of the two functions is guaranteed and only formal sector firms can be found at higher productivity levels. As a result, φ_i^* and φ_f^* are determined by the following two conditions:

$$\pi_i(\varphi_i^*) = 0 \tag{2.9}$$

and

$$\pi_f(\varphi_f^*) = \pi_i(\varphi_f^*). \tag{2.10}$$

Notably, for the extreme case of $\delta = 0$ and $\lambda = 0$, firms would have no incentive to join the formal sector and the model would collapse to the one-sector specification in Egger and Kreickemeier (2009). If on top of that, $\theta = 0$ holds, that is workers only value the expected

[9]Breaking even at a lower productivity requires that $\varphi_i^* < \varphi_f^*$ for φ_i^* from $\pi_i(\varphi_i^*) = 0$ & φ_f^* from $\pi_f(\varphi_f^*) = 0$. From equation (2.6): $\varphi_i^* = \left[\frac{f_i}{(1-\delta)^\sigma}\frac{\sigma M}{Y}\right]^{\frac{1}{\xi}}(E_i\bar{w}_i + E_f\bar{w}_f)\rho^{\frac{1}{\theta-1}}$ and $\varphi_f^* = \left[f_f\frac{\sigma M}{Y}\right]^{\frac{1}{\xi}}(E_i\bar{w}_i + E_f\bar{w}_f)\rho^{\frac{1}{\theta-1}}(1-\lambda)$. Hence, $\frac{(1-\lambda)^{-\xi}}{(1-\delta)^\sigma} < \frac{f_f}{f_i}$.

wage in the economy and wages are not firm-specific, labor markets would clear and the model would further collapse to the model described in Melitz (2003).

2.2.5 Firm-specific variables

The relative difference between any two firms can entirely be described by their productivity φ, government enforcement δ, the formal sector productivity bonus λ and their resulting formality status, as in Melitz (2003) and Egger and Kreickemeier (2009). To begin with, using (2.8) and (2.4) results in

$$\frac{w_i(\varphi_i)}{w_f(\varphi_f)} = \left(\frac{\varphi_i}{\varphi_f}\right)^{\theta} (1-\lambda)^{\theta} < 1 \text{ and } \frac{p_i(\varphi_i)}{p_f(\varphi_f)} = \left(\frac{\varphi_i}{\varphi_f}\right)^{\theta-1} (1-\lambda)^{\theta-1}(1-\delta)^{-1} > 1. \quad (2.11)$$

Consistent with the empirical literature, informal wages are lower than formal wages for two reasons. First, wages are a function of firm productivity and formal sector firms are high-productivity firms. Second, the formal sector productivity bonus acts as a wage premium for formal sector employment. This results in an informal wage gap (Bargain and Kwenda, 2011; de Paula and Scheinkman, 2011; Günther and Launov, 2012). Similarly, (2.11) allows for a comparison of the relative prices $p_i(\varphi_i)/p_f(\varphi_f)$, and shows that formal firms charge lower prices than informal firms. Intuitively, due to their productivity bonus and higher productivity level, formal firms are able to translate lower marginal costs into lower prices for their products. This is in line with the findings of Foster et al. (2008), who show a negative correlation between physical firm productivity and output prices. Moreover, higher enforcement, as a driver of informal sector production costs, translates into higher prices charged by informal producers. In addition, using (2.3) and (2.5), I can compare the quantities and revenues between firms of the two sectors.

$$\frac{q_i(\varphi_i)}{q_f(\varphi_f)} = \left(\frac{\varphi_i}{\varphi_f}\right)^{\sigma(1-\theta)} (1-\lambda)^{\sigma(1-\theta)}(1-\delta)^{\sigma} < 1 \text{ and}$$
$$\frac{r_i(\varphi_i)}{r_f(\varphi_f)} = \left(\frac{\varphi_i}{\varphi_f}\right)^{\xi} (1-\lambda)^{\xi}(1-\delta)^{\sigma-1} < 1. \tag{2.12}$$

Formal firms are not just able to translate higher productivity into lower prices, but they also produce larger quantities than their informal counterparts (La Porta and Shleifer, 2008).[10] In combination, the revenue of firms in the formal sector is higher than in the informal sector (Fajnzylber et al., 2011). Furthermore, (2.13) illustrates the labor demand of an informal sector firm $l_i(\varphi)$ relative to the labor demand of a formal sector firm $l_f(\varphi)$.

$$\frac{l_i(\varphi_i)}{l_f(\varphi_f)} = \left(\frac{\varphi_i}{\varphi_f}\right)^{\sigma(1-\theta)-1} (1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1} < 1. \tag{2.13}$$

To capture the positive correlation between productivity level and employment, that is $l_i(\varphi) < l_f(\varphi)$, I assume $\sigma(1-\theta)-1 > 0$, analogous to Egger and Kreickemeier (2009).[11] In this setup the assumption is relevant for another reason. Given this assumption, informal firms hire less labor than formal firms due to the productivity bonus of formal sector firms (La Porta and Shleifer, 2008; de Paula and Scheinkman, 2011; Fajnzylber et al., 2011). Moreover, high-productivity firms pay not just higher wages, but also hire more workers (Brown and Medoff, 1989).

Using the zero profit conditions for both sectors (2.9) and (2.10), I can specify the distance

[10] La Porta and Shleifer (2011) also suggest that informal firms produce lower-quality products than their formal counterparts. In the model, firms produce symmetric varieties at different costs. As mentioned in Melitz (2003), an alternative interpretation of productivity in Melitz (2003)-type models is that firms produce varieties of different quality at the same cost. Given this interpretation, the model implicitly reflects the lower quality of informal sector products. Verhoogen (2008) models product quality explicitly, albeit does so using heterogeneous workers.

[11] An interpretation of the condition comes from rewriting it as $1/\rho < 1/\theta$, that is the love of variety $1/\rho$ needs to be greater than the inverse of the fairness consideration parameter θ. Intuitively, for a lower love of variety $1/\rho$, the cheaper varieties are demanded relatively more, which are produced by higher-productivity firms. Hence, higher-productivity firms hire more workers. On the other hand, a higher fairness preference θ raises the wages paid by high-productivity firms and accordingly a decrease in those firms' hiring. To correspond to the empirical literature, as described in Egger and Kreickemeier (2009), I assume $1/\rho < 1/\theta$ holds.

of informal to formal sector cutoff productivity level relative to the formal sector cutoff productivity level $\frac{\varphi_f^* - \varphi_i^*}{\varphi_f^*}$.

$$\frac{\varphi_f^* - \varphi_i^*}{\varphi_f^*} = 1 - \left(\frac{f_i}{f_f - f_i}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}} (1-\delta)^{\frac{-\sigma}{\xi}}. \tag{2.14}$$

This allows the analysis of inter-firm productivity differences between the marginal informal and the marginal formal firm with regard to policy changes and is summarized in Proposition 2.

Proposition 2. *The relative productivity distance of formal to informal sector firms* $\frac{\varphi_f^* - \varphi_i^*}{\varphi_f^*}$ *is decreasing in* f_i, δ *and* λ *and increasing in* f_f.

Proof. See appendix A.1. □

The intuition for Proposition 2 is as follows. An increase in factors that make informal sector participation more costly (f_i, δ) or factors that make formal sector production more profitable (λ) raises the informal sector productivity cutoff level φ_i^* relative to the formal sector productivity cutoff level φ_f^* and thereby diminishes the distance in relative productivity levels. The distance in relative productivity levels increases for an increase in the formal sector entry cost f_f through a reduction in the profitability of formal sector participation.

2.2.6 Firm productivity distribution and free entry

Firms are indexed by their productivity φ, hence firm size distribution, aggregate employment and aggregate output of the economy hinge on the productivity distribution. A commonly used distribution in Melitz (2003)-type models is the Pareto distribution. It is both tractable and fits empirical findings on firm size and the productivity distribution well (Ax-

tell, 2001). The distribution is given by $G(\varphi)$ with density $g(\varphi)$ and shape parameter $k > \xi$.[12] The lower bound of productivities is normalized to 1.

$$G(\varphi) = 1 - \varphi^{-k} \text{ and } g(\varphi) = k\varphi^{-(k+1)}. \tag{2.15}$$

There exists a mass M_e of prospective entrants, all identical ex-ante, to the intermediate sector.[13] Entering entails a fixed cost of $f_e > 0$ and allows firms to draw a productivity φ from the distribution $G(\varphi)$. Firms only start producing if the expected profit of production is non-negative. In equilibrium the average profit of active firms, conditional on successful market entry, is equal to the sunk cost f_e. This is described by the free entry condition:

$$\frac{\int_{\varphi_i^*}^{\varphi_f^*} \pi_i(\varphi) g(\varphi) \mathrm{d}\varphi}{G(\varphi_f^*) - G(\varphi_i^*)} + \frac{\int_{\varphi_f^*}^{\infty} \pi_f(\varphi) g(\varphi) \mathrm{d}\varphi}{1 - G(\varphi_f^*)} = f_e. \tag{2.16}$$

Using the cutoff productivity levels and wage equations for both sectors, I can describe (2.7), the average wage income per worker in the economy, as

$$E_i \bar{w}_i + E_f \bar{w}_f = L^{-1} \left[\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\infty} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi \right]. \tag{2.17}$$

As firms price their goods with a constant markup $1/\rho$ over marginal costs, the wage income of employed workers is equal to a constant share of output $(E_i \bar{w}_i + E_f \bar{w}_f)L = \rho Y$.[14] Through (2.16), the expected profits of all firms equal their initial investment f_e. Therefore, the workers' income is the only disposable income for consumption and a natural utilitarian measure for welfare, as in Egger and Kreickemeier (2009), and can be written as:

$$\frac{Y}{L} = \frac{(E_i \bar{w}_i + E_f \bar{w}_f)}{\rho}. \tag{2.18}$$

[12] A Pareto distributions has a finite mean only if its shape parameter $k > 1$. Productivity is Pareto distributed and labor as well as revenue are power functions of productivity. Therefore, also firm size and revenue are Pareto distributed. For the distributions of firm size and revenue to have a finite mean, $\frac{k}{\xi - \theta} > 1$ and $\frac{k}{\xi} > 1$, respectively, have to hold. Thus, as in Egger and Kreickemeier (2009), $k > \xi$ is assumed.

[13] M_e is exogeneously given and without loss of generality normalized to 1.

[14] The aggregate revenue in the economy is described by Y, because $P = 1$. It consists of both the firms' and the workers' share of the aggregate revenue. Due to the monopolistic competition assumption and resulting prices characterized by a constant markup $1/\rho$ over marginal costs, the shares are constant proportions. A constant fraction $1/\sigma$ of the firm revenue accrues to the firm and $(\sigma - 1)/\sigma = \rho$ accrues to the workers of the firm. Hence, the wage income of all employed workers $(E_i \bar{w}_i + E_f \bar{w}_f)L$ has to equal their constant share of the aggregate revenue ρY.

2.2.7 Employment

The share of employment in the economy consists of two parts: informal sector employment share E_i and formal sector employment share E_f. Building on the condition of Proposition 1, the employment share can be written as

$$E = E_i + E_f = L^{-1}\left[\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\infty} l_f(\varphi)g(\varphi)\mathrm{d}\varphi\right]. \tag{2.19}$$

Next, I examine the relative employment share (E_i/E_f) to determine the effect of policy changes.

$$\frac{E_i}{E_f} = (1-\delta)^{\sigma}(1-\lambda)^{\chi+k}\left[\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi} - 1\right], \tag{2.20}$$

where $\chi \equiv \sigma(1-\theta) - k - 1 < 0$.[15]

Proposition 3. *The ratio of informal employment share to formal employment share $\frac{E_i}{E_f}$ is increasing in f_f and decreasing in f_i, δ, λ.*

Proof. See appendix A.2. □

Proposition 3 and Proposition 2 jointly shed light on the mechanics of the economy. A reduction in informal sector profitability or increase in formal sector profitability (i.e. increase in f_i, δ and λ) leads to a decrease in relative productivity distance and a decrease in informal sector employment relative to formal sector employment. Similarly, a decrease in formal sector profitability (i.e. increase in f_f) increases the relative productivity distance and increases relative informal sector employment. Intuitively, reducing informal sector profitability or increasing formal sector profitability drives the least-productive informal sector firms out of the market. As a result, the informal sector sheds labor and informal sector average productivity increases. This extends Egger and Kreickemeier (2009) to a new adjustment margin. Informal and formal sector employment are affected differently by

[15] $k > \xi$ is assumed. This implies $\sigma(1-\theta) - k - 1 + \theta < 0$ and thus $\sigma(1-\theta) - k - 1 < 0$.

changes in the economy. The employment effect of one sector can buffer the employment effect of the other one.

2.2.8 Wage inequality

Prior to the hiring process workers are identical and subsequently can be employed in either the informal or formal sector. Additionally, wages in this model are firm-specific. Therefore, two types of wage inequality can be disentangled. First, given the productivity difference between the two sectors and the informal sector wage gap, I consider the wage inequality between informal and formal workers. Second, as all workers are identical in skill level, I analyze wage inequality among all employed workers similar in spirit to Egger and Kreickemeier (2012).[16]

The measure of between-group wage inequality is the ratio of the formal sector average wage relative to the informal sector average wage:

$$\frac{\bar{w_f}}{\bar{w_i}} = (1-\lambda)^{-\theta}\left[1-\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi}\right]\left[1-\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\xi-k}\right]^{-1} > 1. \tag{2.21}$$

As formal production entails a productivity bonus and is characterized by high-productivity firms, the average wage in the formal sector is higher than in the informal sector and the ratio is strictly greater than one.

Second, I measure the wage inequality among all employed workers using the Gini-coefficient. Calculating the Gini-coefficient for the two-sector economy requires two steps. First, I calculate the Lorenz curve $Q(\gamma)$ by relating the share of employment to the share

[16]The analysis in this model differs to the one in Egger and Kreickemeier (2012) in two ways. First, Egger and Kreickemeier (2012) consider heterogeneous individuals and examine wage inequality between self-selected entrepreneurs and salaried workers. Second, workers consider firm revenue in their fair wage preference, which leads to an exporter wage premium. Opposed to that, I examine wage inequality among identical workers that can be employed in the informal or formal sector and workers consider firm productivity in their fair wage preference.

of wage bill for firms with productivity below $\bar{\varphi} \in [\varphi_i^*, \infty]$. Because employment and wages in the informal sector differ from the formal sector, the Lorenz curve consists of two segments and requires lengthy calculations that can be found in appendix A.3. Second, the Gini-coefficient $G_{(a)}$, where subscript (a) stands for autarky, follows from the Lorenz curve through $G_{(a)} = 1 - 2\int_0^1 Q(\gamma)\mathrm{d}\gamma$. $G_{(a)}$ is then described by

$$G_{(a)} = G_f \left[1 + \frac{2\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{k-\xi}}{\theta \Gamma \Delta} \left\{ \chi \left[\Upsilon - \Xi \left(\frac{\varphi_i^*}{\varphi_f^*} \right)^{\theta} + [\Xi - \Upsilon] \left(\frac{\varphi_i^*}{\varphi_f^*} \right)^{-\chi} \right] + \theta \Upsilon \left[1 - \left(\frac{\varphi_i^*}{\varphi_f^*} \right)^{-\chi} \right] \right\} \right], \tag{2.22}$$

where $G_f \equiv \frac{\theta}{\theta - 2(\xi - k)}$,[17] $\Gamma \equiv (1-\delta)^\sigma - \left[(1-\delta)^\sigma - (1-\lambda)^{-\xi+\theta}\right]\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\chi}$, $\Delta \equiv (1-\delta)^\sigma - \left[(1-\delta)^\sigma - (1-\lambda)^{-\xi}\right]\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{k-\xi}$, $\Upsilon \equiv (1-\delta)^{2\sigma} - (1-\delta)^\sigma (1-\lambda)^{-\xi}$ and $\Xi \equiv (1-\delta)^{2\sigma} - (1-\delta)^\sigma (1-\lambda)^{-\xi+\theta}$. The Gini-coefficient in the two-sector economy $G_{(a)}$ depends on the ratio of the two cutoff productivity levels $(\varphi_i^*/\varphi_f^*)$, which is a proxy for the relative sector size. For the extreme cases of $(\varphi_i^*/\varphi_f^*) = 1$, i.e. all firms are formal, and $(\varphi_i^*/\varphi_f^*) = 0$, i.e. all firms are informal, the specification collapses to the single-sector economy Gini-coefficient G_f. In the two-sector economy, that is $(\varphi_i^*/\varphi_f^*) \in (0,1)$, $G_{(a)} > G_f$ holds and the wage distribution is more unequal than in the single-sector economy. Moreover, for $\theta \in (0,1)$, i.e. workers value firm-specific wages, the Gini-coefficient is strictly greater than 0.[18]

2.3 The open economy

To explore how the presence of an informal sector may mediate the impact of trade liberalization, I extend the closed economy specification by adding international trade with n symmetric countries. The symmetry assumption allows me to focus on firm-level effects and

[17] G_f is the Gini-coefficient of a purely-formal or purely-informal economy. This result is derived in appendix A.3.

[18] For the extreme case of $\theta = 0$, i.e. all workers receive the same wage, $G_f = 0$ and the economy would be perfectly equal.

renders country indices obsolete. Moreover, a world in which every country is characterized by sector dualism is sensible, since informality is a global phenomenon (Schneider et al., 2010). Two types of costs are distinguished for firms participating in international trade. As has been empirically shown by Roberts and Tybout (1997), sunk costs of exporting critically determine export participation. Firms have to cover a fixed exporting cost $f_x > f_f$, in addition to the domestic entry cost, to participate in trade. The fixed cost f_x can be interpreted as a one-time expense for knowledge or infrastructure needed to engage in international trade and allows firms to access all n markets. Subscript x is used henceforth to describe variables related to export activities. In addition, firms face a variable trade cost that is modeled in the form of an iceberg trade cost $\tau > 1$, i.e. for one unit to arrive at the destination market, τ units have to be shipped.

2.3.1 The firm's decision to export

Given the previous constraint on informal firms being characterized by lower productivities than formal firms, it is never profitable for informal firms to export.[19] Intuitively, informal firms decide against formality out of profitability considerations arising from the formal sector fixed cost f_f. Exporting induces an even higher fixed cost f_x than the formal sector participation already does. Hence, the same profitability considerations will lead informal sector firms to not be able to profitably export. The complete exclusion of informal sector firms from exporting is stylized. Yet, this model result is supported by the empirical literature that finds that informal firms rarely export (Batra et al., 2003; Bigsten et al., 2004; La Porta and Shleifer, 2008). The result is summarized in Proposition 4:

[19] What is required for informal exporting to be profitable at a lower productivity level than formal exporting, i.e. $\varphi_i < \varphi_f$ from $\pi_i^x(\varphi_i) = (1-\delta)^\sigma n \frac{Y}{\sigma M} \left\{\varphi_i^{\theta-1}(E_i\bar{w}_i + E_f\bar{w}_f)^{1-\theta}\rho^{-1}\tau\right\}^{1-\sigma} - f_x = 0$ & $\pi_f^x(\varphi_f) = n\frac{Y}{\sigma M}\left\{\left(\frac{\varphi_f}{1-\lambda}\right)^{\theta-1}(E_i\bar{w}_i + E_f\bar{w}_f)^{1-\theta}\rho^{-1}\tau\right\}^{1-\sigma} - f_x = 0$. The resulting requirement is $(1-\delta)^{\frac{\sigma}{\xi}} > (1-\lambda)^{-1}$, which is a contradiction given that $\delta \in [0,1)$ and $\lambda \in (0,1)$.

Proposition 4. *Informal sector firms do not find it profitable to export.*

In regards to the formal sector, empirical studies find a clear correlation between export participation and firm productivity, i.e. the highest-productivity firms in an economy self-select into exporting (Bernard and Jensen, 1995; Roberts and Tybout, 1997). Hence, the results focus on parameters that satisfy $\varphi_x^* > \varphi_f^*$, where φ_x^* stands for the cutoff productivity level at which exporting becomes profitable, and assumes that exporters are characterized by a higher productivity level than non-exporters. Therefore upon drawing a productivity φ, a firm in the open economy decides on its formality status and export participation according to $\max\{\pi_i(\varphi), \pi_f(\varphi), \pi_f(\varphi) + \pi_x(\varphi), 0\}$. The number of firms operating in the domestic market then consists of informal sector firms and formal sector firms, which are domestic, as well as foreign exporters, i.e. $M = M_i + M_f + (1+n)M_x$. The sufficient condition for the productivity sorting is summarized in Proposition 5:[20]

Proposition 5. *If* $\frac{f_x \tau^{\frac{\xi}{1-\theta}}}{n(1-\lambda)^{-\xi}} > \frac{f_f - f_i}{(1-\lambda)^{-\xi} - (1-\delta)^{\sigma}}$, *then exporting firms are higher-productivity firms than non-exporting formal sector firms; that is* $\varphi_x^* > \varphi_f^*$.

The sorting depends on the entry costs to the informal and formal sector (f_i and f_f), informal sector enforcement (δ), formal sector productivity bonus (λ) and the variables determining the costs and benefits of trade (f_x, τ and n). Intuitively, the inequality compares two cost-benefit ratios. If the cost-benefit ratio of exporting $\frac{f_x \tau^{\frac{\xi}{1-\theta}}}{n(1-\lambda)^{-\xi}}$ is higher than the cost-benefit ratio of domestic production $\frac{f_f - f_i}{(1-\lambda)^{-\xi} - (1-\delta)^{\sigma}}$, then a higher productivity is required to be able to profit from exporting.

Given the variable and fixed cost, the formal sector firm revenue function is

[20] Ensuring $\varphi_x^* > \varphi_f^*$ for φ_f^* from $\pi_i(\varphi_f^*) = \pi_f(\varphi_f^*)$ and φ_x^* from $\pi_x(\varphi_x^*) = 0$ is sufficient to sort domestic productivity levels below export productivity levels. This results in $\varphi_f^* = \left[\frac{(f_f - f_i)M\sigma}{Y((1-\lambda)^{-\xi} - (1-\delta)^{\sigma})}\right]^{\frac{1}{\xi}} (E_i \bar{w}_i + E_f \bar{w}_f)\rho^{\frac{1}{\theta-1}}$ and $\varphi_x^* = \left[\frac{f_x n \sigma M}{Y}\right]^{\frac{1}{\xi}} (E_i \bar{w}_i + E_f \bar{w}_f)(\frac{\rho}{\tau})^{\frac{1}{\theta-1}}(1-\lambda)$. In combination, $\frac{f_x \tau^{\frac{\xi}{1-\theta}}}{n(1-\lambda)^{-\xi}} > \frac{f_f - f_i}{(1-\lambda)^{-\xi} - (1-\delta)^{\sigma}}$.

$$r(\varphi) = \begin{cases} r_f(\varphi) \text{ if the firm sells domestically,} \\ r_f(\varphi) + n\tau^{1-\sigma} r_f(\varphi) \text{ if the firm exports.} \end{cases} \tag{2.23}$$

A firm's profit from exporting is described by

$$\pi_x(\varphi) = \frac{r_f(\varphi) n \tau^{1-\sigma}}{\sigma} - f_x. \tag{2.24}$$

In addition to (2.9) and (2.10), there is a new condition to determine the export participation productivity cutoff level φ_x^*:

$$\pi_x(\varphi_x^*) = 0. \tag{2.25}$$

In summary, to achieve the productivity sorting of firms in the open economy according to the empirical literature, the model builds on the results of Propositions 1, 4 and 5. That is, informal sector firms are assumed to be the lowest-productivity firms followed by domestic formal firms. Lastly, formal firms that export are the highest-productivity firms. Given this, there are no informal sector exporters.

2.3.2 Firm-specific variables

I can express the relationship between formal firms and formal exporting firms as ratios solely in terms of their productivity levels, variable trade costs τ and the number of countries n, independent of assumptions on the distribution of firm productivity. The price and quantities refer solely to the export markets. However, the profits of exporting firms stem from both domestic and foreign sales. Hence, the total labor demand and revenues of exporting firms consist of both the ones for the domestic market and the export market.

Exporters pay the same wage as formal sector producers conditional on productivity, i.e. $w_f(\varphi)$. However, if Proposition 5 holds, exporters are more productive than non-exporting

formal firms, $w_f(\varphi_x^*) > w_f(\varphi_f^*)$ holds and an exporter wage premium applies. As a result, the model captures the empirical observation that exporting firms pay higher wages than non-exporting firms (Bernard and Jensen, 1995).

$$\frac{p_f(\varphi_f)}{p_x(\varphi_x)} = \left(\frac{\varphi_f}{\varphi_x}\right)^{\theta-1} \tau^{-1} < 1 \text{ and } \frac{q_f(\varphi_f)}{q_x(\varphi_x)} = \left(\frac{\varphi_f}{\varphi_x}\right)^{\sigma(1-\theta)} \tau^{\sigma} > 1. \tag{2.26}$$

Given the same productivity, in foreign markets the price is higher and the quantity sold is lower than in the domestic market.

$$\frac{r_f(\varphi_f)}{r_x(\varphi_x)} = \left(\frac{\varphi_f}{\varphi_x}\right)^{\xi} \frac{1}{1+n\tau^{1-\sigma}} < 1 \text{ and } \frac{l_f(\varphi_f)}{l_x(\varphi_x)} = \left(\frac{\varphi_f}{\varphi_x}\right)^{\sigma(1-\theta)-1} \frac{1}{1+n\tau^{1-\sigma}} < 1. \tag{2.27}$$

With regard to revenue and labor demand, both are increasing in the number of countries n and decreasing in the variable trade cost τ for exporters relative to formal non-exporters. These model results are in line with the commonly stated firm-level evidence on exporters being characterized by higher employment and higher revenues than their non-exporting counterparts (Bernard and Jensen, 1995).

Equation (2.28) allows me to analyze the distance between formal sector productivity cut-off φ_f^* and exporting cutoff productivity level φ_x^* relative to the exporting cutoff productivity level φ_x^*:

$$\frac{\varphi_x^* - \varphi_f^*}{\varphi_x^*} = 1 - \left(\frac{(f_f - f_i)n\tau^{1-\sigma})}{f_x}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1}. \tag{2.28}$$

The results are summarized in Proposition 6 and can be separated into two groups. First, the effects that make international trade more attractive to firms (increase in n or decrease in f_x or τ) close the relative distance between the productivities. Trade liberalization allows for increased sales of exporting firms, directly benefiting their profitability, and decreases the required productivity level for participation. For non-exporting formal sector firms, an increased number of foreign competitors in the domestic market drives down profitability and increases productivity requirements. The second group are factors that also influence

domestic firms directly. Factors increasing the profitability of formal sector participation relative to informal sector participation (increase in f_i, δ and λ) lower the productivity threshold of becoming formal, but do not affect export participation as much. As a result, the relative distance between exporting and domestic formal firms increases. The opposite holds true for the formal sector entry cost f_f. Formal sector participation is more affected than export participation, as exporters are high-productivity firms, and the productivity distance decreases.

Proposition 6. *The relative distance in cutoff productivities* $\frac{\varphi_x^* - \varphi_f^*}{\varphi_x^*}$ *is decreasing in* f_f *and* n*. It is increasing in* f_i*,* f_x*,* δ*,* λ *and* τ*.*

Proof. See appendix A.4. □

Lastly, comparing $\varphi_x^* = (f_x/f_i)^{\frac{1}{\xi}}(n\tau^{1-\sigma})^{-\frac{1}{\xi}}(1-\lambda)(1-\delta)^{\frac{\sigma}{\xi}}\varphi_i^*$, i.e. the cutoff productivity level of the marginal exporting and marginal informal sector firms highlights what drives their difference. The ratio of sector entry costs, trade variables and the productivity bonus lead to a higher productivity requirement for exporting firms relative to informal sector producers. Similar to the cutoff productivity levels, the difference between these key variables is driven by potential government enforcement for informal sector firms, the productivity bonus of formal sector firms and the trade parameters.

To derive the new free entry condition in the open economy, I extend (2.16) to include potential exporting profit:

$$\frac{\int_{\varphi_i^*}^{\varphi_f^*} \pi_i(\varphi) g(\varphi) \mathrm{d}\varphi}{G(\varphi_f^*) - G(\varphi_i^*)} + \frac{\int_{\varphi_f^*}^{\varphi_x^*} \pi_f(\varphi) g(\varphi) \mathrm{d}\varphi}{G(\varphi_x^*) - G(\varphi_f^*)} + \frac{\int_{\varphi_x^*}^{\infty} \left[\pi_f(\varphi) + \pi_x(\varphi)\right] g(\varphi) \mathrm{d}\varphi}{1 - G(\varphi_x^*)} = f_e. \tag{2.29}$$

2.3.3 Employment

Employment in the open economy consists of three segments: informal, formal and formal exporter employment. The employment share in the economy then is

$$E = L^{-1}\left[\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_x^*}^{\infty} l_x(\varphi)g(\varphi)\mathrm{d}\varphi\right]. \tag{2.30}$$

To analyze the impact of trade liberalization on employment, I first delineate the effect into the employment of the informal and formal sectors. Formal sector employment adjusts along two margins. The high-productivity formal firms become exporters and hire additional workers to be able to serve the foreign demand. After trade liberalization, foreign competitors enter the domestic market and more varieties of the intermediate good are sold domestically (increase in M). As competitive pressure rises, the demand for each variety decreases and the profitability of all firms is reduced. Low-productivity formal firms informalize to remain profitable. As a result, formal sector employment is affected negatively, dampening total employment. Informal sector firms do not experience the productivity bonus λ and thus hire fewer workers than formal sector firms at the same productivity level. This is obvious when comparing the labor demand ratio $l_i(\varphi_1)/l_f(\varphi_2) = (\varphi_1/\varphi_2)^{\sigma(1-\theta)-1}(1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1}$. Whether the hiring effect of exporting firms or the labor shedding of informalized firms dominates depends on the key characteristics of the economy. Thus, the effect of trade liberalization on formal sector employment is ambiguous.

Informal sector employment is also affected along two margins. With falling demand for each input variety, the lowest-productivity informal producers are forced out of the market and release labor. Along the other margin, the least-productive formal sector firms become informal and thereby increase informal sector employment. Given the Pareto productivity distribution, the labor releasing effect is stronger than the labor hiring and therefore infor-

mal sector employment unambiguously decreases upon trade liberalization.[21] The empirical evidence on the adjustment of informal sector employment through trade liberalization is ambiguous with a wide range of definitions of informality and data sets in use.[22] My research provides theoretical support for the finding of decreasing informal sector employment with trade liberalization (Fiess and Fugazza, 2012; McCaig and Pavcnik, 2014).

Lastly, I analyze the total employment in the economy as a combination of the employment adjustments of both sectors. As illustrated in Figure 2.2, liberalizing trade changes the position of both sectors along the productivity distribution. Three forces determine the change in total employment: an employment gain as a result of exporter hiring, an employment loss caused by the informalization of the least-productive formal sector firms and an employment loss that occurs as the least-productive informal sector firms exit the market. While the informal sector unambiguously reduces its size, the effect of trade liberalization on formal sector employment is ambiguous, thus rendering the total employment effect ambiguous. The magnitude of each sectoral adjustment and accordingly the direction of total employment adjustment is determined by the economy's characteristics, such as entry costs to both sectors. The move from autarky to full integration is stylized. However, the aforementioned results hold also for gradual trade integration, as measured by a reduction in τ or f_x.[23]

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[21] $\frac{E_{i(t)}}{E_{i(a)}} = \left[1 + n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-\theta}{\xi}}$
$\left[1 + \frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{((1-\lambda)^{-\xi}-(1-\delta)^{\sigma})^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{\theta}{\xi}-1}$, where the subscript (a) and (t) stand for autarky and trade. $\left(\frac{E_{i(t)}}{E_{i(a)}}\right) < 1$ because $-\frac{\theta}{\xi} < 0$ and $\frac{\theta}{\xi} - 1 < 0$. Hence, informal sector employment unambiguously decreases upon trade liberalization.

[22] My model focuses on firm-level informality as registration non-compliance. Thus, all workers employed by a firm are either formal or informal workers. Defining informality from a labor market perspective, i.e. as the evasion of labor market regulations, allows firms to hire both informal and formal workers by, for instance, evading social security contributions for only some of their workers. As a consequence of trade liberalization and increased competitive pressure, firms might substitute formal with informal workers, potentially leading to an increase or no change in informal employment as found for example by Goldberg and Pavcnik (2003).

[23] Proof for this is available from the author upon request.

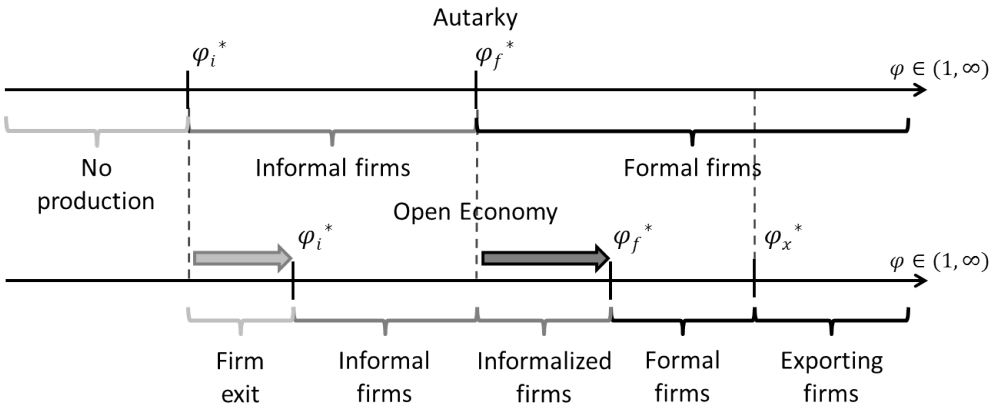


Figure 2.2: Sector sorting along the productivity distribution in autarky and the open economy.

This highlights a key contribution of this model. In Egger and Kreickemeier (2009) there are only two forces at work. The highest-productivity firms become exporters and hire additional workers; the lowest-productivity firms exit the market and shed labor. In sum, Egger and Kreickemeier (2009) find an unambiguous employment decrease. The existence of an informal sector gives rise to a third force, i.e. the informalization of low-productivity formal firms, which dampens the reallocation of labor towards more productive firms. The economy's characteristics affect the three forces and accordingly the magnitude of each. This result, as summarized in Proposition 7, bridges the gap between the original model of Egger and Kreickemeier (2009) and the mixed empirical evidence on the relationship between trade openness and unemployment (Davidson and Matusz, 2009; Dutt et al., 2009; Felbermayr et al., 2011b; Menezes-Filho and Muendler, 2011).

Proposition 7. *Trade liberalization reduces informal sector employment unambiguously and can either reduce or increase formal sector employment. In combination, the effect of trade liberalization on total employment in the economy is ambiguous in the presence of informality.*

Proof. See appendix A.6. □

To gain further insight into the mechanics of the model, analogously to the closed economy

case, I can describe the informal sector employment share relative to the formal sector employment share:

$$\left(\frac{E_i}{E_f}\right)_{(t)} = \eta \left(\frac{E_i}{E_f}\right)_{(a)}, \tag{2.31}$$

where $\eta \equiv \left[1 + n\tau^{1-\sigma}\left(\frac{\varphi_f^*}{\varphi_x^*}\right)^{-\chi}\right]^{-1} < 1$. Subscript (a) and (t) stand for autarky and trade. The intuition follows from the earlier result. Informal sector employment unambiguously decreases, while formal sector employment may either increase or decrease. In combination, trade liberalization unambiguously reduces the informal sector employment share relative to the formal sector share. This leads to Proposition 8:

Proposition 8. *Trade liberalization decreases the ratio of informal employment to formal employment.*

2.3.4 Welfare

The average wage income per worker $(E_i\bar{w}_i + E_f\bar{w}_f)$ in the open economy is described by all three cutoff productivities and, in combination with (2.18), determines the aggregate output in the open economy.

$$\begin{aligned}(E_i\bar{w}_i + E_f\bar{w}_f) = L^{-1}\Bigg[&\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)w_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi)w_f(\varphi)g(\varphi)\mathrm{d}\varphi \\ &+ \int_{\varphi_x^*}^{\infty} l_x(\varphi)w_f(\varphi)g(\varphi)\mathrm{d}\varphi\Bigg].\end{aligned} \tag{2.32}$$

The effect of trade liberalization on welfare, as measured by the aggregate output of the economy per capita, is similar to the employment effect. The intuition is as follows. Trade liberalization allows the highest-productivity firms to become exporters and shifts resources towards the most-productive firms in the economy. Thereby aggregate formal sector output is increased. The lowest-productivity formal firms, however, switch to informal sector

production. The result is a reduction in aggregate formal sector output through the loss of the formal sector productivity bonus. In sum, the effect of trade on the aggregate formal sector output is ambiguous. The informal sector is affected along two margins, as well. The lowest-productivity informal sector firms cease production and decrease aggregate informal sector output, while the informalization of the lowest-productivity formal firms increases the aggregate output of the informal sector. Depending on the economy's characteristics the former may or may not compensate for the latter, rendering the effect on aggregate informal sector output ambiguous. As before, depending on the key parameters of the economy, the net effect of trade liberalization on the aggregate output of the whole economy can be positive or negative. This result also holds for gradual trade liberalization (decrease in τ or f_x).[24] The effect of trade on aggregate output in this model is more nuanced than in Egger and Kreickemeier (2009), who find an unambiguous increase in aggregate output through trade liberalization. The ambiguous result highlights the effect of the informal sector on resource allocation, as suggested by Hsieh and Klenow (2009) and Bruhn (2013), that can either lead to an increase in aggregate output (McCaig and Pavcnik, 2013), and hence welfare, or decrease in aggregate output upon trade liberalization. Proposition 9 summarizes this result.

Proposition 9. *Trade liberalization in the presence of informality has an ambiguous effect on the aggregate output of the informal sector, the formal sector and in sum on the welfare of the economy.*

Proof. See appendix A.6. □

[24] Proof for this is available from the author upon request.

2.3.5 Wage inequality

Trade liberalization affects wage inequality indirectly by adjusting the number of workers employed in the informal and formal sector.[25] As before, I first analyze between-group wage inequality.

$$\left(\frac{\bar{w_f}}{\bar{w_i}}\right)_{(t)} = \omega \left(\frac{\bar{w_f}}{\bar{w_i}}\right)_{(a)}, \tag{2.33}$$

where $\omega \equiv \left[1 + n\tau^{1-\sigma}\left(\frac{\varphi_x^*}{\varphi_f^*}\right)^{\xi-k}\right]\left[1 + n\tau^{1-\sigma}\left(\frac{\varphi_x^*}{\varphi_f^*}\right)^{\chi}\right]^{-1} > 1$. Between-group wage inequality in the open economy is higher than under autarky. Intuitively, trade liberalization raises the competitive pressure in the economy and forces the least-productive informal firms to exit and the lowest-productivity formal firms to informalize. The informal firms paying the lowest wages exit and higher-wage formal firms start informal production. This raises the informal sector average wage. With regard to the formal sector, the highest-wage exporters hire more workers and the lowest-wage formal firms informalize. The average wage of the formal sector increases and does so at a greater magnitude than the informal sector average wage. Hence, the average wages diverge and between-group inequality increases.

Similarly, wage inequality among all employed workers measured by the Gini-coefficient hinges on the share of employment in both sectors. The derivation of the Gini- coefficient is analogous to the closed economy, albeit more complicated.[26] The Lorenz curve consists of not just informal and formal workers, but also workers employed by exporting firms.[27] Trade liberalization affects wage inequality indirectly through the employment shares and can either increase or decrease wage inequality. The intuition for this result derives from Proposition

[25] My model focuses on the interaction between the informal and formal sector and accordingly ignores an exporter wage premium conditional on firm productivity. The model can be extended to include a fair wage constraint that uses firm revenue and not firm productivity as firm-internal reference point. This would lead to an exporter wage premium and could provide another source for wage inequality, even among formal workers.

[26] Given its complicated nature, the Gini-coefficient for the open economy is derived in Appendix A.5.

[27] For the extreme case of $(\varphi_i^*/\varphi_x^*) = 0$, i.e. no firm exports, the open economy Gini-coefficient collapses to the autarky specification. If in addition to that, $(\varphi_i^*/\varphi_f^*) = 0$ or $(\varphi_i^*/\varphi_f^*) = 1$ are imposed, the coefficient further collapses to the formal-sector-only specification.

8. Both a purely-formal and a purely-informal economy feature the same Gini-coefficient, which is strictly lower than that of an economy featuring both sectors.[28] Trade liberalization increases the formal sector employment share relative to informal sector employment share. If initially formal sector employment is large relative to informal sector employment, a relative increase in the formal labor share pushes the economy closer to a purely-formal economy. Hence, wage inequality decreases. The opposite holds true if the formal sector is relatively small before trade trade liberalization. Due to the relative formalization of labor through trade, the economy diverges from a purely-informal economy. Trade then increases wage inequality.[29]

Proposition 10. *Trade liberalization increases between-group wage inequality and has an ambiguous effect on wage inequality among all employed workers.*

Proof. See appendix A.6. □

2.4 Conclusion

Previous trade models did not reconcile heterogeneous firms, labor market frictions and informality in the form of registration non-compliance. In this paper, I developed a simple general equilibrium trade model with one production factor, namely labor. Firms in the model are heterogeneous in productivity and pay a fair wage depending on the firm's productivity and the average wage of employed workers in the economy. Depending on their productivity, firms select into informal sector production, formal sector production or ex-

[28] For a derivation of this result, see Appendix A.3. As shown by Helpman et al. (2010), the Gini-coefficient depends only on the shape parameter of the wage distribution, but not its lower limit. Both informal and formal sector wage distribution feature the same shape parameter and thus the same inequality.

[29] The intuition here is similar to the effect of a conditional exporter wage premium on wage inequality, as shown empirically by Akerman et al. (2013) and theoretically by Helpman et al. (2010). The findings suggest that a major share of overall wage inequality arises from the wage differences between firms in the same industry paid to workers with similar characteristics, i.e. within-industry wage inequality. Moreover, wage inequality is driven by the employment adjustments of these firms upon trade liberalization.

porting. By introducing informality into heterogeneous firm trade models with labor market frictions, the model shows analytically how informality distorts resource allocation in an economy. Trade liberalization leads to a decrease in informal sector employment and affects formal sector employment ambiguously. Depending on the characteristics of the economy, total employment and welfare can either decrease or increase. Opening the economy to trade affects wage inequality among employed workers ambiguously and ultimately depends on the number of formal sector firms relative to informal sector firms in the economy. Wage inequality between informal and formal workers increases as the formal sector average wage rises faster than the average wage earned by informal sector workers.

The implication of this framework for policy-makers is clear. While trade liberalization achieves the often targeted reduction in informal employment, the economic conditions in a country ultimately determine whether trade is beneficial or detrimental in regard to employment, welfare and wage inequality in the presence of informality. Hence, this setup emphasizes the need to consider the existence of an informal sector and the economic environment jointly in policy decisions on trade.

Several extensions of this work would provide for interesting future research endeavors. First, replacing the productivity sharing motif of the fair wage specification with revenue sharing would lead to a wage premium for exporters from foreign sales conditional on firm productivity, and can possibly entail different distributional consequences than the present work. Second, including heterogeneous workers and allowing firms to hire both informal and formal workers is a useful extension to capture the empirical findings of works with labor market-specific definitions of informality. Lastly, introducing informality with a broader definition as tax evasion and registration non-compliance and in a public finance framework would inform optimal taxation and enforcement decisions in the presence of an informal sector.

CHAPTER 3

INFORMALITY AMONG MULTI-PRODUCT FIRMS

> "The transition from informal to formal enterprise status is also gradual; indeed, single firms [...] can carry out some activities informally and others formally at the same time."
> de Beer et al. (2013, p. 13)

3.1 Introduction

The extant theoretical literature employs a dichotomous definition of informality: firms either comply with or evade regulations such as firm registration or taxation.[1] However, in reality firms face a multitude of regulations, and informality is a multi-dimensional concept. A recent study by the World Intellectual Property Organization on the traditional medicine practitioner (TMP) industry in Ghana, where informality accounts for about 40% of the country's GDP (Schneider et al., 2010), highlights this. It notes, "[e]ven though there is a significantly high level of business registration among the TMPs - and this is done in conformity to the legal requirements for practicing - the level of formalization of their business was limited." (Essegbey et al. (2014, p. 15)) More specifically, while 67% of surveyed TMPs had registered their business, only 52% had registered at least one of their products with the Food and Drugs Authority, a legal requirement in Ghana.

The empirical literature classically finds that costly firm-level regulation drives firm-level informality (de Soto, 1989; Djankov et al., 2002; Auriol and Warlters, 2005; Antunes and de V. Cavalcanti, 2007; Ulyssea, 2010), but more recent work shows that also product-level

[1] This literature considers, for instance, the effect of informality on unemployment (Fields, 1975), size dualism (Rauch, 1991), quality dualism (Banerji and Jain, 2007), contractual dualism (Basu et al., 2011) and trade liberalization (Becker, 2014).

regulations matter: they encourage the evasion of product-level regulation by formal firms (Essegbey et al., 2014), drive firm-level informality (Loayza et al., 2005) and determine firms product choice more broadly (Bernard et al., 2010; Goldberg et al., 2010). Given the focus of the theoretical informality literature on only firm-level regulation and as no model to date captures all the aforementioned empirical findings on product-level regulations, I develop a model of heterogeneous multi-product firms that endogenizes product choice and informality at both the product- and firm-level to answer two questions: What are the impacts of both firm- and product-level regulations on informality? How does product-level regulation impact firms' product choice in the presence of informality?

This model, along the lines of Bernard et al. (2010), provides a tractable setup to answer these questions and consists of four core components. First, firms are heterogeneous in productivity and, conditional on firm productivity, are characterized by heterogeneous skills in the production of a continuum of goods. Second, firms are exposed to both firm- and product-level regulation and firms' decision on whether to comply with or evade regulation occurs at two levels. Informality at the firm-level is defined to be firm registration non-compliance. Similarly, informality at the product-level is defined to be product registration non-compliance. This allows for registered, and hence formal, firms that may produce goods informally by evading product-level regulation corresponding to Essegbey et al. (2014).[2] Third, formality decisions at both levels are made under the consideration of the costs and benefits of formality and informality. Firms operate rationally and informality at both levels is therefore an entrepreneurial choice (e.g. de Mel et al., 2013; La Porta and Shleifer, 2014). Fourth, the model explores firms' product choice not just as product scope, but also by measuring product diversification using a product-level Gini and Herfindahl index.[3]

[2]The complete evasion of product registration of informal firms seems particularly fitting for Ghana's TMP, given that the sector, as described in Essegbey et al. (2014), was originally entirely informal.

[3]The empirical literature on multi-product firms and international trade commonly measures diversification by product scope, that is the number of distinct products per firm (Iacovone and Javorcik, 2008; Bernard et al., 2009; Arkolakis and Muendler, 2010; Bernard et al., 2010; Goldberg et al., 2010; Bernard et al., 2011). In the literature on sectoral and export diversification two alternative measures are commonly employed: the Herfindahl index as absolute (Imbs and Wacziarg, 2003; Klinger and Lederman, 2004; Koren

The model suggest that in addition to firm-level regulation, product-level regulation is also an important driver of informality. While firm-level regulation has a direct effect on firms' decision to register their business, an increase in the cost to comply with the product-level regulation incentivizes firms to informalize along two dimensions. First, higher product regulation cost has a direct effect in making the production of goods in compliance with registration requirements more costly and leads to fewer registered goods. Second, an increase in this cost has an indirect effect by decreasing the profitability of registering a business, and therein having the option to produce registered goods. Therefore, while the complexity of firm-level regulations have taken the primary focus in the policy discourse on curbing informality (see e.g. World Bank, 2013), this result indicates that product-level regulations should also be part of the discussion.

Furthermore, the model highlights the effect of product-level regulation on firms' product choice. In terms of product scope, i.e. the number of distinct products produced by a firm, formal firms produce more products than informal firms and hence can be considered more diversified. However, the product revenue-based indicators predict the opposite. That is, formal firms are less diversified than informal firms measured by the Gini coefficient and, when controlling for firm productivity, by the Herfindahl index. This result is interesting in the light of the literature that demonstrates welfare gains through product variety (e.g. Krugman, 1979; Romer, 1994; Klenow and Rodríguez-Claire, 1997; Broda and Weinstein, 2006). More specifically, as Arkolakis et al. (2008) show, the extent of welfare gains from product variety does not just depend on the number of varieties (extensive margin), but also the extent to which these new varieties are imported or consumed (intensive margin). Importantly, only the Gini coefficient and the Herfindahl index consider the intensive margin

and Tenreyro, 2007; Cadot et al., 2011) and the Product-Gini as relative measure of diversification (Imbs and Wacziarg, 2003; Cadot et al., 2011). For a detailed discussion on the different indices the interested reader is referred to Cadot et al. (2013). I do not derive a product-level Theil index. Both the Gini-coefficient and the Theil index are scale independent measures of inequality (see e.g. Allison, 1978; Bourguignon, 1979; Thon, 1982). As the Pareto distribution used in this model is scale invariant, both the Gini and Theil index only depend on the shape parameter of the Pareto distribution and lead to similar results.

of firms' product diversification, where product scope measures diversification only by the extensive margin. Hence, given that formal firm are less diversified when considering the intensive margin, the policy target of greater formalization of economies entails a loss in product diversity and has potentially adverse consequences for welfare.

This paper makes therefore four important contributions. First, this is the first model to examine the drivers of informality in a multi-product setting. Second, the model is the first to consider specifically product-level regulation and its impact on informality as well as product diversification in the light of the recent empirical evidence. Third, the model captures informality within the formal sector, that is evasion of product registration by registered firms, that has been empirically observed, yet theoretically neglected in the previous literature. Fourth, in addition to measuring product diversification simply by product scope, the model proposes the use of two revenue-based measures, the Gini coefficient and Herfindahl index at the firm-level. As this paper shows, the two indicators can readily be implemented in this type of multi-product firm model, facilitate bringing theoretical models to the data and provide for richer predictions than just using product scope. Therefore, this parsimonious setup is the first model to jointly consider firm heterogeneity, multiple products and informality in one framework and provides empirically testable predictions that shed light on the sector and diversification choices of firms in the presence of both product- and firm-level regulation.

I proceed with a description of the model in section 3.2, and section 3.3 concludes the paper.

3.2 The model

Consider an economy with an aggregate consumer that supplies L units of labor (section 3.2.1). A continuum of firms, heterogeneous in productivity, produce a range of goods and decide to comply with or evade regulations at the firm- and product-level (section 3.2.2).

3.2.1 Demand: The aggregate consumer

The aggregate consumer has a utility function described by the following CES-preferences over a continuum of identical products a in the interval $[0, 1]$:

$$U = \left[\int_0^1 C_a^{\iota} \mathrm{d}a\right]^{\frac{1}{\iota}}, 0 < \iota < 1, \tag{3.1}$$

where $\kappa \equiv \frac{1}{1-\iota}$ is the elasticity of substitution between products. The consumer derives utility from the consumption of differentiated varieties of each of the products. Therefore, the consumption of product a consists of a consumption index C_a of individual varieties v. The consumption index C_a is described by

$$C_a = \left[\int_{v \in V} q_a(v)^{\rho} \mathrm{d}v\right]^{\frac{1}{\rho}}, 0 < \rho < 1, \tag{3.2}$$

where $q_a(v)$ is the consumption of variety v of product a and $\rho \equiv \frac{\sigma-1}{\sigma}$. σ is the elasticity of substitution between product varieties. I assume $\sigma > \kappa$, that is a higher substitutability between product varieties than across products.[4] The price index for each product a depends on the prices of the individual varieties $p_a(v)$ and follows as

$$P_a = \left[\int_{v \in V} p_a(v)^{1-\sigma} \mathrm{d}v\right]^{\frac{1}{1-\sigma}}. \tag{3.3}$$

The wage rate w serves as the numeraire. Given the focus on firm informality, labor market impacts of regulation and informality lie outside of the scope of this paper and

[4]For instance, in the case of Ghana's TMP this implies that the consumer has a higher elasticity of substitution between a specific medicine produced by different firms than across different medicines.

therefore are not explicitly considered.[5] The aggregate consumer maximizes utility subject to the constraint that the aggregate expenditure R_a over the continuum of products is equal to aggregate labor income described by L with w normalized to 1:

$$L = \int_0^1 C_a P_a \mathrm{d}a = \int_0^1 R_a \mathrm{d}a. \tag{3.4}$$

As common in a monopolistic competition setup, the utility-maximizing $q_a(v)$, i.e. the demand for variety v of product a, depends on the aggregate expenditure for the product R_a, the product's price index P_a, the price of the variety $p_a(v)$ and the elasticity of substitution σ:

$$q_a(v) = R_a P_a^{\sigma-1} p_a(v)^{-\sigma}. \tag{3.5}$$

3.2.2 Supply: Formal and informal firms

In a manner well known from Melitz (2003), firms are initially identical. Upon entering the market, however, firms do not just draw a firm-specific productivity φ, but also a product-specific skill β_a for each product of the continuum of products. This allows each firm to produce a unique variety v of each of the products. However, firms with the same firm productivity φ behave in the same manner and are accordingly henceforth only indexed by it. A firm's marginal cost of producing a product is decreasing in both its firm-specific productivity φ and the product-specific skill β_a. Firm output $q_a(\varphi, \beta_a)$ of good a is linear in labor input l_a for the product, that is $q_a(\varphi, \beta_a) = \varphi \beta_a l_a$.

Firms decide on their compliance with regulations, and hence their formality, on two levels.[6] First, firms are legally required to register, which incurs firm-level fixed cost F_f. Alternatively, firms can choose to evade registration by only paying F_i and become informal

[5] The interested reader is referred to the model in Becker (2014) that jointly considers heterogeneous firms, informality and labor markets.

[6] Appendix B.5 develops an extension with export regulations and provides for additional interesting results.

at the firm-level. I assume $F_i < F_f$ to capture the findings of the empirical literature that firm registration, particularly in the developing country context, is an arduous procedure and costly (Schneider and Enste, 2000; Djankov et al., 2002; Auriol and Warlters, 2005; Antunes and de V. Cavalcanti, 2007). Henceforth, all informal sector variables feature subscript i and formal sector variables subscript f.

Second, firms are legally required to register each of their products at product-level fixed cost f_f. As a benefit of compliance with product-level regulation, and hence formality at the product-level, firms experience an exogenous productivity bonus $\lambda \in [0, 1)$ for the registered product. The productivity bonus can be seen as the result of protection by the rule of law for that product (de Soto, 1989; La Porta and Shleifer, 2008; Dabla-Norris et al., 2008) and the product-specific productivity is described by $\frac{\varphi}{1-\lambda}$.[7] Alternatively, firms can evade product-level regulation by paying f_i. In the context of Ghana's TMPs, "[the firms] who did not register any of their products gave reasons such as the cumbersome nature of the registration procedures and the fees charged being too high." (Essegbey et al. (2014, p. 2)) To capture this observation, I assume $f_i < f_f$. However, evading product-level registration entails the probability of government enforcement $\delta \in (0, 1)$ and loss of product revenue upon detection of that specific product,[8] a reflection of the institutional quality of the economy (Loayza, 1996; Dabla-Norris et al., 2008). All firm- and product-level fixed costs are measured in labor units.

Formal and informal firms maximize their profit by charging a constant markup $(1/\rho)$ over the product-specific marginal cost for each of their products. Considering the aforementioned costs and benefits, the prices for products produced in evasion of and in compliance with

[7] This bonus of formality corresponds to the recent findings of the empirical works on the effect of formality on firm performance. Controlling for firm characteristics and self-selection into the formal sector, these studies find a significant effect of formality alone, particularly of increasing firm profits (Fajnzylber et al., 2009, 2011; McKenzie and Sakho, 2010; Rand and Torm, 2012a).

[8] Intuitively, if a government agent discovers an unregistered product on the market, the specific product and the associated revenue will be confiscated.

product regulation are described by:[9]

$$p_{ai}(\varphi, \beta_a) = \left((1-\delta)^{\sigma}\rho\varphi\beta_a\right)^{-1} \text{ and } p_{af}(\varphi, \beta_a) = \left(\rho\frac{\varphi}{1-\lambda}\beta_a\right)^{-1}. \tag{3.6}$$

Given consumer demand for the products of each firm described by (3.5), the revenue for product a produced in evasion of or compliance with product regulation by a firm with productivity φ and product skill β_a is

$$r_{ai}(\varphi, \beta_a) = (1-\delta)^{\sigma} R_a \left(\rho P_a \varphi \beta_a\right)^{\sigma-1} \text{ and } r_{af}(\varphi, \beta_a) = R_a \left(\rho P_a \frac{\varphi}{1-\lambda}\beta_a\right)^{\sigma-1}. \tag{3.7}$$

Lastly, taking the product-level fixed costs into account, the product-level profits for product a differ according to firm productivity φ, product-specific skill β_a and whether a product is registered or not. They are described by

$$\begin{aligned} \pi_{ai}(\varphi, \beta_a) &= (1-\delta)^{\sigma}\frac{R_a}{\sigma}\left(\rho P_a \varphi \beta_a\right)^{\sigma-1} - f_i \text{ and} \\ \pi_{af}(\varphi, \beta_a) &= \frac{R_a}{\sigma}\left(\rho P_a \frac{\varphi}{1-\lambda}\beta_a\right)^{\sigma-1} - f_f. \end{aligned} \tag{3.8}$$

The firm-specific productivity φ is assumed to be distributed Pareto with the cumulative distribution function $G(\varphi) = 1 - \varphi^{-\alpha}$ and density function $g(\varphi) = \alpha\varphi^{-\alpha-1}$, due to the fit of the Pareto distribution to the empirically observed firm productivity distribution (Axtell, 2001; Helpman et al., 2004). Additionally, I follow Bernard et al. (2011) in assuming that the product-specific skill is also distributed Pareto with the cumulative distribution function $Z(\beta) = 1 - \beta^{-k}$ and density function $z(\beta) = k\beta^{-k-1}$. The lower bound of both distributions is normalized to 1. Lastly, I assume $\alpha > k > \sigma - 1$ to ensure a finite mean firm size.

I proceed by solving the model in two steps. First, I solve the firms' choice of products, taking their decision on joining the formal or informal sector as given (section 3.2.2.1). Second, I solve for the firms' choice of sector given their firm productivity φ (section 3.2.2.2).

[9]The following product-level prices and revenues are the same for formal and informal firms and only differ between registered and unregistered products.

Lastly, I examine the impact of product-regulation on firms' product choice as measured by product scope (section 3.2.2.3), Product-Gini (section 3.2.2.4) and Herfindahl index (section 3.2.2.5), and conclude by comparing the three indicators (sections 3.2.2.6).

3.2.2.1 Firms' product choice

In the model, corresponding to the Ghanaian TMP sector where some registered firms evade product-level regulation (Essegbey et al., 2014), registered firms may evade regulation for their products, and hence produce them informally. Unregistered, and hence informal, firms evade regulations for all their products. With the same production technology and demand structure for all identical products, the pricing of a product and accordingly the product-level profit depends solely on firm productivity φ, product-specific skill β and whether a product is registered or not. Accordingly, I henceforth omit the product-specific subscript a.

For informal firms there exists a product skill threshold level $\beta_i^*(\varphi)$ at which a firm with productivity φ just breaks even in producing an unregistered product. The reason for this is the product-level fixed cost f_i that limits the profitability of an unregistered product $\pi_i(\varphi, \beta)$ described in (3.8). $\beta_i^*(\varphi)$ is defined by

$$\pi_i(\varphi, \beta_i^*(\varphi)) = 0. \tag{3.9}$$

Any product for which the firm draws a higher product skill than $\beta_i^*(\varphi)$ can be profitably produced by the firm. Any product with a lower product skill is unprofitable and hence will not be produced. Notably, $\beta_i^*(\varphi)$ depends on the firm-specific productivity φ. A high firm productivity compensates for a low product-specific skill and accordingly high-productivity firms are able to produce even low product skill products profitably, that is $\beta_i^*(\varphi)$ is decreasing in φ.[10]

[10]Mathematically $\frac{\partial \beta_i^*(\varphi)}{\partial \varphi} = -\left[\frac{f_i \sigma}{(1-\delta)^\sigma R}\right]^{\frac{1}{\sigma-1}} (\rho P)^{-1} \varphi^{-2} < 0.$

Formal firms, on the other hand, may produce goods in compliance with or evasion of product-level regulations. Intuitively, as product registration at f_f is more costly than informal production at f_i, firms only register products if the registration provides them for a higher profitability than informal production. Accordingly, products in which a firm draws a low product-specific skill will not be registered and high skill products will be registered. Therefore, the lower product-skill threshold $\beta_i^*(\varphi)$ is defined as for informal firms by (3.9). In addition, there exists a threshold level $\beta_f^*(\varphi)$ that determines the minimum product skill threshold for registered products defined by

$$\pi_i(\varphi, \beta_f^*(\varphi)) = \pi_f(\varphi, \beta_f^*(\varphi)) \tag{3.10}$$

above which registration of a product is more profitable than unregistered production. In sum, if a formal firm draws a product-specific skill above $\beta_f^*(\varphi)$, it will produce the product in compliance with the product regulation. A skill draw below $\beta_f^*(\varphi)$, but above $\beta_i^*(\varphi)$ leads to the evasion of product regulation for that product, and a draw below $\beta_i^*(\varphi)$ means that the firm will not produce the product since the production would incur negative profits. The sorting $\beta_i^*(\varphi) < \beta_f^*(\varphi)$ is ensured if $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma} < \frac{f_f}{f_i}$, which I henceforth assume holds.[11] The intuition for this condition is as follows. Only if the benefit of formal production relative to the potential government enforcement of informality $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma}$ is smaller than the cost of registering a good relative to producing an unregistered good $\frac{f_f}{f_i}$, a higher product skill is required to benefit from the registration of a good compared to unregistered production.[12]

[11] The condition follows from the assumption that, given the same firm productivity, producing goods in evasion of product regulation is profitable at a lower product skill level than producing goods in compliance of that regulation. This requires that $\beta_i^* < \beta_f^*$ for β_i^* from $\pi_i(\beta_i^*, \varphi) = 0$ & β_f^* from $\pi_f(\beta_f^*, \varphi) = 0$. $\beta_i^* = \left[\frac{f_i \sigma}{(1-\delta)^\sigma R}\right]^{\frac{1}{\sigma-1}} (\rho P \varphi)^{-1}$ and $\beta_f^* = \left[\frac{f_f \sigma}{R}\right]^{\frac{1}{\sigma-1}} \left(\rho P \frac{\varphi}{1-\lambda}\right)^{-1}$. Hence, $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma} < \frac{f_f}{f_i}$. As both $\pi_i(\varphi, \beta)$ and $\pi_f(\varphi, \beta)$ are monotonically increasing in β, single-crossing of the two functions is ensured and $\beta_i^*(\varphi) < \beta_f^*(\varphi)$ holds.

[12] In this model, firms produce goods of the same quality at different prices. It is conceivable that unregistered, and hence informal products, are of lower quality. An alternative interpretation of Melitz (2003)-type models is that firms produce products of different quality at the same cost. Given the alternative interpretation, this model implicitly captures a quality and hence demand difference between registered and unregistered products. Heterogeneous firms and heterogeneous product quality are explicitly modeled in Verhoogen (2008), albeit in a setup of heterogeneous workers.

Since the product skill draws of firms over the continuum of identical products are i.i.d. and given the law of large numbers, the expected profit of a firm over the continuum of products is equal to the expected profit for an individual product, which equals the probability of drawing a product-specific skill above the threshold levels. Accordingly, total firm profit of an informal firm that does not comply with firm-level regulation depends on firm productivity φ and is described by

$$\pi_i(\varphi) = \int_{\beta_i^*(\varphi)}^{\infty} \left[(1-\delta)^{\sigma} \frac{R}{\sigma} (\rho P \varphi \beta)^{\sigma-1} - f_i \right] z(\beta) \mathrm{d}\beta - F_i. \tag{3.11}$$

Formal firms, on the other hand, can produce products both in evasion of and/or compliance with product-level regulation, and pay a firm-level registration fee F_f:

$$\begin{aligned} \pi_f(\varphi) = & \int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} \left[(1-\delta)^{\sigma} \frac{R}{\sigma} (\rho P \varphi \beta)^{\sigma-1} - f_i \right] z(\beta) \mathrm{d}\beta \\ & + \int_{\beta_f^*(\varphi)}^{\infty} \left[\frac{R}{\sigma} \left(\rho P \frac{\varphi}{1-\lambda} \beta \right)^{\sigma-1} - f_f \right] z(\beta) \mathrm{d}\beta - F_f. \end{aligned} \tag{3.12}$$

The share of registered products that a formal firm produces is equal to the probability of drawing a product skill above the threshold $\beta_f^*(\varphi)$, i.e. $1 - Z(\beta_f^*(\varphi)) = \beta_f^*(\varphi)^{-k}$. The share of unregistered products is described by the probability of drawing a product-specific skill above the informal product-skill threshold $\beta_i^*(\varphi)$, but below the formal threshold $\beta_f^*(\varphi)$, i.e. $Z(\beta_f^*(\varphi)) - Z(\beta_i^*(\varphi)) = \beta_i^*(\varphi)^{-k} - \beta_f^*(\varphi)^{-k}$. Using (3.9) and (3.10), I can write the share of unregistered products relative to the share of registered products as

$$\frac{\beta_i^*(\varphi)^{-k} - \beta_f^*(\varphi)^{-k}}{\beta_f^*(\varphi)^{-k}} = \left[\frac{f_i}{f_f - f_i} \right]^{\frac{-k}{\sigma-1}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1 \right]^{\frac{-k}{\sigma-1}} - 1. \tag{3.13}$$

The right hand side of (3.13) is independent of φ. Therefore, while the share of the whole continuum of products that is produced by a firm depends on its firm productivity φ, the relative share of unregistered to registered products is the same for all formal firms and independent of φ. A comparative statics exercise on (3.13) provides for intuitive results. Parameters that increase the relative profitability of production in compliance with product

regulation (decrease in f_f or increase in f_i, λ, δ) lead to a higher relative share of registered products.

Proposition 11. *The share of unregistered relative to registered products of a formal firm is increasing in f_f and decreasing in f_i, λ and δ.*

Proof. See appendix B.1. □

3.2.2.2 Firms' sector choice

Having solved the product choice of firms, as second step I solve firms' sector choice. Given their firm-level productivity φ, firms choose to either register their firm and become formal, evade firm-level registration and become informal or not produce at all according to the profitability of the activity (e.g. de Mel et al., 2013; La Porta and Shleifer, 2014), that is $\max\{\pi_i(\varphi), \pi_f(\varphi), 0\}$. This poses the question how informal and formal firms are distributed over the productivity spectrum. The empirical literature provides an answer to this question: informal firms are lower-productivity firms and formal firms are higher-productivity firms (La Porta and Shleifer, 2008; de Paula and Scheinkman, 2011). Analogously to the product skill threshold levels, the firm-level fixed costs lead to the firm-level productivity threshold levels φ_i^* and φ_f^*, which are the productivity levels above which firms select into informal and formal production, respectively. The thresholds are determined with the help of (3.11) and (3.12) by

$$\pi_i(\varphi_i^*) = 0 \tag{3.14}$$

and

$$\pi_i(\varphi_f^*) = \pi_f(\varphi_f^*). \tag{3.15}$$

If a firm draws a firm-level productivity below φ_i^*, it will not produce at all. For a draw above φ_i^*, but below φ_f^*, the firm becomes informal, and for a draw above φ_f^* the firm

becomes formal. The sorting $\varphi_i^* < \varphi_f^*$ is ensured if $0 < \frac{\left[f_f - f_i\right]^{\frac{k+1-\sigma}{(1-\sigma)k}}}{\left[(1-\lambda)^{1-\sigma} - (1-\delta)^{\sigma}\right]^{\frac{k}{\sigma-1}}} / \frac{\left[f_i\right]^{\frac{k+1-\sigma}{(1-\sigma)k}}}{\left[(1-\delta)^{\sigma}\right]^{\frac{k}{\sigma-1}}} < \frac{F_f - F_i}{F_i}$, which I henceforth assume holds.[13] Intuitively, this condition compares the benefit-cost-ratio of formality, $\left[f_f - f_i\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} / \left[(1-\lambda)^{1-\sigma} - (1-\delta)^{\sigma}\right]^{\frac{k}{\sigma-1}}$, to the one of informality, $\left[f_i\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} / \left[(1-\delta)^{\sigma}\right]^{\frac{k}{\sigma-1}}$. Only if the cost-benefit of formal production relative to informal production is greater than 0, it will be attractive for any firm to produce formally. However, if the ratio is smaller than the relative firm registration costs $\frac{F_f - F_i}{F_i}$, only high-productivity firms will find it economically feasible to register.

Similar to the share of registered and unregistered products, due to an i.i.d. firm productivity distribution and the law of large numbers, the share of formal firms is equal to the probability of a productivity draw above the formality threshold φ_f^*, i.e. $1 - G(\varphi_f^*) = \varphi_f^{*-\alpha}$, and the share of informal firms equals the probability of drawing a productivity between φ_i^* and φ_f^*, i.e. $Z(\varphi_f^*) - Z(\varphi_i^*) = \varphi_i^{*-\alpha} - \varphi_f^{*-\alpha}$. Using (3.14) and (3.15) that determine the productivity cutoff levels, I derive the share of informal firms relative to formal firms:

$$\frac{\varphi_i^{*-\alpha} - \varphi_f^{*-\alpha}}{\varphi_f^{*-\alpha}} = \left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}} \left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} - 1. \tag{3.16}$$

Intuitively, factors that make formal sector participation relatively more costly or decrease its benefits (increase in F_f, f_f, decrease in F_i, f_i, λ, δ) lead to a relatively larger informal sector. Importantly, when considering both types of regulation, not just firm-level, but also

[13] The condition results from two assumptions. First, informal firms break even at a lower productivity than formal firms, i.e. $\varphi_i^* < \varphi_f^*$ for φ_i^* from $\pi_i(\varphi_i^*) = 0$ & φ_f^* from $\pi_f(\varphi_f^*) = 0$.
$\varphi_i^* = F_i^{\frac{1}{k}} \left[\frac{R}{\sigma}\right]^{\frac{1}{\sigma-1}} (\rho P)^{-1} f_i^{\frac{k+1-\sigma}{(\sigma-1)k}} (1-\delta)^{\frac{\sigma}{1-\sigma}} \left[\frac{\sigma-1}{k+1-\sigma}\right]^{\frac{-1}{k}}$ and
$\varphi_f^* = F_f^{\frac{1}{k}} \left[\frac{R}{\sigma}\right]^{\frac{1}{\sigma-1}} (\rho P)^{-1} f_i^{\frac{k+1-\sigma}{(\sigma-1)k}} (1-\delta)^{\frac{\sigma}{1-\sigma}} \left[\frac{\sigma-1}{k+1-\sigma}\right]^{\frac{-1}{k}} \left[\left[\frac{f_i}{f_f - f_i}\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{k}{\sigma-1}} + 1\right]^{-\frac{1}{k}}$. Hence, $\left[\frac{f_i}{f_f - f_i}\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{k}{\sigma-1}} < \frac{F_f - F_i}{F_i}$. Second, marginal profitability with respect to productivity is higher in the formal sector, i.e. $\frac{\partial \pi_i}{\partial \varphi} < \frac{\partial \pi_f}{\partial \varphi}$. $\frac{\partial \pi_i}{\partial \varphi} = k\varphi^{k-1} \left[\frac{R}{\sigma}\right]^{\frac{-k}{1-\sigma}} (\rho P)^k f_i^{\frac{\sigma-1-k}{\sigma-1}} (1-\delta)^{\frac{-k\sigma}{1-\sigma}} \left[\frac{\sigma-1}{k+1-\sigma}\right]$ and
$\frac{\partial \pi_f}{\partial \varphi} = k\varphi^{k-1} \left[\frac{R}{\sigma}\right]^{\frac{-k}{1-\sigma}} (\rho P)^k f_i^{\frac{\sigma-1-k}{\sigma-1}} (1-\delta)^{\frac{-k\sigma}{1-\sigma}} \left[\frac{\sigma-1}{k+1-\sigma}\right] \left[\left[\frac{f_i}{f_f - f_i}\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{k}{\sigma-1}} + 1\right]^{-\frac{1}{k}}$.
Hence, $0 < \left[\frac{f_i}{f_f - f_i}\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{k}{\sigma-1}}$. Jointly, $0 < \left[\frac{f_i}{f_f - f_i}\right]^{\frac{k+1-\sigma}{(1-\sigma)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{k}{\sigma-1}} < \frac{F_f - F_i}{F_i}$. As both $\pi_i(\varphi)$ and $\pi_f(\varphi)$ are monotonically increasing in φ, single-crossing of the two functions is ensured and $\varphi_i^* < \varphi_f^*$ holds.

product-level regulation f_f steers informal sector participation.[14] This provides the rational for the findings of Loayza et al. (2005), who show product market regulations to be drivers of informality in a cross-country context.

Proposition 12. *The share of informal relative to formal firms is increasing in F_f, f_f and decreasing in F_i, f_i, λ and δ.*

Proof. See appendix B.2. □

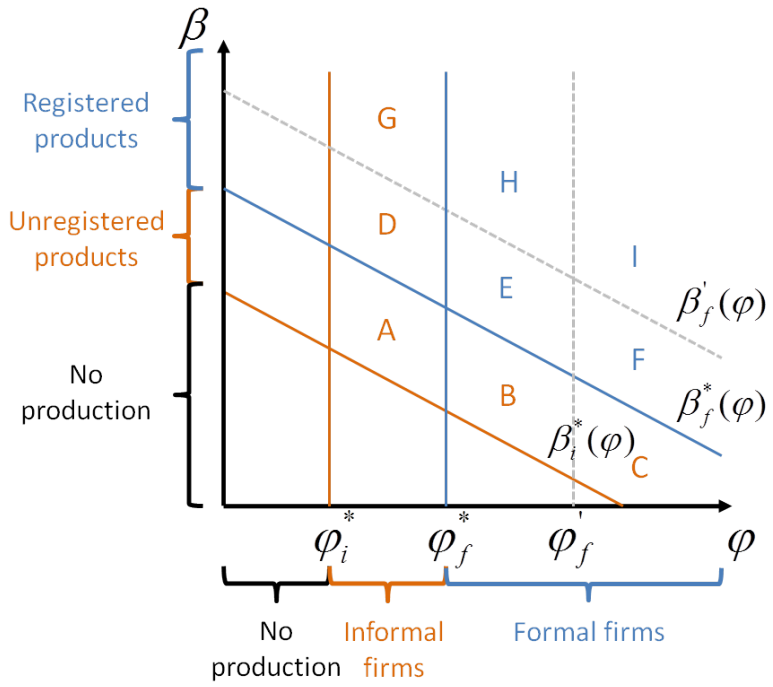


Figure 3.1: Sorting of firms and products along the productivity and product skill dimensions.

The results of Propositions 11 and 12 can be graphically illustrated to highlight the effect of product regulation on both the share of informal firms and unregistered products in the market. Figure 3.1 pictures all products of an economy within the firm productivity and product skill dimensions. The curves $\beta_i^*(\varphi)$ and $\beta_f^*(\varphi)$ are the product skill threshold levels

[14] This is particularly striking in contrast to a setup with only firm-level regulations in place as derived in appendix B.6 or in Becker (2014).

following from (3.9) and (3.10):

$$\beta_i^*(\varphi) = \left[\frac{f_i\sigma}{(1-\delta)^\sigma R}\right]^{\frac{1}{\sigma-1}} (\rho P\varphi)^{-1} \tag{3.17}$$

and

$$\beta_f^*(\varphi) = \left[\frac{(f_f - f_i)\,\sigma}{R}\right]^{\frac{1}{\sigma-1}} (\rho P\varphi)^{-1} \left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right]^{\frac{1}{1-\sigma}}. \tag{3.18}$$

As higher productivity firms are able to produce products at a lower product-specific skill, the product skill thresholds $\beta_i^*(\varphi)$ and $\beta_f^*(\varphi)$ are decreasing in firm productivity.[15] The firm productivity thresholds φ_i^* and φ_f^*, however, are independent of product skill. They follow from the combination of their definitions (3.14) and (3.15) with the product skill cutoff thresholds (3.17) and (3.18):

$$\varphi_i^* = F_i^{\frac{1}{k}} \left[\frac{k+1-\sigma}{\sigma-1}\right]^{\frac{1}{k}} f_i^{\frac{\sigma-k-1}{(1-\sigma)k}} \left[\frac{R(1-\delta)^\sigma}{\sigma}\right]^{\frac{1}{1-\sigma}} (\rho P)^{-1} \tag{3.19}$$

and

$$\begin{aligned}\varphi_f^* = {} & [F_f - F_i]^{\frac{1}{k}} \left[\frac{k+1-\sigma}{\sigma-1}\right]^{\frac{1}{k}} [f_f - f_i]^{\frac{\sigma-k-1}{(1-\sigma)k}} \\ & \left[\frac{R(1-\delta)^\sigma}{\sigma}\right]^{\frac{1}{1-\sigma}} (\rho P)^{-1} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma} - 1\right]^{\frac{1}{\sigma-1}}.\end{aligned} \tag{3.20}$$

Firms with firm productivity above φ_i^* and below φ_f^* evade firm registration. Firms with productivity level above φ_f^* register their firm, thus being formal firms. Similarly, products for which a formal firm draws a product skill above $\beta_i^*(\varphi)$ but below $\beta_f^*(\varphi)$ are produced in evasion of product regulation, and products with product skill above $\beta_f^*(\varphi)$ are registered products. Unregistered products accordingly take up space ABCDG. However, the effect of a change in firm-level regulation F_f differs to that of a change in product-level regulation f_f. More costly firm-level regulation, i.e. an increase in F_f, ceteris paribus affects firms' decision to register their business and shifts the productivity threshold level from φ_f^* to

[15] Mathematically, $\frac{\partial \beta_i^*(\varphi)}{\partial \varphi} = -\left[\frac{f_i\sigma}{(1-\delta)^\sigma R}\right]^{\frac{1}{\sigma-1}} (\rho P)^{-1} \varphi^{-2} < 0$ and
$\frac{\partial \beta_f^*(\varphi)}{\partial \varphi} = -\left[\frac{(f_f-f_i)\sigma}{R}\right]^{\frac{1}{\sigma-1}} \left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right]^{\frac{1}{1-\sigma}} (\rho P)^{-1} \varphi^{-2} < 0.$

$\varphi_f^{'}$ ($\frac{\partial \varphi_f^*}{\partial F_f} > 0$ from (3.20)). Yet, the decision on the compliance with product regulation is not affected. When deciding on product registration, the firm level regulation cost F_f is already sunk and firms optimize only at the product-level, which mathematically means that (3.18) does not depend on F_f.[16] The result is an increase in the share of informal firms, and accordingly unregistered products. Unregistered products take up space ABCDEGH and informalization at the product-level has increased. In contrast to this, an increase in product-level regulation cost f_f makes not just product registration more costly and thus shifts the product registration threshold from $\beta_f^*(\varphi)$ to $\beta_f^{'}(\varphi)$ ($\frac{\partial \beta_f^*(\varphi)}{\partial f_f} > 0$ from (3.17)), but also makes formal sector participation less attractive ($\frac{\partial \varphi_i^*}{\partial f_f} > 0$ from (3.19)) and shifts the productivity threshold from φ_f^* to $\varphi_f^{'}$.[17] As a result, both the share of informal firms and unregistered products in the economy rise to take up space ABCDEFGH, while the number of registered products decreases to only take up space I. By having an effect on both the share of informal firms and unregistered products, product-level regulation has a stronger effect than firm-level regulation on the extent of informality at the product-level.

3.2.2.3 Product Scope

A firm's product scope $K(\varphi)$ is defined as the number of distinct products a firm produces. Because product skill draws are i.i.d. over the continuum of products, $K(\varphi)$ is equal to the probability of drawing a product skill above the product skill threshold $\beta_i^*(\varphi)$, i.e. $1 - Z(\beta_i^*(\varphi))$. Both informal and formal firms do not register their lowest product skill goods and the relevant product skill threshold is in both cases $\beta_i^*(\varphi)$. Hence, the product-level regulation does not affect the product scope of firms. The product scope of both type of firms are

$$K_i(\varphi) = 1 - Z(\beta_i^*(\varphi)) = \beta_i^*(\varphi)^{-k} \text{ and } K_f(\varphi) = 1 - Z(\beta_i^*(\varphi)) = \beta_i^*(\varphi)^{-k}. \tag{3.21}$$

[16] $\beta_i^*(\varphi)$ and φ_i^* do not depend on F_f and are unaffected.
[17] $\beta_i^*(\varphi)$ and φ_i^* do not depend on f_f and are unaffected.

As the threshold is decreasing in firm productivity, product scope is increasing in firm productivity.[18] Therefore, higher productivity firms are more diversified measured by the product scope, which corresponds to the theoretical and empirical findings of Bernard et al. (2010) and Bernard et al. (2011).

3.2.2.4 Product-Gini

Originally a measure of inequality, the Gini coefficient is commonly employed as a measure of diversification at the industry-level, for instance in the context of sectoral and export diversification (e.g. Imbs and Wacziarg, 2003; Cadot et al., 2011). I employ the Gini coefficient at the product-level to examine the product revenue distribution and hence the product diversification of a firm. The derivation of the Product-Gini for informal firms requires two steps. First, I derive γ, i.e. the share of products that are produced with a product skill below $\bar{\beta}$ of the total number of products a firm produces:

$$\gamma = \frac{\int_{\beta_i^*(\varphi)}^{\bar{\beta}} \beta z(\beta) \mathrm{d}\beta}{\int_{\beta_i^*(\varphi)}^{\infty} \beta z(\beta) \mathrm{d}\beta} = 1 - \left(\frac{\bar{\beta}}{\beta_i^*(\varphi)} \right)^{-k}. \tag{3.22}$$

Next, I derive the share of product revenue of products with product skill below $\bar{\beta}$ relative to total firm revenue Q_i as

$$Q_i = \frac{\int_{\beta_i^*(\varphi)}^{\bar{\beta}} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta}{\int_{\beta_i^*(\varphi)}^{\infty} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta} = 1 - \left(\frac{\bar{\beta}}{\beta_i^*(\varphi)} \right)^{\sigma-k-1}. \tag{3.23}$$

Lastly, substituting (3.22) into (3.23) leads to the Lorenz curve $Q_i(\gamma)$:

$$Q_i(\gamma) = 1 - [1 - \gamma]^{\frac{\sigma-k-1}{-k}}, \tag{3.24}$$

which has the desired properties $Q_i(0) = 0$, $Q_i(1) = 1$ and $\frac{\partial Q_i(\gamma)}{\partial \gamma} > 0$. The Product-Gini of

[18] Substituting for $\beta_i^*(\varphi)$ leads to $K_i(\varphi) = \left[\frac{f_i \sigma}{(1-\delta)^\sigma R} \right]^{\frac{k}{1-\sigma}} (\rho P \varphi)^k$ and accordingly $\frac{\partial K_i(\varphi)}{\partial \varphi} > 0$.

informal firms G_i derives from

$$G_i = 1 - 2\int_0^1 Q_i(\gamma)\mathrm{d}\gamma = \frac{\sigma - 1}{2k + 1 - \sigma}. \tag{3.25}$$

Given its relative nature, G_i is independent of firm productivity φ, and hence the total number of products a firm produces. The product-level Gini only captures the distribution of the product revenues relative to the whole firm revenue. Firms that are neither registered on a firm- nor on a product-level are subject to government enforcement δ for all products and thus enforcement does not affect the relative distribution. Further, the distribution of product revenue follows the product skill distribution and accordingly G_i only depends on the product skill distribution parameter k and the elasticity of substitution between the products of different firms σ.[19]

The derivation of the Product-Gini of formal firms G_f is more complicated as formal firms register only some of their products. The individual steps necessary to derive G_f can be found in appendix B.3.

$$\begin{aligned} G_f = G_i \left[\frac{2}{\Omega(\sigma-1)}\right] \Bigg\{ & \frac{2k+1-\sigma}{2}\left[\Omega + 2\phi^k\left[(1-\delta)^\sigma - \Omega\right]\right] \\ & + \phi^{2k+1-\sigma} k\left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right] - (1-\delta)^\sigma(k+1-\sigma)\Big\}, \end{aligned} \tag{3.26}$$

where $\phi \equiv (\beta_i^*(\varphi)/\beta_f^*(\varphi))$ and $\Omega \equiv \left[(1-\delta)^\sigma + \phi^{k+1-\sigma}\left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right]\right]$. Besides the Pareto distribution parameter k and the elasticity of substitution between products σ, G_f depends on ϕ and Ω that are proxies for the relative share of unregistered to registered products produced by a formal firm. Firms that are formal at the firm-level do not register

[19] Informal firms only differ in their threshold product skill level $\beta_i^*(\varphi)$ and hence the lower bound of their product revenue distribution. A truncated Pareto is still Pareto, albeit with a lower minimum bound and mean described by $\beta_i^*(\varphi)\,[k/(k-1)]$. As the Gini-coefficient is scale independent (see e.g. Allison, 1978; Thon, 1982), only the Pareto distribution parameter matters and all firms that are informal at the firm-level are characterized by the same product-level Gini. Notably, the same G_i would also hold if there were no product-level regulations in place and a firm would produce all products. See appendix B.6.2 for a derivation of this result.

a share of their goods under the probability of government enforcement δ and produce their registered products with the productivity bonus λ. Given this, unregistered products generate a relatively lower revenue per product and registered products generate a relatively higher revenue. Thus, the Lorenz curve has two segments.

In a model where firms register all their products, as for instance in Bernard et al. (2010), firms' product diversification would be described by G_i. However, as formal firms may comply with or evade product regulation, their Lorenz curve is kinked and product diversification is described by G_f. The product-level regulation f_f has two effects. First, it influences firms' choice of firm-level informality or formality, and thus whether diversification of the firm is measured by G_i or G_f. Second, f_f enters ϕ, determines the relative share of unregistered products and hence the absolute value of G_f.

3.2.2.5 Herfindahl Index

The Herfindahl index is an absolute measure of diversification that captures both the distribution of a firm's revenue among its products and the number of distinct products. To measure the product diversification of a firm I derive it in two steps. For informal firms I first derive the revenue share $s_i(\beta)$ of an unregistered product that is produced with product skill β of total firm revenue:

$$s_i(\beta) = \frac{r_i(\varphi, \beta)}{\int_{\beta_i^*(\varphi)}^{\infty} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta} = \frac{k+1-\sigma}{k} \beta_i^*(\varphi)^{1+k-\sigma} \beta^{\sigma-1}. \tag{3.27}$$

Second, the product-level Herfindahl index for informal firms $H_i(\varphi)$ is computed as the integral over the squared revenue shares for all produced products:

$$H_i(\varphi) = \int_{\beta_i^*(\varphi)}^{\infty} s_i(\beta)^2 z(\beta) \mathrm{d}\beta = H \beta_i^*(\varphi)^k, \tag{3.28}$$

where $H = (k+1-\sigma)^2 / [k(k+2-2\sigma)] > 1$.[20] Similar to the Product-Gini, the Herfindahl

[20] Rewriting $H > 1$ leads to $(\sigma-1)^2 > 0$, which holds because $\sigma > 1$.

index depends on the product skill distribution parameter k and the elasticity of substitution between products σ, both captured by H.[21] Further, the product-level Herfindahl index, similar to the product scope, depends on firm productivity φ. Higher productivity firms are characterized by a lower $\beta_i^*(\varphi)$ and produce more distinct product. Hence, firm revenue is distributed over a wider range of products and the Herfindahl index indicates these firms as more diversified.[22]

The product-level Herfindahl index of formal firms $H_f(\varphi)$ consists of two pieces. First, the product revenue share of unregistered products and second the product revenue share of registered products. The derivation is more arduous than for informal firms and the interested reader is therefore referred to appendix B.4.

$$H_f(\varphi) = H\beta_i^*(\varphi)^k \Omega^{-2}\omega, \tag{3.29}$$

where $\omega \equiv \left[(1-\delta)^{2\sigma} + \phi^{k+2-2\sigma}\left[(1-\lambda)^{2-2\sigma} - (1-\delta)^{2\sigma}\right]\right]$ and $\Omega^{-2}\omega > 1$.[23] Notably, $H_f(\varphi)$ consists of three parts. First, H reflects the product revenue distribution as a result of the product skill distribution within a firm and the elasticity of substitution between product varieties. Second, $\beta_i^*(\varphi)^k$ captures the increasing number of products a higher productivity firm can produce due to a lower product skill threshold.[24] A larger number of products reduces the Herfindahl index.[25] Lastly, $\Omega^{-2}\omega$ reflects the skew of the revenue distribution, because the share of registered products generates relatively higher product revenue than the share of unregistered products. The less even distribution of revenue among all products

[21] Without any product-level regulations in place, $\beta_i^*(\varphi) = 1$ and the product-level Herfindahl reduces to H. This result is derived in appendix B.6.3.

[22] Substituting for $\beta_i^*(\varphi)$ leads to $H_i(\varphi) = H\left[\frac{f_i\sigma}{(1-\delta)^\sigma R}\right]^{\frac{k}{\sigma-1}} (\rho P\varphi)^{-k}$ and accordingly $\frac{\partial H_i(\varphi)}{\partial \varphi} < 0$.

[23] Rewriting leads to
$\Omega^2 - \omega = (1-\lambda)^{2-2\sigma}\left[\phi^{2k+2-2\sigma} - \phi^{k+2-2\sigma}\right] +$
$(1-\delta)^{2\sigma}\left[\phi^{2k+2-2\sigma} + \phi^{k+2-2\sigma} - 2\phi^{k+1-\sigma}\right] + (1-\delta)^\sigma(1-\lambda)^{1-\sigma}\left[\phi^{k+1-\sigma} - 1\right] < 0$, which holds because $\phi \in (0,1)$.

[24] Mathematically $\frac{\partial \beta_i^*(\varphi)}{\partial \varphi} < 0$.

[25] Substituting for $\beta_i^*(\varphi)$ leads to $H_f(\varphi) = H\left[\frac{f_i\sigma}{(1-\delta)^\sigma R}\right]^{\frac{k}{\sigma-1}} (\rho P\varphi)^{-k}\Omega^{-2}\omega$ and accordingly $\frac{\partial H_f(\varphi)}{\partial \varphi} < 0$.

entails less diversification and increases the Herfindahl index.

Because there exists informality at the product-level, some firms diversification is described by $H_f(\varphi)$. Without the possibility of the evasion of product-level regulation, as for instance in Bernard et al. (2010), diversification of all firms would be described by $H_i(\varphi)$. Therefore, similar to the Product-Gini, also the Herfindahl index is affected by the product-level regulation f_f in two ways. First, the product-level regulation affects firms' choice of sector and accordingly whether diversification of the firm is measured by $H_i(\varphi)$ or $H_f(\varphi)$. Second, f_f enters $\Omega^{-2}\omega$, which captures the extent to which the revenue distribution is skewed through informal and formal production of goods, and thus the absolute value of $H_f(\varphi)$.

3.2.2.6 Comparison of the indicators

The diversification of an informal and a formal firm, measured by the relative product scope, $K_i(\varphi_i)/K_f(\varphi_f)$, can be compared using (3.21):

$$\frac{K_i(\varphi_i)}{K_f(\varphi_f)} = \left(\frac{\varphi_i}{\varphi_f}\right)^k < 1. \tag{3.30}$$

The difference in product scope only depends on the relative productivity difference between the two firms. Because informal sector firms are characterized by a lower productivity than formal sector firms (cf. (3.16)), they produce a smaller number of distinct products and are less diversified as measured by product scope. This corresponds to the empirical finding in CIEM (2012).

Contrary to that, (3.25) and (3.26) in combination show that unregistered firms are more

diversified than registered firms measured by the Product-Gini:

$$\frac{G_i}{G_f} = \left[\frac{2}{\Omega(\sigma-1)}\right]^{-1} \left\{\frac{2k+1-\sigma}{2}\left[\Omega + 2\phi^k\left[(1-\delta)^\sigma - \Omega\right]\right] + \phi^{2k+1-\sigma}k\left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right] - (1-\delta)^\sigma(k+1-\sigma)\right\}^{-1} < 1. \tag{3.31}$$

The product-level Gini captures the concentration of revenue of formal firms among registered products through $\phi \in (0,1)$. Informal firms produce only unregistered products. Therefore, formal firms are less diversified than informal firms and $G_i/G_f < 1$.[26] Notably, while the product-level regulation f_f affects the absolute value of G_f through ϕ, $G_f > G_i$ holds in any case.

Lastly, using (3.28) and (3.29) leads to the relative difference in diversification of firms in both sectors measured by the Herfindahl index, $H_i(\varphi_i)/H_f(\varphi_f)$, which depends on firms' productivity difference, formality status and economic parameters:

$$\frac{H_i(\varphi_i)}{H_f(\varphi_f)} = \Omega^2\omega^{-1}\left(\frac{\varphi_f}{\varphi_i}\right)^k. \tag{3.32}$$

The difference in product diversification between informal and formal firms is driven by two components. First, higher-productivity firms are able to produce a wider range of distinct products given product-level regulation and hence the relative difference in diversification of two firms depends on their relative productivities. Second, formal firms produce both registered and unregistered products. As most of formal firms' profit is generated by registered goods, the product revenue distribution of formal firms is skewed. This is captured by $\Omega^2\omega^{-1} < 1$ that decreases $H_i(\varphi_i)/H_f(\varphi_f)$ and indicates that, controlling for firm productivity φ, formal firms are less diversified than informal firms. Similar to the case of the Product-Gini, while the product-level regulation affects $H_f(\varphi)$ through $\Omega^2\omega^{-1}$, formal

[26] $\left[\frac{2}{\Omega(\sigma-1)}\right]^{-1}\left\{\frac{2k+1-\sigma}{2}\left[\Omega + 2\phi^k\left[(1-\delta)^\sigma - \Omega\right]\right] + \phi^{2k+1-\sigma}k\left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right] - (1-\delta)^\sigma(k+1-\sigma)\right\}^{-1} < 1$ can be rewritten as $[k+1-\sigma]\left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma\right]\left[\phi^{k+1-\sigma} - \phi^{2k+1-\sigma}\right] > 0$.
Because $(1-\lambda)^{1-\sigma} > (1-\delta)^\sigma$, $[k+1-\sigma] > 0$ and $\phi \in (0,1)$, $G_i/G_f < 1$ holds.

firms are always less diversified than informal firms given the same firm productivity φ.[27]

Proposition 13. *As measured by product scope, formal firms are more diversified than informal firms. By contrast, formal firms are less diversified than informal firms measured by the Product-Gini and, when controlling for productivity, by the product-level Herfindahl index.*

3.3 Conclusion

In this paper I build a model of heterogeneous multi-product firms in the presence of both product- and firm-level regulations. I capture a multi-dimensional concept of informality and explain firms' sector choice and diversification decision in the presence of these two type of regulations. The results indicate that the product-level regulation is an important driver of informality at both firm- and product-level. Further, the model shows that while formal firms produce more distinct products than informal firms and can therefore be considered more diversified, the Gini coefficient and Herfindahl index predict the opposite.

The present work offers two avenues for fruitful future research. First, considering both product- and firm-level regulations in a general equilibrium setup would provide a richer set of predictions. Increasing product-level regulation might not only lead to an adjustment of the number of products by a given a firm, but also have general equilibrium impacts that further affect the demand for all products. This extension would be particularly interesting with regard to the impacts of trade on informality in a multi-product setting. If foreign market access is reserved for formal firms and registered products, resource reallocation is likely. Similarly, extending the model to explicitly feature labor market frictions along the lines of Becker (2014) would provide interesting insights into the impact of product-level regulation

[27] These diversification results are particularly interesting in comparison to the variant of the model developed in appendix B.6 in which firms do not face a product-level regulation and as a result all firms are equally diversified as measured by any of the three indicators.

on employment, particularly in general equilibrium. Resource reallocation jointly with labor market frictions could potentially lead to greater inequality between workers employed in heterogeneous firms. Therefore, future research should carefully consider the far-reaching effects of product-level regulation, which my model shows to be a new and important driver of informality and determinants of product diversification.

CHAPTER 4

TRADE LIBERALIZATION, FORMALITY AND CORRUPTION: THEORY AND EVIDENCE

4.1 Introduction

Informality as a response to regulations and frictions in the institutional environment, such as corruption (Johnson et al., 1998; Friedman et al., 2000; Dreher and Schneider, 2010; Buehn and Schneider, 2012), has received ample attention due to its distortionary effect on the resource reallocation process (La Porta and Shleifer, 2008; Hsieh and Klenow, 2009; D'Erasmo and Moscoso Boedo, 2012). Yet, recent work shows that liberalization policies, such as trade liberalization, and the institutional environment interact (Aghion et al., 2008; Sharma, 2009; Topalova, 2010). Trade liberalization specifically can induce reform of inefficient institutions (Khandelwal et al., 2013) and decrease corruption (Ades and Di Tella, 1999; Treisman, 2000; Gatti, 2004; Dutt et al., 2009; Dutt and Traca, 2010). This renders the joint impact of trade liberalization and corruption on the formality decision of firms unclear and indicates that, particularly given the global prevalence of both informality and corruption (Buehn and Schneider, 2012), the topic requires further scrutiny.

To shed light on the issue, I develop a model that features heterogeneous firms, international trade and endogenous corruption in the presence of firm-level informality. Firms are heterogeneous in production cost and decide on becoming informal, formal or exporters according to profitability considerations. A corrupt official demands a bribe from the visible formal firms, while being aware that firms can opt into informality to evade graft payments. The model makes three important predictions. First, the formal sector is smaller in an economy with higher formal sector registration cost and accordingly more corruption. As corruption is an additional burden to formal firms, informality is relatively more profitable

for the highest-cost formal firms, which induces them to informalize. Second, trade liberalization, in the form of a reduction in import tariffs, decreases the size of the formal sector. As barriers to trade are lowered, low-cost domestic firms are able to sell more goods abroad, but at the same time more foreign competitors enter the domestic market. With more firms operating domestically, competition intensifies and the highest-cost formal firms have to resort to informality to sustain production. Third, the responsiveness of the formal sector to trade liberalization is less pronounced in economies with higher registration cost, that is more corrupt economies. The intuition for this result is as follows. Trade liberalization intensifies domestic competition, which reduces the revenue of all non-exporting firms and shrinks the size of the formal sector. Faced with less opportunity to extract rents, the corrupt official finds it optimal to reduce her bribe request and therefore allows more firms to remain in the formal sector.

The three model predictions are validated using a panel data set of Vietnamese small- and medium-sized enterprises (SME). The data set includes both informal and formal firms over the period 2005-2009, which covers Vietnam's accession to the WTO in 2007 and thus a substantial trade liberalization episode. To deal with the potential endogeneity of Vietnam's import tariff rates to firm-level informality, I employ China's tariff levels around its accession to the WTO in 2001 as an instrumental variable. Both China and Vietnam are governed by a socialist single-party regime that adopted principles of a free market economy and the similarity in their development path is striking.[1] Vietnam began following China's structural adjustment since the implementation of its economic reform Doi Moi in 1986 that was closely crafted after China's reform 8 years prior and so it is not surprising that Vietnam joined the WTO in 2007, just six years after China's WTO accession in 2001. Given the similarities in economic development, economic structure and political system between China and Vietnam around the respective times of their WTO accession (Chaponnière et al., 2008; Chaponnière

[1]For a detailed review of the literature comparing the economic development of China and Vietnam see Malesky and London (2014).

and Cling, 2009), the Chinese tariff rates are strong predictors for Vietnam's tariff rates, yet are plausibly exogenous to the firm-level informality decisions in Vietnam six years later. Further, the survey features questions on bribe payments of all firms that I use to capture the variation in the regional extent of corruption.[2] In sum, the combination of variation in tariff rates between industries and extent of corruption between different regions during a period of trade liberalization allows me to identify the effect of trade liberalization, corruption and their interaction on firm-level formality.

Corresponding to the model prediction, the instrumental variable panel regression results show that a one percentage point reduction in tariff rates is associated with a decrease in firm-level formality of 7.6 percentage points in the subsequent year. This demonstrates firm informalization as an adjustment margins of firms in response to trade as theoretically predicted in Becker (2014). Further, a higher extent of regional corruption is associated with significantly lower rates of formality. Lastly, the interaction between trade liberalization and the extent of regional corruption is statistically significant and negative in its effect on firm-level formality, which indicates a lower responsiveness of the formal sector to trade liberalization in more corrupt regions.

With its focus on trade, corruption and informality, this paper is related to three strains of literature. First, the paper follows the growing body of literature that studies the drivers of informality empirically (e.g. de Soto, 1989; Schneider and Enste, 2000; Djankov et al., 2002; Dabla-Norris et al., 2008) and theoretically (e.g. Fields, 1975; Rauch, 1991; Basu et al., 2014; Becker, 2014). In particular, it is related to the empirical work of Rand and Torm (2012a) and Gajigo and Hallward-Driemeier (2012) who show that informality is an active firm-level response to corruption in the formal economy. Second, it relates to the literature studying the impact of trade liberalization on informality. So far this literature has predominantly

[2]Controlling for corruption at the regional level is sensible because, as elaborated in Rand and Torm (2012a), the different provinces in Vietnam are able to operate fairly autonomously and therefore corruption is likely to vary between different regions.

focused on informal employment (Goldberg and Pavcnik, 2003; Aleman-Castilla, 2006; Fiess and Fugazza, 2012; Paz, 2014; Acosta and Montes-Rojas, 2014; McCaig and Pavcnik, 2014), rather than firm-level informality. The exception is Nataraj (2011) who finds no statistically significant effect of trade liberalization on firm-level formality, albeit using cross-sectional data. Lastly, the paper adds to the theoretical literature on firms and corruption. Ades and Di Tella (1999) study the effect of competition on the extent of corruption. Choi and Thum (2005) consider both the informal and formal economy and show that the informal sector is complementary to corruption. Lastly, Dreher et al. (2009) extend upon this work by demonstrating that higher institutional quality can decrease both corruption and informality.

Given this previous literature, the contribution of the paper are threefold. First, this is the first paper to study the impact of trade and corruption as well as their interaction on the formal sector in the presence of informality. Second, the paper is the first to show the causal impact of trade liberalization on firm-level formality in a panel setting, that is it demonstrates the informalization of firms in response to trade liberalization. Third, the paper is also the first to show that the impact of trade liberalization on firm formality is actually conditional on the institutional environment and that the responsiveness of the formal sector to trade is lower in the presence of corruption.

The aforementioned findings highlight an important new reason why policy makers should be concerned about corruption. The heterogeneous firm trade literature spearheaded by Melitz (2003) indicates that trade liberalization increases aggregate productivity through its pro-competitive effect. That is, the least-productive formal firms exit due to increased competition and resources are reallocated towards the most-productive formal firms that benefit from increased export opportunities. Yet, as this paper shows, in corrupt economies the formal sector is less responsive to trade. Corrupt officials lower their graft requests upon trade liberalization, which in turn allows the least-productive formal firms to sustain formal production rather than being forced out. Therefore, corruption hampers the selection

mechanism that is a crucial driver through which trade increases formal sector aggregate productivity and hence welfare. On the bright side, the paper also shows in line with previous work, that trade liberalization does alleviate corruption, which gives policy makers further reason to embrace trade openness.

I proceed with the theoretical model in section 4.2. Section 4.3 describes the data used and is followed by the empirical strategy employed in this paper in section 4.4. The results of the analysis are detailed in section 4.5, section 4.6 summarizes robustness exercises and section 4.7 concludes the paper.

4.2 Theory

The world consists of two fully symmetric countries (home and abroad). Given the symmetry of the countries, I henceforth focus solely on home, noting that the same results hold for abroad. Each country is populated by firms that are heterogeneous in production cost C. Firms draw C from a distribution function $F(C)$, with $F(0) = 0$, $F(\infty) = 1$ and $\frac{\partial F(C)}{\partial C} > 0$. All firms produce an identical good and each firm faces the same firm-level demand D, which given that there is only one output is also firm-level demand, and is further explained in section 4.2.1. Given the heterogeneity in cost C, however, firm-level profit $\pi(C)$ is firm-specific, as detailed in section 4.2.2.

4.2.1 Demand

I assume demand is such that it decreases with competition in the economy. To lend it shape, I simply assume that each country's aggregate demand is fully inelastic at M. As all firms produce an identical product, the demand M is equally shared among the number of

domestically operating firms N. Each firms' individual demand D is therefore described by

$$D = \frac{M}{N}. \tag{4.1}$$

Notably, this setup with decreasing demand for a higher number of domestically operating firms can be interpreted as firms operating in monopolistic competitors as in Melitz (2003). Each firm produces a differentiated product and consumers value product variety. Heterogeneity in production cost, similar to firm productivity in Melitz (2003), leads to heterogeneity in firm profits. An increase in domestically available varieties, while still allowing for profits of individual firms, decreases the demand for each individual variety.

4.2.2 Supply: Formal and informal firms

Firms are able to become formal (subscript f) or informal (subscript i) sector producers and the costs and benefits of participating in either sector are modeled according to stylized facts arising from the empirical literature. Firms face additional regulatory burden of joining the formal sector that can be imagined to consist of registration costs or red tape and capture the extent of the institutional quality in the economy (de Soto, 1989; Djankov et al., 2002). More specifically, a higher regulation cost α captures a lower institutional quality of the economy. This incurs additional cost of $\alpha > 0$. Notably, I am agnostic as to whether the regulation is beneficial or purely red tape and consider α to be exogenous, that is the regulation is not installed by the corrupt official. One possible interpretation of this setup is that the regulation / costs and benefits are set by the central government, however, firms face a corrupt official at the regional level that takes the federal regulation as given. Therefore, formal firm production cost is described by $(1+\alpha)C$.[3] Given that formal firms are visible to the government, they are subject to an endogenous bribe request G from a corrupt official

[3]This corresponds to the finding of Beck et al. (2005) who show that legal obstacles as regulatory burden have a stronger effect on smaller firms, where firm size in this model corresponds to firm-specific profits or the inverse of cost draw C.

(Gajigo and Hallward-Driemeier, 2012; Rand and Torm, 2012a). I assume that the official cannot observe the firm-specific production cost C, and accordingly firm profit. As a result, the official demands the same bribe G from all formal firms. Further, formal firms are able to export goods in addition to their domestic sales for which they face an import tariff abroad. The import tariff is modeled in the form of an iceberg cost $\tau > 1$, that is for one unit of output to arrive abroad, τ units have to be exported. As exports are only conducted by firms that are also active domestically, these firms already pay bribes and do not have to pay an additional bribe for their export activity. Moreover, given that they ship their products, but do not have facilities abroad, they are not subject to graft requests. As I am interested in the informalization margin, that is the firms that decide to between informality and formality, I focus only on one type of bribe. Appendix C.1 develops an extension of the model in which the corrupt official can price discriminate in her bribe request between non-exporting and exporting firms. The results are consistent with this specification. Lastly, firms can evade additional firm regulation, that is avoid α, and become informal. However, informality comes at risk of government enforcement with probability $\delta \in (0, 1)$ that leads to the loss of firm revenue (Loayza, 1996; Dabla-Norris et al., 2008). Hence, the expected firm revenue in the informal sector is $(1 - \delta)D$. Informal firms are excluded from exporting, which is stylized, but largely supported by the empirical literature (Batra et al., 2003; Bigsten et al., 2004; La Porta and Shleifer, 2008). The profit for informal and formal firms as well as exporting activities are described by

$$\pi_i(C) = D(1 - \delta) - C, \tag{4.2}$$

$$\pi_f(C) = D - (1 + \alpha)C - G \tag{4.3}$$

and

$$\pi_x(C) = \frac{D}{\tau} - (1 + \alpha)C. \tag{4.4}$$

Firms choose to become informal, formal or exporters given their cost draw C and according to $\max\{0, \pi_i(C), \pi_f(C), \pi_f(C) + \pi_x(C)\}$. This leaves the question of how firms sort

into the different activities. The heterogeneity in firm cost is a reflection of firms' heterogeneity in productivity, that is low-cost producers are high-productivity firms. Given that exporters are empirically found to be high-productivity firms (Bernard and Jensen, 1995; Roberts and Tybout, 1997; Delgado et al., 2002) and informal firms are commonly characterized as low-productivity producers (La Porta and Shleifer, 2008; Dabla-Norris et al., 2008; de Paula and Scheinkman, 2011), I assume that the economy's parameters are such that the following sorting of firms holds:

$$\begin{aligned} C &> (1-\delta)D \text{ Exit} \\ (1-\delta)D \geq C &> \frac{\delta D - G}{\alpha} \text{ Become informal} \\ \frac{\delta D - G}{\alpha} \geq C &> \frac{D}{\tau(1+\alpha)} \text{ Become formal and sell domestically} \\ \frac{D}{\tau(1+\alpha)} &\geq C \text{ Become formal, sell domestically and export.} \end{aligned} \tag{4.5}$$

The theoretical trade literature commonly employs the Pareto distribution to model the distribution of firm productivity distribution given its empirical fit and tractability (see e.g. Corcos et al., 2012). As firms' heterogeneity in the production cost C reflects their heterogeneity in productivity, I follow the literature in assuming that firm costs are similarly distributed according to the power-law distribution $F(C) = \left(\frac{C}{C_{max}}\right)^k$ with $C \in (0, C_{max})$, where without loss of generality I normalize $C_{max} = 1$. The distributional assumption allows me to derive closed form solutions, while maintaining a realistic distribution of firm costs.

Given this sorting and the distributional assumption, the number of domestically operating firms N can be described by the share of domestic firms as well as the share of foreign exporters selling domestically, that is $N = [F(C_i^*) + F(C_x^*)]$. $C_i^* = (1-\delta)D$ and $C_x^* = D/[\tau(1+\alpha)]$ are the threshold cost levels from (4.5) below which domestic and foreign exporting firms, respectively, start operating. In combination with (4.1), the endogenous firm-level demand is

$$D = M^{\frac{1}{k+1}} \left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{1}{k+1}}. \tag{4.6}$$

In the economy there exists a corrupt official who demands a bribe G from all visible, that is formal, firms. The official is aware of the distribution of firm cost $F(C)$ and the costs of informal as well as formal production, yet cannot price discriminate between firms as production cost C is private information. The official therefore demands the same bribe G from all formal firms and maximizes her revenue through

$$\max_{G} GF\left(C_f\right), \tag{4.7}$$

where $F(C_f) = F\left(\frac{\delta D - G}{\alpha}\right)$ is the share of formal firms in the economy. The revenue maximizing bribe G^* follows as

$$G^* = \left[\frac{k}{k+1}\right]\delta D = \left[\frac{k}{k+1}\right]\delta M^{\frac{1}{k+1}}\left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{1}{k+1}}. \tag{4.8}$$

The optimal bribe consists of two components. The first part is $[k/k+1]$, where k is the firm cost distribution's shape parameter. For an economy with more equally distributed production costs (lower k), and thus more equally distributed firm profits, a lower bribe request to reach a wider spectrum of firms is optimal. Second, the bribe request considers δD, the share of the revenue that only formal firms receive. Therefore, the corrupt official considers both the distribution of firms in an economy as well as the additional benefit of formality.[4]

Given (4.5), (4.6) and (4.8), the threshold cost level for formal sector participation in the presence of corruption, C_f^*, is described by

$$C_f^* = \left[\frac{1}{k+1}\right]\frac{\delta}{\alpha}M^{\frac{1}{k+1}}\left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{1}{k+1}}. \tag{4.9}$$

Having established the baseline model, I proceed by examining three scenarios: i) a reduction in import tariff τ, ii) a change in the regulatory burden α and iii) the combination

[4]For instance, for $k = 1$, a uniform distribution of firm costs, the official finds it optimal to charge half of δD. For $k > 1$, the firm cost distribution implies fewer low-cost firms and it becomes optimal to charge a higher bribe to induce only the most profitable low-cost firms to remain formal and pay the bribe.

of both. First, trade liberalization as reduction in import tariffs decreases corruption in the economy:

$$\frac{\partial G^*}{\partial \tau} = \left[\frac{k}{k+1}\right]^2 \delta M^{\frac{1}{k+1}} \left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{k+2}{k+1}} \tau^{-k-1}(1+\alpha)^{-k} > 0. \tag{4.10}$$

The intuition for this prediction is as follows. With trade liberalization comes increased domestic competition that reduces firm-level revenue for each firm and incentivizes the marginal firms to informalize. Accordingly, the potential rents to be extracted by the corrupt official decrease as well. In response, the official finds it optimal to lower her bribe request in line with the empirical work showing that trade liberalization is associated with less corruption (Ades and Di Tella, 1999; Treisman, 2000; Gatti, 2004; Dutt et al., 2009; Dutt and Traca, 2010). Moreover, the decrease in revenue for each firm makes informality more profitable for the marginal formal firm and the formal sector decreases in size. $F(C_f^*) = C_f^{*k}$ describes the size of the formal economy and accordingly a comparative statics exercise on C_f shows this result:

$$\frac{\partial C_f^*}{\partial \tau} = \left[\frac{\delta M^{\frac{1}{k+1}}}{(k+1)\alpha}\right] \left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{k+2}{k+1}} \left[\frac{k}{k+1}\right] \tau^{-k-1}(1+\alpha)^{-k} > 0. \tag{4.11}$$

Proposition 14. *A bilateral reduction in import tariffs decreases the size of the formal sector.*

Second, I examine the effect of a higher regulatory burden. Intuitively, a higher regulatory cost α has two effect. First, it creates a higher barrier to enter the formal economy and thus limits the number of formal firms. Second, with less firms operating in the economy, each operating firm earns a higher revenue.[5] As a result, the corrupt official finds it profitable to increase her bribe request as a consequence of higher regulatory burden in line with the empirical literature (Djankov et al., 2002; Svensson, 2005):

$$\frac{\partial G^*}{\partial \alpha} = \left[\frac{k}{k+1}\right] \delta \frac{\partial D}{\partial \alpha} > 0. \tag{4.12}$$

[5]Mathematically $\frac{\partial D}{\partial \alpha} = D\left[\frac{k}{k+1}\right]\left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-1} \tau^{-k}(1+\alpha)^{-k-1} > 0.$

As the cost of formality increases, the marginal formal firm will find it more profitable to become informal, and the formal sector decreases in size:

$$\frac{\partial C_f^*}{\partial \alpha} = \left[\frac{\delta M^{\frac{1}{k+1}}}{(k+1)\alpha}\right]\left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{1}{k+1}} \tag{4.13}$$
$$\left[-\alpha^{-1} + \frac{\frac{k}{k+1}\tau^{-k}(1+\alpha)^{-k-1}}{(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}}\right] < 0.$$

Proposition 15. *The formal sector is smaller in an economy with a higher firm registration cost, and thus more corruption.*

Lastly, I examine the response of the formal sector to trade liberalization depending on the extent of corruption in the economy. Intuitively, corruption is higher in an economy with higher regulatory burden. While trade liberalization decreases the size of the formal sector, it also decreases corruption. Therefore, in economies with higher regulatory burden, and thus higher bribe demands, trade liberalization will entail lower bribe demands. The lower bribe demands make formal sector production relatively cheaper and mitigate some of the informalization caused by trade liberalization:

$$\frac{\partial^2 C_f^*}{\partial \tau \partial \alpha} = \left[\frac{\delta M^{\frac{1}{k+1}}\tau^{-k-1}}{(k+1)^2\alpha}\right]\left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-\frac{1}{k+1}-1} \tag{4.14}$$
$$\left[-\frac{k}{(1+\alpha)^{k+1}} - \frac{\alpha^{-1}}{(1+\alpha)^k} + \frac{\tau^{-k}}{(1+\alpha)^{2k+1}}\left[\frac{k(k+2)}{k+1}\right]\left[(1-\delta)^k + \tau^{-k}(1+\alpha)^{-k}\right]^{-1}\right] < 0.$$

This is summarized in the third proposition:

Proposition 16. *The responsiveness of the formal sector to trade liberalization is smaller in an economy with a higher firm registration cost, and thus more corruption.*

4.3 Data

The panel data used in this study stems from a survey of Vietnamese small and medium sized enterprises conducted by the Central Institute for Economic Management of the Ministry

of Planning and Investment of Vietnam, the Institute of Labour Science and Social Affairs of the Ministry of Labour, Invalids and Social Affairs of Vietnam and the Development Economics Research Group of the University of Copenhagen. Every two years about 2,500 enterprises are surveyed with a large share of repeated observations allowing for the panel structure of the data. I concentrate on the three most recent and publicly available rounds, which are for the years 2005, 2007 and 2009 covering Vietnam's accession to the WTO in 2007.

The population from which the firm sample is drawn has two sources: the population of registered, and hence formal, firms comes from the Industrial Survey and the population of non-registered businesses from the Establishment Census, both conducted by the General Statistics Office (GSO) of Vietnam.[6] To be included in the population firms have to have less than 300 employees, but at least one full-time employee and are not to be state-owned enterprises. The population of firms covers 10 provinces (Hanoi, Hai Phong, Ho Chi Minh City, Ha Tay, Phu Tho, Nghe An, Quang Nam, Khanh Hoa, Lam Dong and Long An), which house about 30% of Vietnam's manufacturing firms. Samples are stratified by ownership form in each area. The survey covers both manufacturing and service enterprises. In line with the heterogeneous trade literature, I restrict my attention to solely manufacturing enterprises, which are classified by the GSO in 2-digit categories and span 18 different industries. Ideally, the economic variables should be normalized with the help of industry-specific deflators. In the case of Vietnam, however, these are not available. Therefore, I deflate all economic variables using the World Bank GDP deflators, with the exception of wages that are adjusted using CPI-based deflators. The base year is 2010.[7]

I define firms as informal given the classical definition of firm registration non-compliance (de Soto, 1989). In the survey this corresponds to any firm that does not have a "Business Registration Certificate". However, not all firms in Vietnam are required to register. Busi-

[6]For a more detailed description of the sampling procedure see **?**.

[7]This data is available at http://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.

ness that earn less than a specific amount set at the district level, which is commonly defined to be the minimum wage level, are exempt from having to register.[8] Similarly, agricultural, forestry, fishery and salt producing firms as well as street hawkers are not required to register their business. However, firms employing more than ten workers have to obtain a business registration certificate nonetheless. As Cling et al. (2012) report, while many firms are not registered, in practice only a very small share of firms are actually exempt from firm registration in Vietnam.

Even though the survey has a large number of recurring firms in each round, there is a notable number of firms that exit or enter the survey. However, I am not able to distinguish firms that exit only the survey from firms that cease to exist. Similarly, I cannot differentiate between new entrants to the survey from firms that just start production. Therefore, I focus solely on firms that operate in all three periods. This allows me also to specifically capture the informalization margin proposed in Becker (2014), that is the decision of existing formal firms to opt out of formality and join the informal sector. Further, I remove 10 firms that earn less than the minimum wage in the survey years and do not employ more than ten workers, that is firms that are not required to register, and trim the data to deal with outliers.[9] This leaves me with a balanced panel of $1,590$ firms over three periods.

The tariff data stems from the World Integrated Trade Solution (WITS), a trade database compiled by the World Bank in collaboration with the United Nations Conference on Trade and Development.[10] The tariff rates are the weighted and effectively applied (AHS) rates categorized by 2-digit ISIC3 specification. To combine the tariff data with the panel data set, I create a concordance of ISIC3 with the Vietnamese GSO's industry codes. For the

[8] 290,000 VND/month, 350,000 VND/month and 540,000 VND/month for the years 2004, 2006 and 2008, respectively. See Decree No. 203/2004/ND-CP of 12/14/2004, Decree No. 94/2006/ND-CP of 09/07/2006 and Decree No. 166/2007/ND-CP of 11/16/2007 for the minimum wage levels in 2004, 2006 and 2008.

[9] More specifically, I trim the 99th and 1st percentile of bribe relative to firm revenue by each year. Further, I remove one observation with negative depreciation and interest rate as infeasible record. Lastly, I trim 99th and 1st percentile of TFP values for both the index number and the Levinsohn & Petrin approach.

[10] The data can be found at http://wits.worldbank.org/.

three GSO industries that make up more than one ISIC3 2-digit category, I manually weigh the WITS tariff rates by import values and calculate the corresponding weighted tariff rates. The economic data in the survey rounds is always for the year prior the survey. Therefore, I match the tariff rate to the respective year of the economic data. For instance, the 2005 round captures the economic data of firms in 2004, which is then matched to the 2003 tariff rates for the one-year lagged tariff and the 2004 tariff rates for the non-lagged tariff specification.

To control for firm productivity, I construct a firm-level TFP measure non-parametrically following Aw et al. (2001) using the index number approach. Index numbers are particularly robust measures when firms employ heterogeneous technology and are therefore a good technique when estimating TFP for both informal and formal firms.[11] I calculate the log of total factor productivity $\ln TFP_{it}$ of firm i in industry j and year t as

$$\ln TFP_{it} = \left(\ln Y_{it} - \overline{\ln Y_t}\right) + \sum_{s=2}^{t} \left(\overline{\ln Y_s} - \overline{\ln Y_{s-1}}\right) - \left[\sum_{r=1}^{n} \frac{1}{2} \left(S_{rit} + \overline{S_{rt}}\right) \left(\ln K_{rit} - \overline{\ln K_{rt}}\right) + \sum_{s=2}^{t} \sum_{r=1}^{n} \frac{1}{2} \left(\overline{S_{rs}} + \overline{S_{rs-1}}\right) \left(\overline{\ln K_{rs}} - \overline{\ln K_{rs-1}}\right)\right], \tag{4.15}$$

where $\ln Y_{it}$ is log of revenue of firm i in year t. $\ln K_{rit}$ is the log of input r, where I consider labor, capital and raw materials. S_{rit} is the expenditure for input r, that is firms' wage bills, depreciation and interest payments as well as raw material costs, relative to firm revenue. All variables with bars are arithmetic means of the variables over all firms in the specific year.

As robustness exercise, I estimate firm-level TFP semi-parametrically following Levinsohn and Petrin (2003). This methodology considers that input choices are endogenous to firm productivity and addresses the issue by using intermediate inputs as a proxy for unobserved and time-varying productivity. In line with the literature, I consider capital as fixed, labor as freely variable and raw materials as semi-fixed input and hence proxy for productivity.

[11] See Van Biesebroeck (2007) for a study benchmarking the different parametrically and non-parametrically TFP estimation techniques.

The dependent variable for the estimation is value-added. The results of both methodologies are close. A simple correlation between the non- and semi-parametric measures results in 0.8366.

To capture the extent of corruption, I rely on survey responses. More specifically, the survey prompts firms on whether they make "informal payments" to officials and on the size of the informal payment. As survey responses to questions on corruption at the firm-level are endogenous to firms' decision on being informal or formal sector firms as well as firm-specific characteristics, I generate a proxy for the regional extent of corruption. As first step, I generate a variable capturing the bribe amount as share of firm revenue. The regional measure of corruption then follows as the mean relative bribe payment by region and survey year. While survey questions on bribe payments might be not entirely reliable given that bribes are illegal, the regional variation in the averages should capture the overall variation in the extent of corruption.

Given the implementation of the survey, two caveats for the interpretation of the results are in order. First, the survey covers only SME and therefore does not represent the entirety of the formal sector that also includes large formal firms. Second, the Establishment Census only considers visible non-registered businesses, that is firms that have fixed business premises. The survey therefore does not represent the complete informal sector. In sum, this means that the survey does neither cover the largest formal nor the smallest informal firms. However, as predicted in Becker (2014), trade liberalization affects particularly the firms at the intersection of formality and informality, which are both informal and formal SME. Therefore, while the data set is not suitable for inferences on the entire spectrum of firms, is well suited to identify the factors that drive firms' formality decision.

Tables 4.1, 4.2 and 4.3 provide summary statistics for the informal and formal firms in the years 2005, 2007 and 2009, respectively. While formal firms make up about 75% of the $1,590$ firms in 2005, 65% of the firms are informal in 2009. This notable decrease in firm informality

coincides with the increasing trade liberalization from 2005 to 2009 and therefore warrants further investigation on the impact of trade liberalization on informality. The summary statistics largely confirm the finding of the previous empirical informality literature with regard to the dualism in firm characteristics (e.g. Dabla-Norris et al., 2008; La Porta and Shleifer, 2008; de Paula and Scheinkman, 2011; Rand and Torm, 2012a). Informal firms are on average lower productivity firms, less likely to export, generate lower revenue and are smaller in firm size. Formal firms, however, more frequently make informal payments to corrupt officials. Notably, while in the model only formal firms make graft payments, the data shows some informal firms bribing as well. As their payments, however, are comparably very small, I follow the previous literature on Vietnamese SME in focusing on formal sector corruption (Rand and Torm, 2012a).

Table 4.1: Summary statistics for the year 2005

	Informal firms $N = 397$			Formal firms $N = 1193$		
Variable	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**
TFP (Index number)	-0.546	0.36	397	-0.04	0.393	1193
Export	0	0	397	0.069	0.253	1193
Does you firm bribe?	0.118	0.323	397	0.484	0.5	1193
Nominal revenue (in 2010 million VND)	167.533	253.416	397	1587.396	4655.095	1193
Log number of employees	1.173	0.759	397	2.198	1.024	1193

Table 4.2: Summary statistics for the year 2007

	Informal firms $N = 494$			Formal firms $N = 1096$		
Variable	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**
TFP (Index number)	-0.45	0.399	494	0.066	0.423	1096
Export	0.008	0.09	494	0.063	0.243	1096
Does you firm bribe?	0.065	0.246	494	0.339	0.473	1096
Nominal revenue (in 2010 million VND)	345.946	686.803	494	2393.674	6194.339	1096
Log number of employees	1.206	0.799	494	2.203	1.07	1096

Table 4.3: Summary statistics for the year 2009

	Informal firms $N = 560$			Formal firms $N = 1030$		
Variable	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**
TFP (Index number)	-0.389	0.347	560	0.084	0.376	1030
Export	0.011	0.103	560	0.078	0.268	1030
Does you firm bribe?	0.136	0.343	560	0.43	0.495	1030
Nominal revenue (in 2010 million VND)	505.833	781.027	558	3771.905	9066.514	1030
Log number of employees	1.062	0.690	560	2.242	1.053	1030

4.4 Empirical strategy

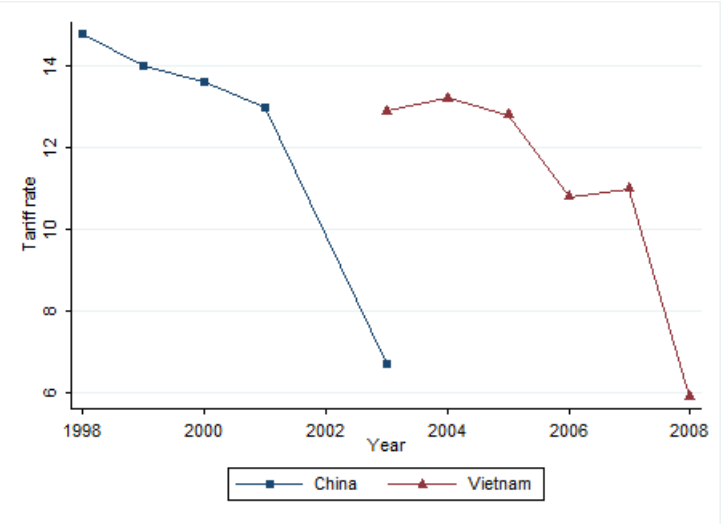
The empirical strategy in this paper exploits the variation of the Vietnamese tariff rates in different industries over a period of trade liberalization and the variation in average bribe payments by region to identify the effect of trade liberalization and corruption on firm-level informality. Because it is possible that Vietnamese policy-makers chose tariff levels around the time of Vietnam's WTO accession in 2007 endogenous to informality, i.e. sectors with a high incidence of formality might strategically receive less or more protection, I employ an instrumental variable strategy. More specifically, I use China's tariff rates around its accession to the WTO several years prior to Vietnam in 2001 as instrument for the Vietnamese tariff rates around 2007.[12] Figure 4.1 illustrates the similar development of the Chinese and Vietnamese weighted average applied tariff rates for manufactured products around their respective WTO accessions in 2001 and 2007.

The similarity in economic structure and development suggests that the historical Chinese tariff rates are good predictors for the Vietnamese rates. Yet, China's tariff rates are arguably not related to firm-level formality in Vietnam six years later. Therefore, I instrument the tariff levels for Vietnam in 2003, 2005 and 2007 with the Chinese tariff levels in 1998, 2000 and 2003, that is the same respective steps around the WTO accession of both countries.[13] Figure

[12]This is similar in spirit to Hu and Liu (2014) who use tariff rates of the Philippines as instrument for Chinese tariff rates to analyze the impact of trade on firm productivity.

[13]The firm-level survey collects economic data for the previous year, e.g. the economic data of the 2005 round is for the year 2004. Accordingly, I use the 2003 tariff data as a one-year lagged tariff level. Further, there is no tariff data available for China in 2002 and 2003 provides the next best substitute.

Figure 4.1: Weighted average applied tariff rates of China and Vietnam for manufactured products in percent.



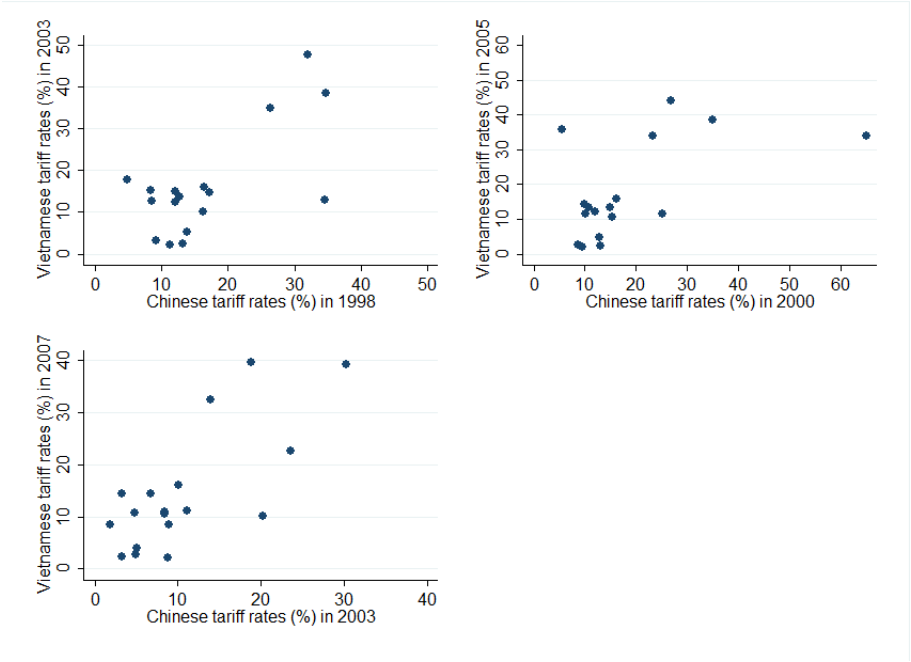
Source: Author's illustration based on

http://data.worldbank.org/indicator/TM.TAX.MANF.WM.AR.ZS/countries/CN-VN

4.2 plots the Chinese tariff rates against the Vietnamese tariff rates in the 18 manufacturing sectors for the respective years. A clear positive relationship between the two variables is visible for all three periods.

Subscript i denotes the individual, j the industry, k the province and t the year. $\text{tariff}^{V}_{1,jt-1}$ is the one-year-lagged Vietnamese tariff rate in industry j and $\text{tariff}^{C}_{1,jt-1}$ is the Chinese tariff rate for the same industry in the same respective year with regard to the WTO accession. I employ lagged tariffs as it is likely that a change in tariff rates requires time to affect firms. For robustness, I also estimate a regression using non-lagged tariff rates, that is using tariff^{V}_{jt} and tariff^{C}_{jt}. corruption_{kt} controls for the institutional drivers of informality, that is the extent of corruption. X_{it} captures a range of firm characteristics, such as TFP, log firm size and export status. Further, I include a set of dummy variables for the individual (c_i), the industry (d_j), the province (e_k) and the year (f_t). Lastly, ϵ_{it} is the disturbance term, which

Figure 4.2: Comparison between Vietnamese and Chinese tariff rates in the years surrounding their respective accession to the WTO.



is allowed be correlated across years for individual observations. The first-stage equation is

$$\text{tariff}^{V}_{jt-1} = a_0 \ \text{tariff}^{C}_{jt-1} + a_1 \ \text{corruption}_{kt} + X'_{it}b + c_i + d_j + e_k + f_t + \epsilon_{it}.$$

To estimate the impact of trade liberalization conditional on corruption, there are two first-stage equations. That is one with the Vietnamese tariff rates as dependent variable and one with the interaction between the Vietnamese tariff and corruption as dependent variable. Moreover, both equations include the interaction term $\text{tariff}^{C}_{jt-1} * \text{corruption}_{kt}$ as independent variable.

Table 4.4 presents the first-stage regression results for the basic specifications. The relationship between the lagged Chinese tariff rates and the lagged Vietnamese tariff rates is positive and significant at the 1% level. The relationship is robust to employing the Levinsohn & Petrin TFP estimator and controlling for firms' legal status as well as export status. All four specifications have a R^2 of 0.918. The test for excluded instruments leads to

a F-statistic ranging from 52.23 to 52.56 for the lagged tariff rates. An underidentification test using the Kleibergen-Paap rk LM statistic rejects underidentification for all previously mentioned specification at the 1% level. Similarly, a Stock-Yogo weak identification test using the Kleibergen-Paap rk Wald F-statistic allows me to reject that the maximum relative bias is at least 10% for all regressions at the 5% level.

In the second stage, I estimate a linear probability model, where the dependent variable, formality_{it}, is a dummy variable that equals 1 if a firm is formally registered. The second-stage regression equation, including the interaction between tariff rates and corruption, is

$$\begin{aligned}\text{formality}_{it} =& \alpha_0 \text{ tariff}^V_{jt-1} + \alpha_1 \text{ corruption}_{kt} + \alpha_2 \text{ tariff}^V_{jt-1} * \text{corruption}_{kt} + X'_{it}\beta + \\ & \mu_i + \nu_j + \omega_k + \theta_t + \varepsilon_{it},\end{aligned}$$

where I include dummy variables for the individual (μ_i), the industry (ν_j), the province (ω_k) and the year (θ_t). ε_{it} is a disturbance term, which is allowed be correlated across years for individual observations. Given the theoretical model in section 4.2, I expect lower tariff rates to decrease firm-level formality ($\alpha_0 > 0$), higher regional corruption to decrease firm-level formality ($\alpha_1 < 0$) and the responsiveness of the formal sector to trade liberalization should be lower in regions with a higher incidence of corruption ($\alpha_2 < 0$).[14]

4.5 Main results

I begin by contrasting a fixed effect linear probability model without instrumental variables with the instrumental variable panel regressions, both without the interaction of tariff rates and corruption. The fixed effect panel regressions show that one-year lagged tariff rates are not statistically significant in any specification (regressions 1-4 in table 4.5). A higher

[14] In the theoretical model a variation in the regulatory cost of formality leads to variation in corruption. In the empirical part, I control for the extent of corruption directly. However, appendix C.2 demonstrates that the extent of regulatory costs are indeed significantly related with the extent of corruption.

Table 4.4: First-stage regression

VARIABLES	(1)	(2)	(3)	(4)
One-year lagged Chinese tariff	0.0619***	0.0620***	0.0619***	0.0619***
	(0.0128)	(0.0128)	(0.0129)	(0.0128)
Regional extent of corruption	-0.0106	-0.0149	-0.00145	-0.0119
	(0.111)	(0.111)	(0.111)	(0.111)
TFP (Index number)	-0.0143		-0.0183	-0.0116
	(0.116)		(0.116)	(0.116)
TFP (Levinsohn&Petrin)		-0.0260		
		(0.0450)		
Log number of employees	-0.0466	-0.0488	-0.0451	-0.0462
	(0.0506)	(0.0485)	(0.0506)	(0.0506)
Export				-0.0694
				(0.155)
Firm legal status FE			Yes	
Observations	4,770	4,770	4,770	4,770
R-squared	0.918	0.918	0.918	0.918
Number of id	1,590	1,590	1,590	1,590

Dependent variable are the lagged Vietnamese tariff rates. All specifications include year, province and industry dummy variables that are not reported. Additionally, regression 3 includes dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

incidence of regional corruption is statistically significant at the 1%-level und negatively associated firm-level formality. Similarly, firm-level TFP and the log number of employees are positively correlated with formality and statistically significant.

The instrumental variable regressions paint a different picture (table 4.6). First, all four specifications indicate that a one percentage point decrease in tariff rates lead to an increase in firm-level informality of $7.5-7.6$ percentage points, which is a significant result at the 10% level for all specifications. Further, with a similar magnitude as in the previous fixed effects estimation, the regional extent of corruption is associated with significantly less firm-level formality. This confirms the predictions of the model as summarized in propositions 14 and 15. In line with previous empirical literature, firm productivity (measured by either the index number and Levinsohn&Petrin approach) and the log number of employees are positive and significantly related with firm-level formality (e.g. La Porta and Shleifer, 2008; Dabla-Norris et al., 2008; de Paula and Scheinkman, 2011). Additionally, regression 4 controls for whether

Table 4.5: Effect of tariffs on firm-level formality - Endogenous tariff rates

VARIABLES	(1)	(2)	(3)	(4)
One-year lagged tariff	0.00398	0.00405	0.00458	0.00401
	(0.00295)	(0.00296)	(0.00295)	(0.00295)
Regional extent of corruption	-0.166***	-0.169***	-0.169***	-0.165***
	(0.0442)	(0.0441)	(0.0440)	(0.0442)
TFP (Index number)	0.0571***		0.0580***	0.0561***
	(0.0212)		(0.0210)	(0.0213)
TFP (Levinsohn&Petrin)		0.0209**		
		(0.00978)		
Log number of employees	0.0567***	0.0652***	0.0545***	0.0566***
	(0.0127)	(0.0124)	(0.0127)	(0.0128)
Export				0.0241
				(0.0305)
Firm legal status FE			Yes	
Observations	4,770	4,770	4,770	4,770
Number of id	1,590	1,590	1,590	1,590

Dependent variable is firm-level formality status. All specifications include year, province and industry dummy variables that are not reported. Additionally, regression 3 includes dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

a firm is an exporter. The coefficient for the exporter dummy is as expected positive, albeit not statistically significant. While there is concern that the number of employees and export status of a firm could be correlated, this is not of much concern given that both are just control variables.

As second main result, I show that the impact of trade liberalization on firm-level formality is conditional on the extent of regional corruption, that is I include the interaction term between lagged tariff rates and the regional extent of corruption. The results are summarized in table 4.7. Notably, the interaction of lagged tariff rates with the regional extent of corruption is negative and statistically significant at the 1% level in all four specifications. This confirms the model prediction summarized in proposition 16, that is the responsiveness of the formal sector to trade liberalization in the presence of informality is lower in regions with a higher extent of corruption. Moreover, the coefficient for the regional extent of is positive when including the interaction term. However, a signifiance test for the marginal effect of

Table 4.6: Effect of tariffs on firm-level formality - second-stage regression

VARIABLES	(1)	(2)	(3)	(4)
One-year lagged tariff	0.0762*	0.0766*	0.0750*	0.0762*
	(0.0409)	(0.0409)	(0.0408)	(0.0409)
Regional extent of corruption	-0.168***	-0.172***	-0.172***	-0.168***
	(0.0442)	(0.0441)	(0.0440)	(0.0442)
TFP (Index number)	0.0569**		0.0582***	0.0558**
	(0.0228)		(0.0225)	(0.0229)
TFP (Levinsohn&Petrin)		0.0222**		
		(0.0103)		
Log number of employees	0.0593***	0.0678***	0.0570***	0.0592***
	(0.0134)	(0.0130)	(0.0133)	(0.0134)
Export				0.0292
				(0.0326)
Firm legal status FE			Yes	
Observations	4,770	4,770	4,770	4,770
Number of id	1,590	1,590	1,590	1,590

Dependent variable is firm-level formality status and the table reports LIML estimates. The instrumental variables are lagged Chinese tariff rates. All specifications include year, province and industry dummy variables that are not reported. Additionally, regression 3 includes dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

the extent of corruption around the mean tariff rates indicates a joint effect between -0.19 and -0.20 for the four specifications. In all four cases the effect is statistically signifcant at the 1%-level.

4.6 Robustness

4.6.1 Instrumented for non-lagged tariff rates

Economic intuition dictates that if a reduction in lagged tariff rates causes lower levels of firm-level formality, then non-lagged tariff rates should affect firm-level formality in the same direction, albeit potentially at a lower rate, which the regression results detailed in table 4.8 confirm. An increase in instrumented for non-lagged tariff rates of one percentage point

Table 4.7: Interaction between lagged tariff rates and regional corruption

VARIABLES	(1)	(2)	(3)	(4)
One-year lagged tariff	0.134**	0.134**	0.134**	0.135**
	(0.0618)	(0.0618)	(0.0618)	(0.0622)
Regional extent of corruption	0.425*	0.419*	0.437*	0.438*
	(0.226)	(0.227)	(0.226)	(0.230)
One-year lagged tariff x	-0.0487***	-0.0485***	-0.0500***	-0.0497***
Regional extent of corruption	(0.0187)	(0.0187)	(0.0187)	(0.0189)
TFP (Index number)	0.0544**		0.0556**	0.0523**
	(0.0258)		(0.0255)	(0.0260)
TFP (Levinsohn&Petrin)		0.0197*		
		(0.0110)		
Log number of employees	0.0684***	0.0764***	0.0661***	0.0683***
	(0.0149)	(0.0144)	(0.0148)	(0.0150)
Export				0.0520
				(0.0363)
Firm legal status FE			Yes	
Observations	4,770	4,770	4,770	4,770
Number of id	1,590	1,590	1,590	1,590

Dependent variable is firm-level formality status and the table reports LIML estimates. The instrumental variables are lagged Chinese tariff rates as well as the respective interaction terms stated in the table. All specifications include year, province and industry dummy variables that are not reported. Additionally, regression 3 includes dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

increases firm-level formality by 2.6 percentage points, about a third of the effect of lagged tariff rates. The coefficients are statistically significant at the 10%-level. The interaction terms of the non-lagged tariff rates with regional corruption are all significant at the 5%-level and negative. Similarly to the coefficient for tariff rates, they're also smaller in magnitude than in the lagged specification. While the extent of regional corruption is not statistically significant, a test of the marginal effect of corruption shows a similar result as in the one-year lagged specification. That is, the marginal effect of corruption around the mean non-lagged tariff rates is between -0.14 and -0.15 for the four specifications and statistically significant at the 1%-level in all cases.

Table 4.8: The effect of trade liberalization and corruption on firm formality using non-lagged tariff rates

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-lagged tariff	0.0262*	0.0262*	0.0266*	0.0261*	0.0372**	0.0372**	0.0381**	0.0373**
	(0.0149)	(0.0149)	(0.0149)	(0.0149)	(0.0182)	(0.0182)	(0.0183)	(0.0182)
Regional extent of corruption	-0.158***	-0.162***	-0.162***	-0.158***	0.281	0.273	0.298	0.287
	(0.0443)	(0.0443)	(0.0442)	(0.0444)	(0.182)	(0.182)	(0.183)	(0.183)
Non-lagged tariff x					-0.0372**	-0.0368**	-0.0390**	-0.0376**
Regional extent of corruption					(0.0155)	(0.0155)	(0.0156)	(0.0155)
TFP (Index number)	0.0663***		0.0676***	0.0655***	0.0635***		0.0645***	0.0620***
	(0.0233)		(0.0231)	(0.0235)	(0.0237)		(0.0235)	(0.0239)
TFP (Levinsohn&Petrin)		0.0259**				0.0233**		
		(0.0107)				(0.0105)		
Log number of employees	0.0502***	0.0600***	0.0476***	0.0501***	0.0559***	0.0652***	0.0536***	0.0558***
	(0.0140)	(0.0134)	(0.0139)	(0.0140)	(0.0140)	(0.0133)	(0.0139)	(0.0140)
Export				0.0191				0.0337
				(0.0372)				(0.0357)
Firm legal status FE			Yes				Yes	
Observations	4,770	4,770	4,770	4,770	4,770	4,770	4,770	4,770
Number of id	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590

Dependent variable is firm-level formality status and the table reports LIML estimates. The instrumental variables are Chinese tariff rates as well as the respective interaction terms stated in the table. All specifications include year, province and industry dummy variables that are not reported. Additionally, regressions 3 and 7 include dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

4.6.2 Unbalanced panel

As a robustness exercise, I explore whether the finding that a reduction in import tariffs decreases firm-level formality also holds for the full sample of firms including new entrants as well as firm exits during the survey rounds. The unbalanced panel consists of $2,337$ firms over the three survey periods. As the regression results in table 4.9 show, the findings using the whole sample largely mirror the balanced panel findings for both the baseline specifications and the specifications featuring the interaction between lagged tariff rates and regional corruption. Notably, the magnitude of the coefficient of the lagged tariff rates in both the baseline as well as the interaction specifications are slightly lower than in the balanced panel. The model in Becker (2014) indicates that trade liberalization induces the exit of the least-productive informal sector firms. Therefore, if predominantly informal firms exit over the course of the survey period and are hence not considered in the balanced panel, the balanced panel estimation should feature a larger coefficient for the effect of tariff rates on firm-level formality as seen here.

Table 4.9: The effect of trade liberalization and corruption on firm formality using the Unbalanced panel

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
One-year lagged tariff	0.0523*	0.0526*	0.0527*	0.0523*	0.0990**	0.0991**	0.102**	0.0997**
	(0.0281)	(0.0281)	(0.0281)	(0.0281)	(0.0398)	(0.0398)	(0.0402)	(0.0399)
Regional extent of corruption	-0.172***	-0.174***	-0.177***	-0.172***	0.375**	0.369**	0.403**	0.382**
	(0.0406)	(0.0405)	(0.0405)	(0.0406)	(0.179)	(0.180)	(0.182)	(0.181)
One-year lagged tariff x					-0.0442***	-0.0439***	-0.0468***	-0.0448***
Regional extent of corruption					(0.0144)	(0.0144)	(0.0146)	(0.0145)
TFP (Index number)	0.0517***		0.0507***	0.0509***	0.0495**		0.0483**	0.0482**
	(0.0195)		(0.0193)	(0.0195)	(0.0211)		(0.0212)	(0.0213)
TFP (Levinsohn&Petrin)		0.0232***				0.0204**		
		(0.00889)				(0.00924)		
Log number of employees	0.0609***	0.0687***	0.0583***	0.0606***	0.0655***	0.0730***	0.0630***	0.0652***
	(0.0115)	(0.0112)	(0.0115)	(0.0115)	(0.0121)	(0.0118)	(0.0120)	(0.0121)
Export				0.0233				0.0391
				(0.0262)				(0.0276)
Firm legal status FE			Yes				Yes	
Observations	6,264	6,264	6,264	6,264	6,264	6,264	6,264	6,264
Number of id	2,337	2,337	2,337	2,337	2,337	2,337	2,337	2,337

Dependent variable is firm-level formality status and the table reports LIML estimates. The instrumental variables are lagged Chinese tariff rates as well as the respective interaction terms stated in the table. All specifications include year, province and industry dummy variables that are not reported. Additionally, regressions 3 and 7 include dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

4.6.3 Alternative measure of corruption

To demonstrate the robustness of the finding that trade liberalization reduces corruption, I employ government inspections as an alternative proxy of corruption. As reported by Rand and Torm (2012a) and Gajigo and Hallward-Driemeier (2012), government inspections in the presence of informality often serve two purposes. First, government officials inspect firms to ensure they comply with regulation, that is they are registered firms. Second, officials may use inspection as an opportunity to extract rents from formal firms in the form of bribe requests. Therefore, while it is initially unclear whether a high degree of regional government inspections should entail more or less firm-level formality, the model indicates that the corruption channel of inspections should become less pronounced upon trade liberalization.

To generate the proxy for regional inspection levels, I first create a dummy variable equaling 1 if a firm has received one or more visits by government inspectors in the survey period. The mean of this dummy variable by province and survey year captures the extent of regional government inspection. The results are detailed in table 4.10. The coefficient for the inspection proxy are positive, albeit not significant for any of the baseline specifications. However, when interacted with the lagged tariff rates, the inspection proxy in all four specifications is positive and the interaction term with tariff rates is negative. Both are significant at the 1%-level. A test for the marginal effect of the extent of regional inspection at the mean one-year lagged tariff rates reveals an effect of 0.12 that is statistically significant at the 1%-level for all four specifications. This indicates that, similar to controlling for corruption, the responsiveness of the formal sector to trade liberalization is lower in regions with a high incidence of government inspections. The intuition for this finding is that inspections are commonly used to request bribes from firms and accordingly regions with a higher extent of corruptions feature also higher inspections. Therefore, using inspections as a proxy for corruption confirms the initial finding.

Table 4.10: The effect of trade liberalization and inspections on firm formality

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
One-year lagged tariff	0.0729*	0.0736*	0.0716*	0.0730*	0.0746**	0.0754**	0.0728*	0.0747**
	(0.0398)	(0.0399)	(0.0398)	(0.0398)	(0.0378)	(0.0379)	(0.0377)	(0.0378)
Regional government inspection	0.0337	0.0385	0.0393	0.0339	0.609***	0.611***	0.604***	0.609***
	(0.0462)	(0.0460)	(0.0456)	(0.0462)	(0.124)	(0.124)	(0.122)	(0.125)
One-year lagged tariff x					-0.0433***	-0.0430***	-0.0425***	-0.0432***
Regional government inspection					(0.00911)	(0.00912)	(0.00900)	(0.00914)
TFP (Index number)	0.0620***		0.0630***	0.0607***	0.0630***		0.0639***	0.0626***
	(0.0227)		(0.0224)	(0.0228)	(0.0222)		(0.0219)	(0.0223)
TFP (Levinsohn&Petrin)		0.0238**				0.0231**		
		(0.0104)				(0.0102)		
Log number of employees	0.0578***	0.0671***	0.0555***	0.0577***	0.0510***	0.0604***	0.0486***	0.0509***
	(0.0133)	(0.0130)	(0.0132)	(0.0133)	(0.0131)	(0.0128)	(0.0130)	(0.0131)
Export				0.0309				0.0100
				(0.0319)				(0.0351)
Firm legal status FE			Yes				Yes	
Observations	4,770	4,770	4,770	4,770	4,770	4,770	4,770	4,770
Number of id	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590

Dependent variable is firm-level formality status and the table reports LIML estimates. The instrumental variables are lagged Chinese tariff rates as well as the respective interaction terms stated in the table. All specifications include year, province and industry dummy variables that are not reported. Additionally, regressions 3 and 7 include dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

4.6.4 Alternative measure of trade liberalization

As an alternative measure of trade liberalization, I employ one-year-lagged industry-level trade ratios, that is the ratio of imports plus exports of each industry relative to the country's GDP for the year prior to a given survey year. The detailed results can be found in table 4.11. The results show that the one-year lagged trade openness indicator is significantly associated with lower firm-level formality rates at the 5%-level across all four baseline specifications, in line with the results for the lagged tariff rates. Additionally, I interact this indicator for trade openness with the regional extent to corruption. Greater trade openness is still statistically significant at the 5%-level and associated with lower-rates of firm-level formality. However, in these specifications, the proxy for corruption, while negative, is insignificant. The interaction term between trade openness and corruption is negative, but only significant for two specifications and only at the 10%-level. As the trade ratios are a more coarse measure of trade liberalization than the tariff rates and potentially endogenous, it is not surprising that the interaction effect with corruption is not significant. Yet, the coefficient in the openness indicator itself confirms the formality decreasing effect of trade liberalization.

Table 4.11: The effect of trade integration and corruption on firm formality

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
One-year lagged openness indicator	-1.588**	-1.586**	-1.406**	-1.574**	-1.732**	-1.732**	-1.544**	-1.719**
	(0.703)	(0.702)	(0.704)	(0.702)	(0.710)	(0.710)	(0.711)	(0.709)
Regional extent of corruption	-0.167***	-0.170***	-0.170***	-0.166***	-0.0825	-0.0855	-0.0877	-0.0811
	(0.0443)	(0.0442)	(0.0441)	(0.0444)	(0.0667)	(0.0668)	(0.0665)	(0.0670)
One-year lagged openness indicator x					-1.468	-1.478*	-1.428	-1.484*
Regional extent of corruption					(0.892)	(0.893)	(0.889)	(0.894)
TFP (Index number)	0.0568***		0.0577***	0.0559***	0.0562***		0.0571***	0.0552***
	(0.0211)		(0.0210)	(0.0212)	(0.0212)		(0.0210)	(0.0213)
TFP (Levinsohn&Petrin)		0.0206**				0.0203**		
		(0.00975)				(0.00973)		
Log number of employees	0.0572***	0.0656***	0.0549***	0.0570***	0.0579***	0.0662***	0.0556***	0.0578***
	(0.0127)	(0.0124)	(0.0127)	(0.0127)	(0.0127)	(0.0124)	(0.0127)	(0.0127)
Export				0.0222				0.0236
				(0.0305)				(0.0304)
Firm legal status FE			Yes				Yes	
Observations	4,770	4,770	4,770	4,770	4,770	4,770	4,770	4,770
Number of id	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590

Dependent variable is firm-level formality status. All specifications include year, province and industry dummy variables that are not reported. Additionally, regressions 3 and 7 include dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

4.6.5 Breakdown of the effect by capital-intensity of the industry

Lastly, I examine whether the impact of trade liberalization on firm-level formality differs between industries with different capital-labor-ratios. To distinguish between different industries, I first separate industries by calculating the industry-level average capital-labor-ratio of firms. Then I classify industries as high- and low-capital-intensity industries if their industry capital-labor-ratio average is above or below the median of all industries. I then compare the regression results without and with interaction term between high and low capital-labor-ratio industries. Notably, 78% of percent of all firms in the more capital-intensive industries are formal, compared to the 59% in the less capital-intensive industries. Intuitively, two interpretations of the capital-intensity of industries is conceivable. First, as Rand and Torm (2012a) suggests, a high capital-labor-ratio could indicate a low mobility of firms and accordingly the effect of trade liberalization and corruption should be stronger. Second, as Svensson (2003) suggests, the capital-labor ratio can be seen as a proxy for future profitability. Therefore, high-capital intensive industries should be more competitive and be less affected by trade liberalization, which also seems supported by the higher share of formal firms in more capital-intensive industries.

The results in table 4.12 indicate that particularly less capital-intensive industries are affected by trade liberalization. The coefficients for these industries mirror both in sign and statistical significance the results for the joint estimation. More capital-intensive industries are not significantly affected by the lagged tariff rates as well as the regional extent of corruption.

One explanation for this finding is that the WTO accession was accompanied by labor-specific regulatory changes that would make formality in less capital-intensive industries more costly. However, as Vogel (2013) reports, the WTO accession of Vietnam was not connected to agreements on labor standards and, as measured through the World Bank's

Doing Business indicators,[15] there has been no major change in labor regulations in Vietnam between 2006 and 2009. Therefore, the finding supports the notion that more capital-intense industries are more competitive, accordingly feature higher formality to start with and will be less adversely affected by trade liberalization.

Table 4.12: Difference in effect of trade liberalization and corruption on firm formality by capital-intensity

	High capital-intensity		Low capital-intensity	
VARIABLES	(1)	(2)	(3)	(4)
One-year lagged tariff	-0.0171	-0.0755	0.0613***	0.0791***
	(0.0365)	(0.0594)	(0.0188)	(0.0218)
Regional extent of corruption	-0.0175	-0.366*	-0.296***	0.190
	(0.0620)	(0.198)	(0.0655)	(0.131)
One-year lagged tariff x		0.0215*		-0.0528***
Regional extent of corruption		(0.0116)		(0.0143)
TFP (Index number)	0.0460	0.0375	0.0313	0.0326
	(0.0307)	(0.0326)	(0.0328)	(0.0326)
Log number of employees	0.0546***	0.0497***	0.0588***	0.0565***
	(0.0166)	(0.0174)	(0.0208)	(0.0205)
Observations	2,555	2,555	1,979	1,979
Number of id	893	893	697	697

Dependent variable is firm-level formality status and the table reports LIML estimates. The instrumental variables are Chinese tariff rates as well as the respective interaction terms stated in the table. All specifications include year, province and industry dummy variables that are not reported. Additionally, regression 3 includes dummy variables for firm legal statuses that are not reported. Heteroskedasticity-robust standard errors clustered at the firm-level are in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

4.7 Conclusion

In this paper I examine the impact of trade on the formal sector in the presence of informality and corruption using a simple heterogeneous firm model and confirm its predictions empirically in a panel data set of Vietnamese SME. The model predicts that while both trade liberalization and corruption decrease the size of the formal sector, the formal sector is actually less responsive to trade in a corrupt economy as trade reduces corruption. There-

[15]Detailed information can be found at http://www.doingbusiness.org/data/exploretopics/labor-market-regulation.

fore, while trade does decrease the formalization of an economy, it also mitigates the effect of corruption as one of the main deterrents of firm formality.

Three extensions of the present work would provide for interesting future work. First, the empirical part of this paper focuses on SME firms and thus the marginal firm deciding on whether to become an informal or formal firm. While this allows me to identify the formality choice of firms and accordingly the selection of firms out of the formal sector, interesting future work could examine the whole spectrum of informal and formal firms, that is considering informal self-employment as well as large firms. That would complement the picture by showing the effects of trade and corruption on aggregate output and employment. Second, in its the current form the model considers a completely inelastic demand structure with fixed prices, which omits an adjustment of prices due to changes in competition. Integrating quasi-linear preferences, would provide for more realistic results, that is implement price adjustments. However, the main driver of the model in the form of competition would still exist and provide for the same qualitative result of a shrinking formal sector and decreasing corruption upon trade liberalization and as a result of increased domestic competition. Third, the model focuses on the formality choice of firms, but does not explicitly model labor markets. An interesting extension of the model could take the present work a step further by considering labor markets and the employment decision of firms in response to trade and corruption jointly.

APPENDIX A

APPENDIX TO CHAPTER 2

A.1 Comparative statics on the relative productivity difference in autarky

I analyze (2.14) in a comparative statics exercise to analyze the effect of the parameters of interest on the relative productivity distance:

$$\begin{aligned}
\frac{\varphi_f^* - \varphi_i^*}{\varphi_f^*} =& 1 - \frac{\varphi_i^*}{\varphi_f^*} = 1 - \left(\frac{f_i}{f_f - f_i}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}} (1-\delta)^{\frac{-\sigma}{\xi}}. \\
\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial f_i} =& \frac{1}{\xi}\left(\frac{f_i}{f_f - f_i}\right)^{\frac{1}{\xi}-1} \left(\frac{f_f}{(f_f - f_i)^2}\right) \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}} (1-\delta)^{\frac{-\sigma}{\xi}} > 0. \\
\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial f_f} =& \frac{1}{\xi}\left(\frac{f_i}{f_f - f_i}\right)^{\frac{1}{\xi}-1} \left(\frac{-f_i}{(f_f - f_i)^2}\right) \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}} (1-\delta)^{\frac{-\sigma}{\xi}} < 0. \\
\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial \delta} =& \left(\frac{f_i}{f_f - f_i}\right)^{\frac{1}{\xi}} \left[\frac{\sigma}{\xi}(1-\delta)^{\frac{-\sigma}{\xi}-1} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}} + \right. \\
& \left. (1-\delta)^{\frac{-\sigma}{\xi}} \frac{\sigma}{\xi}\sigma(1-\delta)^{\sigma-1} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}-1}\right] > 0. \\
\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial \lambda} =& \left(\frac{f_i}{f_f - f_i}\right)^{\frac{1}{\xi}} (1-\delta)^{\frac{-\sigma}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{1}{\xi}-1} (1-\lambda)^{-\xi-1} > 0.
\end{aligned}$$

A.2 Comparative statics on informal relative to formal employment share in autarky

I analyze (2.20) in a comparative statics exercise to analyze the effect of the parameters of interest on the relative employment in the two sectors:

$$
\begin{aligned}
\frac{E_i}{E_f} =& (1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1}\left[\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi}-1\right].\\
\frac{\partial \frac{E_i}{E_f}}{\partial f_i} =& (1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1}\chi\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi-1}\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial f_i}<0.\\
\frac{\partial \frac{E_i}{E_f}}{\partial f_f} =& (1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1}\chi\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi-1}\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial f_f}>0.\\
\frac{\partial \frac{E_i}{E_f}}{\partial \delta} =& -\sigma(1-\delta)^{\sigma-1}(1-\lambda)^{\sigma(1-\theta)-1}\left[\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi}-1\right]+\\
& (1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1}\chi\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi-1}\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial \delta}<0.\\
\frac{\partial \frac{E_i}{E_f}}{\partial \lambda} =& -(\sigma(1-\theta)-1)(1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-2}\left[\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi}-1\right]\\
& +(1-\delta)^{\sigma}(1-\lambda)^{\sigma(1-\theta)-1}\chi\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\chi-1}\frac{\partial \frac{\varphi_i^*}{\varphi_f^*}}{\partial \lambda}<0.
\end{aligned}
$$

A.3 Wage inequality in autarky

First, I compute the Lorenz curve by relating the share of employment to the share of the wage bill. Using the Lorenz curve, I derive the Gini-coefficient.

Purely-formal economy

Share in employment of firms with productivity below $\bar{\varphi}$:
$\gamma_f(\varphi) = \frac{\int_{\varphi_f^*}^{\bar{\varphi}} l_f(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_f^*}^{\infty} l_f(\varphi) g(\varphi) \mathrm{d}\varphi} = 1 - \left(\frac{\bar{\varphi}}{\varphi_f^*}\right)^{\chi}$

Share in wage bill of firms with productivity below $\bar{\varphi}$:
$Q_f(\varphi) = \frac{\int_{\varphi_f^*}^{\bar{\varphi}} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_f^*}^{\infty} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi} = 1 - \left(\frac{\bar{\varphi}}{\varphi_f^*}\right)^{\xi - k}$

The Lorenz curve is $Q_f(\gamma_f) = 1 - (1 - \gamma_f)^{\frac{\xi - k}{\chi}}$ and the Gini-coefficient follows from $G_f = 1 - 2\int_0^1 Q_f(\gamma_f)\mathrm{d}\gamma_f = \frac{\theta}{\theta - 2(\xi - k)}$.

Purely-informal economy

Share in employment of firms with productivity below $\bar{\varphi}$:
$\gamma_i(\varphi) = \frac{\int_{\varphi_i^*}^{\bar{\varphi}} l_i(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\infty} l_i(\varphi) g(\varphi) \mathrm{d}\varphi} = 1 - \left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\chi}$

Share in wage bill of firms with productivity below $\bar{\varphi}$:
$Q_i(\varphi) = \frac{\int_{\varphi_i^*}^{\bar{\varphi}} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\infty} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi} = 1 - \left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\xi - k}$

The Lorenz curve is $Q_i(\gamma_i) = 1 - (1 - \gamma_i)^{\frac{\xi - k}{\chi}}$ and the Gini-coefficient follows from $G_i = 1 - 2\int_0^1 Q_i(\gamma_i)\mathrm{d}\gamma_i = \frac{\theta}{\theta - 2(\xi - k)}$.

As a purely-formal and purely-informal economy have the same Gini-coefficient, they feature the same wage inequality. Because the wage distribution directly depends on the Pareto distribution, productivity dispersion among firms in the economy determines wage inequality, that is $\frac{\partial G_f}{\partial k} = \frac{-2\theta}{[\theta - 2(\xi - k)]^2} < 0$. Hence, wage inequality measured by the Gini coefficient, is increasing in firm productivity dispersion (lower k). As supported by the literature, higher dispersion of firm productivity creates higher wage inequality by spreading out the

range of wages paid in the economy. This is empirically supported by Davis and Haltiwanger (1991) and Faggio et al. (2010) and has theoretically been shown in Helpman et al. (2010) and Egger and Kreickemeier (2012).

Economy with informal and formal sector

I first estimate the Lorenz curve and then derive the Gini-coefficient. However, I have to distinguish between informal and formal workers. The Lorenz curve then consists of two segments. The first share of workers is employed in the informal sector:

Share in employment of firms with productivity below $\bar{\varphi}$:

$$\gamma = \frac{\int_{\varphi_i^*}^{\bar{\varphi}} l_i(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\infty} l_f(\varphi) g(\varphi) \mathrm{d}\varphi} = \frac{(1-\delta)^\sigma \left[1 - \left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^\chi\right]}{\Gamma},$$

where $\Gamma \equiv (1-\delta)^\sigma - \left[(1-\delta)^\sigma - (1-\lambda)^{-\xi+\theta}\right] \left(\frac{\varphi_f^*}{\varphi_i^*}\right)^\chi$.

Share in wage bill of firms with productivity below $\bar{\varphi}$:

$$Q_i = \frac{\int_{\varphi_i^*}^{\bar{\varphi}} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\infty} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi} = \frac{(1-\delta)^\sigma \left[1 - \left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\xi-k}\right]}{\Delta},$$

where $\Delta \equiv (1-\delta)^\sigma - \left[(1-\delta)^\sigma - (1-\lambda)^{-\xi}\right] \left(\frac{\varphi_f^*}{\varphi_i^*}\right)^{\xi-k}$.

The first segment of the Lorenz curve is $Q_i(\gamma) = \frac{(1-\delta)^\sigma}{\Delta} \left[1 - \left[1 - \frac{\gamma\Gamma}{(1-\delta)^\sigma}\right]^{\frac{\xi-k}{\chi}}\right]$.

Second, including workers employed in the formal sector:

Share in employment of firms with productivity below $\bar{\varphi}$:

$$\gamma = \frac{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\bar{\varphi}} l_f(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\infty} l_f(\varphi) g(\varphi) \mathrm{d}\varphi} = 1 - \frac{\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^\chi (1-\lambda)^{-\xi+\theta}}{\Gamma}$$

Share in wage bill of firms with productivity below $\bar{\varphi}$:

$$Q_f = \frac{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\bar{\varphi}} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\infty} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi} = 1 - \frac{\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\xi-k} (1-\lambda)^{-\xi}}{\Delta}$$

The second segment of the Lorenz curve is $Q_f(\gamma) = 1 - \frac{(1-\lambda)^{-\xi}}{\Delta}\left[\frac{(1-\gamma)\Gamma}{(1-\lambda)^{-\xi+\theta}}\right]^{\frac{\xi-k}{\chi}}$.

Jointly, the Lorenz curve is described by $Q(\gamma) = \begin{cases} Q_i(\gamma) \text{ if } \gamma \in [0, b_i) \\ Q_f(\gamma) \text{ if } \gamma \in [b_i, 1] \end{cases}$,

where $b_i = \frac{(1-\delta)^{\sigma}\left[1-\left(\frac{\varphi_f^*}{\varphi_i^*}\right)^{\chi}\right]}{\Gamma}$ is the share of workers employed in the informal sector.

The Lorenz curve $Q(\gamma)$ has the desired properties $Q_i(b_i) = Q_f(b_i)$, $Q(0) = 0$, $Q(1) = 1$ and $\frac{\partial Q(\gamma)}{\partial \gamma} > 0$.

The Gini-coefficient follows from $G = 1 - 2\int_0^1 Q(\gamma)\mathrm{d}\gamma$:
$G = G_f\left[1 + \frac{2\phi^{k-\xi}}{\theta\Gamma\Delta}\left\{\chi\left[\Upsilon - \Xi\phi^{\theta} + [\Xi - \Upsilon]\,\phi^{-\chi}\right] + \theta\Upsilon\left[1 - \phi^{-\chi}\right]\right\}\right]$, where $\phi \equiv \frac{\varphi_i^*}{\varphi_f^*} \in (0,1)$.

$G > G_f$ if $\frac{\chi}{-\theta}\left[1 + \frac{\Xi}{\Upsilon}\frac{\left[\phi^{-\chi} - \phi^{\theta}\right]}{\left[1-\phi^{-\chi}\right]}\right] - 1 > 0$.

Hence, I analyze $f(\phi) = \frac{\chi}{-\theta}\left[1 + \frac{\Xi}{\Upsilon}\frac{\left[\phi^{-\chi} - \phi^{\theta}\right]}{\left[1-\phi^{-\chi}\right]}\right] - 1$ for $\phi \in (0,1)$

$\lim_{\phi\to 0} f(\phi) = \frac{k-\xi}{\theta} > 0$

Using L'hôpital's rule, it is clear that $\lim_{x\to c}\frac{g(\phi)}{h(\phi)} = \lim_{x\to c}\frac{g'(\phi)}{h'(\phi)}$. Hence, $\lim_{\phi\to 1} f(\phi) = \frac{k-\xi}{\theta} - \frac{\chi}{\theta}\frac{\Xi}{\Upsilon}\lim_{\phi\to 1}\left[-1 - \frac{\theta}{\chi}\phi^{\chi+\theta}\right] = \frac{k-\xi}{\theta}\left[\frac{\Upsilon-\Xi}{\Upsilon}\right] > 0$.

Lastly, I show that $f(\phi)$ is strictly monotone in $\phi \in (0,1)$. Using the L'hôpital's monotonicity rule,[1] it is clear that $\frac{g(\phi)}{h(\phi)}$ is strictly monotone in ϕ if $\frac{g'(\phi)}{h'(\phi)}$ is strictly monotone in ϕ on (a,b) with $f(a) = g(a) = 0$ or $f(b) = g(b) = 0$. Accordingly, I find $\frac{\partial\left(\frac{f'(\phi)}{g'(\phi)}\right)}{\partial\phi} = \frac{\Xi}{\Upsilon}(\xi - k)\phi^{\theta+\chi-1} < 0$.

As $f(\phi)$ is strictly monotone and > 0 in $\phi \in (0,1)$, the Gini-coefficient of the economy with informality is strictly larger than the one of a purely-formal economy. That means independent of its size, the existence of an informal sector increases wage inequality among ex-ante identical workers. Intuitively, the two-sector economy wage distribution is characterized by a

[1] See Lemma 2.2 in Anderson et al. (1993) for a detailed explanation and proof of the L'hôpital's monotonicity rule.

discrete jump in the form of an informal sector wage gap. As part of the population receives a lower wage, not just because of the firm productivity dispersion, but also because of the wage gap, wage inequality has to be higher.

A.4 Comparative statics on the relative productivity difference with trade

I analyze (2.28) in a comparative statics exercise to analyze the effect of the parameters of interest on the relative productivity distance:

$$\begin{aligned}
\frac{\varphi_x^* - \varphi_f^*}{\varphi_x^*} = 1 - \frac{\varphi_f^*}{\varphi_x^*} =& 1 - \left(\frac{(f_f - f_i)n\tau^{1-\sigma}}{f_x}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1}. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial f_i} =& -\frac{(f_f - f_i)^{\frac{1}{\xi}-1}}{\xi} \left(\frac{n\tau^{1-\sigma}}{f_x}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1} < 0. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial f_f} =& \frac{(f_f - f_i)^{\frac{1}{\xi}-1}}{\xi} \left(\frac{n\tau^{1-\sigma}}{f_x}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1} > 0. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial f_x} =& -\frac{f_x^{-\frac{1}{\xi}-1}}{\xi} \left((f_f - f_i)n\tau^{1-\sigma}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1} < 0. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial \tau} =& \frac{(1-\sigma)\tau^{\frac{1-\sigma-\xi}{\xi}}}{\xi} \left(\frac{(f_f - f_i)n}{f_x}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1} < 0. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial n} =& \frac{n^{\frac{1}{\xi}-1}}{\xi} \left(\frac{(f_f - f_i)\tau^{1-\sigma}}{f_x}\right)^{\frac{1}{\xi}} \left((1-\lambda)^{-\xi} - (1-\delta)^{\sigma}\right)^{\frac{-1}{\xi}} (1-\lambda)^{-1} > 0. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial \delta} =& \left(\frac{(f_f - f_i)n\tau^{1-\sigma}}{f_x}\right)^{\frac{1}{\xi}} (1-\lambda)^{-1} (\frac{-\sigma}{\xi})(1-\delta)^{\sigma-1} \left((1-\lambda)^{-\xi} - (1-\delta)\right)^{\frac{-1}{\xi}-1} < 0. \\
\frac{\partial \frac{\varphi_f^*}{\varphi_x^*}}{\partial \lambda} =& \left(\frac{\varphi_i^*}{\varphi_f^*}\right) (1-\lambda)^{-1} \frac{1}{((1-\delta)^{\sigma}/(1-\lambda)^{-\xi}) - 1} < 0.
\end{aligned}$$

A.5 Wage inequality with trade

I first estimate the Lorenz curve and then derive the Gini-coefficient. For this Gini-coefficient I have to distinguish three segments: informal workers, formal workers and export firm workers. Accordingly, the Lorenz curve consists of three segments. The first share of workers is employed in the informal sector:

Share in employment of firms with productivity below $\bar{\varphi}$:

$$\gamma = \frac{\int_{\varphi_i^*}^{\bar{\varphi}} l_i(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_x^*}^{\infty} l_x(\varphi) g(\varphi) \mathrm{d}\varphi} = \frac{(1-\delta)^{\sigma}\left[1-\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\chi}\right]}{\Gamma+\Psi},$$

where $\Gamma \equiv (1-\delta)^{\sigma} - \left[(1-\delta)^{\sigma} - (1-\lambda)^{-\xi+\theta}\right]\left(\frac{\varphi_f^*}{\varphi_i^*}\right)^{\chi}$ and

$\Psi = (1-\lambda)^{-\xi+\theta} n \tau^{1-\sigma}\left(\frac{\varphi_x^*}{\varphi_i^*}\right)^{\chi}$.

Share in wage bill of firms with productivity below $\bar{\varphi}$:

$$Q_1 = \frac{\int_{\varphi_i^*}^{\bar{\varphi}} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_x^*}^{\infty} l_x(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi} = \frac{(1-\delta)^{\sigma}\left[1-\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\xi-k}\right]}{\Delta+\Omega},$$

where $\Delta \equiv (1-\delta)^{\sigma} - \left[(1-\delta)^{\sigma} - (1-\lambda)^{-\xi}\right]\left(\frac{\varphi_f^*}{\varphi_i^*}\right)^{\xi-k}$ and $\Omega = (1-\lambda)^{-\xi} n \tau^{1-\sigma}\left(\frac{\varphi_x^*}{\varphi_i^*}\right)^{\xi-k}$.

The first segment of the Lorenz curve is $Q_1(\gamma) = \frac{(1-\delta)^{\sigma}}{\Delta+\Omega}\left[1 - \left[1 - \frac{\gamma[\Gamma+\Psi]}{(1-\delta)^{\sigma}}\right]^{\frac{\xi-k}{\chi}}\right]$.

Second, including formal workers:

Share in employment of firms with productivity below $\bar{\varphi}$:

$$\gamma = \frac{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\bar{\varphi}} l_f(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_x^*}^{\infty} l_x(\varphi) g(\varphi) \mathrm{d}\varphi} = \frac{\Gamma - (1-\lambda)^{-\xi+\theta}\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\chi}}{\Gamma+\Psi}$$

Share in wage bill of firms with productivity below $\bar{\varphi}$:

$$Q_2 = \frac{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\bar{\varphi}} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi) w_i(\varphi) g(\varphi) \mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi} + \int_{\varphi_x^*}^{\infty} l_x(\varphi) w_f(\varphi) g(\varphi) \mathrm{d}\varphi = \frac{\Delta - (1-\lambda)^{-\xi}\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\xi-k}}{\Delta+\Omega}$$

The second segment of the Lorenz curve is $Q_2(\gamma) = \frac{\Delta - (1-\lambda)^{-\xi}\left[\frac{\Gamma-\gamma(\Gamma+\Psi)}{(1-\lambda)^{-\xi+\theta}}\right]^{\frac{\xi-k}{\chi}}}{\Delta+\Omega}$.

Third, including workers employed in exporting firms:

Share in employment of firms with productivity below $\bar{\varphi}$:
$\gamma = \frac{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_x^*}^{\bar{\varphi}} l_x(\varphi)g(\varphi)\mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_x^*}^{\infty} l_x(\varphi)g(\varphi)\mathrm{d}\varphi} = \frac{1-(1+n\tau^{1-\sigma})(1-\lambda)^{-\xi+\theta}\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\chi}}{\Gamma+\Psi}$

Share in wage bill of firms with productivity below $\bar{\varphi}$:
$Q_3 = \frac{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)w_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi)w_f(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_x^*}^{\bar{\varphi}} l_x(\varphi)w_f(\varphi)g(\varphi)\mathrm{d}\varphi}{\int_{\varphi_i^*}^{\varphi_f^*} l_i(\varphi)w_i(\varphi)g(\varphi)\mathrm{d}\varphi + \int_{\varphi_f^*}^{\varphi_x^*} l_f(\varphi)w_f(\varphi)g(\varphi)\mathrm{d}\varphi} + \int_{\varphi_x^*}^{\infty} l_x(\varphi)w_f(\varphi)g(\varphi)\mathrm{d}\varphi = 1 - \frac{(1+n\tau^{1-\sigma})(1-\lambda)^{-\xi}\left(\frac{\bar{\varphi}}{\varphi_i^*}\right)^{\xi-k}}{\Delta+\Omega}$

The last segment of the Lorenz curve is $Q_3(\gamma) = 1 - \frac{(1+n\tau^{1-\sigma})(1-\lambda)^{-\xi}}{\Delta+\Omega}\left[\frac{(1-\gamma)(\Gamma+\Psi)}{(1-\lambda)^{-\xi+\theta}(1+n\tau^{1\sigma})}\right]^{\frac{\xi-k}{\chi}}$.

Jointly, the Lorenz curve is described by $Q(\gamma) = \begin{cases} Q_1(\gamma) \text{ if } \gamma \in [0, b_i) \\ Q_2(\gamma) \text{ if } \gamma \in [b_i, b_f) \\ Q_3(\gamma) \text{ if } \gamma \in [b_f, 1] \end{cases}$,

where $b_i = \frac{(1-\delta)^{\sigma}\left[1-\left(\frac{\varphi_f^*}{\varphi_i^*}\right)^{\chi}\right]}{\Gamma+\Psi}$ is the share of workers employed in the informal sector and $b_f = \frac{\Gamma-(1-\lambda)^{-\xi+\theta}\left(\frac{\varphi_x^*}{\varphi_i^*}\right)}{\Gamma+\Psi}$ is the share of workers employed in non-exporting firms.

The Lorenz curve $Q(\gamma)$ has the desired properties $Q_1(b_1) = Q_2(b_1)$, $Q_2(b_2) = Q_3(b_2)$, $Q(0) = 0$, $Q(1) = 1$ and $\frac{\partial Q(\gamma)}{\partial \gamma} > 0$. The Gini-coefficient follows from $G = 1 - 2\int_0^1 Q(\gamma)\mathrm{d}\gamma$:

$$\begin{aligned} G =& G_f\Big[1 + \frac{2\phi^{k-\xi}}{\theta(\Gamma+\Psi)(\Delta+\Omega)}\big\{\chi\left[\Upsilon - \Xi\phi^{\theta} + [\Xi - \Upsilon]\,\phi^{-\chi} + \right. \\ & (1-\lambda)^{-2\xi+\theta}n\tau^{1-\sigma}\left[\mu^{-\chi}\phi^{k-\xi} - \mu^{k-\xi}\phi^{-\chi}\right] + \mu^{k-\xi}(1-\delta)^{\sigma}(1-\lambda)^{-\xi}n\tau^{1-\sigma}\left[\phi^{-\chi} - 1\right] + \\ & \mu^{-\chi}(1-\delta)^{\sigma}(1-\lambda)^{-\xi+\theta}n\tau^{1-\sigma}\left[1 - \phi^{k-\xi}\right] \\ & \left. +\theta\left[\Upsilon\left[1-\phi^{-\chi}\right] + (1-\lambda)^{-2\xi+\theta}n\tau^{1-\sigma}\mu^{k-\xi-\chi}\phi^{k-\xi}\right]\big\}\Big] \end{aligned}$$

, where $\mu \equiv \frac{\varphi_i^*}{\varphi_x^*}$.

Table A.1: Economy parameters for two scenarios.

		Scenario 1	Scenario 2	Scenario 3
Total workforce	L	1.0	1.0	1.0
Elasticity of substitution	σ	3.8	2.3	5.95
Pareto distribution parameter	k	3.4	3.5	4.0
Formal fixed cost	f_f	1.0	1.2	3.0
Informal fixed cost	f_i	0.3	0.5	0.7
Exporting fixed cost	f_x	1.5	3.0	4.0
Fairness parameter	θ	0.5	0.4	0.2
Productivity bonus	λ	0.5	0.3	0.1
Iceberg transportation cost	τ	1.7	1.4	2.5
Number of foreign countries	n	5	1	10
Probability of detection	δ	0.0	0.0	0.0

A.6 Numerical simulation for the key variables

Because of the complexity of the equations, I show that the aggregate output of the informal sector, formal sector and entire economy, and the formal and total employment can increase or decrease upon trade liberalization. To do this I compute the numerical value of the key variables in autarky and upon trade liberalization for three scenarios with different economy parameters within the assumptions of the model, as summarized in table B.1. I then calculate the ratio of the trade variable relative to the respective autarky variable and show that the ratio can be greater or less than 1.

The parameter specifications in table B.1 are within the following constraints of the various Propositions and assumptions of the model:

- $\frac{(1-\lambda)^{-\xi}}{(1-\delta)^{\sigma}} < \frac{f_f}{f_i}$
- $\frac{k+1-\theta}{1-\theta} > \sigma > \frac{1}{1-\theta}$
- $\frac{f_x \tau^{\frac{\xi}{1-\theta}}}{n(1-\lambda)^{-\xi}} > \frac{f_f - f_i}{(1-\lambda)^{-\xi} - (1-\delta)^{\sigma}}$

The equations for the key variables are as follows:

$$\frac{E_{(t)}}{E_{(a)}} = \left[1 + n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-\theta}{\xi}}$$
$$\left[1 + \frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{((1-\lambda)^{-\xi}-(1-\delta)^{\sigma})^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{\theta}{\xi}-1}$$
$$\left[1 + \frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{\theta+k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-\theta-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-\theta-k)}{\xi}}}{((1-\lambda)^{-\xi+\theta}-(1-\delta)^{\sigma})((1-\lambda)^{-\xi}-(1-\delta)^{\sigma})^{\frac{\theta+k-\xi}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{\theta+k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-\theta-k)}{\xi}}+(1-\delta)^{\sigma}}\right].$$

$$\frac{E_{f(t)}}{E_{f(a)}} = \left[1 + n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-\theta}{\xi}}$$
$$\left[1 + \frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{((1-\lambda)^{-\xi}-(1-\delta)^{\sigma})^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{\theta}{\xi}-1}$$
$$\left[1 + n\tau^{1-\sigma}\left(\left(\frac{(f_f-f_i)n\tau^{1-\sigma}}{f_x}\right)^{\frac{-1}{\xi}}\left((1-\lambda)^{-\xi}-(1-\delta)^{\sigma}\right)^{\frac{1}{\xi}}(1-\lambda)\right)^{\chi}\right].$$

$$\frac{E_{i(t)}}{E_{i(a)}} = \left[1 + n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-\theta}{\xi}}$$
$$\left[1 + \frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{((1-\lambda)^{-\xi}-(1-\delta)^{\sigma})^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{\theta}{\xi}-1}.$$

$$\frac{(E_i\bar{w}_i + E_f\bar{w}_f)_{(t)}}{(E_i\bar{w}_i + E_f\bar{w}_f)_{(a)}} = \left[1 + n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-k}{\xi(k+1)}}$$
$$\left[1 + \frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{((1-\lambda)^{-\xi}-(1-\delta)^{\sigma})^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{\xi+k}{\xi(k+1)}},$$

where $\frac{Y_{(t)}}{Y_{(a)}} = \frac{(E_i\bar{w}_i+E_f\bar{w}_f)_{(t)}}{(E_i\bar{w}_i+E_f\bar{w}_f)_{(a)}}$.

$$\frac{(E_f\bar{w}_f)_{(t)}}{(E_f\bar{w}_f)_{(a)}} = \left[1+n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-k}{\xi(k+1)}} \left[1+\frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{\left((1-\lambda)^{-\xi}-(1-\delta)^{\sigma}\right)^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{k(1-\xi)}{\xi(k+1)}} \left[1+n\tau^{1-\sigma}\left(\left(\frac{(f_f-f_i)n\tau^{1-\sigma})}{f_x}\right)^{\frac{-1}{\xi}}\left((1-\lambda)^{-\xi}-(1-\delta)^{\sigma}\right)^{\frac{1}{\xi}}(1-\lambda)\right)^{\xi-k}\right],$$

where $Y_f = \frac{E_f\bar{w}_f L}{\rho}$ and $\frac{Y_{f(t)}}{Y_{f(a)}} = \frac{(E_f\bar{w}_f)_{(t)}}{(E_f\bar{w}_f)_{(a)}}$.

$$\frac{(E_i\bar{w}_i)_{(t)}}{(E_i\bar{w}_i)_{(a)}} = \left[1+n\left(\frac{f_x}{f_i n\tau^{1-\sigma}}\right)^{\frac{-k}{\xi}}(1-\lambda)^{-k}(1-\delta)^{\frac{-k\sigma}{\xi}}\right]^{\frac{-k}{\xi(k+1)}} \left[1+\frac{(1-\lambda)^{-k}(n\tau^{1-\sigma})^{\frac{k}{\xi}}\left(\frac{f_x}{f_i}\right)^{\frac{\xi-k}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}}{\left((1-\lambda)^{-\xi}-(1-\delta)^{\sigma}\right)^{\frac{k}{\xi}}\left(\frac{f_i}{f_f-f_i}\right)^{\frac{k-\xi}{\xi}}(1-\delta)^{\frac{\sigma(\xi-k)}{\xi}}+(1-\delta)^{\sigma}}\right]^{\frac{k(1-\xi)}{\xi(k+1)}},$$

where $Y_i = \frac{E_i\bar{w}_i L}{\rho}$ and $\frac{Y_{i(t)}}{Y_{i(a)}} = \frac{(E_i\bar{w}_i)_{(t)}}{(E_i\bar{w}_i)_{(a)}}$.

$$G_{(a)} = G_f\left[1+\frac{2\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{k-\xi}}{\theta\Gamma\Delta}\left\{\chi\left[\Upsilon-\Xi\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{\theta}+[\Xi-\Upsilon]\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\chi}\right]+\theta\Upsilon\left[1-\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\chi}\right]\right\}\right].$$

$$
\begin{aligned}
G_{(t)} =& G_f \Bigg[1 + \frac{2\phi^{k-\xi}}{\theta(\Gamma+\Psi)(\Delta+\Omega)} \Big\{\chi\left[\Upsilon - \Xi\phi^{\theta} + [\Xi - \Upsilon]\,\phi^{-\chi} + \right. \\
& (1-\lambda)^{-2\xi+\theta} n\tau^{1-\sigma}\left[\mu^{-\chi}\phi^{k-\xi} - \mu^{k-\xi}\phi^{-\chi}\right] \\
& + \mu^{k-\xi}(1-\delta)^{\sigma}(1-\lambda)^{-\xi} n\tau^{1-\sigma}\left[\phi^{-\chi} - 1\right] + \\
& \mu^{-\chi}(1-\delta)^{\sigma}(1-\lambda)^{-\xi+\theta} n\tau^{1-\sigma}\left[1 - \phi^{k-\xi}\right] \\
& \left. + \theta\left[\Upsilon\left[1-\phi^{-\chi}\right] + (1-\lambda)^{-2\xi+\theta} n\tau^{1-\sigma}\mu^{k-\xi-\chi}\phi^{k-\xi}\right]\Big\}\Bigg].
\end{aligned}
$$

The results are summarized in table A.2. The three scenarios highlight the different impact that trade liberalization has, given the various economic parameters. In scenario 1, total employment, formal employment and aggregate formal output increase, while informal employment, aggregate informal output, total aggregate output and the Gini-coefficient decrease. In scenario 2, formal employment, aggregate informal output, aggregate formal output, total aggregate output and the Gini-coefficient increase, while informal and total employment decrease. Lastly, scenario 3 leads to yet another outcome upon trade liberalization. Employment and aggregate output of all sectors and the entire economy decrease, but the Gini-coefficient increases. Hence, the effect of trade liberalization on all variables, except for informal employment, is ambiguous and depends on the parameters of the economy.

Table A.2: Numerical results of the key variables with trade liberalization relative to autarky.

	Scenario 1	Scenario 2	Scenario 3
$E_{(t)}/E_{(a)}$	1.11241	0.99977	0.99346
$E_{f(t)}/E_{f(a)}$	1.25219	1.09506	0.98681
$E_{i(t)}/E_{i(a)}$	0.67790	0.99947	0.89984
$Y_{(t)}/Y_{(a)}$	0.66809	1.00097	0.99051
$Y_{f(t)}/Y_{f(a)}$	1.45032	4.41278	0.99576
$Y_{i(t)}/Y_{i(a)}$	0.59766	1.00005	0.89783
$G_{(t)}/G_{(a)}$	0.91485	1.00796	1.00033

APPENDIX B

APPENDIX TO CHAPTER 3

B.1 Share of unregistered relative to registered products

$$\left(\frac{\beta_i^*(\varphi)}{\beta_f^*(\varphi)}\right)^{-k} - 1 = \left[\frac{f_i}{f_f - f_i}\right]^{\frac{-k}{\sigma-1}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-k}{\sigma-1}} - 1.$$

$$\frac{\partial\left(\frac{\beta_i^*(\varphi)}{\beta_f^*(\varphi)}\right)^{-k}-1}{\partial f_i} = \left[\frac{-k}{\sigma-1}\right] \left[\frac{f_f}{(f_f-f_i)^2}\right] \left[\frac{f_i}{f_f-f_i}\right]^{\frac{-k}{\sigma-1}-1} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-k}{\sigma-1}} < 0.$$

$$\frac{\partial\left(\frac{\beta_i^*(\varphi)}{\beta_f^*(\varphi)}\right)^{-k}-1}{\partial f_f} = \left[\frac{k}{\sigma-1}\right] \left[\frac{f_i}{(f_f-f_i)^2}\right] \left[\frac{f_i}{f_f-f_i}\right]^{\frac{-k}{\sigma-1}-1} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-k}{\sigma-1}} > 0.$$

$$\frac{\partial\left(\frac{\beta_i^*(\varphi)}{\beta_f^*(\varphi)}\right)^{-k}-1}{\partial \lambda} = -k \left[\frac{f_i}{f_f-f_i}\right]^{\frac{-k}{\sigma-1}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-k}{\sigma-1}-1} (1-\lambda)^{-\sigma}(1-\delta)^{-\sigma} < 0.$$

$$\frac{\partial\left(\frac{\beta_i^*(\varphi)}{\beta_f^*(\varphi)}\right)^{-k}-1}{\partial \delta} = \left[\frac{-k\sigma}{\sigma-1}\right] \left[\frac{f_i}{f_f-f_i}\right]^{\frac{1}{\sigma-1}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-k}{\sigma-1}-1} (1-\lambda)^{1-\sigma}(1-\delta)^{-\sigma-1} < 0.$$

B.2 Share of informal relative to formal firms

$$\left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1 = \left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}} \left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} - 1.$$

$$\frac{\partial \left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1}{\partial F_i} = -\frac{\alpha}{k}\left[\frac{F_f}{(F_f - F_i)^2}\right]\left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}-1}\left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} < 0.$$

$$\frac{\partial \left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1}{\partial F_f} = \frac{\alpha}{k}\left[\frac{F_i}{(F_f - F_i)^2}\right]\left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}-1}\left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} > 0.$$

$$\frac{\partial \left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1}{\partial f_i} = \left[\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}\right]\left[\frac{f_f}{(f_f - f_i)^2}\right]\left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}}\left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}-1} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} < 0$$

$$\frac{\partial \left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1}{\partial f_f} = \left[\frac{\alpha(k+1-\sigma)}{(\sigma-1)k}\right]\left[\frac{f_i}{(f_f - f_i)^2}\right]\left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}}\left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}-1} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} > 0.$$

$$\frac{\partial \left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1}{\partial \lambda} = -\alpha\left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}}\left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}-1} (1-\lambda)^{-\sigma}(1-\delta)^{-\sigma} < 0.$$

$$\frac{\partial \left(\frac{\varphi_i^*}{\varphi_f^*}\right)^{-\alpha} - 1}{\partial \delta} = \left[\frac{-\alpha\sigma}{\sigma-1}\right]\left[\frac{F_i}{F_f - F_i}\right]^{-\frac{\alpha}{k}}\left[\frac{f_i}{f_f - f_i}\right]^{\frac{-\alpha(k+1-\sigma)}{(\sigma-1)k}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}-1} (1-\lambda)^{1-\sigma}(1-\delta)^{-\sigma-1} < 0.$$

B.3 Product-Gini of formal firms

The first segment of the Lorenz curve consists of unregistered products. Therefore, I first derive the number of products produced with a product skill below $\bar{\beta}$:

$$\gamma = \frac{\int_{\beta_i^*(\varphi)}^{\bar{\beta}} \beta z(\beta) \mathrm{d}\beta}{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} \beta z(\beta) \mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} \beta z(\beta) \mathrm{d}\beta} = 1 - \left(\frac{\bar{\beta}}{\beta_i^*(\varphi)} \right)^{-k}. \tag{B.1}$$

The next step is calculating the share in revenue of unregistered products that are produced with a product skill below $\bar{\beta}$:

$$Q_1 = \frac{\int_{\beta_i^*(\varphi)}^{\bar{\beta}} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta}{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta} = \frac{(1-\delta)^\sigma}{\Omega} \left[1 - \left(\frac{\bar{\beta}}{\beta_i^*(\varphi)} \right)^{\sigma-k-1} \right], \tag{B.2}$$

where $\phi \equiv (\beta_i^*(\varphi)/\beta_f^*(\varphi))$ and $\Omega \equiv \left[(1-\delta)^\sigma + \phi^{k+1-\sigma} \left[(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma \right] \right]$. Combining (B.1) and (B.2) leads to the first segment of the Lorenz curve $Q_1(\gamma)$:

$$Q_1(\gamma) = \frac{(1-\delta)^\sigma}{\Omega} \left[1 - [1-\gamma]^{\frac{k+1-\sigma}{k}} \right]. \tag{B.3}$$

The second segment of the Lorenz curve consists of registered products. The number of products produced with product skill below $\bar{\beta}$ are

$$\gamma = \frac{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} \beta z(\beta) \mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\bar{\beta}} \beta z(\beta) \mathrm{d}\beta}{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} \beta z(\beta) \mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} \beta z(\beta) \mathrm{d}\beta} = 1 - \left(\frac{\bar{\beta}}{\beta_i^*(\varphi)} \right)^{-k}. \tag{B.4}$$

Subsequently, I calculate the share in revenue of products produced with product skill below $\bar{\beta}$:

$$Q_2 = \frac{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\bar{\beta}} r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta}{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta} = 1 - \frac{(1-\lambda)^{1-\sigma}}{\Omega} \left(\frac{\bar{\beta}}{\beta_i^*(\varphi)} \right)^{\sigma-k-1}. \tag{B.5}$$

Combining (B.4) and (B.5), leads to the second segment of the Lorenz curve $Q_2(\gamma)$:

$$Q_2(\gamma) = 1 - \frac{(1-\lambda)^{1-\sigma}}{\Omega} [1-\gamma]^{\frac{k+1-\sigma}{k}}. \tag{B.6}$$

Jointly, the Lorenz curve is described by

$$Q(\gamma) = \begin{cases} Q_1(\gamma) \text{ if } \gamma \in [0, b) \\ \\ Q_2(\gamma) \text{ if } \gamma \in [b, 1] \end{cases}, \tag{B.7}$$

where $b = 1 - \phi^k$ is the share of unregistered products produced by a firm. The Lorenz curve $Q(\gamma)$ has the desired properties $Q(0) = 0$, $Q(1) = 1$, $Q_1(b) = Q_2(b)$ and $\frac{\partial Q(\gamma)}{\partial \gamma} > 0$. The Gini-coefficient follows from $G_f = 1 - 2\int_0^1 Q(\gamma)\mathrm{d}\gamma$:

$$G_f = G_i \left\{ \frac{2}{\Omega(\sigma - 1)} \left[\frac{2k + 1 - \sigma}{2} \left[\Omega - 2\phi^k \left[(1 - \delta)^{\sigma - 1} + \Omega \right] \right] \right. \right.$$
$$\left. \left. -\phi^{1+2k-\sigma} k \left[(1 - \lambda)^{1-\sigma} - (1 - \delta)^{\sigma - 1} \right] - (1 - \delta)^{\sigma - 1} (\sigma - 1 - k) \right] \right\}.$$

B.4 Herfindahl index of formal firms

The revenue share of an unregistered product that is produced with product skill β of total firm revenue is

$$s_1(\beta) = \frac{r_i(\varphi,\beta)}{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} r_i(\varphi,\beta)z(\beta)\mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} r_f(\varphi,\beta)z(\beta)\mathrm{d}\beta} = (1-\delta)^{\sigma}\frac{k+1-\sigma}{k}\beta_i^*(\varphi)^{1+k-\sigma}\Omega^{-1}\beta^{\sigma-1}. \tag{B.8}$$

Moreover, the revenue share of a registered product that is produced with product skill β of total firm revenue is

$$s_2(\beta) = \frac{r_f(\varphi,\beta)}{\int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} r_i(\varphi,\beta)z(\beta)\mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} r_f(\varphi,\beta)z(\beta)\mathrm{d}\beta} = (1-\lambda)^{1-\sigma}\frac{k+1-\sigma}{k}\beta_i^*(\varphi)^{1+k-\sigma}\Omega^{-1}\beta^{\sigma-1}. \tag{B.9}$$

The Herfindahl index results from the combination of the two:

$$H_f = \int_{\beta_i^*(\varphi)}^{\beta_f^*(\varphi)} s_1(\beta)^2 z(\beta)\mathrm{d}\beta + \int_{\beta_f^*(\varphi)}^{\infty} s_2(\beta)^2 z(\beta)\mathrm{d}\beta = H\beta_i^*(\varphi)^k\Omega^{-2}\omega,$$

where $\omega \equiv (1-\delta)^{2\sigma} + \phi^{k+2-2\sigma}\left[(1-\lambda)^{2-2\sigma} - (1-\delta)^{2\sigma}\right]$.

B.5 International trade

In this section I consider an extension of the model featuring international trade. Consider a world of $n+1$ symmetric countries. Besides informality and formality, firms can choose to export a share of their products to n countries. Export activities require the firm-level fixed costs $F_x > F_f$ to reflect the findings of Roberts and Tybout (1997) that fixed costs are critical determinants of export participation. Intuitively, firms need not just register their firm, but face additional costs and time requirements to comply with firm-level export regulations. Given the mounting empirical evidence on the exclusion of informal firms from international trade (Batra et al., 2003; Bigsten et al., 2004; La Porta and Shleifer, 2008), I proceed with the assumption that the registration for exporting entails an intense government screening that leads to the probability of government enforcement $\delta = 1$ and accordingly renders informal production economically infeasible. To model the product registration requirement and learning about export markets, I assume that firms incur a fixed cost $f_x > f_f$ for each exported product at the product-level. The transportation of products to foreign markets is costly and modeled as variable iceberg cost $\tau > 1$, that is for one good to arrive at the destination country, τ goods have to be shipped. The product-level profits for exported goods are therefore described by

$$\pi_x(\varphi, \beta) = n\tau^{1-\sigma}\frac{R}{\sigma}\left(\rho P\frac{\varphi}{1-\lambda}\beta\right)^{\sigma-1} - f_x. \tag{B.10}$$

As firms have different product skills for the individual products they produce, this poses the question which products will be exported. The empirical literature provides an answer to this question (e.g. Iacovone and Javorcik, 2008; Bernard et al., 2011): core products, i.e. the products the firm has the highest product skill in, are sold both at home and abroad. Peripheral products, i.e. products that the firm has a low product skill in, are sold only at home. Mathematically, if $f_f < \frac{f_x\tau^{\sigma-1}}{n}$, then firms export high-product skill products and sell

low-product skill products only domestically.[1] The condition corresponds to the firm-level condition for export participation in Melitz (2003) and Bernard et al. (2011).[2]

The firm-level profits and product skill threshold levels for informal and formal firms and important assumptions are as described in section 3.2.2. Exporting firms, however, cannot produce goods informally. Therefore, the product skill threshold levels for domestic and exported products $\beta_t^*(\varphi)$ and $\beta_x^*(\varphi)$, respectively, of exporting firms are determined by

$$\pi_f(\varphi, \beta_t^*(\varphi)) = 0 \tag{B.11}$$

and

$$\pi_x(\varphi, \beta_x^*(\varphi)) = 0. \tag{B.12}$$

Notably, $\beta_t^*(\varphi)$ differs from $\beta_f^*(\varphi)$ in that $\beta_t^*(\varphi)$ is the threshold at which formal production is economically feasible, whereas $\beta_f^*(\varphi)$ defines the threshold at which formal production is more profitable than informal production of a product. Total profit of exporting firms therefore is

$$\begin{aligned}\pi_x(\varphi) = &\int_{\beta_t^*(\varphi)}^{\infty} \left[\frac{R}{\sigma}\left(\rho P \frac{\varphi}{1-\lambda}\beta\right)^{\sigma-1} - f_f\right] z(\beta)\mathrm{d}\beta - F_f \\ &+ \int_{\beta_x^*(\varphi)}^{\infty} \left[\frac{n\tau^{1-\sigma}R}{\sigma}\left(\rho P \frac{\varphi}{1-\lambda}\beta\right)^{\sigma-1} - f_x\right] z(\beta)\mathrm{d}\beta - F_x.\end{aligned} \tag{B.13}$$

Firms now have four choices and maximize profit according to $\max\{0, \pi_i(\varphi), \pi_f(\varphi), \pi_x(\varphi)\}$. That means they can either seize production, remain fully informal, register their firm, but evade product regulation for a share of their products, or register their firm for domestic and export activities and register their entire catalog of products. The empirical literature on

[1] I derive $\beta_t^*(\varphi)$ from $\pi_f(\varphi, \beta_t^*(\varphi) = 0$ and $\beta_x^*(\varphi)$ from $\pi_x(\varphi, \beta_x^*(\varphi) = 0$. Accordingly, $\beta_t^*(\varphi) = \left[\frac{f_f \sigma}{R}\right]^{\frac{1}{\sigma-1}} (\rho P \frac{\varphi}{1-\lambda})^{-1}$ and $\beta_x^*(\varphi) = \left[\frac{f_x \sigma}{Rn\tau^{1-\sigma}}\right]^{\frac{1}{\sigma-1}} (\rho P \frac{\varphi}{1-\lambda})^{-1}$. To ensure $\beta_t^*(\varphi) < \beta_x^*(\varphi)$, $f_f < \frac{f_x \tau^{\sigma-1}}{n}$ has to hold.

[2] Notably, in this setup f_x is a one-time payment independent of the number of export markets n to reflect stringent product-regulation that occurs once for a product independent of the number of destination markets.

trade and firm productivity finds that high-productivity firms export and low-productivity firms only serve the domestic market (e.g. Bernard and Jensen, 1995; Roberts and Tybout, 1997; Delgado et al., 2002; Wagner, 2007). To capture this, the threshold level φ_x^* above which firms decide to become exporters is defined by

$$\pi_f(\varphi_x^*) = \pi_x(\varphi_x^*). \tag{B.14}$$

In sum, if a firm draws a firm-level productivity below φ_i^*, it will not produce at all. For a draw above φ_i^*, but below φ_f^*, the firm becomes informal. For a draw above φ_f^*, but below φ_x^* the firm becomes formal. Lastly, a draw above φ_x^* leads the firm to become an exporter. The sorting $\varphi_f^* < \varphi_x^*$ is ensured if

$$\left[\frac{F_f - F_i}{F_x}\right]^{\frac{1}{k}} \left[\frac{(f_f - f_i)^{\frac{\sigma-k-1}{1-\sigma}}}{(1-\lambda)^k} \left[f_f^{\frac{\sigma-k-1}{\sigma-1}} + (n\tau^{1-\sigma})^{\frac{k}{\sigma-1}} f_x^{\frac{\sigma-k-1}{\sigma-1}})\right] \Xi^{\frac{k}{1-\sigma}}\right.$$
$$\left. + \frac{k}{(1-\sigma)\Xi}\left[1 + (1-\delta)^\sigma\left[\phi^{\sigma-k-1} - 1\right]\right] + \frac{1-\sigma}{(f_f - f_i)(\sigma-k-1)}\left[f_f + f_i\left[\phi^{-k} - 1\right]\right]\right]^{\frac{1}{k}} < 1,$$

with $\Xi \equiv [(1-\lambda)^{1-\sigma} - (1-\delta)^\sigma]$. The condition follows from the combination of the formality cutoff condition described by (3.15) and (B.14).

The share of the exported products of the continuum of products is described by $1 - Z(\beta_x^*(\varphi)) = \beta_x^*(\varphi)^{-k}$. Similarly, the share of domestically sold products is determined by $1 - Z(\beta_t^*(\varphi)) = \beta_t^*(\varphi)^{-k}$. Therefore, I can express the share of exported relative to domestically sold products as

$$\left(\frac{\beta_x^*}{\beta_t^*}\right)^{-k} = \left[\frac{f_x}{f_f}\right]^{\frac{-k}{\sigma-1}} n^{\frac{k}{\sigma-1}} \tau^{-k}. \tag{B.15}$$

The results of a comparative statics analysis on (B.15) are intuitive. Factors that increase the profitability of exporting (decrease in f_x, τ or increase in n) or increase the cost of domestic sales (increase in f_f) increase the relative share of exported products.

B.5.1 Product Scope

The number of distinct products produced by an exporting firm is determined by the probability of drawing a product skill above the firm-specific product skill threshold of production. This follows from

$$K_x(\varphi) = 1 - Z(\beta_t^*(\varphi)) = \beta_t^*(\varphi)^{-k}. \tag{B.16}$$

B.5.2 Product-Gini

The Lorenz curve that captures the product revenue distribution of exporters has two distinct segments. The first segment considers only domestically sold products and the second steeper segment captures the revenue generated from products that are sold both at home and abroad. I first derive the share of products that are produced with a product skill below $\bar{\beta}$ of the total number of products a firm produces

$$\gamma = \frac{\int_{\beta_t^*(\varphi)}^{\bar{\beta}} \beta z(\beta) \mathrm{d}\beta}{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} \beta z(\beta) \mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty} \beta z(\beta) \mathrm{d}\beta} = 1 - \left(\frac{\bar{\beta}}{\beta_t^*(\varphi)} \right)^{-k} \tag{B.17}$$

The next step is calculating the revenue share of domestically sold products that are produced with product skill below $\bar{\beta}$ of total firm revenue:

$$\begin{aligned} Q_1 =& \frac{\int_{\beta_t^*(\varphi)}^{\bar{\beta}} r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta}{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty} (1 + n\tau^{1-\sigma}) r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta} \\ =& \frac{\left[\left(\frac{\bar{\beta}}{\beta_f^*(\varphi)} \right)^{\sigma-k-1} - 1 \right]}{\Psi}, \end{aligned} \tag{B.18}$$

where $\xi = (\beta_t^*(\varphi)/\beta_x^*(\varphi))$ and $\Psi \equiv 1 + n\tau^{1-\sigma}\xi^{k+1-\sigma}$. The first segment of the Lorenz curve is

$$Q_1(\gamma) = \frac{\left[[1-\gamma]^{\frac{k+1-\sigma}{k}} - 1 \right]}{\Psi}. \tag{B.19}$$

The second segment consists of the goods that are also exported. The share of products that are produced with a product skill below $\bar{\beta}$ of all products is

$$\gamma = \frac{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} \beta z(\beta) \mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\bar{\beta}} \beta z(\beta) \mathrm{d}\beta}{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} \beta z(\beta) \mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty} \beta z(\beta) \mathrm{d}\beta} = 1 - \left(\frac{\bar{\beta}}{\beta_t^*(\varphi)} \right)^{-k}. \tag{B.20}$$

The share in revenue of the products that are also exported and produced with a product skill below $\bar{\beta}$ is

$$\begin{aligned} Q_2 =& \frac{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\bar{\beta}} r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta}{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} r_i(\varphi, \beta) z(\beta) \mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty} (1 + n\tau^{1-\sigma}) r_f(\varphi, \beta) z(\beta) \mathrm{d}\beta} \\ =& 1 + \frac{\left(\frac{\bar{\beta}}{\beta_t^*(\varphi)} \right)^{\sigma - k - 1}}{\Psi}. \end{aligned} \tag{B.21}$$

In combination they lead to the second segment of the Lorenz curve:

$$Q_2(\gamma) = 1 + \frac{[1 - \gamma]^{\frac{k+1\sigma}{k}}}{\Psi}. \tag{B.22}$$

Jointly, the Lorenz curve is described by

$$Q(\gamma) = \begin{cases} Q_1(\gamma) \text{ if } \gamma \in [0, c) \\ Q_2(\gamma) \text{ if } \gamma \in [c, 1] \end{cases}, \tag{B.23}$$

where $c = 1 - \xi^k$ is the share of domestically sold goods relative to the share products that are also exported. The Lorenz curve $Q(\gamma)$ has the desired properties $Q(0) = 0$, $Q(1) = 1$, $Q_1(c) = Q_2(c)$ and $\frac{\partial Q(\gamma)}{\partial \gamma} > 0$. The Gini-coefficient follows from $G_x = 1 - 2\int_0^1 Q(\gamma) \mathrm{d}\gamma$:

$$\begin{aligned} G_x = G \Bigg\{ \frac{2}{\Psi(\sigma - 1)} \Bigg[& \frac{2k + 1 - \sigma}{2} \left[\Psi - 2\xi^k \left[\Psi + 1 \right] \right] \\ & - \xi^{1 + 2k - \sigma} k n \tau^{1-\sigma} - k \Big] \Bigg\}. \end{aligned} \tag{B.24}$$

G_x depends on ξ, a proxy for the share of exported relative to only domestically sold products, and Ψ that captures the skew of the product revenue distribution.

B.5.3 Herfindahl index

The Herfindahl index of exporting firms considers the revenue of two types of products: the products only sold domestically and the products that are sold at home and abroad. The second group of products, the ones also exported, generate a higher revenue due to the multiple markets they're sold in.

The revenue share $s_t(\beta)$ of a domestically sold good product with product skill β of total firm revenue is

$$\begin{aligned} s_t(\beta) =& \frac{r_f(\varphi,\beta)}{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} r_f(\varphi,\beta)z(\beta)\mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty}(1+n\tau^{1-\sigma})r_f(\varphi,\beta)z(\beta)\mathrm{d}\beta} \\ =& \frac{k+1-\sigma}{k}\beta_t^*(\varphi)^{1+k-\sigma}\Psi^{-1}\beta^{\sigma-1}. \end{aligned} \tag{B.25}$$

Moreover, the revenue share $s_x(\beta)$ of a product that is also exported and produced with product skill β of total firm revenue is

$$\begin{aligned} s_x(\beta) =& \frac{(1+n\tau^{1-\sigma})r_f(\varphi,\beta)}{\int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} r_f(\varphi,\beta)z(\beta)\mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty}(1+n\tau^{1-\sigma})r_f(\varphi,\beta)z(\beta)\mathrm{d}\beta} \\ =& (1+n\tau^{1-\sigma})\frac{k+1-\sigma}{k}\beta_f^*(\varphi)^{1+k-\sigma}\Psi^{-1}\beta^{\sigma-1}. \end{aligned} \tag{B.26}$$

The Herfindahl index results from the combination of the two:

$$H_x = \int_{\beta_t^*(\varphi)}^{\beta_x^*(\varphi)} s_t(\beta)^2 z(\beta)\mathrm{d}\beta + \int_{\beta_x^*(\varphi)}^{\infty} s_x(\beta)^2 z(\beta)\mathrm{d}\beta = H\beta_t^*(\varphi)^k\Psi^{-2}\psi, \tag{B.27}$$

where $\psi \equiv \left[1+\xi^{k+2-2\sigma}\left[2n\tau^{1-\sigma}+n^2\tau^{2-2\sigma}\right]\right]$ and $\Psi^{-2}\psi > 1$.[3]

As in the case of firms that produce both unregistered and registered products, the Herfindahl index for firms that export a share of their goods and sell some of their products only domestically consists of three major components. First, H captures the product skill

[3] $\Psi^{-2}\psi > 1$ holds if $\Psi^2 - \psi < 0$. Rewriting leads to $n^2\tau^{2-2\sigma}\xi^{k+2-2\sigma}\left[\xi^k - 1\right] + 2n\tau^{1-\sigma}\xi^{k+1-\sigma}\left[1-\xi^{1-\sigma}\right] < 0$, which holds because $\xi \in (0,1)$ and $1-\sigma < 0$.

distribution and elasticity of substitution between product varieties. $\beta_t^*(\varphi)^k$ reflects the number of products a firm produces depending on its firm productivity φ. A higher firm productivity leads to a lower threshold, larger number of products produced by a firm and a lower Herfindahl index.[4] Lastly, $\Psi^{-2}\psi$ captures the concentration of firm revenue among a few core products that are sold both at home and abroad and therefore increases the Herfindahl index.

B.5.4 Comparisons

First, I compare diversification of exporting firms relative to informal and formal firms by comparing product scope of the firms.

$$\frac{K_i(\varphi_i)}{K_x(\varphi_x)} = \left[\frac{f_f}{f_i}\right]^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{\sigma k}{\sigma-1}} (1-\lambda)^k \left(\frac{\varphi_i}{\varphi_x}\right)^k. \tag{B.28}$$

Exporting firms produce all their goods in compliance with product-level regulations. Therefore, the difference in product scope between informal and exporting firms depends besides their relative productivity difference also on the costs and benefits of informal and formal production. The two components work in opposite directions. First, exporting firms are higher-productivity firms and are therefore able to produce goods at a lower product skill level. Therefore, the relative productivity difference decreases the informal relative to the exporting product scope. Second, evading product-level regulation allows firms to produce goods at a lower product skill and hence increases the informal relative to the formal product scope.[5]

$$\frac{K_f(\varphi_f)}{K_x(\varphi_x)} = \left[\frac{f_f}{f_i}\right]^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{\sigma k}{\sigma-1}} (1-\lambda)^k \left(\frac{\varphi_f}{\varphi_x}\right)^k. \tag{B.29}$$

As formal firms can evade product registration, the product scope of formal relative to

[4]Substituting for $\beta_t^*(\varphi)$ leads to $H_x(\varphi) = H\left[\frac{f_f\sigma}{R}\right]^{\frac{k}{\sigma-2}} (\rho P \frac{\varphi}{1-\lambda})^{-k}\Psi^{-2}\psi$ and accordingly $\frac{\partial H_x(\varphi)}{\partial \varphi} < 0$.

[5]Given an earlier assumption, $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma} < \frac{f_f}{f_i}$ holds. Rewriting leads to $(f_f/f_i)^{\frac{k}{\sigma-1}}(1-\delta)^{\frac{\sigma k}{\sigma-1}}(1-\lambda)^k > 1$.

exporting firms is the same as the previous relationship between informal and exporting firms and consists of the same two components. Comparing the lowest-productivity exporting firm and the highest-productivity formal firm, i.e. $(\varphi_f/\varphi_x) = 1$, shows that export participation entails less diversification, as measured by product scope, for the marginal exporter.

Second, I compare diversification between the different firms using the Product-level Gini.

$$\frac{G_i}{G_x} = \left[\frac{2}{\Psi(\sigma-1)}\right]^{-1} \left[\frac{2k+1-\sigma}{2}\left[\Psi - 2\left[1-\xi^k\right] - 2\xi^k\Psi\right] + kn\tau^{1-\sigma}\xi^{2k+1-\sigma} + k\right]^{-1} < 1. \tag{B.30}$$

Exporting firms produce all their goods in compliance with product regulation, however, the majority of their revenue stems from core goods that are sold domestically and abroad. ξ captures this as a proxy for the share of products sold domestically relative to the ones that are also exported. The intuition is as follows. When a select group of core products generate the majority of firm revenue, in this case the goods that are also exported, firms are less diversified than when all goods are sold only domestically. Therefore, $G_i/G_x < 1$ and informal firms are more diversified than exporting firms.[6]

$$\frac{G_f}{G_x} = \left[\frac{G_i}{G_f}\right]^{-1}\left[\frac{G_i}{G_x}\right]. \tag{B.31}$$

Measured by the Product-Gini, formal non-exporting firms may or may not be more diversified than exporting firms. As the Product-Gini is a relative measure, the absolute number of products produced by each firm does not matter and hence firm productivity does not influence this measure of diversification. The two components that matter are the extent to which non-exporting firms' revenue is concentrated among registered products versus the extent to which exporting firms' revenue is concentrated among the core products that are

[6] $\frac{G_i}{G_x} < 1$ if $\frac{2}{\Psi(\sigma-1)}\left[\frac{2k+1-\sigma}{2}\left[\Psi - 2\left[1-\xi^k\right] - 2\xi^k\Psi\right] + kn\tau^{1-\sigma}\xi^{2k+1-\sigma} + k\right] > 1$.
The condition can be rewritten as $(k+1-\sigma)n\tau^{1-\sigma}\left[\xi^{k+1-\sigma} - \xi^{2k+1-\sigma}\right] > 0$. Because $\xi \in (0,1)$, $k+1-\sigma > 0$ and $k > 1$ the condition holds and the Product-Gini of informal firms is lower than the one of exporting formal firms.

Table B.1: Economy parameters for two scenarios.

		Scenario 1	Scenario 2
Total workforce	L	1.0	1.0
Elasticity of substitution	σ	3.4	3.4
Product skill distribution parameter	k	5.0	5.0
Formal fixed cost	F_f	4.0	4.0
Informal fixed cost	F_i	1.0	1.0
Exporting fixed cost	F_x	10.0	10.0
Formal fixed cost	f_f	4.0	4.0
Informal fixed cost	f_i	1.0	1.0
Exporting fixed cost	f_x	10.0	10.0
Productivity bonus	λ	0.3	0.3
Probability of detection	δ	0.1	0.1
Iceberg transportation cost	τ	1.4	1.4
Number of foreign countries	n	**1**	**3**
$\frac{G_f}{G_x}$		**1.36**	**0.94**

sold domestically and exported. Depending on which of the two components dominates, non-exporting firms are more or less diversified than exporting firms. To demonstrate that G_f/G_x can be smaller or greater than 1, I compute the numerical value of the key variables for two scenarios as shown in table B.1. The first scenario considers a world consisting of only home and abroad. The second scenario assumes three foreign countries. All parameters are within the constraints of the model.

Lastly, I compare product diversification of firms using the Herfindahl index.

$$\frac{H_i(\varphi_i)}{H_x(\varphi_x)} = \left[\frac{f_i}{f_f}\right]^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{-k\sigma}{\sigma-1}} (1-\lambda)^{-k} \Psi^2 \psi^{-1} \left(\frac{\varphi_x}{\varphi_i}\right)^k. \tag{B.32}$$

The diversification of informal relative to exporting firms measured by the Herfindahl index consists of three components. As before, the first component is the relative productivity difference φ_x/φ_i. Second, as informal firms evade product regulation for all and exporting firms for none of their products, the diversification ratio depends also on the relative costs and benefits of evasion of versus compliance with product regulation $[f_i/f_f]^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{-k\sigma}{\sigma-1}} (1-\lambda)^{-k}$. The evasion of product-level regulation allows firms to produce goods at a lower product skill and therefore more overall products. As a result, this component indicates a higher relative

diversification of informal firms.[7] Lastly, $\Psi^2\psi^{-1}$ captures the fact that exporting firms sell their core products domestically and abroad. The concentration of firm revenue on a few core products entails a less equal product revenue distribution and accordingly a higher Herfindahl index. In sum, given the same firm productivity, informal firms are more diversified than exporting firms.

$$\frac{H_f(\varphi_f)}{H_x(\varphi_x)} = \left[\frac{f_i}{f_f}\right]^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{-k\sigma}{\sigma-1}} (1-\lambda)^{-k} \Psi^2 \psi^{-1} \Omega^{-2} \omega \left(\frac{\varphi_x}{\varphi_f}\right)^k. \tag{B.33}$$

Lastly, comparing formal non-exporting and exporting firms brings all the previous components together. On the one hand, the ability of non-exporting firms to produce informally, captured by $[f_i/f_f]^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{-k\sigma}{\sigma-1}} (1-\lambda)^{-k}$, and the revenue concentration of exporting firms on core products, $\Psi^2\psi^{-1}$, indicate a higher diversification of non-exporting relative to exporting firms. On the other hand, the revenue concentration on formal products of non-exporting firms, $\Omega^{-2}\omega$, and the productivity difference between exporting and non-exporting firms, $\varphi_x/\varphi_f > 1$, indicates a lower diversification of non-exporting relative to exporting firms. The result is ambiguous.

[7] Given an earlier assumption, $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} < \frac{f_f}{f_i}$ holds. Rewriting leads to $(f_i/f_f)^{\frac{k}{\sigma-1}} (1-\delta)^{\frac{-\sigma k}{\sigma-1}} (1-\lambda)^{-k} < 1$.

B.6 Firm-level regulation without product-level regulation

This section considers the model setup without product-level regulation, along the lines of Becker (2014). Firms only face firm-level fixed cost F_f, but can evade the registration fee and become informal by paying fixed cost $F_i < F_f$ just to set up shop. Firms aiming to export have to pay $F_x > F_f$, which reflects the additional costs of learning about export markets as well as export regulations. This captures the finding of Roberts and Tybout (1997) that sunk costs are critical determinants of export participation. As there are no boundaries to the profitability of the production of each product, every firm produces all products of the continuum. Notably, variables with subscript x describe export activities and $\pi_x(\varphi)$ is the firm-level profit of exporting that firms receive in addition to their domestic profit. The informal, formal and exporting profit of a firm with productivity φ respectively are

$$\pi_i(\varphi) = \int_1^\infty \left[(1-\delta)^\sigma \frac{R}{\sigma}(\rho P \varphi \beta)^{\sigma-1}\right] z(\beta)\mathrm{d}\beta - F_i, \tag{B.34}$$

$$\pi_f(\varphi) = \int_1^\infty \left[\frac{R}{\sigma}\left(\rho P \frac{\varphi}{1-\lambda}\beta\right)^{\sigma-1}\right] z(\beta)\mathrm{d}\beta - F_f \tag{B.35}$$

and

$$\pi_x(\varphi) = \int_1^\infty \left[\frac{n\tau^{1-\sigma}R}{\sigma}\left(\rho P \frac{\varphi}{1-\lambda}\beta\right)^{\sigma-1}\right] z(\beta)\mathrm{d}\beta - F_x. \tag{B.36}$$

The threshold levels φ_i^* and φ_f^* are determined as in section 3.2.2 by (3.14) and (3.15) and informal sector firms are lower-productivity firms than formal sector firms. The sorting $\varphi_i^* < \varphi_f^*$ is ensured if $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma} < \frac{F_f}{F_i}$.[8] Notably, the condition is equivalent to the corresponding one in Becker (2014).

In addition to the cutoff productivity levels defined by (3.14) and (3.15), firms are able

[8]The condition results from the assumption that informal firms break even at a lower productivity level than formal firms. Breaking even at a lower productivity requires that $\varphi_i^* < \varphi_f^*$ for φ_i^* from $\pi_i(\varphi_i^*) = 0$ & φ_f^* from $\pi_f(\varphi_f^*) = 0$. $\varphi_i^* = \left[\frac{F_i\sigma}{(1-\delta)^\sigma R}\right]^{\frac{1}{\sigma-1}} (\rho P) \left[\frac{k+1-\sigma}{k}\right]^{\frac{1}{\sigma-1}}$ and $\varphi_f^* = \left[\frac{F_f\sigma}{R}\right]^{\frac{1}{\sigma-1}} (\rho P)^{\frac{1}{1-\lambda}} \left[\frac{k+1-\sigma}{k}\right]^{\frac{1}{\sigma-1}}$. Hence, $\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^\sigma} < \frac{F_f}{F_i}$. Since both profit functions are monotonically increasing in productivity, a single crossing of the profit functions is ensured and the productivity sorting is achieved.

to export and do so if exporting leads to positive profits. The threshold level φ_x^* above which firms decide to become exporters is defined by

$$\pi_x(\varphi_x^*) = 0. \tag{B.37}$$

Export activities are conducted by firms in addition to their domestic sales. That means firms maximize their profit by deciding on $\max\{0, \pi_i(\varphi), \pi_f(\varphi), \pi_f(\varphi) + \pi_x(\varphi)\}$. The empirical literature on firm-level productivity and exporting finds that higher-productivity firms export and lower-productivity firms supply only the domestic market (Bernard and Jensen, 1995, 1999; Delgado et al., 2002; Wagner, 2007). This sorting of $\varphi_f^* < \varphi_x^*$ is ensured if $\frac{\left[F_f - F_i\right]^{\frac{1}{\sigma-1}}}{\left[(1-\lambda)^{1-\sigma} - (1-\delta)^{\sigma}\right]^{\frac{1}{\sigma-1}}} < \frac{F_x^{\frac{1}{\sigma-1}}\tau}{n^{\frac{1}{\sigma-1}}(1-\lambda)^{-1}}$.[9] Intuitively, only if the cost benefit ratio of formality is lower than the one of exporting, only the highest-productivity firms will export. This condition also corresponds to Becker (2014).

The share of informal and formal firms in an economy is equal to the probability of drawing a productivity above the respective threshold level. Specifically, the share of formal firms is $1 - G(\varphi_f^*) = \varphi_f^{*-k}$ and the share of informal firms follows from $G(\varphi_f^*) - G(\varphi_i^*) = \varphi_i^{*-k} - \varphi_f^{*-k}$. Using (3.14) and (3.15), I derive the number of informal relative to formal firms depending only on the policy parameters:

$$\frac{\varphi_i^{*-\alpha} - \varphi_f^{*-\alpha}}{\varphi_f^{*-\alpha}} = \left[\frac{F_i}{F_f - F_i}\right]^{\frac{-\alpha}{\sigma-1}} \left[\frac{(1-\lambda)^{1-\sigma}}{(1-\delta)^{\sigma}} - 1\right]^{\frac{-\alpha}{\sigma-1}} - 1. \tag{B.38}$$

The effect of changing these parameters is intuitive. For an increase in factors that decrease formal sector profitability relative to the informal sector (increase in F_f or decrease in λ, δ, F_i), the relative share of informal firms‘ increases.

[9] Ensuring $\varphi_x^* > \varphi_f^*$ for φ_f^* from $\pi_i(\varphi_f^*) = \pi_f(\varphi_f^*)$ and φ_x^* from $\pi_x(\varphi_x^*) = 0$ is sufficient to sort domestic productivity levels below export productivity levels. This results in $\varphi_f^* = (F_f - F_i)^{\frac{1}{\sigma-1}} \left[\frac{R}{\sigma}\right]^{\frac{1}{1-\sigma}} \left[\frac{(1-\lambda)^{1-\sigma} - (1-\delta)^{\sigma}}{(1-\delta)^{\sigma}}\right]^{\frac{1}{1-\sigma}} \left[\frac{k+1-\sigma}{k}\right]^{\frac{1}{\sigma-1}} (\rho P)^{-1}$ and $\varphi_x^* = F_x^{\frac{1}{\sigma-1}} \left[\frac{R}{\sigma}\right]^{\frac{1}{1-\sigma}} n^{\frac{1}{1-\sigma}} \tau (1-\lambda) \left[\frac{k+1-\sigma}{k}\right]^{\frac{1}{\sigma-1}} (\rho P)^{-1}$. In combination, $\frac{\left[F_f - F_i\right]^{\frac{1}{\sigma-1}}}{\left[(1-\lambda)^{1-\sigma} - (1-\delta)^{\sigma}\right]^{\frac{1}{\sigma-1}}} < \frac{F_x^{\frac{1}{\sigma-1}}\tau}{n^{\frac{1}{\sigma-1}}(1-\lambda)^{-1}}$.

B.6.1 Product Scope

Since there are is no product-level regulation in place, the minimum product skill threshold equals the lower limit of product skill draws, i.e. 1. Thus, all firms produce all products.[10] Moreover, as all firms produce all products, product scope is equal for informal, formal and exporting firms.

B.6.2 Product-Gini

First, I derive the number of products with product skill below $\bar{\beta}$ relative to the total amount of products:

$$\gamma = \frac{\int_1^{\bar{\beta}} \beta z(\beta) \mathrm{d}\beta}{\int_1^{\infty} \beta z(\beta) \mathrm{d}\beta} = 1 - \bar{\beta}^{-k}. \tag{B.39}$$

Next, the revenue share of products with product skill below $\bar{\beta}$ of total firm revenue is

$$Q = \frac{\int_1^{\bar{\beta}} r(\varphi, \beta) z(\beta) \mathrm{d}\beta}{\int_1^{\infty} r(\varphi, \beta) z(\beta) \mathrm{d}\beta} = 1 - \bar{\beta}^{\sigma-k-1}. \tag{B.40}$$

Lastly, both equations can be combined to calculate the Lorenz curve

$$Q(\gamma) = 1 - [1 - \gamma]^{\frac{\sigma-k-1}{-k}} \tag{B.41}$$

and the Product-Gini

$$G = 1 - 2 \int_0^1 Q(\gamma) \mathrm{d}\gamma = \frac{\sigma - 1}{2k + 1 - \sigma}. \tag{B.42}$$

Because the relative revenue shares are not affected by the sector choice, the derivation of the Product-Gini is the same for all firms and the product revenue distribution follows the Pareto product skill distribution. Given its relative nature, G is independent of firm productivity φ. Therefore, all firms are equally diversified as measured by the Product-Gini.

[10] Mathematically: $K(\varphi) = 1 - Z(1) = 1$.

Moreover, product diversification measured by the Product-Gini is increasing in the elasticity of substitution σ.[11]

B.6.3 Herfindahl Index

The revenue share $s(\beta)$ of a product produced with product skill β of total firm revenue is

$$s(\beta) = \frac{r(\varphi, \beta)}{\int_1^\infty r(\varphi, \beta) z(\beta) \mathrm{d}\beta} = \frac{k+1-\sigma}{k} \beta^{\sigma-1} \tag{B.43}$$

and the Herfindahl index follows from

$$H = \int_1^\infty s(\beta)^2 z(\beta) \mathrm{d}\beta = \frac{(k+1-\sigma)^2}{k(k+2-2\sigma)}. \tag{B.44}$$

This derivation follows the same procedure for informal, formal and exporting firms, as sector specific differences do not influence the relative revenue shares. Moreover, all firms produce the whole continuum of products. Therefore, all firms are equally diversified, as measured by the Herfindahl index, and diversification is increasing in the elasticity of substitution σ.[12]

[11] $\frac{\partial G}{\partial \sigma} = \frac{2k}{(\sigma-2k-1)^2} > 0$.

[12] $\frac{\partial H}{\partial \sigma} = \frac{-2k(k+1-\sigma)(k+2-2\sigma)+2k(2k+2-2\sigma)}{k^2(k+2-2\sigma)^2} > 0$, because $\sigma > 1$.

APPENDIX C

APPENDIX TO CHAPTER 4

C.1 Price discrimination in the bribe request between non-exporting and exporting formal firms

This section develops an extension of the model in which the corrupt official can distinguish exporting firms from non-exporting formal firms and accordingly price discriminates between firms in her bribe request. The costs and benefits of informality and formality are as before. However, exporters now do not pay the same bribe G as non-exporting formal firms, but face an exporter-specific graft S. The profit for exporting firms including both domestic sales as well as exports are described by

$$\pi_x(C) = D(1+\tau^{-1}) - 2(1+\alpha)C - S. \tag{C.1}$$

Firms choose to become informal, formal or exporters given their cost draw C and according to $\max\{0, \pi_i(C), \pi_f(C), \pi_x(C)\}$. As before, I assume that the economy's parameters are such that the following sorting of firms holds:

$$\begin{aligned}
C > (1-\delta)D &\text{ Exit} \\
(1-\delta)D \geq C > \frac{\delta D - G}{\alpha} &\text{ Become informal} \\
\frac{\delta D - G}{\alpha} \geq C > \frac{D\tau^{-1} + G - S}{(1+\alpha)} &\text{ Become formal and sell domestically} \\
\frac{D\tau^{-1} + G - S}{(1+\alpha)} \geq C &\text{ Become formal, sell domestically and export,}
\end{aligned} \tag{C.2}$$

where only the threshold for exporters differs from the previous specification without price discrimination in bribes. To derive simple and intuitive closed form solutions, I assume that firm cost in the economy are distributed uniformly, that is $F(C) = C$ with $C \in [0, 1]$.

The corrupt official now maximizes her revenue by choosing the optimal bribe demand G and S from formal non-exporting and exporting firms according to

$$\max_{G,S} SF\left(C_x\right) + G\left[F\left(C_f\right) - F\left(C_x\right)\right], \tag{C.3}$$

where as before C_f and C_x are the threshold cost levels below which firms become formal non-exporting and exporting firms, respectively.

The optimal bribe requests result from a combination of the two FOC and are

$$G^* = \frac{\delta D}{2} \tag{C.4}$$

as well as

$$S^* = \frac{D}{2}\left[\delta + \tau^{-1}\right]. \tag{C.5}$$

Notably, the bribe request from formal firms G is as before. However, the official charges a higher bribe for exporting firms ($S^* > G^*$), because she is aware of their higher profitability. More specifically, she charges the same markup (1/2) from both domestic and export revenue. The combination of (C.2), (C.4) and (C.5) results in the threshold levels $C_f^* = \frac{\delta D}{2\alpha}$ and $C_x = \frac{D}{2\tau(1+\alpha)}$. The endogenous firm-level demand therefore is

$$D = M^{\frac{1}{2}}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-\frac{1}{2}}. \tag{C.6}$$

Lastly, given the demand, the threshold for formal sector participation is

$$C_f^* = \frac{\delta}{2\alpha}M^{\frac{1}{2}}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-\frac{1}{2}}. \tag{C.7}$$

I analyze the same three scenarios as before: a change in i) import tariffs τ, ii) formal sector regulation α and iii) both. First, higher import tariffs entail fewer foreign competitors in the domestic market and accordingly increase the revenue of each operating non-exporting

firm.[1] As a result, the official finds it optimal to increase the bribe she demands from non-exporting formal firms:

$$\frac{\partial G^*}{\partial \tau} = \frac{\delta}{2}\frac{\partial D}{\partial \tau} > 0. \tag{C.8}$$

However, the effect of higher import tariffs on the bribe requested from exporting firms is ambiguous. Higher import tariffs force the highest-cost exporting firms to seize their exporting activities, while the firms that are able to maintain exporting generate higher revenues. Depending on which of the two effects is stronger, the official finds it optimal to decrease or increase the graft:

$$\frac{\partial S^*}{\partial \tau} = \frac{1}{2}D\tau^{-2}\left[\frac{1}{4}\left[\delta + \tau^{-1}\right]\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1} - 1\right], \tag{C.9}$$

which can be smaller or greater than 0 depending on whether $2(1-\delta)(1+\alpha) + \frac{1}{2}(\tau^{-1} - \delta)$ is smaller or greater than 0.

Because the higher import tariffs lead to higher bribe requests from formal firms, as before, they also entail a higher share of formal firms:

$$\frac{\partial C_f^*}{\partial \tau} = \frac{\delta D}{4\alpha}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1}\frac{1}{\tau^2 2(1+\alpha)} > 0. \tag{C.10}$$

Next, I examine a change in the regulatory cost of formality α. Higher regulatory costs limit the number of firms that find formality profitable and limit domestic competition. As a result, the revenue of all operating domestic firms increases.[2] In response, the corrupt official finds it optimal to increase both the graft requests from formal non-exporting and non exporting firms:

$$\frac{\partial G^*}{\partial \alpha} = \frac{\delta}{2}\frac{\partial D}{\partial \alpha} > 0 \tag{C.11}$$

and

$$\frac{\partial S^*}{\partial \alpha} = \frac{1}{2}\frac{\partial D}{\partial \alpha}\left[\delta + \tau^{-1}\right] > 0. \tag{C.12}$$

[1] Mathematically, $\frac{\partial D}{\partial \tau} = \frac{1}{4}D(1+\alpha)^{-1}\tau^{-2}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1} > 0.$

[2] Mathematically, $\frac{\partial D}{\partial \alpha} = \frac{1}{4}D(1+\alpha)^{-2}\tau^{-1}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1} > 0.$

The higher cost of formal sector participation in combination with a higher cost of corruption translates into fewer formal sector firms:[3]

$$\frac{\partial C_f^*}{\partial \alpha} = \frac{\delta D}{2\alpha}\left[\frac{1}{4}(1+\alpha)^{-2}\tau^{-1}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1} - \alpha^{-1}\right] < 0. \tag{C.13}$$

Lastly, I examine the response of the formal sector to tariff liberalization in more corrupt economies, that is economies with a higher regulatory barrier α that translates into higher bribe requests. As in the case without price discrimination in the bribe request, the responsiveness of the formal sector is lower in economies featuring more corruption:[4]

$$\begin{aligned}\frac{\partial^2 C_f^*}{\partial \tau \partial \alpha} =& \frac{D\delta}{8\alpha(1+\alpha)\tau}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1} \\ & \left[\frac{3}{4}\left[(1-\delta)^k + \frac{1}{2}\tau^{-1}(1+\alpha)^{-1}\right]^{-1}\tau^{-1}(1+\alpha)^{-2} - \frac{2\alpha+1}{(1+\alpha)\alpha}\right] < 0.\end{aligned} \tag{C.14}$$

In sum, introducing price discrimination of the corrupt official between non-exporting and exporting formal firms does not alter the main results of the model, that is i) lower import tariffs reduce the size of the formal sector, ii) the formal sector is smaller in more corrupt economies and iii) the formal sector is less responsive to trade liberalization in more corrupt economies.

[3] $\frac{\delta D}{8\alpha(1+\alpha)^2\tau}\frac{1}{2}\tau^{-1}(1+\alpha)^{-1-1} - \frac{\delta D}{2\alpha^2} < 0$ can be rewritten as $\frac{4\tau(1+\alpha)^2(1-\delta)+2(1+\alpha)}{\alpha} > 1$, which holds because $\alpha > 0$, $\delta \in (0,1)$ and $\tau > 1$.

[4] This can be rewritten as $(2\alpha+1)\alpha^{-1}(1-\delta) + (1+\alpha)^{-1}\tau^{-1}\left[\frac{\alpha+2}{4\alpha}\right] > 0$, which holds because $\alpha > 0$, $\delta \in (0,1)$ and $\tau > 1$.

C.2 Relationship between regulations and corruption

To test whether the regulatory costs of formality are significantly related to the extent of corruption, I generate a dummy variable that equals 1 when a firm reports that it took more than 15 days to receive a business registration license. Then, similar to the corruption proxy, I calculate the mean of this dummy variable by year and region to capture the variation in institutional quality and regulatory cost of formality by region. This follows Rand and Torm (2012b), who report that 15 days is the government's stated time requirement for obtaining the business registration license and is in the spirit of Djankov et al. (2002), who find that a large part of the business registration cost arises from the time required to deal with red tape.

Table C.1 present the results for three different regressions that relate the extent of regional corruption to the proxy capturing the variation of regulatory cost by region. The first specification is a fixed effect regression using the balanced panel of firms. The second regression pools all firm-level data. The third specification collapses the data by region and year and regresses the time requirement on the regional extent of corruption. The time requirement for registration is significantly associated with a higher extent of corruption in all three specifications at the 1%-level. This supports my model setup in which an increase in the regulatory cost α, that is the cost of red tape, increases the extent of corruption.

Table C.1: The relationship between the regional level of bureaucracy and corruption

VARIABLES	(1)	(2)	(3)
Regional time to registration	0.666*** (0.0149)	0.670*** (0.0150)	0.650** (0.213)
Observations	4,770	4,770	30
R-squared	0.578	0.746	0.756
Number of id	1,590		

Dependent variable is the regional extent of corruption. Regressions 1 and 2 include year, province and industry dummy variables that are not reported. The standard errors for all three regressions are heteroskedasticity-robust. The standard errors for regression 1 as well as 2 are clustered at the firm- and for regression 3 at the regional-level and are presented in parentheses. ***, ** and * indicate a p-value smaller than 0.01, 0.05 and 0.1, respectively.

BIBLIOGRAPHY

Acosta, P. and Montes-Rojas, G. 2014. Informal jobs and trade liberalisation in Argentina. *Journal of Development Studies*, 50(8):1104–1118.

Ades, A. and Di Tella, R. 1999. Rents, competition, and corruption. *American Economic Review*, 89(4):982–993.

Aghion, P., Burgess, R., Redding, S. J., and Zilibotti, F. 2008. The unequal effects of liberalization: Evidence from dismantling the license raj in India. *American Economic Review*, 98(4):1397–1412.

Akerlof, G. A. and Yellen, J. L. 1990. The fair wage-effort hypothesis and unemployment. *Quarterly Journal of Economics*, 105(2):255–283.

Akerman, A., Helpman, E., Itskhoki, O., Muendler, M.-A., and Redding, S. 2013. Sources of wage inequality. *American Economic Review*, 103(3):214–219.

Aleman-Castilla, B. 2006. The effect of trade liberalization on informality and wages: Evidence from Mexico. CEP Discussion Paper 763, Centre for Economic Performance, LSE.

Allison, P. D. 1978. Measures of inequality. *American Sociological Review*, 43(6):865–880.

Amiti, M. and Davis, D. R. 2012. Trade, firms, and wages: Theory and evidence. *Review of Economic Studies*, 79(1):1–36.

Anderson, G. D., Vamanamurthy, M. K., and Vuorinen, M. 1993. Inequalities for quasiconformal mappings in space. *Pacific Journal of Mathematics*, 160(1):1–18.

Antunes, A. R. and de V. Cavalcanti, T. V. 2007. Start up costs, limited enforcement, and the hidden economy. *European Economic Review*, 51(1):203–224.

Arkolakis, C. and Muendler, M.-A. 2010. The extensive margin of exporting products: A firm-level analysis. Working Paper 16641, National Bureau of Economic Research.

Arkolakis, C., Demidova, S., Klenow, P. J., and Rodríguez-Claire, A. 2008. Endogenous variety and the gains from trade. *American Economic Review*, 98(2):444–450.

Auriol, E. and Warlters, M. 2005. Taxation base in developing countries. *Journal of Public Economics*, 89(4):625–646.

Aw, B. Y., Chen, X., and Roberts, M. J. 2001. Firm-level evidence on productivity differentials and turnover in Taiwanese manufacturing. *Journal of Development Economics*, 66 (1):51–86.

Axtell, R. L. 2001. Zipf distribution of U.S. firm sizes. *Science*, 293(5536):1818–1820.

Baltagi, B. H., Baskaya, Y. S., and Hulagu, T. 2013. How different are the wage curves for formal and informal workers? Evidence from Turkey. *Papers in Regional Science*, 92(2): 271–283.

Banerji, A. and Jain, S. 2007. Quality dualism. *Journal of Development Economics*, 84(1): 234–250.

Bargain, O. and Kwenda, P. 2011. Earnings structures, informal employment, and self-employment: New evidence from Brazil, Mexico, and South Africa. *Review of Income and Wealth*, 57:100–122.

Basu, A. K., Chau, N. H., and Kanbur, R. 2011. Contractual dualism, market power and informality. IZA Discussion Papers 5845, Institute for the Study of Labor (IZA).

Basu, A. K., Chau, N. H., and Kanbur, R. 2014. Contractual dualism, market power and informality. *Economic Journal*, page Forthcoming.

Batra, G., Kaufmann, D., and Stone, A. H. W. 2003. *Investment climate around the world: Voices of the firms from the world business environment survey.* The World Bank, Washington, D.C.

Beck, T., Demirgüç-Kunt, A., and Maksimovic, V. 2005. Financial and legal constraints to growth: Does firm size matter? *Journal of Finance*, 60(1):137–177.

Becker, D. 2014. Heterogeneous firms and informality: The effects of trade liberalization on labor markets. Working Paper 2014-13, Charles H. Dyson School of Applied Economics and Management, Cornell University.

Bernard, A. B. and Jensen, J. B. 1995. Exporters, jobs, and wages in U.S. manufacturing: 1976-1987. *Brookings Papers on Economic Activity. Microeconomics*, 1995:67–112.

Bernard, A. B. and Jensen, J. B. 1999. Exceptional exporter performance: Cause, effect, or both? *Journal of International Economics*, 47(1):1–25.

Bernard, A. B., Jensen, J. B., and Schott, P. K. 2009. Importers, exporters and multinationals: A portrait of firms in the U.S. that trade goods. In Dunne, T., Jensen, J. B., and Roberts, M. J., editors, *Producer Dynamics: New Evidence from Micro Data*, NBER Chapters, pages 513–552. National Bureau of Economic Research, Inc, Cambridge, MA.

Bernard, A. B., Redding, S. J., and Schott, P. K. 2010. Multiple-product firms and product switching. *American Economic Review*, 100(1):70–97.

Bernard, A. B., Redding, S. J., and Schott, P. K. 2011. Multiproduct firms and trade liberalization. *Quarterly Journal of Economics*, 126(3):1271–1318.

Bewley, T. 2005. Fairness, reciprocity, and wage rigidity. In Gintis, H., Bowles, S., Boyd, R., and Fehr, E., editors, *Moral sentiments and materials interests: The foundations of cooperation in economic life*, pages 303–338. MIT Press, Cambridge, MA.

Bigsten, A., Kimuyu, P., and Lundvall, K. 2004. What to do with the informal sector? *Development Policy Review*, 22(6):701–715.

Blanchard, O. and Giavazzi, F. 2003. Macroeconomic effects of regulation and deregulation in goods and labor markets. *Quarterly Journal of Economics*, 118(3):879–907.

Blanchflower, D. G. and Oswald, A. J. 1995. An introduction to the wage curve. *Journal of Economic Perspectives*, 9(3):153–167.

Bourguignon, F. 1979. Decomposable income inequality measures. *Econometrica*, 47(4): 901–920.

Broda, C. and Weinstein, D. E. 2006. Globalization and the gains from variety. *Quarterly Journal of Economics*, 121(2):541–585.

Brown, C. and Medoff, J. 1989. The employer size-wage effect. *Journal of Political Economy*, 97(5):1027–1059.

Bruhn, M. 2013. A tale of two species: Revisiting the effect of registration reform on informal business owners in Mexico. *Journal of Development Economics*, 103:275–283.

Bucheli, M. and González, C. 2007. An estimation of the wage curve for Uruguay. Documentos de Trabajo 11/07, Departamento de Economía, Facultad de Ciencias Sociales. Universidad de la República, Uruguay.

Buehn, A. and Schneider, F. 2012. Corruption and the shadow economy: Like oil and vinegar, like water and fire? *International Tax and Public Finance*, 19(1):172–194.

Bustos, P. 2011. Trade liberalization, exports, and technology upgrading: Evidence on the impact of MERCOSUR on Argentinian firms. *American Economic Review*, 101(1): 304–340.

Cadot, O., Carrére, C., and Strauss-Kahn, V. 2011. Export diversification: What's behind the hump? *Review of Economics and Statistics*, 93(2):590–605.

Cadot, O., Carrére, C., and Strauss-Kahn, V. 2013. Trade diversification, income, and growth: What do we know? *Journal of Economic Surveys*, 27(4):790–812.

Chaponnière, J.-R. and Cling, J.-P. 2009. Vietnam's export-led growth model and competition with China. *Économie Internationale*, (118):101–130.

Chaponnière, J.-R., Cling, J.-P., and Zhou, B. 2008. Vietnam following in China's footsteps: The third wave of emerging Asian economies. Working Paper Series 2008/84, World Institute for Development Economic Research (UNU-WIDER).

Choi, J. P. and Thum, M. 2005. Corruption and the shadow economy. *International Economic Review*, 46(3):817–836.

CIEM. 2012. Characteristics of the Vietnamese business environment: Evidence from a SME survey in 2011. Technical report, Central Institute for Economic Management (CIEM), Hanoi.

Cling, J.-P., Razafindrakoto, M., and Roubaud, F. 2012. To be or not to be registered? Explanatory factors behind formalizing non-farm household businesses in Vietnam. *Journal of the Asia Pacific Economy*, 17(4):632–652.

Corcos, G., Del Gatto, M., Mion, G., and Ottaviano, G. I. 2012. Productivity and firm selection: Quantifying the new gains from trade. *Economic Journal*, 122(561):754–798.

Dabla-Norris, E., Gradstein, M., and Inchauste, G. 2008. What causes firms to hide output? The determinants of informality. *Journal of Development Economics*, 85(12):1–27.

Danthine, J.-P. and Kurmann, A. 2007. The macroeconomic consequences of reciprocity in labor relations. *Scandinavian Journal of Economics*, 109(4):857–881.

Davidson, C. and Matusz, S. J. 2009. *International trade with equilibrium unemployment*. Princeton University Press.

Davis, D. R. and Harrigan, J. 2011. Good jobs, bad jobs, and trade liberalization. *Journal of International Economics*, 84(1):26–36.

Davis, S. J. and Haltiwanger, J. 1991. Wage dispersion between and within U.S. manufacturing plants, 1963-86. *Brookings Papers on Economic Activity. Microeconomics*, 1991: 115–200.

de Beer, J., Fu, K., and Wunsch-Vincent, S. 2013. The informal economy, innovation and intellectual property - Concepts, metrics and policy considerations. Economic Research Working Paper 10, World Intellectual Property Organization.

de Mel, S., McKenzie, D., and Woodruff, C. 2013. The demand for, and consequences of, formalization among informal firms in Sri Lanka. *American Economic Journal: Applied Economics*, 5(2):122–150.

de Paula, A. and Scheinkman, J. A. 2011. The informal sector: An equilibrium model and some empirical evidence from Brazil. *Review of Income and Wealth*, 57:8–26.

de Soto, H. 1989. *The other path*. Harper and Row, New York, NY.

Delgado, M. A., Fariñas, J. C., and Ruano, S. 2002. Firm productivity and export markets: A non-parametric approach. *Journal of International Economics*, 57(2):397–422.

D'Erasmo, P. N. and Moscoso Boedo, H. J. 2012. Financial structure, informality and development. *Journal of Monetary Economics*, 59(3):286–302.

Djankov, S., La Porta, R., Lopez-De-Silanes, F., and Shleifer, A. 2002. The regulation of entry. *Quarterly Journal of Economics*, 117(1):1–37.

Dreher, A. and Schneider, F. 2010. Corruption and the shadow economy: an empirical analysis. *Public Choice*, 144(1-2):215–238.

Dreher, A., Kotsogiannis, C., and McCorriston, S. 2009. How do institutions affect corruption and the shadow economy? *International Tax and Public Finance*, 16(6):773–796.

Dutt, P. and Traca, D. 2010. Corruption and bilateral trade flows: Extortion or evasion? *Review of Economics and Statistics*, 92(4):843–860.

Dutt, P., Mitra, D., and Ranjan, P. 2009. International trade and unemployment: Theory and cross-national evidence. *Journal of International Economics*, 78(1):32–44.

Egger, H. and Kreickemeier, U. 2009. Firm heterogeneity and the labor market effects of trade liberalization. *International Economic Review*, 50(1):187–216.

Egger, H. and Kreickemeier, U. 2012. Fairness, trade, and inequality. *Journal of International Economics*, 86(2):184–196.

Essegbey, G. O., Awuni, S., Essegbey, I. T., Akuffobea, M., and Micah, B. 2014. Country study on innovation, intellectual property and the informal economy: Traditional herbal medicine in Ghana. Committee on Development and Intellectual Property (CDIP), Thirteenth Session CDIP/13/INF/2, World Intellectual Property Organization.

Ethier, W. J. 1982. National and international returns to scale in the modern theory of international trade. *American Economic Review*, 72(3):389–405.

Faggio, G., Salvanes, K. G., and Van Reenen, J. 2010. The evolution of inequality in productivity and wages: Panel data evidence. *Industrial and Corporate Change*, 19(6): 1919–1951.

Fajnzylber, P., Maloney, W. F., and Montes-Rojas, G. V. 2009. Releasing constraints to growth or pushing on a string? Policies and performance of Mexican micro-firms. *Journal of Development Studies*, 45(7):1027–1047.

Fajnzylber, P., Maloney, W. F., and Montes-Rojas, G. V. 2011. Does formality improve micro-firm performance? Evidence from the Brazilian SIMPLES program. *Journal of Development Economics*, 94(2):262–276.

Fehr, E. and Falk, A. 1999. Wage rigidity in a competitive incomplete contract market. *Journal of Political Economy*, 107(1):106–134.

Felbermayr, G., Prat, J., and Schmerer, H.-J. 2011a. Globalization and labor market outcomes: Wage bargaining, search frictions, and firm heterogeneity. *Journal of Economic Theory*, 146(1):39–73.

Felbermayr, G., Prat, J., and Schmerer, H.-J. 2011b. Trade and unemployment: What do the data say? *European Economic Review*, 55(6):741–758.

Fields, G. S. 1975. Rural-urban migration, urban unemployment and underemployment, and job-search activity in LDCs. *Journal of Development Economics*, 2(2):165–187.

Fiess, N. M. and Fugazza, M. 2012. Informality and openness to trade: Insights from cross-sectional and panel analyses. *Margin: The Journal of Applied Economic Research*, 6(2): 235–275.

Fiess, N. M., Fugazza, M., and Maloney, W. F. 2010. Informal self-employment and macroeconomic fluctuations. *Journal of Development Economics*, 91(2):211–226.

Foster, L., Haltiwanger, J., and Syverson, C. 2008. Reallocation, firm turnover, and efficiency: Selection on productivity or profitability? *American Economic Review*, 98(1): 394–425.

Friedman, E., Johnson, S., Kaufmann, D., and Zoido-Lobaton, P. 2000. Dodging the grabbing hand: The determinants of unofficial activity in 69 countries. *Journal of Public Economics*, 76(3):459–493.

Gajigo, O. and Hallward-Driemeier, M. 2012. Why do some firms abandon formality for informality? Evidence from African countries. Working Paper 159, African Development Bank.

Gatti, R. 2004. Explaining corruption: Are open countries less corrupt? *Journal of International Development*, 16(6):851–861.

Goldberg, P. K., Khandelwal, A. K., Pavcnik, N., and Topalova, P. 2010. Multiproduct firms and product turnover in the developing world: Evidence from India. *Review of Economics and Statistics*, 92(4):1042–1049.

Goldberg, P. K. and Pavcnik, N. 2003. The response of the informal sector to trade liberalization. *Journal of Development Economics*, 72(2):463–496.

Günther, I. and Launov, A. 2012. Informal employment in developing countries: Opportunity or last resort? *Journal of Development Economics*, 97(1):88–98.

Heid, B., Larch, M., and Riaño, A. 2013. The rise of the maquiladoras: A mixed blessing. *Review of Development Economics*, 17(2):252–267.

Helpman, E. and Itskhoki, O. 2010. Labour market rigidities, trade and unemployment. *Review of Economic Studies*, 77(3):1100–1137.

Helpman, E., Melitz, M. J., and Yeaple, S. R. 2004. Export versus FDI with heterogeneous firms. *American Economic Review*, 94(1):300–316.

Helpman, E., Itskhoki, O., and Redding, S. J. 2010. Inequality and unemployment in a global economy. *Econometrica*, 78(4):1239–1283.

Howitt, P. 2002. Looking inside the labor market: A review article. *Journal of Economic Literature*, 40(1):125–138.

Hsieh, C.-T. and Klenow, P. J. 2009. Misallocation and manufacturing TFP in China and India. *Quarterly Journal of Economics*, 124(4):1403–1448.

Hsieh, C.-T. and Klenow, P. J. 2014. The life cycle of plants in India and Mexico. *Quarterly Journal of Economics*, 129(3):1035–1084.

Hu, A. G. and Liu, Z. 2014. Trade liberalization and firm productivity: Evidence from Chinese manufacturing industries. *Review of International Economics*, 22(3):488–512.

Iacovone, L. and Javorcik, B. S. 2008. Multi-product exporters: Diversification and micro-level dynamics. Policy Research Working Paper Series 4723, World Bank.

Imbs, J. and Wacziarg, R. 2003. Stages of diversification. *American Economic Review*, 93 (1):63–86.

Johnson, S., Kaufmann, D., and Zoido-Lobatón, P. 1998. Regulatory discretion and the unofficial economy. *American Economic Review*, 88(2):387–392.

Khandelwal, A. K., Schott, P. K., and Wei, S.-J. 2013. Trade liberalization and embedded institutional reform: Evidence from Chinese exporters. *American Economic Review*, 103 (6):2169–2195.

Klenow, P. J. and Rodríguez-Claire, A. 1997. Quantifying variety gains from trade liberalization. Mimeo, Graduate School of Business, University of Chicago.

Klinger, B. and Lederman, D. 2004. Discovery and development: An empirical exploration of "new" products. Policy Research Working Paper Series 3450, World Bank.

Koren, M. and Tenreyro, S. 2007. Volatility and development. *Quarterly Journal of Economics*, 122(1):243–287.

Kreickemeier, U. and Nelson, D. 2006. Fair wages, unemployment and technological change in a global economy. *Journal of International Economics*, 70(2):451–469.

Krugman, P. R. 1979. Increasing returns, monopolistic competition, and international trade. *Journal of International Economics*, 9(4):469–479.

La Porta, R. and Shleifer, A. 2008. The unofficial economy and economic development. *Brookings Papers on Economic Activity*, 2008:275–352.

La Porta, R. and Shleifer, A. 2011. The unofficial economy in Africa. Working Paper 16821, National Bureau of Economic Research.

La Porta, R. and Shleifer, A. 2014. Informality and development. *Journal of Economic Perspectives*, 28(3):109–126.

Levinsohn, J. and Petrin, A. 2003. Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, 70(2):317–341.

Loayza, N. V. 1996. The economics of the informal sector: A simple model and some empirical evidence from Latin America. *Carnegie-Rochester Conference Series on Public Policy*, 45:129–162.

Loayza, N. V., Oviedo, A. M., and Serven, L. 2005. The impact of regulation on growth and informality - cross-country evidence. Policy Research Working Paper Series 3623, World Bank.

Malesky, E. and London, J. 2014. The political economy of development in China and Vietnam. *Annual Review of Political Science*, 17(1):395–419.

McCaig, B. and Pavcnik, N. 2013. Moving out of agriculture: Structural change in Vietnam. Working Paper 19616, National Bureau of Economic Research.

McCaig, B. and Pavcnik, N. 2014. Export markets and labor allocation in a low-income country. Working Paper 20455, National Bureau of Economic Research.

McKenzie, D. and Sakho, Y. S. 2010. Does it pay firms to register for taxes? The impact of formality on firm profitability. *Journal of Development Economics*, 91(1):15–24.

Melitz, M. J. 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6):1695–1725.

Menezes-Filho, N. A. and Muendler, M.-A. 2011. Labor reallocation in response to trade reform. Working Paper 17372, National Bureau of Economic Research.

Mullainathan, S. and Schnabl, P. 2010. Does less market entry regulation generate more entrepreneurs? Evidence from a regulatory reform in Peru. In Lerner, J. and Schoar, A., editors, *International differences in entrepreneurship*, National Bureau of Economic Research Conference Report, pages 159–177. University of Chicago Press, Chicago, IL.

Nataraj, S. 2011. The impact of trade liberalization on productivity: Evidence from India's formal and informal manufacturing sectors. *Journal of International Economics*, 85(2): 292–301.

Paz, L. S. 2014. The impacts of trade liberalization on informal labor markets: A theoretical and empirical evaluation of the Brazilian case. *Journal of International Economics*, 92(2): 330–348.

Perry, G. E., Maloney, W. F., Arias, O. S., Fajnzylber, P., Mason, A. D., and Saavedra, J. 2007. *Informality: Exit and exclusion*. The World Bank, Washington, D.C.

Prado, M. 2011. Government policy in the formal and informal sectors. *European Economic Review*, 55(8):1120–1136.

Radchenko, N. 2014. Heterogeneity in informal salaried employment: Evidence from the Egyptian labor market survey. *World Development*, 62:169–188.

Ramos, R., Duque, J. C., and Surinach, J. 2010. Is the wage curve formal or informal? Evidence for Colombia. *Economics Letters*, 109(2):63–65.

Rand, J. and Torm, N. 2012a. The benefits of formalization: Evidence from Vietnamese manufacturing SMEs. *World Development*, 40(5):983–998.

Rand, J. and Torm, N. 2012b. The benefits of formalization: Evidence from Vietnamese manufacturing SMEs. *World Development*, 40(5):983–998.

Rauch, J. E. 1991. Modelling the informal sector formally. *Journal of Development Economics*, 35(1):33–47.

Roberts, M. J. and Tybout, J. R. 1997. The decision to export in Colombia: An empirical model of entry with sunk costs. *American Economic Review*, 87(4):545–564.

Romer, P. 1994. New goods, old theory, and the welfare costs of trade restrictions. *Journal of Development Economics*, 43(1):5–38.

Schneider, F. and Enste, D. H. 2000. Shadow economies: Size, causes, and consequences. *Journal of Economic Literature*, 38(1):77–114.

Schneider, F., Buehn, A., and Montenegro, C. E. 2010. New estimates for the shadow economies all over the world. *International Economic Journal*, 24(4):443–461.

Sharma, S. 2009. Entry regulation, labor laws, and informality. Policy Research Working Paper Series 48927, World Bank.

Svensson, J. 2003. Who must pay bribes and how much? Evidence from a cross section of firms. *Quarterly Journal of Economics*, 118(1):207–230.

Svensson, J. 2005. Eight questions about corruption. *Journal of Economic Perspectives*, 19 (3):19–42.

Thon, D. 1982. An axiomatization of the Gini coefficient. *Mathematical Social Sciences*, 2 (2):131–143.

Topalova, P. 2010. Factor immobility and regional impacts of trade liberalization: Evidence on poverty from India. *American Economic Journal: Applied Economics*, 2(4):1–41.

Treisman, D. 2000. The causes of corruption: A cross-national study. *Journal of Public Economics*, 76(3):399–457.

Tybout, J. R. 2000. Manufacturing firms in developing countries: How well do they do, and why? *Journal of Economic Literature*, 38(1):11–44.

Ulyssea, G. 2010. Regulation of entry, labor market institutions and the informal sector. *Journal of Development Economics*, 91(1):87–99.

Van Biesebroeck, J. 2007. Robustness of productivity estimates. *Journal of Industrial Economics*, 55(3):529–569.

Verhoogen, E. A. 2008. Trade, quality upgrading, and wage inequality in the Mexican manufacturing sector. *Quarterly Journal of Economics*, 123(2):489–530.

Vogel, D. 2013. Global trade linkages: National security and human security. In Aggarwal, V. K. and Govella, K., editors, *Linking Trade and Security: The Political Economy of the Asia Pacific*, book 2, pages 23–48. Springer-Verlag New York, New York, NY.

Wagner, J. 2007. Exports and productivity: A survey of the evidence from firm-level data. *World Economy*, 30(1):60–82.

World Bank. 2013. *Doing Business 2014: Understanding Regulations for Small and Medium-Size Enterprises*. World Bank Group, Washington, D.C.