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Essays on Industrial Development and Political Economy of Africa

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To Ete and Meyie

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Eyerusalem Siba
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Abstracts

Paper 1: Returns to Capital and Informality

We study the pattern of returns to capital in the formal and informal manufacturing sectors in Ethiopia. We use a rich panel dataset of manufacturing firms in the formal sector for the period 1996-2006 and two rounds of repeated cross-sectional data of the urban informal sector firms. Both parametric and semi-parametric regression techniques are used to study the magnitude and pattern of returns to capital. Our results show that the median return to capital in the formal sector is 15-21%, while in the informal sector it is 52-140%. Higher returns in the informal sector potentially explain growing informality in Ethiopia. Investment in the informal sector is, however, limited since returns to capital decline as owner's share of time spent in the enterprise decreases. This restricts both formal and informal firms from establishing new informal firms in order to take advantage of the higher returns in the sector. Unlike the prediction of the poverty trap hypothesis, we find that returns to capital decrease with capital stock, creating an opportunity for small firms to grow by re-investing their profit. Making firm locations closer to customers affordable, creating equitable linkages with the formal sector and providing assistance on marketing skills are therefore policy recommendations that can encourage growth and eventual graduation of informal sector firms.

Paper 2: The Performance of New Firms: Evidence from Ethiopia's Manufacturing Sector

We investigate the relative importance of technological and demand constraints for firm performance using a panel dataset of Ethiopian manufacturing sector (1996-2006). Previous empirical research on firm performance use revenue based productivity which confounds true efficiency with price effects. Using information on price and physical quantity of firms' products, we decompose revenue based productivity into physical productivity, price and idiosyncratic demand shocks. Comparison of various components of productivity across firms, using product and firm fixed effect estimation, reveals that entrants have lower demand and output prices than established firms. However, we do not find a robust difference in productivity between entrants and established firms. Thus, young and small firms are found to be most vulnerable

to demand constraints. Analysis of firm survival using probit regression reveals that firms' market access is a more important determinant of survival than productivity. Securing access to markets and providing assistance on marketing skills during most vulnerable stage of firm entry are intervention areas so that efficient firms with long term growth prospect are not driven out of business.

Paper 3: The Effects of Agglomeration and Competition on Prices and Productivity: Evidence for Ethiopia's Manufacturing Sector

We use census panel data on Ethiopian manufacturing firms to analyze the effects of enterprise clustering on two key determinants of firm performance: physical productivity and output prices. We show that distinguishing between productivity and prices is important for understanding the effects of agglomeration and competition. We find a negative and statistically significant effect of agglomeration of firms on prices, suggesting that new entry leads to higher competitive pressure in the local economy. We also find a positive and statistically significant effect of agglomeration on physical productivity, consistent with the notion that clustering leads to positive externalities. The net effect of enterprise clustering on revenue-based measures of performance is small and not significantly different from zero. Our results thus highlight the importance of separating price from productivity effects in this type of analysis. Cluster formation through creating industrial zones; and enhancing networking, technological learning as well as firm competition are key policy recommendations to boost enterprise productivity and cluster-based industrial development.

Paper 4: Ethnic Cleansing or Resource Struggle in Darfur? An Empirical Analysis

The conflict in Darfur has been described both as an ethnic cleansing campaign, carried out by the Sudanese government and its allied militias, and as a local struggle over dwindling natural resources between African farmers and Arab herders. In this paper, we use a previously unexploited data set to analyze the determinants of Janjaweed attacks on 530 civilian villages in Southwestern Darfur during the campaign that started in 2003. Our results clearly indicate that attacks have been targeted at villages dominated by the major rebel tribes, resulting in a massive displacement of those populations. Resource variables, capturing access to water and land quality, also appear to have played an important role. These patterns suggest that attacks in the area were motivated by both ethnic cleansing and resource capture, although the ethnic variables consistently have a larger impact.

Summary of the Thesis

This thesis consists of four self-contained essays summarized below.

1 Returns to Capital and Informality

According to the 2005 national labor force survey of Ethiopia, 71% of the urban employment is in the informal sector (CSA, 2006). The mere size of the sector makes it both a policy concern and an instrument for employment creation and poverty alleviation. It is a concern because firms in the sector operate in a complex business environment outside the umbrella of supporting institutions that provide access to finance and secure property rights, hampering their productivity. They also operate in localized markets with limited access to reliable and wider markets. Thus, it is not a coincidence that the informal sector is widely associated with working poverty and low productivity that limit its prospects of providing a sustainable livelihood (ILO, 2008). Supporting informal firms with the aim of improving their productivity, growth potential as well as eventual graduation from the sector is at the core of many development programs (MOTI, 1997; ILO, 2008). A central question for policy makers is, therefore, whether informal firms hold a potential for income growth for their owners and for becoming successful large firms in the future.

One hypothesis on the growth constraints of microenterprises, which primarily constitute informal and small formal firms, is that these firms may be locked in a poverty cycle which is difficult for them to break out from, leading to a “poverty trap”. According to the ”poverty trap” hypothesis, firm growth is constrained by poor access to external financial resources in combination with low return to investment for firms with limited capital to start with (McKenzie et al., 2006). The poverty trap not only limits firm growth, it also discourages graduation into the formal sector and hence leads to persistent informality.

The current study primarily investigates the second dimension of the poverty trap hypothesis: the relationship between returns to capital and firm size in an

effort to understand whether credit constraints are binding constraints to long-term firm growth, when present. The study also poses two research questions that are related to firms' decision to enter the formal sector: whether returns to investment are higher in the formal sector and whether small firms can grow upon entry into the formal sector. To answer these research questions, we analyze the magnitude and pattern of returns to capital across different size categories and sectors using both parametric and semi-parametric regression techniques. We use a panel dataset (1996-2006) of formal firms and two rounds of repeated cross-sectional data (1996 and 2003) for the urban informal firms in the manufacturing sector in Ethiopia.

The empirical results indicate that median returns to capital are higher in the informal sector. The higher return may imply better market fundamentals or pronounced financial constraints in the sector. If it is indeed the former, one form of mechanism to take advantage of better market fundamentals would be to establish new informal firms. This possibility, however, is limited in the sector because of the organizational structure of informal firms. This is because; our empirical results show a declining median returns to capital as the share of owner's time in the total labor input of informal enterprise decreases. Owner's time may play an important role for enterprise performance both because it implies increased supervision on workers' effort and owners may possess skills that are not easy to find in the labor market. This makes establishing new informal firms not a viable strategy to take advantage of higher returns in the informal sector and leaves informal firms with the option of growing by saving and re-investing their profits.

On the other hand, median returns to capital in the formal sector do not decrease as the share owners' time in total labor input of the enterprise decreases, allowing small firms to take advantage of the higher returns to capital by establishing new formal firms. The difference in returns to capital in the two sectors may then be explained by differences in business environment: formal firms, for instance, are contractual firms in which the physical presence of owners can be made less important by introducing enforceable employment rules and regulations, paying higher 'efficiency' wages and hiring management staff to induce higher workers' effort. Further evidence against better market fundamentals in the informal sector is also found when comparing formal and informal firms with comparable capital stock. Median returns are higher in the formal sector. This indicates that for small informal firms there is a premium for staying informal, but as they get larger, they are better off joining the formal sector.

Coming to the issue of firm growth, there is no empirical support for the presence of poverty trap both in the formal and informal sectors since returns to capital decline with invested capital stock. This implies that small firms can grow by re-investing their profits even if they are credit constrained provided that firms have a secure access to markets to realize the actual profits and that profits are not diverted into other competing household needs. When micro entrepreneurs were asked about the main factor constraining the current operation and expansion of their enterprises, lack of/inadequate market and shortage of working capital topped the list. These shortages are inevitable since the enterprises mainly serve localized markets and very few informal firms strategically locate themselves close to markets, competitors or raw material sources. Making firm locations closer to customers affordable, creating equitable linkages with the formal sector and providing assistance on marketing skills are therefore policy recommendations that can encourage growth and eventual graduation of informal sector firms.

2 The Performance of New Firms: Evidence from Ethiopia's Manufacturing Sector

In this paper, we investigate the economic performance of new firms in Ethiopian manufacturing sector. The sector experienced rapid increase in firm entry with the number of firms in the market growing by 83% over the period 1996-2006. However, exit rate among new firms in Ethiopia has been high too (Gebreeyesus, 2008). We investigate two research questions: why do new firms have high exit rate? And how do they perform conditional on survival? Previous studies have shown that likelihood of survival decreases when economic performance of firms deteriorates (Frazer, 2005; Söderbom et al. 2006; Gebreeyesus, 2008; Shiferaw, 2009) and that economic performance increases with firm age (Sleuwaegen and Goedhuys, 2002; Van Biesebroeck, 2005). A common interpretation of these findings is that African markets drive out poorly performing firms and that firms learn to update their productivity as they grow older.

Better economic performance of firms is often inferred in much of the literature from high sales value of output conditional on factor inputs: revenue-based productivity measure. This measure of firm performance, however, confounds output price with physical productivity (Katayama et al., 2008; Foster et al., 2008). In this study, we show that it is essential to distinguish between physical productivity and high prices to analyze whether the type of firms most likely to survive in Africa are those most able to extract rents and charge higher prices or those with highest productivity. Similarly, previous results on learning using revenue-based productivity are also subject to this concern. To our knowledge, no previous study in the literature on African manufacturing firms makes this distinction. The study also contributes to the debate on which types of skills matter for enterprise success in Africa by investigating the relative importance of technological and demand constraints for firm performance (Pack, 1993; Sutton & Kellow, 2010).

In this study, we seek to fill these gaps in the literature using firm-level panel data set of Ethiopian manufacturing sector (1996-2006). Availability of product module information in our dataset enables us to construct product-specific prices and quantities at firm-level. Equipped with this information, we can thus distinguish between prices, physical productivity and product demand shocks to investigate how these correlate with the likelihood of exit and how they develop in the first few years following entry into the market.

Comparison of various components of productivity across firms, using product and firm fixed effect estimation, reveals that entrants have lower demand and output prices than established firms. However, we do not find a robust difference in physical productivity between entrants and established firms. Thus, young and small firms are found to be most vulnerable to demand constraints. Analysis of firm survival using probit regression reveals that firms' market access, demand shocks in particular, is a more important determinant of survival than productivity. Securing access to markets and providing assistance on marketing skills during most vulnerable stage of firm entry are intervention areas so that efficient firms with long term growth prospects are not driven out of business.

3 The Effects of Agglomeration and Competition on Prices and Productivity: Evidence for Ethiopia's Manufacturing Sector

Geographical agglomeration, or clustering, of enterprises can be an important source of improved firm performance. By locating close to suppliers, customers and competitors, an enterprise may be able to benefit from information spillovers, obtain better access to skilled labor, and face lower cost of capital and transaction costs (Marshall, 1920). Various studies have shown that agglomeration economies are an important source of productivity and employment growth in developed countries (Glaeser et al., 1992; Henderson, 1997; Combes, 2000; Blien et al., 2006). However, very few studies exist providing quantitative evidence on effects of agglomeration economies in Africa (Fafchamps and El Hamine, 2004; Fafchamps and Söderbom, 2011).

If markets are poorly integrated, an increase in the number of firms in the local market also creates competitive pressure forcing firms to be more efficient in order to stay in the market. Previous studies have shown that competition enhances the incentive to engage in innovation, improve firm productivity and cut output prices (Aghion et al., 2009; Bigsten et al., 2009; Syverson, 2007).

One methodological weakness of previous studies on the effect of agglomeration and competition on firm performance is the use of productivity measure that confounds price with true productivity effects (Foster et al., 2008). The most common productivity measure used is the sales value of enterprise output conditional on factor inputs: revenue-based productivity measure. Katayama et al. (2008), for instance, argue that findings that geographically clustered firms are relatively productive attributed to agglomeration economies may simply reflect higher prices in urban areas.

The current study empirically analyzes the effects of enterprise clustering on firm performance in Ethiopia. It contributes to the literature by separately investigating the price and productivity effects of competition and enterprise clustering using census based panel data of Ethiopian manufacturing sector over the period 1996-2006. Key to our analysis is the availability of information on price and physical quantity of firm's products. Using the information on firm's physical output, we investigate the effects of clustering and local competition on physical productivity: physical output conditional on factor inputs.

We measure cluster size by the number of producers in firm's local market. The premise of the current study is that, in a poorly integrated economy, an increase in the number of producers in a given location may have two effects. First, entry into the local market may be associated with a reduction in the market power and in the output prices of established firms following new entry. Second, entry may lead to higher productivity, either because competition provides a disciplinary device on firms or because the higher density of firms results in externalities and more general agglomeration effects.

We find that agglomeration of firms reduces output prices, suggesting that new entry leads to higher competitive pressure in the local economy. In addition, consistent with the notion that clustering leads to positive externalities and enhances competition, we find a positive and statistically significant effect of agglomeration on physical productivity. However, we do not find any robust effect of the conventional revenue based productivity measures such as sales or value added net of factor input. Our results thus highlight the importance of separating price from productivity effects for understanding the effects of agglomeration. Cluster formation through creating industrial zones; and enhancing networking, technological learning as well as firm competition are key policy recommendations to boost enterprise productivity and cluster-based industrial development.

4 Ethnic Cleansing or Resource Struggle in Darfur? An Empirical Analysis

Darfur is a westernmost province of Sudan with a population of about 6.5 million inhabitants. The population is often categorized as “African” farmers and Nomadic “Arab” tribes. The African tribes are usually sedentary agriculturalists and include some of the indigenous tribes Fur, Masalit and Zaghawa. The Arab tribes typically practice nomadic lifestyle with seasonal migration across farmland which is a cause for the long standing resource struggle between different groups in Darfur for fertile land and access to water. The issue of land became more critical following the growing pressure on natural resources as a result of land degradation, and expanding agricultural land to meet the demands of increased population (O’Fahey & Tubiana, 2009; Abdul-Jalil, 2006).

The recent conflict in Darfur started in 2003 when Sudanese Liberation Army (SLA) and Justice and Equality Movement (JEM) opposition groups, mainly from Fur, Masalit and Zahgawa tribes, attacked government outposts due to their perceived marginalization of Darfur in a national context. The government of Sudan (GoS) and local militias, the Janjaweed, made a counter-insurgency campaign during 2003 on civilian villages (Flint and de Wal, 2008). By 2008, 300,000 deaths and 2.7 million displacements of individuals are reported as a result of the conflict (BBC, 2008). The current study focuses on this second dimension of the conflict and investigates what determines which civilian villages are attacked or not and also the intensity of attack.

There is a debate in the literature on whether the conflict was an ethnic cleansing campaign, carried out by the Sudanese government and its allied militias or a local resource struggle between African farmers and Arab herders. The official view of the GoS is the latter, and it claims that there was no government involvement in the conflict. The importance of land degradation and a deteriorating climate for understanding Darfur has been emphasized by (UNEP, 2007; Sachs, 2006). However, using annual data on rainfall in Darfur, Kevane and Gray (2008) fail to find any clear link between rainfall and conflict onset.

The International Criminal Court (ICC, 2010) and United Nations Security Council (2005), on the other hand, claim that ethnic cleansing, often described as a sustained attempt by one group to remove another group - defined in ethnic, religious, or political terms - from a given territory, is the main motivation of the conflict in Darfur. In the most recent version of the warrant of arrest against Sudan's president, the ICC briefly refers to "acts of murder and extermination" that were perpetrated against the Fur, Masalit, and Zaghawa groups in certain localities in West Darfur (ICC, 2010, p 6).

In this study, we test these hypotheses in explaining the counter-insurgency attacks against 530 civilian villages in Southwestern Darfur. Key to our analysis is the availability of detailed information on ethnic composition of each village before and after the conflict from all known villages in the area. On the basis of GIS data, we also create a number of proxy variables for appropriable natural resources, the density of vegetation, access to alluvial soils and distance to surface water. We propose two main hypotheses to be tested in the empirical analysis: The probability and intensity of attacks on villages should increase with the proportion of rebel tribes in a village's population and with the level of appropriable natural resources.

We also offer a basic theoretical framework for understanding how ethnic cleansing might emerge as an equilibrium outcome in a conflict between competing groups. A key insight from our model is that village attacks by the militia, primarily interested in resource capture, will only take place: if the perceived social costs of attacking certain ethnic groups have decreased due to government propaganda aimed at making the groups in question legitimate targets of attack; if the direct opportunity cost of predation is low due to poor normal production potential, and if the militia are relatively more dominant than the villagers, probably because of government support.

Our empirical analysis demonstrates that the proportion of the rebel tribes, the Fur, Masalit, and Zaghawa, in the population is a robust determinant of the probability and intensity of attacks. This result is robust to the choice of alternative resource variables, control variables, samples, and levels of aggregation. Resource variables, capturing access to water and land quality, also appear to have played an important role. These patterns suggest that attacks in the area were motivated by both ethnic cleansing and resource capture, although the ethnic variables consistently have a larger impact.

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Paper I

Returns to Capital and Informality

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Abstract

In this paper we study the pattern of returns to capital in the formal and informal manufacturing sectors in Ethiopia. We use a rich panel dataset of manufacturing firms in the formal sector for the period 1996-2006 and two rounds of repeated cross-sectional data of the urban informal sector firms. Both parametric and semi-parametric regression techniques are used to study the magnitude and pattern of returns to capital. Our results show that the median return to capital in the formal sector is 15-21%, while in the informal sector it is 52-140%. Higher returns in the informal sector potentially explain growing informality in Ethiopia. Investment in the informal sector is, however, limited since returns to capital decline as the amount of time a firm owner spends in her enterprise decreases. This time constraint restricts both formal and informal firms from establishing new informal firms in order to take advantage of the higher returns in the sector. Unlike the prediction of the poverty trap hypothesis, we find that returns to capital decrease with capital stock, creating an opportunity for small firms to grow by re-investing their profit.

Key Words: Returns to capital, Informal sector, Poverty trap, Credit Constraints, Ethiopia
JEL Classification: L25, O12, O16, O17, O55

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1 Introduction

The growing phenomenon of informality in Africa is mainly a result of stagnation of the overall economy, and entry barriers as well as regulatory burdens in the formal sector (Xaba et al., 2000). In sub-Saharan Africa, it contributes 41% to the non-agricultural share of GDP and employs 72% of the labor force in the non-agricultural sectors (ILO, 2002). According to the 2005 national labor force survey of Ethiopia, 71% of the urban employment is in the informal sector. This makes the sector a potential instrument for employment creation and poverty alleviation. The informal sector in Africa is, however, widely associated with working poverty and low productivity that limit its prospects of providing a sustainable livelihood (ILO, 2008). Informal firms operate in a complex business environment outside the umbrella of supporting institutions that provide access to finance and secure property rights, hampering their productivity. They also operate in localized markets with limited access to reliable and wider markets.

Supporting informal firms with the aim of improving their productivity, growth potential as well as eventual graduation from the sector is at the core of many development programs; see for example the national micro and small enterprises development strategy of Ethiopia (MOTI, 1997) and decent work strategies for the informal economy of ILO (ILO, 2008). A central question for policy makers is, therefore, whether informal firms hold a potential for income growth for their owners and for becoming successful large firms in the future. Such a growth prospect would imply a potential for the improvement of the thin industrial base of Africa and its contribution to economic development and poverty reduction.

The current study aims at investigating the presence of a poverty trap in the Ethiopian formal and informal sectors. Credit constraints and increasing returns to investment are the two building blocks of the "poverty trap" hypothesis. According to the hypothesis, firm growth is constrained by poor access to external financial resources in combination with low return to investment for firms with limited capital to start with. Firms are then locked in a "poverty trap" due to inability to mobilize both internal and external financial resources (McKenzie et al., 2006). Whether Ethiopian firms are credit constrained or not is not the focus of the current study. Rather, we are interested in investigating whether it is binding to firm growth, when present. We do so, by investigating the second dimension of poverty trap hypothesis: the relationship between returns to capital and firm size. A poverty trap in the informal sector, if present, would imply lack of graduation and persistence of informality. Whereas the presence of a poverty trap in the formal sector not only limits the growth prospect of small formal firms but also discourages formalization.

To this end, the study answers mainly two research questions that are key for the decision to enter the formal sector. First, does the formal sector offer an attractive return to investment for informal firms to join? This relates to the occupational choice literature where informality is explained by high cost of being formal relative to its benefits: earning differentials (Carneiro and Heneley, 2001; Fajnzylber et al., 2006; Badaoui et al., 2010; McKenzie and Sakho, 2010), ability to participate in productivity enhancing public services (Leverson and Maloney, 1998; Bigsten et al., 2004) and more efficient credit markets (Straub, 2005; Antunes and Cavalcanti, 2007; Dabla-Norris et al., 2008).

The empirical findings on benefits of formality are mixed. Based on estimated productivity differentials of small formal and informal firms in Kenya, Bigsten et al. (2004) argue that informality is driven mainly by the cost of being formal rather than by the productivity differential between firms in the two sectors. Fajnzylber et al., on the other hand, find higher profits due to formalization: paying taxes and belonging to business association in particular. Mckenzie and Sakho also find that formality increases profits only for mid-sized firms, but lowers profits for both the smaller and larger firms. Our study contributes to this discussion by investigating size threshold effects in benefits of formality using a sample of both informal firms and firms larger than micro and small enterprises (MSEs). To our knowledge, this is the first attempt to provide a micro-level explanation for informality in Africa using differences in returns to capital.

This brings us to the second research question: is there a growth potential for small firms upon entry? Particularly, does the formal sector provide a conducive business environment for small firms to grow incrementally by re-investing their profits? The prospect of incremental growth is important for the entry decision because, when faced with borrowing constraints, firms can save and mobilize internal financial resources to grow in the formal sector. Low returns to investment for a smaller amount of starting capital, however, forces firms to enter only as large firms in order to have a better growth prospects. Such a requirement may create an entry barrier to the formal sector for firms that are unable to mobilize a large amount of external finance.

Previous studies have found a negative relationship between firm size and growth in Africa (Sleuwaegen and Goedhuys, 2002; Gebreeyesus and Bigsten, 2007). Yet, the African manufacturing sector remains to be dual largely attributed to a regulatory burden, credit markets and commercial policies bias against small firms, returns to size, geographically fragmented localized markets as well as skewed demand toward simpler goods (Fafchamps, 1994; Sleuwaegen and Goedhuys, 2002; Tybout, 2000).[1] According to Fafchamps, large African firms benefit from returns to size and government policies, while microenterprises take advantage of their ability to bypass laws and regulations and lower labor costs. Medium-size firms, on the other hand, are too small to capture returns to size and qualify for direct government support but too large to avoid laws and regulation. Hence, firms with easy access to capital enter

[1] Dual industrial structure is defined by the co-existence of a small number of large firms producing the largest share of output and a very large number of small firms but not so many mid-sized firms.

the industry at the high end, while firms with limited financial resources can only enter at the low end. He argues that small firms cannot incrementally grow by reinvesting annual profits if the cost disadvantage of middle-sized firms is sufficiently large. Similarly, Sleuwaegen and Goedhuys find that very few small firms grow to a large scale, whereas formal firms that start at a large scale have a relatively stronger growth performance as they grow older in Cote d'Ivoire.

The current study aims to contribute to the above growth and industrial structure literature by empirically investigating whether small firms can grow by re-investing their profit; whether credit constraints are binding to firm growth and whether it explains the persistence and expansion of informal sector. We use two rounds of cross-sectional data for the informal sector and eleven years of panel data for the formal sector in Ethiopia. Both parametric and non-parametric regression techniques are used to estimate returns to capital and to investigate its relationship with invested capital stock.

Our results show that returns to capital decrease with capital stock in both the formal and informal sectors. Contrary to the poverty trap hypothesis, this implies that small firms can grow even if they are credit constrained by re-investing their profit. We also find that, controlling for firm size, informal firms have higher returns to capital than formal firms. The higher return may indicate investment opportunities, and hence explain the expansion of informality in Ethiopia; or it may indicate the presence of financial constraints, which might have restricted investment in the sector. If indeed high returns indicate the former, we expect informal firms to invest and grow. Investment in the informal sector is, however, limited because of the organizational structure of informal firms. We find that returns to capital decline as the share of owner's time in total labor input of the enterprise decreases. In the formal sector, on the other hand, we find an opposite pattern of returns to capital. The rest of the paper is organized as follows: Section 2 discusses the conceptual framework and testable hypotheses of the study; Section 3 presents discussions on data and descriptive statistics; Section 4 presents the empirical results and robustness checks of our main findings; and Section 5 concludes.

2 Conceptual Framework

2.1 Previous Research

A relatively small number of studies have estimated returns to capital in developing countries. Using the Cobb-Douglas production function, Bigsten et al. (2000) estimate the median returns to capital to be 22% across manufacturing firms in five African countries. McKenzie et al. (2006), using a cross-section of microenterprises in Mexico, estimate annual returns to capital to be 180% for microenterprises investing less than \$200 and 40-50% for firms investing more than \$500. Recent studies focus on mitigation of ability bias and measurement error in returns to capital estimation by using a natural experiment of credit shock due to policy change (Banerjee and Duflo, 2004) and randomized allocation of capital for firms (De Mel et al., 2008). Experimental studies find largely similar estimates of returns to capital to the non-experimental evidence. Banerjee and Duflo (2004) find annual returns to capital in medium-sized Indian firms to be at least 72%, while De Mel et al. (2008) estimate annual returns to capital in Sri Lankan microenterprises to be 55-63%.

The evidence on returns to physical capital in developing countries suggests that the returns are relatively high for small firms and well above the market interest rates. However, investment in these firms does not always respond to returns.[2] Capital constraints and uncertainty are the most commonly cited reasons for such a pattern. Firms do not take on investment opportunities with higher rate of return whenever they are uncertain about their ability to capture the returns to their investment; and credit constraints limit them even when they want to invest. Under capital market imperfections, due to imperfect information, cumbersome contract enforcement and lack of competition among lenders, a firm's profitability affects its capacity to finance investment.[3]

Studies focusing on microenterprises (De Mel et al., 2008; McKenzie et al., 2006) suggest credit constraint as the primary explanation for the higher rate of returns to investment in small firms. However, most studies on Africa's manufacturing sector show that credit constraints play a limited role in explaining low investment despite high profit rates. Bigsten et al. (1999) find that of an additional unit of profit, only 6-10% is used to raise the rate of investment. In their 2003 study, testing for credit constraints in the manufacturing sector of six African countries, Bigsten et al. do not find strong evidence that firms, with the exception of small firms, may be credit constrained. Studies on investment in Africa, on the other hand, find that firm-level investment is negatively affected by uncertainty due to investment irreversibility and conclude that risk rather than financial constraints has a strong negative effect on investment (Bigsten et al., 1999; 2005; Gebreeyesus, 2006; Shiferaw, 2009).

The current study aims to contribute to the literature by investigating whether credit constraints are binding to firm growth in Ethiopian formal and informal manufacturing sectors. We draw on the poverty trap literature which attributes low investment rates to the joint presence of credit constraint and increasing returns to capital. First, we investigate the relationship between returns to capital and firm size and its implication to the existence of a poverty trap. We then develop alternative testable hypotheses in explaining the growth and persistence of informality.

[2] Anagol and Udry (2006), for instance, compare returns to capital in pineapple cultivation vs. traditional maize and cassava cultivation in Ghana. They note that despite a higher return in pineapple cultivation, not many firms switch to it.

[3] See Banerjee (2003) for a theoretical discussion of causes of capital market imperfection and Banerjee and Duflo (2005) for extensive review of literature on returns to capital and investment.

2.2 Returns to Capital Estimations

The first step to estimate returns to invested capital stock, is to use estimates from a regression of log profit on polynomials of log capital stock together with other control variables.

$$\ln \Pi_i = \beta_0 + \beta_1 \ln K_i + \beta_2 (\ln K_i)^2 + \cdots + \beta_n (\ln K_i)^n + \Gamma_1 X_i + \epsilon_i \quad (1)$$

where Π_i is profit, K_i is capital stock of firm i and X_i is a set of control variables such as firm age and employment, sector and year effects. Additional human capital and other owner characteristics are used for the informal sector.[4] Median regression technique is implemented to estimate all the profit equations in this study to mitigate the bias introduced by influential observations and measurement errors in returns to capital estimations.[5] The implied conditional median return to capital is calculated using equation 2:[6]

$$\frac{\partial Med\left[\Pi_i \left|()\right.\right]}{\partial K_i} = \left(\beta_1 + 2\beta_2 \ln K_i + \cdots + n * \beta_n (\ln K_i)^{n-1}\right) * \left[\frac{Med\left[\Pi_i \left|()\right.\right]}{K_i}\right] \quad (2)$$

The estimation of returns to capital using higher order polynomial depends on the degree of polynomial used.[7] To allow for functionally less restrictive estimation of returns to capital, median regression of log profit on categories of capital stock based on percentiles of capital stock is also used,

$$\ln \Pi_i = \theta_0 + \theta_1 Kcat10_i + \theta_2 Kcat20_i + \cdots + \theta_n Kcat100_i + \Gamma_2 X_i + \epsilon_i \quad (3)$$

where capital stock is sliced up into ten percentiles. $Kcat10_i = 1$ means that capital stock of firm i is less than or equal to the 10^{th} percentile for the sample, $Kcat20_i = 1$ implies that firm i's capital stock falls between the 10^{th} and 20^{th} percentiles and so on. In this specification, conditional meadian returns to capital (R) are estimated by dividing a change in the median profit by a change in the median capital stock between two consecutive capital categories:

$$R = \frac{\Pi_z - \Pi_{z-1}}{K_z - K_{z-1}} = \frac{\left(\exp^{\theta_z - \theta_{z-1}} - 1\right) * \Pi_{z-1}}{\Delta K} \quad (4)$$

[4] Unfortunately, we do not have such human capital variables for the formal sector, but we believe that the impact of owner characteristics is more pronounced in the informal firms as they are often run without hiring additional workers.

[5] Using the Shapiro-Wilk test for normality rejects the normality of log profit both for formal and informal sector at 1%.

[6] Eq. (2) estimates the conditional median returns to capital for each value of capital stock in our sample. When comparing median returns across sectors, we rely on median of the median returns to capital throughout the paper.

[7] The degree of the polynomial is decided by increasing the degree of capital stock until the next highest polynomial degree of capital stock is insignificant.

where z denotes percentiles of capital. Observed median profit and capital stock are used to estimate (4), and the θ's are obtained from (3).

Finally, we use partial linear regression techinqe to estimate the functional relationship between returns to capital and capital stock

$$\ln \Pi_i = \psi^{'} X_i + f\left(\ln K_i\right) + \epsilon_i \tag{5}$$

where the functional form of $f()$ is unspecified.[8] ϵ_i is a mean-zero error term with variance σ_ϵ^2, and the vector X_i includes a set of control variables such as firm age, sector, and year effects specified parametrically. A combination of differencing and smoothening techniques (Yatchew, 1997; 2003) is used to estimate (5). The parametric component is first estimated as if there is no non-parametric component by using the differencing technique. This procedure involves sorting the data by capital stock such that $K_1 \leq K_2 \leq ... \leq K_n$, where n is number of observation. We then differnce the sorted data:

$$\ln \Pi_j - \ln \Pi_{j-1} = \left(X_j - X_{j-1}\right)\psi + \left(f\left(\ln K_j\right) - f\left(\ln K_{j-1}\right)\right) + \left(\epsilon_j - \epsilon_{j-1}\right) \tag{6}$$

where $j = 1, 2, ..., n$ indicates the number of observation.[9] Equation (6) is estimated using least squares and inference based on the differenced equation still holds in a similar way as in full parametric specifications (Yatchew,1997; 2003; Lokshin,2003).[10] We then use smoothening techniques to estimate f non-parametrically. Deducting the parametric component $\psi^{'} X_i$ from the dependent variable, we estimate the non-parametric component $f\left(\ln K_i\right)$ and the first order derivative $f'\left(\ln K_i\right)$ using locally weighted regression of Fan (1992).[11]

2.3 Testable Hypotheses

We start our analysis by comparing returns to capital estimates across different firm size categories. Increasing marginal returns to capital would be consistent with the poverty trap hypothesis. Returns can be higher for the smallest firms for a number of reasons. First, credit constraints can explain the inability of small firms to take advantage of high returns. The presence of decreasing returns to capital, however, would imply that credit constraints are less binding for long-term growth of small firms. This is only true provided that firms have secure access to market to realize the actual profits and provided that profits are not diverted into other competing household needs. For these reasons, credit constraints may remain important in the short-term.

[8] Except that f is single valued, has a bounded first order derivative, and that the parametric and non-parametric components are additively separable.

[9] When the sample size increases, $f(K_j) - f(K_{j-1}) \longrightarrow 0$ since f has bounded first order derivative.

[10] The STATA command PLREG by Lokshin (2003) is used to estimate difference-based partial linear regression.

[11] The implied returns to capital is given by $R = \frac{f^{'}(\ln K_i) * \exp^{X\widehat{\psi} + \widehat{f}(\ln K_i)}}{K}$

Alternatively, returns to capital can be higher for small firms due to their organizational structure, since small firms tend to adopt a traditional way of organizing business that requires the presence of the owner most of the time. Owners' labor supply may play crucial role in firm performance possibly because small firms cannot afford to pay their employees high wages to compensate for labor supervision (Fafchamps and Söderbom, 2006) and/or because of difficulty of matching skills suitable in small firms possibly due to differences in skills between the owner and the alternative external labor. It is often the case that, owners of informal firms have skills inherited from family in similar line of business which may be hard to find by hiring external labor. This in turn limits the possibility of the owner to establish many new small firms to take advantage of the higher returns to capital. If this labor supply constraint is binding, we would expect higher returns to capital in firms with larger share of owner's time in total labor input. We test this hypothesis using (7):

$$\begin{aligned} \ln \Pi_i &= \rho_0 + \rho_1 \ln K_i + \rho_2 (\ln K_i)^2 + ... + \rho_n (\ln K_i)^n + \alpha_1 Sh\_own_i \\ &+ \alpha_2 (\ln K_i * Sh\_own_i) + \gamma \ln (Lnon - owner) + \Gamma_3 X_i + \varepsilon_i \quad (7) \end{aligned}$$

where $\ln (Lnon - owner)$ is labor input by non-owners and Sh_own_i is owners' labor share in total labor inputs. Since very few informal firms hire external labor $\gamma \ln (Lnon - owner)$ is:

$$\gamma_1 I_{\{non-own>0\}} * \ln (Lnon - owner) + \gamma_2 * \left(1 - I_{\{non-own>0\}}\right).$$

where $I_{\{non-own>0\}}$ is a dummy variable equal to one if there is positive labor input from non-owners and zero otherwise. Return to capital is then estimated using (8) in which the share of owner's time affects return to capital via two channels: the elasticity of profit with respect to capital and the level of expected profit.

$$\begin{aligned} \frac{\partial Med [\Pi_i |()]}{\partial K_i} &= \left(\rho_1 + 2\rho_2 \ln K_i + ... + n\rho_n (\ln K_i)^{n-1} + \alpha_2 Sh\_own_i\right) \\ & * \left[\frac{Med [\Pi_i |()]}{K_i}\right] \quad (8) \end{aligned}$$

The effect of share of owner's time on median returns to capital can be analyzed using the cross derivative of profit with respect to capital and shares $\frac{\partial^2 Med[\Pi_i|()]}{\partial Sh\_own_i \partial K_i}$,given by (9):

$$\alpha_2 \left[\frac{Med [\Pi_i |()]}{K_i}\right] + (\rho_1 + 2\rho_2 \ln K_i + ... + n * \rho_n (\ln K_i)^{n-1} + \alpha_2 Sh\_own_i) * \frac{1}{K_i} \left[\frac{\partial Med [\Pi_i |()]}{\partial Sh\_own_i}\right] \quad (9)$$

Based on which $\frac{\partial^2 Med[\Pi_i|(K_i,X_i)]}{\partial Sh\_own_i \partial K_i} > 0$ is taken as supporting evidence for the organizational structure hypothesis.

3 Data and Descriptive Statistics

The data used in this study comes from the Central Statistical Agency (CSA) of Ethiopia. Two rounds of repeated cross section of the urban informal sector survey (1996 & 2003) are used. Multi-stage stratified sampling design was used to select the sample of urban informal sector surveys, in which the primary sampling units were enumeration areas (EAs).[12] First, sample EAs were selected from the 1994 population and housing census based on probability proportional to size. Next, a fresh list of households was prepared for the selected EAs, where one enumerator was assigned to make a complete list of households in a selected EA by going from house to house. Finally, 30 households per EA were systematically selected and surveyed. A total of 31,175 informal sector operators from all major urban centers of Ethiopia were covered in the 1996 and 2003 surveys. Forty percent (12,488) of these firms are from the manufacturing sector, which this study focuses on.

A firm is considered to belong to the informal sector if it meets all of the following criteria: it employs fewer than 10 workers, does not keep book of accounts, is not licensed by any government agency, and produces goods and services primarily for the market rather than for subsistence (CSA, 2003). Urban informal sector enterprises are typically home based or individual establishments operated by the owner with few or no employees. According to the agency, "they are for the most part operating on a very small scale and with a low level of organization. Most of them have very low levels of productivity and income, with little or no access to organized markets, credit institutions, modern technology, formal training and many public services and amenities" (CSA, 2003: 1).

The entrepreneurs were asked about their major reasons for choosing to operate in the informal sector. Strikingly, for 40% of the operators, lack of alternative source of income is the major reason for participating in the informal sector. Another 42% stated small investment requirement as a main reason for choosing the informal sector. The former suggests that people are pushed into the informal sector by factors such as poor performance of the overall economy and that the urban informal sector is a coping mechanism for the less privileged in the society.

Formal banks, microfinance institutions and the government in general play less important roles in supporting establishments in the urban informal sector. Own savings followed by loans and donations from friends and family are the main sources of initial capital. In 2003, a significant number of operators (40%) lacked sufficient capital despite the fact that firms in the informal

[12] Enumeration area (EA) is a unit of land delineated for the purpose of enumerating population and housing units without omission and duplication. An EA in urban areas usually consists of 150-200 housing units.

sector are established with a very low initial capital.[13] When asked about the main factor constraining the current operation and expansion of their enterprises, lack of/inadequate market and shortage of working capital topped the list. These shortages are inevitable since the enterprises mainly serve localized markets and very few informal firms strategically locate themselves close to markets/customers, competitors or raw material sources. The proportion of the operators who located their enterprise at home or in its vicinity was 86% in 2003, and the primary reasons for doing so were that the owner lives there (47%) and other locations were deemed unaffordable (30%). When asked about what type of assistance informal sector entrepreneurs would need from the government, more than 70% of the operators identified access to working place, better access to bank loans, and assistance with marketing.

Census-based panel data on Ethiopian manufacturing establishments collected by CSA is used to analyze the formal sector. The dataset includes all establishments employing at least 10 workers and use electricity in production for the period 1996-2006. The dataset includes capital, labor, raw material and energy inputs as well as other industrial costs and net indirect taxes. The number of firms grew from around 600 in 1996 to over 1000 in 2006.

As can be seen in Table 1, informal firms are younger than their formal counterparts with an average firm age of 9 years. The sector is female dominated (79%) with an average number of years of schooling of 2.4. Owner's labor input takes major share of total labor input in the informal firms.[14] In fact, only 18% of the informal firms have workers besides the owner, with a zero median share of paid labor. Formal firms, on the other hand, are mainly operated by hired labor with a minimal share of labor input of the owners: the working proprietors, active partners, and family workers.[15] The share of a formal sector firm owner's time is calculated as a ratio of the number of working proprietors, active partners, and family workers to the total number of persons engaged.[16]

It is also shown that informal firms have lower capital and profit than formal firms. Capital stock is measured by the average of capital stock at the beginning and end of the year at replacement value.[17] The latter is constructed

[13] Eighty-two percent of firms in the urban informal sector are established with an initial capital of less than 500 birr.

[14] Total labor input in the informal sector is measured as the number of days in a year worked by the owner and paid and unpaid partners and unpaid family members; paid permanent, contract and temporary workers; and paid and unpaid apprentices.

[15] Labor input in the formal sector is measured as the number of persons engaged rather than number of days worked due to data limitation. Total labor input in formal sector measures the number of: working proprietors, active partners, and family workers; permanent production and administrative workers; paid and unpaid apprentices.

[16] A corresponding and more comparable measure for the informal sector would be the share of family labor, defined as the share of the number of days per annum owners and unpaid family members worked in total labor input of a firm. This and a dummy variable (No other incomet) with a value of one if the owner does not have any other income-generating activity and zero otherwise are alternatively used to capture owners' time spent in the firm.

[17] Eight formal sector firms with capital stock greater than 150 million Ethiopian birr are

by adding net investment and beginning of the year capital stock adjusted for depreciation rate. Different depreciation rates are assumed for different categories of capital.[18] Profit, in the formal sector, is defined as value added less total wage expenditure and capital cost.[19] Profit for the informal sector is, on the other hand, monthly profit times number of months operated.[20]

4 Empirical Analysis

4.1 Returns to Capital, Firm Size and Informality

Table 2 presents results of the full parametric specification (1). We employ a median regression technique on the pooled dataset for both formal and informal firms. Log annual profit is regressed on third and fourth degree polynomials of log capital stock for informal and formal sector firms, respectively. In addition we control for firm age, employment, year and sector specific effects. Employment is measured using the total labor input used together with the share of paid labor. Additional human capital variables such as the age, gender, and educational status of the owner/manager of the informal sector firms are also included. In line with the literature on learning effect, the quadratic firm age effect implies that firms perform better as they get older until a threshold level after which age has a negative effect on profit. Firms with larger employment size and with higher shares of paid labor are found to have higher profits. The latter possibly indicates that firms that employ external labor are more profitable than those run by only the owners and family members. Among the owner characteristics, male-owned/managed firms have larger profits in the informal sector.

As shown in Table 2, we find that median returns to capital are higher in the informal sector than in the formal sector. Median return to capital is estimated to be 21% for formal firms (Column 1) and 140% for informal firms (Column 3). When adding additional control variables such as firm size, age and human capital variables, returns to capital estimates are lower for both formal (15%) and informal firms (52%). The estimates are in line with previous estimates of returns to capital. Bigsten et al. (2000) find median returns to capital of 22% in the formal sector of five African countries, whereas De Mel et

considered outliers and are hence taken out of this analysis, which leaves us with 8,876 firm-year observations.

[18] We used 5% for dwelling houses, non-residential buildings, and construction works, 8% for machinery and equipment, and 10% for vehicles and furniture and other fixtures. The perpetual inventory method (PIM) is implemented to construct capital stock from the formal sector panel data.

[19] Deducting capital cost, which includes equipment rental, interest payments, amortization, and dividend payments, in profit calculation may over-estimate profits for firms that do not rent equipment or borrow, but controls for cost of capital in returns to capital estimations.

[20] We adopt this method for the informal sector as annual profits are not directly requested in the questionnaire.

al. (2008) find annual returns to capital of 55-63% for microenterprises in Sri Lanka. McKenzie et al. (2006) also find annual returns to capital in Mexican microenterprises to be in the order of 180% for microenterprises investing less than $200 and 40-50% for firms investing more than $500.

In Table 3, returns to capital are also estimated using a less restrictive specification by regressing log profit on capital stock categories along with the other control variables. In column 1 and 2, the coefficient estimates of capital dummies increase with capital stock which indicates increasing profit with firm size. Profits are also increasing with firm age and labor input. As before, adding control variables drives down the coefficient estimates of capital stock. Similar patterns are observed in the informal sector (Column 3 and 4). Coefficients of capital generally increase with capital stock though not linearly as in columns 1 and 2. Table 4 reports the implied median returns to capital for each capital stock category based on the coefficient estimates in Columns 2 and 4 of Table 3 and calculated median profit and capital stock from the dataset. The median returns to capital for the smallest formal firm is 16.5% and for the largest formal firm it is just 5.5%. On the other hand, the median returns to capital for the smallest informal firm is over 300%, but it gradually decreases as a firm's capital stock increases.

Further, the largest informal firm with a median capital stock of 16,425 birr earns a median return to capital of only 1%, whereas a formal firm with comparable capital stock earns at least 16.5%, the highest returns to capital in the formal sector.[21] This indicates that for the very small informal firms there is a premium for staying informal, but as they get larger, they may be better off joining the formal sector. If the largest informal firms and the smallest formal firms are similar in all other aspects, our finding may also indicate benefits of being in the formal sector.

In all of the specifications above, we find that returns to capital are higher in the informal sector. One may suspect that the estimates are possibly influenced by measurement error in profit and capital stock. Yet if there is indeed a measurement error in our capital stock variable, it rather leads to attenuation bias, which underestimates the marginal returns to capital.[22] Furthermore, since measurement errors are more prone in the informal sector, it does not explain why informal firms have higher returns to capital.

Finaly, we also find that median returns to capital decline with capital stock both in parametric (Figures 1-4) and non-parmatric specifications using Fan's (1992) non-parametric regression technique (Figures 5-6). Table 5 presents coefficient estimates of the parametric components using third-order

[21] Such a firm may belong to the $Kcat10_i$ (for $K_i \in [0, 29559]$) or $Kcat20_i$ (for $K_i \in (29559, 73224]$) category in the formal sector as $Kcat100_i = 1$, in the informal sector, if $K_i \in [7406, 550321]$. We expect median returns to capital, for formal firms belonging to $Kcat10_i$, to be higher than 16.5% in light of the evidence that return to capital is declining with capital stock.

[22] The direction of bias in profit per capital ratio, on the other hand, is not obvious. Formal firms may under-estimate profit to evade taxes whereas informal firms may misreport firm performance as they do not keep book of accounts.

differencing. As before, firm age, employment, and a larger share of paid labor are associated with larger profit. The latter effect is, however, insignificant for the informal sector as shown in Column 2.

4.2 Firm Growth, Credit Constraints and Owner's Labor Supply

If returns to capital are higher in the informal sector, it suggests that both informal and formal firms can establish a number of informal firms to take advantage of the higher returns in the sector. To test this possibility, we investigate the role of organizational structure in explaining investment in the informal sector. We do so by controlling for the share of owner's time in the total labor input and its interaction with the level of capital stock. In Table 6, the share of owner's time spent in an enterprise is positively associated with profitability, yet its interaction effect with capital stock is negative and highly significant, indicating that the effect of owner's time on enterprise profitability is larger for firms with smaller capital stock. The result is robust to the use of alternative proxy for owner's time: share of family labor in total number of days worked in the enterprise (Column 2).[23] Although we do not have owner's time data for formal firms, we find similar results in Column 4 using share of working proprietors, family members, and active partners in the total number of persons engaged in the enterprise.

We also calculate the associated returns to capital with varying levels of the share of the time spent by owners in an enterprise. We find that, controlling for all other explanatory variables in (7), the median returns to capital in the informal sector decreases as the share of owner's time in total labor input of the enterprise declines.[24] An alternative interpretation of this would be that the owner focuses mostly on high-returns units and hence a reverse causality. However, the majority of informal firms (85%) are single-unit firms and their owners commonly have no additional income generating activity (82%).[25] The result suggests that the operation of informal firms is organized in such a way that the physical presence of the owner is required. This is in line with the predominance of home-based firms and firms located in the vicinity of the owner's home in the urban informal sector. The physical presence requirement, therefore, restricts the possibility that formal and informal firms can establish many new informal firms to take advantage of the higher returns to capital in the sector.

[23] Similar results are obtained when using a dummy variable, $No\ other\ income_t$, equal to one if the owner does not engage in other income-generating activities and zero otherwise. Results are not shown here in the interest of space.

[24] solving (9) we see that returns are increasing with shares if: $\frac{Med[\Pi_i|(K_i,X_i)]}{K_i}\left[\alpha_2 + (\alpha_1 + \alpha_2 \ln K_i)\left(\rho_1 + 2\rho_2 \ln K_i + ... + n * \rho_n (\ln K_i)^{n-1} + \alpha_2 Sh\_own_i\right)\right]$ is positive.

[25] When the dummy variable, $No\ other\ income_t$ is interacted with capital stock, median return to capital is higher for firms in which owners engage in other income-generating activities. This result runs against the reverse causality argument above.

In the formal sector, on the other hand, firms seem to operate in a different business environment. The median returns to capital in the formal sector increases as the share of the owners' time in total labor input of the enterprise decreases. The result implies that small firms can take advantage of the higher returns to capital by establishing other new formal firms. This may have something to do with the fact that formal firms are contractual where certain enforceable employment rules and regulations, higher "efficiency" wages and hiring management staff induce higher workers' effort and making the physical presence of the owner less important.

Our findings relate to other studies in the literature. An ILO (2005) study on Ethiopia, Kenya, and Tanzania also shows that women prefer to make the so-called "latent" or horizontal expansion, i.e., establishing more than one firm simultaneously with the intent to diversify, instead of taking risk in vertical expansion in terms of developing an existing firm through expansion, innovation and product improvement. However, the current study on the Ethiopian informal manufacturing sector, of which women constitute about 80%, has shown that returns to capital declines as the share of owner's time spent on the enterprise declines. This limits the possibility of female operators to profitably practice horizontal expansion in the urban informal sector in Ethiopia. Shiferaw (2009), on the other hand, shows that multi-unit firms in the Ethiopian formal manufacturing sector are more likely to survive than single unit firms, suggesting that business expansion through branching out is a viable survival strategy.

Higher returns in the informal sector may also be due to more pronounced financial constraints that limit investment in the sector. Differentiating between the effects of market fundamentals and credit constraint on investment is a challenge. The pattern of returns to capital in relation to capital stock, however, indicates that credit constraints may not be binding for firm growth in the medium term as firms can save and re-invest. As can be seen in Figures 1-6, both parametric and semi-parametric regression results indicate that returns to capital are decreasing in capital stock for both formal and informal firms. Thus, even credit-constrained firms can grow by re-investing their profits. While this is evidence against the presence of a poverty trap in the Ethiopian manufacturing sector, re-investment can still be constrained by inability of firms to save and re-invest profits due to other household needs such as food, education, and healthcare expenditures. Such competing needs make capital accumulation, innovation, and expansion difficult (Gomez, 2008). Moreover, growth and job creation prospects of informal firms may be limited by lower initial profit due to lack of/inadequate markets, which is reported to be one of the major constraints in the current operation of informal firms. Encouraging vertical expansion of existing firms through market development, creating equitable linkages and marketing skills development are therefore important policy intervention areas.

4.3 Robustness Checks

The findings above might be affected by unobserved firm-specific effects such as ability of the entrepreneur. Since the informal sector dataset is a repeated cross-section, we are unable to control for firm fixed effects. Instead, we include a proxy for the ability of the entrepreneur as an additional control variable. Firms entering the sector because the owner likes the job or expects the activity to bring higher income, or because the activity is in the owner's family tradition, are expected to have a higher ability than firms entering for example because they lack alternative income sources or the activity requires only a small investment. *Ability_H* is a binary variable equal to one for the former reasons for entry and zero for the latter. Similarly, Gunther and Launov (2006) categorize the informal sector as consisting of "voluntary entry" and "involuntary entry" segments.[26]

As shown in Table 6, Column 3, firms with higher entrepreneurial ability have significantly higher profits than those who entered their current activity for reasons such as lack of alternative source of income and small investment requirement. The pattern of returns to capital, with respect to the share of owner's time in the enterprise, is in line with the organizational structure hypothesis discussed in the previous section. Firms with higher share of owner's time have higher returns to capital. However, returns to capital decline with the share of owner's time spent on the activity.

To control for ability bias in the formal sector, we exploit the panel dimension of our dataset to estimate profit equation. To use a fixed effect model, our explanatory variables should be strictly exogenous. But the exogeneity requirement might be violated due to possible measurement errors and omitted variables such us unobserved firm productivity and favorable demand shocks that affect input use. First differencing models, on the other hand, provide us with a possibility of using lagged explanatory variables and/or their lagged first differences as instruments using the difference GMM of Arellano and Bond (1991) and the system GMM developed by Blundell and Bond (1998), respectively.

Table 7 presents two-step system GMM esimates of profit equation for the formal sector. Log capital and labor, labor shares and their interaction with capital stock are instrumented with their two-period lagged first differences along with levels of other explanatory variables and lagged instruments. Using the Hansen test, we do not reject the validity of the over-identifying restrictions. Estimates of median returns to capital fall in the range obtained in the pooled regressions (Tables 2-6). As before, the share of owners' labor

[26] The "voluntary entry" represents the competitive part into which individuals enter voluntarily because, given their specific characteristics, they expect to earn more than they would in the formal sector. The "involuntary entry" is the part that consists of individuals who were rationed out of the formal (and possibly the "voluntary entry" informal) labor market. Using similar methodology, informal employment in Ethiopia is found to be predominantly involuntary with only 5-20% firms classified as "voluntary entry" (Ruffer and Knight, 2007).

and its interaction with capital stock have significantly positive and negative effects on profit, respectively (Columns 2 and 3) and median returns to capital decline with owners' share of total labor input.[27]

5 Conclusions

In this study, we investigate the presence of poverty trap in Ethiopian manufacturing sector that may result from the joint presence of credit constraints and increasing returns to capital with firm size. The current study primarily investigates the latter in an effort to understand whether credit constraints are binding constraints to long-term firm growth, when present. Poverty trap not only limits firm growth, it also discourages graduation into the formal sector and hence leads to persistent informality.

To this end, the study poses two research questions related to firms' decision to enter the formal sector: whether returns to investment are higher in the formal sector and whether firms can grow upon entry into the formal sector. To answer these research questions, we analyze the magnitude and pattern of returns to capital across different size categories and sectors. We use a rich panel dataset for the period 1996-2006 for the formal firms and two rounds of repeated cross-sectional data for the urban informal firms.

The empirical results indicate that returns to capital are higher in the informal sector. Higher returns in the informal sector may indicate better market fundamentals or pronounced financial constraints in the sector. In the case of the former, we would expect formal and informal firms to establish new informal firms to take advantage of the higher returns. However, investment in the informal sector is limited by the evidence that returns to capital are declining as the share of owner's time in total labor input of the enterprise declines. This may be due to inability to compensate for reduced supervision by paying higher wages or the difficulty to match owners' skills by hiring external labor in the informal sector. Moreover, when comparing formal and informal firms with comparable capital stock, we find that returns are higher in the formal sector. This indicates that for the very small informal firms there is a premium for staying informal, but as they get larger, they may be better off joining the formal sector.

On the other hand, returns to capital in the formal sector increase as the share of owners' time in total labor input of the enterprise decreases, allowing small firms to take advantage of the higher returns to capital by establishing new formal firms. The difference in returns to capital in the two sectors may be explained by differences in business environment: formal firms, for instance, are contractual firms where the physical presence of owners can be made less important by introducing enforceable employment rules and regulations, paying higher "efficiency" wages and hiring management staff to induce higher workers' effort.

[27] Median returns range from 15.7% (for minimum share) to -4% (for maximum share).

We also find that returns to capital are decreasing with capital stock in both sectors. This implies that credit constraints are less binding for firm growth in the long-term. Thus, our findings are evidence against the presence of a "poverty trap" in the Ethiopian manufacturing sector. However, credit constraints may remain to be important in the short-term as market conditions determine the realization of actual profits and as other competing household needs might divert realized profits. Encouraging vertical expansion of existing firms through market development, making firm locations closer to customers affordable and creating equitable linkages with the formal sector are therefore important policy intervention areas to encourage growth and eventual graduation of firms in the informal sector. Differentiating between market fundamentals and financial constraints in explaining investment patterns is the natural next step for future research.

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Table 1: Descriptive statistics

	Informal Sector			Formal Sector		
Variable Description	**Mean**	**Median**	**N**	**Mean**	**Median**	**N**
Real annual profit	1232.26	497.43	11912	1450088	57068.39	8876
Profit divided by capital stock	48.45	5.09	10299	335.85	0.20	8774
Log of real annual profit	6.36	6.50	10311	12.04	11.68	6801
Log of capital stock	4.69	4.38	10728	13.20	13.20	8774
Log of no. of days worked per year	5.25	5.38	12307			
Share of days the owner worked	0.91	1	12307			
Share of days family members and owners worked	0.98	1	12307			
No other income$_t$ =1 if the owner does not engage in other income- generating activities	0.82	1	12458			
Log no. of persons engaged				3.45	3.14	8332
Share of working proprietors, active partners, and family workers				0.08	0	8332
Share of paid labor$_t$	0.02	0	12421	0.90	1	8332
lnL(of non-owners)=Log no. of (days worked) non-owners	0.95	0	12313	3.4	3.09	8213
No employees =1 if no employee	0.82	1	12313			
Firm age in years	8.85	5	11984	11.38	4	8727
Age of Informal sector owner/manager	39.64	38	12479			
Gender of Operator (male=1)	0.21		12488			
Operator’s years of Schooling	2.38	0	12484			
Ability Dummy =1 if ability is higher	0.14		12488			

Source: Own calculations. Ethiopian birr is the unit of financial variables and GDP deflator is used to express financial variables in real terms.

Table 2: Parametric estimation of returns to capital using median regression

	Formal		Informal	
VARIABLES	(1)	(2)	(3)	(4)
$\ln K_t$	1.425***	1.036***	0.890***	0.287***
	(0.263)	(0.233)	(0.0442)	(0.0399)
$(\ln K)^2_t$	-0.377***	-0.263***	-0.120***	-0.0368***
	(0.0526)	(0.0468)	(0.00981)	(0.00853)
$(\ln K)^3_t$	0.0307***	0.0215***	0.00523***	0.00167***
	(0.00380)	(0.00339)	(0.000621)	(0.000531)
$(\ln K)^4_t$	-0.000722***	-0.000512***		
	(9.25e-05)	(8.26e-05)		
Firm age $_t$		0.0142***		0.0265***
		(0.00370)		(0.00374)
Firm age $_t^2$		-0.000131*		-0.000499***
		(6.71e-05)		(9.14e-05)
$\ln L_t$		0.543***		0.691***
		(0.0284)		(0.0179)
Share of paid labor$_t$		0.258**		0.242*
		(0.118)		(0.135)
Age of owner/Manager$_t$				-0.00616
				(0.00530)
Age of owner/Manager^2_t				-0.00242
				(0.00569)
Male owner/manager $_t$				1.138***
				(0.0552)
Years of schooling of owner/manager $_t$				0.0136
				(0.00945)
Years of schooling of owner/manager^2_t				0.0857
				(0.0768)
Year	Yes	Yes	Yes	Yes
Sector	Yes	Yes	Yes	Yes
Obs	6222	6222	8436	8431
Pseudo R2	0.4033	0.4478	0.1016	0.2293
Median returns to K	20.83%	14.94%	139.8%	52.97%

Notes: Dependent variable is log annual profit. Unreported constant included. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Returns to capital using median regression

	Formal Sector		Informal Sector	
VARIABLES	(1)	(2)	(3)	(4)
K_cat20_t	0.434***	0.298***	0.0816	0.0886
	(0.0821)	(0.0816)	(0.0857)	(0.0688)
K_cat30_t	0.617***	0.365***	0.263***	0.197***
	(0.0820)	(0.0816)	(0.0852)	(0.0683)
K_cat40_t	0.962***	0.666***	0.428***	0.229***
	(0.0831)	(0.0834)	(0.0850)	(0.0684)
K_cat50_t	1.211***	0.866***	0.431***	0.288***
	(0.0823)	(0.0833)	(0.0850)	(0.0683)
K_cat60_t	1.812***	1.349***	0.572***	0.306***
	(0.0834)	(0.0851)	(0.0856)	(0.0689)
K_cat70_t	2.585***	1.785***	0.719***	0.453***
	(0.0852)	(0.0896)	(0.0858)	(0.0693)
K_cat80_t	3.469***	2.319***	0.586***	0.403***
	(0.0859)	(0.0936)	(0.0863)	(0.0695)
K_cat90_t	4.219***	2.853***	0.325***	0.174**
	(0.0885)	(0.101)	(0.0855)	(0.0688)
K_cat100_t	5.385***	3.513***	0.496***	0.376***
	(0.0904)	(0.113)	(0.0862)	(0.0697)
Firm age $_t$		0.0118***		0.0273***
		(0.00341)		(0.00418)
Firm age $_t^2$		-9.16e-05		-0.000547***
		(6.19e-05)		(0.000104)
lnL_t		0.571***		0.682***
		(0.0257)		(0.0196)
Share of paid $labor_t$		0.280***		0.234*
		(0.108)		(0.141)
Age of owner/$Manager_t$				-0.00309
				(0.00588)
Age of owner/$Manager^2_t$				-0.00502
				(0.00633)
Male owner/$manager_t$				1.042***
				(0.0664)
Years of schooling of owner/manager $_t$				0.00466
				(0.0101)
Years of schooling of owner/$manager^2_t$				0.126
				(0.0812)
Year	Yes	Yes	Yes	Yes
Sector	Yes	Yes	Yes	Yes
Observations	6222	6222	7303	7303
Pseudo R2	0.3978	0.4437	0.0690	0.1922

Notes: Dependent variable is log annual profit. K_cat10, a dummy for capital stock belonging to the 10^{th} percentile, is taken as a reference group. Column 3 & 4 are estimated for sample of firms with capital stock worth more than 10 birr at replacement value. Standard errors in parentheses. Unreported constant included. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Median returns to capital by percentiles of capital in the formal and informal sector

	Formal Sector				Informal Sector			
Percentiles	Profit	K	θ	Returns	Profit	K	θ	Returns
10	16721.53	13538.19	0		420	15.57	0	
20	23538.91	48792.97	0.298	16.47%	427.27	27.97	0.0886	313.96%
30	30144.02	102815.5	0.365	3.02%	533.60	42.30	0.197	341.26%
40	42325.62	200449.2	0.666	10.84%	628.12	61.69	0.229	89.49%
50	57698.36	359310.6	0.866	5.90%	612	89.61	0.288	136.72%
60	94207.05	707323.1	1.349	10.29%	623.42	138.14	0.306	22.90%
70	139642.5	1372908	1.785	7.74%	780	243.92	0.453	93.33%
80	325567	2940272	2.319	6.29%	932.22	582.81	0.403	-11.23%
90	895561.8	6729345	2.853	6.06%	700	2752.69	0.174	-8.79%
100	2522789	2.20E+07	3.513	5.48%	857.93	16424.83	0.376	1.15%

Note: Profit and K measure median profit and capital stock for each percentiles of capital stock. θ is the coefficients of capital stock categories taken from Columns 2 and 4 of Table 3 for the formal and informal sectors respectively.

Table 5: Partial linear regression with 3rd order differencing

	Formal Sector	Informal Sector
VARIABLES	**(1)**	**(2)**
Firm age_t	0.0154***	0.0268***
	(0.00343)	(0.00398)
Firm age_t^2	-0.000162***	-0.000523***
	(6.25e-05)	(9.87e-05)
lnL_t	0.534***	0.651***
	(0.0264)	(0.0189)
Share of paid $labor_t$	0.254**	0.0574
	(0.108)	(0.134)
Age of owner/Manager $_t$		0.000501
		(0.00556)
Age of owner/$Manager^2_t$		-0.00800
		(0.00598)
Male owner/manager $_t$		0.783***
		(0.0661)
Years of schooling of owner/manager $_t$		-0.00428
		(0.00963)
Years of schooling of owner/$manager^2_t$		0.199**
		(0.0783)
Year	Yes	Yes
Sector	Yes	Yes
Observations	6219	7300
R-squared	0.163	0.288

Notes: Partial linear regression model with Yatchew's (1998) weighting matrix. Clustered standard errors at firm level in parentheses. Estimations for the informal sector are made for K>10 as in table 3 columns 3 and 4. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Organizational structure and returns to K; median regressions with bootstrapped standard errors

	Informal Sector			Formal Sector
VARIABLES	**(1)**	**(2)**	**(3)**	**(4)**
lnK	0.477***	0.558***	0.492***	0.890***
	(0.0524)	(0.0661)	(0.0482)	(0.286)
$(\ln K)^2$	-0.0488***	-0.0500***	-0.0489***	-0.230***
	(0.00915)	(0.00937)	(0.00879)	(0.0582)
$(\ln K)^3$	0.00206***	0.00208***	0.00203***	0.0193***
	(0.000583)	(0.000603)	(0.000585)	(0.00421)
$(\ln K)^4$				-0.000468***
				(0.000102)
lnK* Share of owner's time	-0.0971***		-0.108***	
	(0.0294)		(0.0326)	
Share of owner's time	3.334***		3.367***	
	(0.333)		(0.350)	
lnK* Share of family labor		-0.162***		
		(0.0516)		
Share of family labor		2.106***		
		(0.398)		
lnK* Share of WFP in total labor				-0.366***
				(0.104)
Share of WFP in total labor				4.232***
				(1.196)
Ability Dummy(High=1)			0.134***	
			(0.0380)	
Share of paid labor$_t$	0.621***	1.623***	0.619***	
	(0.148)	(0.271)	(0.147)	
lnL (of non-owners)$_t$	0.812***	0.462***	0.801***	0.536***
	(0.0582)	(0.0434)	(0.0533)	(0.0308)
No employees (Yes=1)	2.641***	2.182***	2.603***	
	(0.196)	(0.241)	(0.184)	
Firm age $_t$	0.0360***	0.0369***	0.0355***	0.0122***
	(0.00437)	(0.00416)	(0.00409)	(0.00350)
Firm age $_t^2$	-0.000766***	-0.000800***	-0.000773***	-0.000107*
	(9.93e-05)	(9.32e-05)	(9.24e-05)	(6.34e-05)
Male owner/manager	1.259***	1.269***	1.233***	
	(0.0689)	(0.0694)	(0.0631)	
Years of schooling of owner/manager	0.0294***	0.0318***	0.0279***	
	(0.00983)	(0.00985)	(0.00954)	
Years of schooling of owner/manager^2	0.0219	-0.00313	0.0307	
	(0.0740)	(0.0749)	(0.0745)	
Observations	8436	8436	8436	6123
Pseudo R2	0.1692	0.1631	0.1699	0.4512
Median returns to K at max share	83%	73.5%	85%	1.9%
Median returns to K at P99th share	83%	73.5%	85%	1.9%
Median returns to K at mean share	72.7%	74.7%	76%	14.5%
Median returns to K at min share	11.5%	59%	12.6%	16.3%

Note: Dependent variable is log annual profit. Share of WFP = Share of working proprietors, family workers and partners in total labor input. Bootstrapped standard errors with 500 replications in parentheses. Unreported constant, year and sector dummies included.*** p<0.01, ** p<0.05, * p<0.1

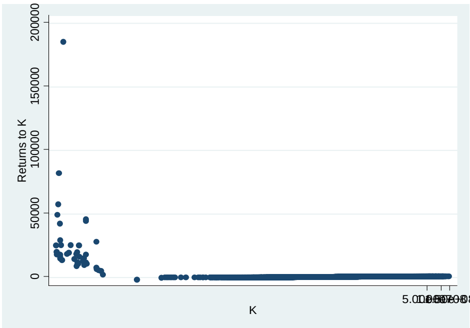
Table 7: Profit equation in formal sector using two-step system-GMM

VARIABLES	(1)	(2)	(3)
$\ln K_t$	0.488***	0.451***	0.511***
	(0.0842)	(0.105)	(0.110)
$\ln L_t$	0.819***		-0.891
	(0.151)		(1.643)
Share of paid labor_t	0.399		
	(0.633)		
Share of WFP in total labor		12.41***	14.80**
		(4.526)	(6.357)
lnK* Share of WFP in total labor		-1.021**	-1.092**
		(0.415)	(0.435)
lnL (of non-owners)$_t$		0.875***	1.600
		(0.162)	(1.626)
Firm age $_t$	0.00162	0.00161	0.0114
	(0.00748)	(0.00764)	(0.00891)
Firm age $_t^2$	-5.33e-05	-7.51e-05	-0.000148
	(0.000105)	(9.79e-05)	(0.000106)
Year	Yes	Yes	Yes
Sector	Yes	Yes	Yes
Observations	6222	6123	6123
Number of eid	1825	1804	1804
AR(1) in 1^{st} differences	0.000	0.000	0.000
AR(2) in 1^{st} differences	0.909	0.673	0.573
#of instruments	159	203	247
Hansen test chi2	125.08	170.03	203.59
P-Value	0.581	0.528	0.701
Wald chi2	2141.19	2143.64	2119.98
P-Value	0.000	0.000	0.000
Median returns to K	16.76%	13.06%	14.62

Notes: Dependent variable is log annual profit. Share of WFP = share of working proprietors, family workers And partners in total labor input. Windmeijer's robust two-step standard errors in parentheses. Log capital and labor, labor shares and their interaction with capital stock are instrumented by their two periods lagged first difference along with levels of the other explanatory variables and levels of lagged instruments.*** p<0.01, ** p<0.05, * p<0.1

Pattern of returns to capital with invested capital stock

A. Pattern of returns to capital from parametric specifications (table 2)



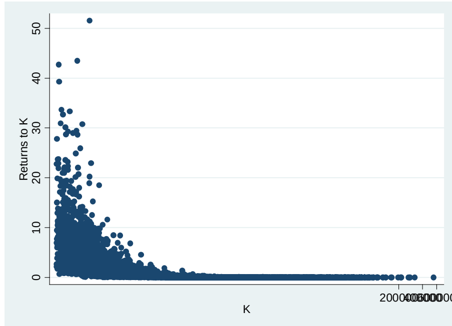
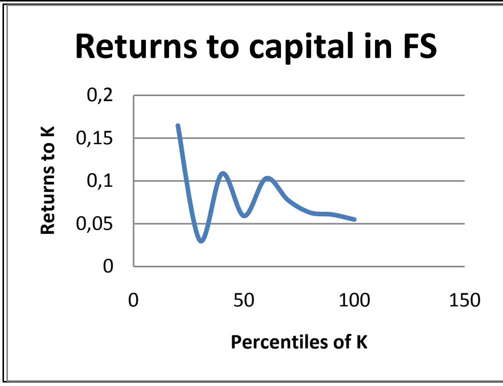


Figure1: Returns to capital in formal sector **Figure2: Returns to capital in informal sector**

B. Pattern of Median returns to capital by K category (table 3-4)



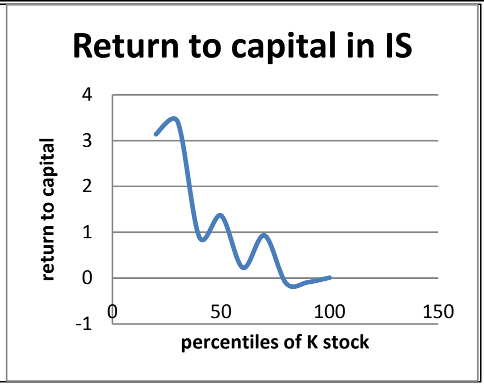
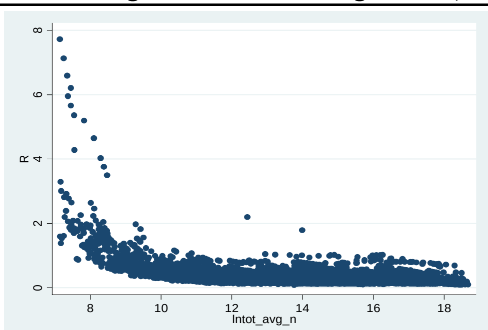


Figure 3: return to Capital in Formal Sector **Figure 4: returns to capital in Informal Sector**

C. Median regression after Fan regression (table 5)



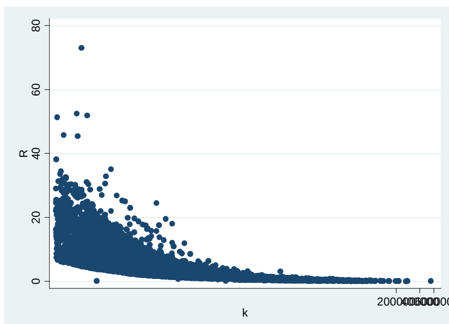


Figure 5. Returns to capital in formal sector **Figure 6. Returns to capital in informal sector**

Paper II

The Performance of New Firms: Evidence from Ethiopia's Manufacturing sector*

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Abstract

In this paper we investigate the relative importance of technological and demand constraints for firm performance using panel dataset of Ethiopian manufacturing sector (1996-2006). Previous empirical research on firm performance use revenue based productivity which confounds true efficiency with price effects. Using information on price and physical quantity of firms' products, we decompose revenue based productivity into physical productivity, price and idiosyncratic demand shocks. Comparison of various components of productivity across firms, using product and firm fixed effect estimation, reveals that entrants have lower demand and output prices than established firms. However, we do not find a robust difference in productivity between entrants and established firms. Thus, young and small firms are found to be most vulnerable to demand constraints. Analysis of firm survival using probit regression reveals that firms' access to secure market is more important determinant of survival than productivity.

Keywords: New firms, Skills, Growth, Survival, African Manufacturing
JEL Classification: M13, M31, L26, D24, L25, O55

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1 Introduction

A common argument in the discussion of Africa's development problems is that the African economies are too dependent on agriculture and natural resource extraction (e.g. Collier, 2008). In view of this, growth in the industrial sector is often seen as a vehicle for diversification and sustainable economic development (Page, 2010). One of the least industrially developed countries in Africa is Ethiopia, where manufacturing accounts for only 5% of total value-added and agriculture employs 85% of the workforce. Hence, Ethiopia needs substantial entry of industrial firms in order to speed up diversification. In fact, over the last decade, gross entry rates in the manufacturing sector have been rather high (on average 7.6% per year). But exit rates among new firms have been high too. According to Gebreeyesus (2008), 60% of entering firms exit the Ethiopian market within 3 years in business. As a result, net entry rates in the sector have not been high enough to increase the relative size of the manufacturing sector in the last decade.

In this paper we study the economic performance of Ethiopia's new firms. We ask two specific questions. First, why do young firms have high exit rates? Previous research on African firms suggests that the likelihood of exit increases as the economic performance of the firm deteriorates. Regression results reported by e.g. Frazer (2005), Söderbom et al. (2006), Gebreeyesus (2008) and Shiferaw (2009) indicate that firms generating low levels of revenue, conditional on factor inputs, tend to have relatively low survival rates. Hence, there is some evidence that African markets drive poorly performing firms out of business. A common interpretation of this finding is that there is "creative destruction" in African markets: as resources get reallocated from poor performers to firms that use these more productively, this contributes to higher aggregate productivity (Frazer, 2005; Söderbom et al., 2006; Gebreeyesus, 2008; Shiferaw, 2007).

However, unless one knows *why* there is a link between the economic performance of the firm and the likelihood of survival, whether the turnover process implies higher aggregate productivity will remain unclear. In particular, it is essential to distinguish physical productivity from high prices, or rents. No previous study in the literature on African firms makes this distinction. Could it be that the type of firms most likely to survive in Africa are not those with the highest productivity but those most able to extract rents and charge high prices? No evidence exists that would enable us to discard this as a possibility. Moreover, in view of the structure of African markets, this would appear a question worth taking seriously. In a poorly integrated market characterized by information problems, rents will be available, and firms that manage to extract these rents may record high levels of revenue even under low levels of productivity. This is just one example of a setting in which a positive relationship between a revenue-based measure of performance and firm survival does not necessarily imply that firm turnover results in aggregate efficiency gains.

In the context of industrial expansion and the contribution to such a process of new firms, patterns of firm survival are informative of one side of the story only. The other is performance conditional on survival. This leads us to our second research question: how do physical productivity, prices and demand develop in the initial years following upon entry? Similar to the literature on firm survival, there exist several studies that study the relationship between revenue-based measures of economic performance and firm age (e.g. Sleuwaegen and Goedhuys, 2002; Van Biesebroeck, 2005), but none that distinguishes between productivity and prices. Sleuwaegen and Goedhuys (2002) infer "learning" from regressions indicating a negative relationship between firm age and sales and employment growth, but unless productivity effects can be isolated from price effects the type of learning implied by such results is unclear. In principle, it is possible that previous results on learning based on revenue-based measures of performance are unrelated to physical productivity gains, which is what the underlying literature really emphasizes (e.g. Jovanovic, 1982).

In this paper we seek to fill these gaps in the literature. To this end, we use a firm-level panel dataset that covers the entire population of domestic manufacturing firms in Ethiopia that use electricity in production and that employ ten or more workers. This dataset has been used in previous work by Bigsten and Gebreeyesus (2007), Gebreeyesus (2008) and Shiferaw (2007, 2009). Importantly for our purposes, this dataset contains a detailed product-level module that enables us to construct product-specific prices and quantities at the firm-level. Equipped with these data, we can thus distinguish between prices and physical productivity and investigate how these correlate with the likelihood of exit and how they develop in the first few years following entry into the market.

Our analysis also relates to an ongoing discussion about the relative importance of different types of skills for enterprise success. Several authors have emphasized lack of technical capacity as a key reason why many firms in developing countries perform poorly (e.g. Pack, 1982; 1993; Lall, 1992). Sutton and Kellow (2010), however, downplays the importance of technology as a key determinant of company success in Africa, arguing that basic manufacturing technology is relatively easy to master. Based on in-depth interviews with leading industrialists in Zambia and Ethiopia, and Kellow highlight "...a crucial role played by detailed knowledge and experience both of the local market and of the international market" (Suttonand Kellow, 2010, p.4) and argues that this kind of expertise "...constitutes a more important aspect of ‘capability’ in the present setting than does any kind of technological know-how." (Sutton and Kellow, 2010, p.4). Establishing the importance of physical productivity for firm survival contributes to this discussion.

Finally, our research addresses some key concerns in the general literature on firm performance. Foster, Haltiwanger and Syversion (2008) and Katayama, Lu and Tybout (2008) show that a revenue-based measure of total factor productivity (TFPR) will confound true efficiency with price, elasticity and scale economies and that the discrepancy between TFPR and a more appropriate measure of physical productivity may be considerable. For example, Foster et al. (2008) note that microeconomic theory predicts a negative correlation between physical productivity and prices, but then find a positive correlation between TFPR and prices in their data. Katayama et al. (2008) find TFPR to be very weakly correlated with alternative productivity measures based on the firm's contribution to consumer and producer surplus, again suggesting that a revenue-based measure of productivity is a poor proxy for true physical productivity.[1]

The rest of the paper is organized as follows. Section 2 defines our price and quantity variables and explains how these are measured in the data and how they are used to decompose TFPR into physical productivity and demand side variables. Section 3 discusses the outcome variables of interest. Section 4 contains the empirical results. The last section concludes and discusses policy implications.

2 Definitions

2.1 Prices and Quantities

As discussed in the introduction, much of our analysis focuses on separating productivity effects from price effects. In particular, we want to distinguish between the effects of prices and productivity on firm survival rates, and document growth patterns in prices and productivity amongst young firms. To this end we use census panel data on Ethiopian manufacturing establishments collected by Central Statistical Agency of Ethiopia (CSA). The dataset, which covers the period 1996-2006, includes all establishments in the country that employ at least 10 workers and that use electricity in production. Hence microenterprises are not represented in the dataset. In 2009, this class of firms accounted for 51% of manufacturing employment but only 11% of total manufacturing value-added. The aggregate economic performance of the manufacturing sector is thus primarily determined by the performance of medium-sized and large firms. We take this to be our population of interest.

Information available in the dataset includes capital, labor, raw material and energy inputs; investment as well as other industrial costs. The number of firms in the manufacturing sector increases from around 600 in 1996 to approximately 1,100 in 2006. Key for our purposes is a special module in the survey instrument on prices and quantities. Every year, each firm has to provide detailed information about the type of products produced, the unit of measurement (e.g. kilos, tonnes etc.), the sales price per unit and the quantity produced, for up to 9 products. Using these data, and ignoring a composite product category labeled 'other products', our starting point is a

[1] Assuming that firms' costs and revenues reflect Bertrand-Nash equilibrium in a differentiated product markets, and incorporating demand system they impute each firm's unobserved quantities, qualities, marginal costs and prices of each product from observed revenues and costs to construct firm's contribution to consumer and producer surplus as welfare-based measure of productivity.

dataset containing approximately 17,000 firm-year-product observations over our sampling period. Several of these, however, refer to products that are not precisely defined or products that will differ markedly in quality. We root out such cases using two rules. Our primary selection rule is based on the idea that a product category should be such that consumers would not differentiate between unlabeled products belonging to it. To illustrate how we use this rule, we would exclude "meat" a priori (on the grounds that there are likely substantial quality differences within this category), but would consider "beer" to be a suitable product category. Of course there are different types of beer, and perhaps one ought to distinguish between dark beer and lager, or between beers of differing alcoholic strength, however this is not possible given the information available. We consider brick of clay, cement block, cement floor tiles and cement to be the least heterogenous types of products in our data, and define these to be 'homogenous' products. In the empirical analysis below, some of the robustness checks will be done based on this subset of homogenous products only.

In addition, we included other set of products based on a secondary selection rule that, in a cross-section of firms producing a given product, the coefficient of variation of output price should not exceed 0.5 and the number of observation should be larger than 100.[2] Taken together, these rules imply we end up with a total of 27 different products in our core sample. These are listed in table A1 in the appendix. Our set of selected products constitutes around 7800 product-year observations covering 13 sectors. Food, Beverage, Textiles, Footwear, Chemicals and Non-Metal sectors constitute 94% of the total product-year observations of selected products.

In our dataset, while most of the products, such as bricks of clay, cement blocks, nails, sugar, bread and wheat flour, are reported separately as a single product, some of our products can be considered to be a composite product aggregating over similar products. These products include: edible oil, liquor and soft drinks among others. This is the level of aggregation CSA uses and we take that as given and assume that there is high substitutability between the components of such aggregated products. The product soft drink for example contains Coca Cola, Fanta and other similar brands of soft drinks. Even though consumers can differentiate between such products, we assume that there is high substitutability between such products and treat soft drink as homogenous product. The same type of argument follows for products such as tea, milled coffee, edible oil, liquor, beer. This is also the approach followed by Foster et al (2008). All quantity measures are standardized so as to have a common unit of measurement, e.g. weights are measured in KG, volumes in liter, areas in square meter or square feet ...etc depending on the product. Output prices are then adjusted using the standardzed unit of measurments.

In table A1, we present summary statistics of nominal output prices of our selected products after controlling for outliers by ignoring the bottom and

[2] Note that products deemed to be homogenous according to the primary selection rule do not necessarily have to satisfy the secondary selection rule.

top 3 percentiles of our observation on product prices. Besides having wide industry coverage, our selected products have a major economic significance for their producers. Table A2 in the appendix presents summary statistics of revenue share of our selected products when these products are the firm's most important product.[3] We define major product as the product with highest revenue share in total output among set of firm's selected products. This will give us a smaller sample size of about 3500 where the average revenue share is 74%. Among firms' major products, all products except Leather garment, Crust and Wet blue hides; and Wires have a median revenue share of 50% or more.

2.2 Productivity and Demand

We assume that the production by firm i of product u at time t can be represented by a production function which we write in logarithmic form as:

$$\log Y_{iut} = \log A_{iut} + \log F(K_{iut}, L_{iut}, M_{iut}, E_{iut}), \tag{1}$$

where Y_{iut} denotes physical output, A_{iut} is physical total factor productivity, K_{iut} is capital stock, L_{iut} is labor input, M_{iut} is raw material inputs, E_{iut} is energy, and $F(\cdot)$ is a Cobb-Douglas function featuring constant returns to scale:

$$\begin{aligned} \log F(K_{iut}, L_{iut}, M_{iut}, E_{iut}) &= (1 - \alpha_{Lj} - \alpha_{Mj} - \alpha_{Ej}) \ln K_{iut} \\ &\quad + \alpha_{Lj} \ln L_{iut} + \alpha_{Mj} \ln M_{iut} + \alpha_{Ej} \ln E_{iut} \end{aligned} \tag{2}$$

where$\alpha_{Lj}, \alpha_{Mj}, \alpha_{Ej}$ are production function parameters, specific to sector j. Taking this framework as our point of departure, we construct two productivity measures: the conventional revenue-based productivity (TFPR), and physical quantity based productivity (TFPQ).

The definition of TFPR is standard and straightforward:

$$TFPR_{it} = \log \left(\sum_u P_{iut} Y_{iut} \right) - \log F(K_{it}, L_{it}, M_{it}, E_{it}),$$

i.e. the log of total sales net of the contribution of the inputs to output. Note that the inputs here are defined at the firm-year level. The parameters $\alpha_{Lj}, \alpha_{Mj}, \alpha_{Ej}$ are estimated using a cost shares approach. Specifically, α_{Lj} is calculated as sector j's average share of the wage bill in total sales, while α_{Mj} and α_{Ej} are calculated as sector averages of the shares of total raw materials and energy expenditure, respectively, in total sales.[4] Labor L_{it} is measured as the number of workers, M_{it} and E_{it} are measured as the firm's expenditure on

[3] The average combined revenue share of our selected products including firm's non-major products is 92%.

[4] Energy input includes expenditures on fuel, electricity; and wood and charcoal.

raw material and energy inputs, and K_{it} is the value of the capital stock.[5] All financial values are expressed in constant terms using a GDP deflator. One implication of defining M_{it}, E_{it} and K_{it} in value terms is that our measure of productivity will reflect heterogeneity in input prices with firms facing higher input prices appearing as less efficient.

The definition of physical productivity (TFPQ) is as follows:

$$TFPQ_{iut} \equiv \log A_{iut} = \log Y_{iut} - \log F(K_{iut}, L_{iut}, M_{iut}, E_{iut}). \tag{3}$$

For multi-product firms we need to deal with aggregation issues. The first issue is that factor inputs are not observed at the product level, which makes it problematic to define $TFPQ_{iut}$ for multiproduct firms. To address this problem we assume that the intensity with which inputs are used for producing product u is proportional to the value share:

$$X_{iut} = \theta_{iut} \times X_{it},$$

$X = \{K, L, M, E\}$, where

$$\theta_{iut} = \frac{P_{iut}Y_{iut}}{\sum_u P_{iut}Y_{iut}} \equiv \frac{P_{iut}Y_{iut}}{P_{it}Y_{it}}.$$

The second aggregation issue, again arising for multiproduct firms, concerns the construction of a firm-year level measure of physical productivity based on product-firm-year level productivity levels defined by (3). Adopting a weighting scheme based on the product revenue shares would not be helpful here as this would yield TFPR. Instead, we focus on the major product of firms, in terms of sales values, and calculate physical productivity for the major product only. Hence, we write

$$TFPQ_{it} = \log Y_{i(u=m)t} - \log F(K_{iut}, L_{iut}, M_{iut}, E_{iut}) - \log \theta_{i(u=m)t}, \tag{4}$$

where $u = m$ indicates the major product for firm i at time t. Note that, for single-product firms, the aggregation issues do not arise; $\log \theta_{i(u=m)t} = 0$.

An important driving factor of output prices is the underlying consumer demand for the products. We obtain a measure of the state of demand by estimating the following demand equation using firms' major product.

$$\log Y_{i(u=m)t} = \beta_1 \ln P_{i(u=m)t} + \sigma_{lt} + \lambda_u + \varepsilon_{iut} \tag{5}$$

where β_1 is the price elasticity, σ_{lt} is a town-year fixed effect (controls for variation in demand across locations and over time), λ_u is product fixed effect and ε_{iut} is residual demand, capturing shifts in the demand curve due to

[5] Capital stock is measured by the average of capital stock at the beginning and end of the year at replacement value. We construct a capital stock using perpetual inventory method where different depreciation rates are assumed for different category of capital. We used 5% for dwelling houses, non-residential buildings and construction works; 8% for machinery and equipment; and 10% for vehicles and furniture and other fixtures.

idiosyncratic demand shocks. To estimate ε_{iut} consistently, we need to take into account the endogeneity of the price variable.[6] Following Foster et al. (2008), we instrument the price variable using physical productivity as defined in (4). We focus on the set of homogenous products with comparable product quality to estimate our demand equation.

3 Outcomes of Interest

3.1 Firm Survival

We start with a simple probit specification where we model the likelihood of firm exit as dependent on revenue-based productivity, firm age, size and a vector of control variables X_t:

$$\Pr(exit_{i,t+1} = 1) = \Phi\left(\theta_0 + \theta_1 \ln(Age_{it}) + \theta_2 \ln(Size_{it}) + \theta_3 \ln TFPR_{it} + X_{it}'\theta_4\right), \tag{6}$$

where $exit_{t+1} = 1$ if firm i exits the market between t and $t+1$ and $\Phi(\cdot)$ is the cumulative density function for the standard normal distribution. The vector of control variables X_{it} includes variables such as: type of ownership; whether the firm has any export; and year, sector and sometimes product fixed effects. We use this specification primarily to relate to the existing literature. Previous studies (e.g. Frazer, 2005; Söderbom et al., 2006; Gebreeyesus, 2008; Shiferaw, 2009) have documented a positive relationship between revenue-based productivity and firm survival, but as discussed in the introduction it is not clear whether this association in the data is due to higher physical productivity or higher prices.

One of our two main goals in this paper is to shed light on the relative importance of physical productivity and output prices for firm survival.

The importance of demand and productivity on firm survival is investigated by generalizing the exit model introduced above as follows:

$$\begin{aligned}\Pr(exit_{i,t+1} &= 1) = \Phi(\theta_0 + \theta_1 \ln Age_{it} + \theta_2 \ln Size_{it} + \theta_{31} \ln TFPQ_{it} \\ &\quad +\theta_{32} Demand_{it} + X_{it}'\theta_4),\end{aligned} \tag{7}$$

where $Demand_{it} \equiv \hat{\varepsilon}_{iut}$ is the estimated residual from (5). Note that $TFPQ$ is defined as output conditional on inputs used in the production process, while *Demand* is defined as output conditional on the price charged to customers. We also consider specifications in which we replace *Demand* by the output

[6] Estimation of our demand equation using OLS will give us biased estimates of the price elasticity as the output price is positively associated with the unobserved component of demand. This is because firms optimally increase output prices as a result of favorable demand shocks. We need an instrument closely related to prices but orthogonal to demand shocks. Supply side variables, such as physical productivity and input prices, are potential candidates as they are correlated with production cost and hence output price. Physical productivity is a relevant IV as efficient firms are likely to have lower costs and pass this on to customers by charging lower output prices.

price directly. Given that these alternative specifications condition on TFPQ, the coefficient on the price variable is interpretable as measuring a demand effect.

3.2 Growth

How do physical productivity, prices and demand develop in the initial years following upon entry? To answer this question we run regressions of the following form:

$$\ln \Psi_{it} = \gamma_0 + \gamma_{11} Enter_{it} + \gamma_{12} \ln Age_{it} + \gamma_2 \ln Size_{it} + X'_{it}\gamma_3 + e_{ijt}, \qquad (8)$$

where Ψ_{it} is physical and revenue-based productivity, price and demand for firm i at year t. $Enter_{it}$ is a dummy variable equal to one if firm i is a new entrant in period t and zero otherwise. We control for firm size, firm age, and a vector of control variables. physical productivity, $TFPQ_{it}$, is used as an additional control variable for price regressions in (8). Controlling for firm size is important for two reasons. First, the demand residual obtained from (5) is dependent on scale; for example, large firms will produce a high level of output conditional on price. Second, it is of interest to see whether firms of differing size have different levels of productivity and demand.

4 Empirical Analysis

Having a dataset that covers the entire population of formal manufacturing firms employing at least 10 workers is key to construct our entry, exit and firm age variables. A firm is considered to be an entrant if it is observed in our dataset for the first time in the sample period 1996-2006. If we observe a firm in 1996 for the first time in our dataset, we use an information on year of establishment to decide whether the firm entered in year 1996 or earlier. We then create a dummy variable $Entry_t = 1$ if a firm enters between $t-1$ and t. Similarly, we construct an $Exit_{t+1}$ dummy equal to one if a firm exits the market between years t and $t+1$. We observe a small number of cases of muliple-entry in our dataset, i.e. firms re-entering the market after exit (less than 5% of the observations fall into this category). When making comparison of performance of firms in different stage of their life cycle, we only consider first time entry. $Entry_t$ is then coded zero for subsequent entries since these firms may have better market information than genuine new entrants. It is also possible that firms exit and enter because they cross the size threshold for the Ethiopian census i.e. 10 workers. We view such cases as exits and entrants for our population of interest which is the formal sector.

Table 1 presents descriptive statistics of the key variables used in this analysis. On average, 23% of the observations constitute entrants while the average exit rate is 21%.[7] Young firms constitute a significant share of our sample. The median firm age is only four years of business experience and 55 % of the firms are aged five years or less. It is also worth noting that majority of the firms (82%) are domestic privately owned firms. As few as 6 % of the firms have any export.

Table 2 shows pair-wise correlations between measures of log output price and the productivity measures netting out product and year fixed effects. We find that physical productivity is negatively correlated with price. This is consistent with the theoretical prediction that more efficient firms can produce at lower cost, enabling them to lower their prices. It is this feature of physical productivity measure that makes it a candidate instrumental variable for output prices in our estimation of demand equation. In contrast, revenue-based productivity is positively related to price.

Estimation of demand equation is key for decomposing demand side variables into price and demand shocks. Table 3 presents results for our demand equation. Town-year fixed effects are included to control for average income of firm's local market over time. Product fixed effects capture scale differences in prices across products. Column (1) shows OLS results. The OLS estimate of the price elasticity is equal to -0.739. We suspect this is severely biased towards zero, as firms likely raise prices in response to positive demand shocks. Consistent with this hypothesis, estimating the demand equation using physical productivity as an instrument for price provides us with a larger negative price elasticity (around -4), suggesting that firms face an elastic demand curve (Column 2).[8]

Demand residuals capture unusually high output demand for a given price. This is potentially capturing quality differences for a given product across firms, which may lead to a biased price elasticity of demand and consequently to a biased measure of demand. We investigate whether this appears to be a problem by adding to the specification an interaction term between the price variable and a dummy for the set of homogenous products in the data (i.e. Brick of clay, Cement Block, Cement floor tiles and Cement). The results, shown in column (3), indicate that the coefficient on this interaction variable is relatively small and wholly statistically insignificant. This suggests the estimated price elasticity is not contaminated by product heterogeneity within product categories. The residuals of our demand equations in column 2 and 3 are used as the basis for calculating idiosyncratic demand shocks for subsequent analysis below.

Next we investigate the persistence in prices, productivity and demand. Current physical productivity, average product price and demand shocks are regressed on their one period lag and a set of control variables including owner-

[7] Of the 23% of entrants, 18% are new entrants ($Age0_t = 1$) with the remaining 5% being multiple entrants.

[8] In the first stage regressions, we find a negative and significant relationship between output price and our instrument: physical productivity with the coefficient of -0.26 and significant at 1 percent for column 2 for instance.

ship status, exports and product dummies.[9] A coefficient closer to one on the lagged dependent variable indicates stronger persistence. Results are shown in Table 4. We find that the demand side variables - log price and demand shock- are more persistent than physical productivity. Differences in firm performance on these key variables and their implication for firm survival are investigated below.

4.1 Firm survival

We start our analysis of firm survival by adopting specifications similar to those used in previous studies. Table 5 thus shows exit probits for which the explanatory variables are firm age, size, revenue-based productivity, and controls. The results indicate that young and small firms are more likely to exit the market than larger and more established firms. The quadratic relationship between firm age and survival indicates that firms have better prospect of survival as they grow older but the contribution of age for survival decreases over time. This result is robust after controlling for ownership ($Public_t$ and $Anyforeign_t$) and whether the firm has any export during the survey year ($Export\ Dummy_t$). In line with previous empirical findings, more productive firms, as measured by value added per employee in column 2, are more likely to survive. However, when using value of output of firm's major product as a measure of productivity, after controlling for input usage, output becomes insignificant in column 3.

We now investigate how the likelihood of firm survival relates to physical productivity and demand. Results based on our extended specification of the exit probit (7) are shown in Table 6. We find that firms with higher output demand are more likely to survive.[10] In contrast, there is no significant physical productivity effect on survival. The marginal impact of demand shocks on probability of survival ranges between 0.94 - 2.16 percentage points. This result is robust to the inclusion of alternative firm size measures except in column 3 where contemporary labor and capital inputs are added at the same time leading demand measures to be insignificant. This is because they are highly correlated with physical productivity which takes contemporary capital and labor into account. Significance is largely improved when we use startup capital and labor inputs (column 4). However, we do not find significance demand effect when use output price instead of demand shocks in column 5. It is also worth noting that, even conditional on performance variables, we find robust evidence that firm age and size matters for firm survival. Hence, small and young firms are unlikely to survive even if they perform well, though prospect of survival improves with firm age.

[9] For firms stating multiple prices for same product in a given year, we take average reported price of the product for each year.

[10] We find very similar pattern when using alternative demand residual using demand residual of col 3 of table 3. These results are not presented to save space.

4.2 Growth

Comparison of various components of productivity across firms in different stage of their life cycle is informative about the nature of competition and business environment in which young firms operate. In particular; we are interested in the growth patterns of new firms in the market. In table 7, we compare productivity, price and demand shocks of entrants to that of established firms controlling for firm size and age, ownership, any exporting as well as year, product and sector dummies. Entrants have lower revenue-based productivity which is due to the lower price they charge for their output and lower demand shocks they face. However, we do not find any significant difference in physical productivity of entrants and established firms in column 4. Whereas firms with larger initial number of workers are more productive and face favorable demand shocks, firms with larger start up capital have lower revenue and physical productivity though they have more favorable demand shock. The quadratic firm age effect, in column 2 and 3, implies that demand and output price of newly established firms catch up with time but no such evidence is found for productivity.

Comparing the performance of new firms using age dummies for the first five years of firms in the market provides better picture on persistence of demand and productivity disadvantages of new firms. In table 8, we add 5 age dummies for the first five years of firms' operation with firm age larger than five years used as base category. New firms (with $Age0_t = 1$) have lower revenue-based productivity due to lower output price and demand they face rather than due to being less efficient than established firms. Price and demand disadvantages of new firms persists until firms' second year, but this is not the case for physical productivity. Lower demand shocks are observed as late as firms' fifth year in column 3. This is in line with the results in table 4, that price and demand shocks are more persistent than productivity. These findings suggest that small and young firms are vulnerable to demand side constraints. And in the absence of evidence of catching up effect with regards to physical productivity, previous results of learning effect may be picking up demand side effects than firms updating their productivity. The evidence that absence of/limited market access is the first major growth constraints reported by firms in our dataset seems to support our findings.

Taken together, we find clear evidence that small and young firms face a significant demand constraints, i.e, lower prices and idiosyncratic demand, early on when they enter the market. There is no robust evidence that entering firms are less efficient than incumbents. When it comes to firm survival, it is demand constraints that matter most rather than physical productivity. Thus the idea that African markets drive out inefficient firms is not strongly supported. The fact that there is some evidence for catching up effect on demand side over time is good news, though how long it takes to close the gaps may matter for firm survival. We find no robust evidence for the presence of catching up effect with regards to technological learning.

5 Conclusions

In this study we investigate the relative importance of supply and demand side constraints to firm performance. Previous firm level studies on productivity and firm performance are limited by the use of revenue-based productivity measure which confounds true efficiency with price effect. The current study takes advantage of the availability of both price and physical quantity of firms' products to decompose revenue-based productivity into physical productivity and price effects using 11 year panel dataset of Ethiopian manufacturing sector.

The idea that African markets drive poorly performing firms out of business is not strongly supported in our firm exit analysis. Age and size matter for firm survival, even conditional on performance variables and the latter do not seem to have strong explanatory power. Hence, small and young firms are unlikely to survive even if they perform well. When comparing physical productivity and demand of entrants with more established firms, young firms are no less productive than mature firms on average but they do face lower demand during the first 1-5 years. This may be part of the explanation as to why young firms have high exit rates.

This is supported by our exit probit regressions using physical productivity and demand side variables of firm performance. We find that firms with favorable demand shocks are less likely to exit with no evidence that physical productivity improves prospect of survival. There is some evidence for catching up effect in closing demand gap with firm age. How long this process takes may matter as firms might be forced to exit the market before they are able to catch up and compete with more established firms. Securing access to markets and providing assistance on marketing skills during most vulnerable stage of firm entry are policy implications of our results. Aggregation of physical productivity for multi-product firms and extension of the analysis to other firm performance measures are the natural next steps.

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Table 1: Descriptive statistics of variables used

Variables	Description	Mean	Median	stdev
<u>Dependent Variables</u>				
$TFPR_t$	Revenue based productivity	2.5	2.42	0.82
$TFPQ\_slct_t$	Physical productivity using firm's major product	0.59	0.93	1.6
Log price	Log output price per unit	2.02	1.49	1.58
$Entry_t$	$Entry_t$=1 if firm enters between t-1 and t	23%		
$Exit_{t+1}$	$Exit_t$=1 if firm exits between t and t+1	21%		
<u>Explanatory Variables</u>				
$(lnVA/L)_t$	Log value added per person	9.3	9.23	1.28
$(lnp_t *Q)_t$	Log value of output of firm's major product	13.46	13.19	2.21
rev_sh	Revenue share of firm's major product	0.74	0.85	0.28
lnK_t	Log of firm's capital stock	13.37	13.23	2.58
lnL_t	Log of firm's labor input	3.72	3.26	1.42
lnE_t	Log of firm's energy input	10.34	10.18	2.5
lnM_t	Log of firm's raw material input	13.3	12.96	2.2
lnKi	Log of startup capital stock	13.19	13.21	2.76
lnLi	Log of startup labor	3.69	3.14	1.47
Firm age_t	Firm age in years	11.60	4	15.78
$Age0_t$	Dummy=1 for Firm age_t =0	18%		
$Age1_t$	Dummy=1 for Firm age_t =1	10.7%		
$Age2_t$	Dummy=1 for Firm age_t =2	8.8%		
$Age3_t$	Dummy=1 for Firm age_t =3	6.8%		
$Age4_t$	Dummy=1 for Firm age_t =4	5.9%		
$Age5_t$	Dummy=1 for Firm age_t =5	4.5%		
$Age6_t$	Dummy=1 for Firm age_t >5	45%		
$Export_t$	Export=1 if a firm has any export in year t	6%		
$Public_t$	A dummy = 1 if publicly owned firm	16%		
Any $foreign_t$	A dummy = 1 if any foreign contribution to firm's current paid up capital	2%		

Source: Authors' calculation based on CSA, 1996-2006 data.

Table 2. Prices, output and productivity: Correlations conditional on product and year fixed effects

	Log output price	Physical productivity	Revenue productivity	Log physical output
Log output price	1.0000			
Physical productivity (TFPQ_slct)	-0.4868*	1.0000		
Revenue productivity (TFPR)	0.0711*	0.8367*	1.0000	
Log physical output	-0.1765*	0.4661*	0.4215*	1.0000

Note: The numbers reported in the table are pair wise correlations of predicted residuals based on OLS regressions in which the price, output and productivity variables are regressed on year and product dummies. * = significant at 1%

Table 3: Estimates of the demand equation

	(1) OLS	(2) 2SLS	(3) 2SLS
Log price$_t$	-0.739***	-3.980***	-4.031***
	(0.1487)	(0.216)	(0.226)
Log price$_t$*Homog$_t$			0.304
			(0.662)
Product dummies	Yes	Yes	Yes
Town-year dummies	Yes	Yes	Yes
Observations	3175	3175	3175
R-squared	0.5990	0.3456	0.3437
Number of town-year	571	571	571

Note: Dependent variable is log physical output. The instrument in col. (2) is TFPQ_slct. The instruments in col. (3) are TFPQ_slct and TFPQ_slct*Homog. Standard errors, clustered at the firm level, in parentheses in col. (1) and conventional standard errors in parentheses in col. (2) & (3). *Homog* is a dummy variable equal to one when the products included are: Brick of Clay, Cement Block, Cement Floor tiles, Cement. These products are hypothesized to be most homogenous. *** p<0.01, ** p<0.05, * p<0.1. Unreported constant included.

Table 4: Persistence in productivity, prices and demand

VARIABLES	(1) Physical productivity	(2) log price	(3) Demand shock
$TFPQ\_slct_{t-1}$	0.344***		
	(0.0308)		
Log average $price_{t-1}$		0.414***	
		(0.0461)	
Demand $Shock_{t-1}$			0.623***
			(0.03728)
$Public_t$	0.149***	-0.140***	0.585***
	(0.0356)	(0.0377)	(0.1309)
Any $foreign_t$	-0.0673	0.0145	0.150
	(0.0649)	(0.0637)	(0. 1825)
Export $Dummy_t$	0.0433	-0.0833	0.282
	(0 .0617)	(0.0542)	(0.175)
Constant	1.273***	0.743***	-0.246
	(0.0767)	(0.1391)	(0.179)
Year	Yes	Yes	Yes
Product	Yes	Yes	Yes
Sector	Yes	Yes	Yes
Observations	2027	2027	2027
R-squared	0.196	0.298	0.466
Number of products	27	27	27

Note: Current productivity, price and demand residuals are regressed on their respective lags in a product fixed effect estimation. The demand shock is the residual for the regression shown in Table 3, col. (2). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Age, size, revenue productivity, and the likelihood of exit: Probit estimates

VARIABLES	(1)	(2)	(3)
Firm age_t	-0.0395***	-0.0388***	-0.0350***
	(0.00680)	(0.00677)	(0.00700)
Firm age $square_t$	0.000591***	0.000586***	0.000496***
	(0.000141)	(0.000140)	(0.000151)
lnK_t	-0.0672***	-0.0509***	-0.0650***
	(0.0188)	(0.0190)	(0.0200)
lnL_t	-0.291***	-0.286***	-0.157**
	(0.0566)	(0.0563)	(0.0700)
lnE_t			-0.0334
			(0.0326)
lnM_t			-0.181***
			(0.0663)
Log revenue share $(lnsh2)_t$			-0.0170
			(0.0940)
$Public_t$	0.161	0.182	0.122
	(0.159)	(0.160)	(0.162)
Any $foreign_t$	0.0997	0.109	0.0426
	(0.264)	(0.266)	(0.275)
Export $Dummy_t$	0.0209	-0.00444	0.0925
	(0.326)	(0.313)	(0.322)
Log (Value $added/L)_t$		-0.104***	
		(0.0296)	
Log value of major $product_t$			0.103
			(0.0719)
Year	Yes	Yes	Yes
Sector	Yes	Yes	Yes
Product			Yes
Observations	2509	2509	2499
Pseduo R2	0.1580	0.1628	0.1694

Note: Dependent variable is $Exit_{t+1}$=1 if a firm exits between t and t+1. The output variable in col. (3) is that underlying the calculation of TFPR. Standard errors clustered at firm level. *** p<0.01, ** p<0.05, * p<0.1. Unreported constant included.

Table 6. Exit using Probit Model

VARIABLES	(1)	(2)	(3)	(4)	(5)
TFPQ_slct $_t$	-0.0259	0.0647	0.00290	0.0247	-0.0118
	(0.0556)	(0.0526)	(0.0565)	(0.0564)	(0.0643)
Demand shock$_t$ (T3:2)$_t$	-0.0610***	-0.0399**	-0.0295	-0.0632***	
	(0.0195)	(0.0203)	(0.0203)	(0.0205)	
lnK$_t$	-0.116***		-0.0733***		
	(0.0214)		(0.0219)		
lnL$_t$		-0.326***	-0.247***		
		(0.0564)	(0.0611)		
lnKi (initial)				-0.0642***	-0.0730***
				(0.0238)	(0.0243)
lnLi (initial)				-0.0800	-0.132**
				(0.0570)	(0.0562)
Log output price $_t$					-0.0944
					(0.107)
Firm age$_t$	-0.0399***	-0.0350***	-0.0366***	-0.0381***	-0.0405***
	(0.00699)	(0.00704)	(0.00699)	(0.00710)	(0.00705)
Firm age square$_t$	0.000504***	0.000515***	0.000519***	0.000493***	0.000532***
	(0.000151)	(0.000154)	(0.000153)	(0.000154)	(0.000151)
Public$_t$	-0.0815	0.139	0.134	-0.0668	-0.0608
	(0.149)	(0.164)	(0.163)	(0.171)	(0.169)
Any foreign$_t$	0.0936	0.0915	0.0968	0.120	0.122
	(0.266)	(0.270)	(0.268)	(0.268)	(0.266)
Export Dummy$_t$	-0.148	-0.0462	0.0243	-0.169	-0.165
	(0.317)	(0.332)	(0.335)	(0.318)	(0.312)
Year	Yes	Yes	Yes	Yes	Yes
Product	Yes	Yes	Yes	Yes	Yes
Sector	Yes	Yes	Yes	Yes	Yes
Observations	2499	2499	2499	2392	2392
Pseudo R2	0.1561	0.1594	0.1636	0.1543	0.1508

Notes: Dependent variable is Exit$_{t+1}$=1 if a firm exits between t and t+1. Standard errors clustered at firm level in parentheses. Unreported constant included. *** p<0.01, ** p<0.05, * p<0.1

Table 7. Prices, demand and productivity: Comparing new entrants to established firms

VARIABLES	(1)	(2)	(3)	(4)
	TFPR	Log P	Demand	TFPQ
$Entry_t$	-0.0744**	-0.0387**	-0.320***	-0.0491
	(0.0317)	(0.0188)	(0.102)	(0.0385)
$TFPQ\_slct_t$		-0.272***		
		(0.0284)		
lnKi (initial)	-0.0641***	-0.00962*	0.127***	-0.0748***
	(0.0125)	(0.00540)	(0.0290)	(0.0134)
lnLi (initial)	0.0565**	0.0113	0.829***	0.0621**
	(0.0284)	(0.0167)	(0.0880)	(0.0306)
Firm age_t	0.00254	0.00405**	0.0241**	-0.00208
	(0.00359)	(0.00184)	(0.0113)	(0.00408)
Firm age $square_t$	-3.54e-05	-8.40e-05***	-0.000444**	6.67e-05
	(4.82e-05)	(2.91e-05)	(0.000209)	(5.94e-05)
$Public_t$	0.102	0.0273	0.0118	0.103
	(0.0668)	(0.0368)	(0.222)	(0.0733)
Any $foreign_t$	-0.0903	-0.0221	-0.110	-0.0937
	(0.104)	(0.0724)	(0.349)	(0.0834)
Export $Dummy_t$	0.120	0.0951	0.435	0.0345
	(0.0789)	(0.0698)	(0.306)	(0.0928)
Year	Yes	Yes	Yes	Yes
Product	Yes	Yes	Yes	Yes
Sector	Yes	Yes	Yes	Yes
Observations	3001	3001	3001	3001
R-squared	0.506	0.953	0.336	0.834

Notes: The dependent variable is TFPR in col. 1 and TFPQ_slct in col. (4). Demand is residual of demand equation in column 2 of table 3. Unreported constant included. Clustered standard errors at firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table. 8, The evolution of prices, demand and productivity for new firms

VARIABLES	(1)	(2)	(3)	(4)
	TFPR	Log P	Demand	TFPQ
$Age0_t$	-0.0966**	-0.0717***	-0.579***	-0.0342
	(0.0405)	(0.0246)	(0.126)	(0.0477)
$Age1_t$	-0.0624	-0.0468*	-0.362***	-0.0214
	(0.0487)	(0.0248)	(0.128)	(0.0528)
$Age2_t$	-0.0447	-0.0187	-0.230*	-0.0359
	(0.0496)	(0.0266)	(0.137)	(0.0572)
$Age3_t$	0.0625	0.0286	0.00211	0.0467
	(0.0500)	(0.0272)	(0.143)	(0.0538)
$Age4_t$	0.0493	-0.0389	-0.206	0.121**
	(0.0513)	(0.0340)	(0.159)	(0.0572)
$Age5_t$	0.00766	-0.0332	-0.260*	0.0563
	(0.0553)	(0.0256)	(0.142)	(0.0608)
$TFPQ\_slct_t$		-0.273***		
		(0.0285)		
lnKi (initial)	-0.0655***	-0.00767	0.134***	-0.0796***
	(0.0121)	(0.00480)	(0.0280)	(0.0133)
lnLi (initial)	0.0598**	0.00412	0.799***	0.0767***
	(0.0247)	(0.0156)	(0.0832)	(0.0274)
$Public_t$	0.106	0.0304	0.0172	0.104
	(0.0654)	(0.0379)	(0.224)	(0.0722)
Any $foreign_t$	-0.0940	-0.0362	-0.179	-0.0796
	(0.104)	(0.0722)	(0.343)	(0.0823)
Export $Dummy_t$	0.118	0.103	0.466	0.0198
	(0.0763)	(0.0694)	(0.302)	(0.0901)
Year	Yes	Yes	Yes	Yes
Product	Yes	Yes	Yes	Yes
Sector	Yes	Yes	Yes	Yes
Observations	3001	3001	3001	3001
R-squared	0.507	0.953	0.336	0.834

Notes: The dependent variable is TFPR in col. 1 and TFPQ_slct in col. (4). Demand is the residual of the demand equation shown in Table 3, column 2. Unreported constant included. Clustered standard errors at firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix

Table A1. Unit price summary for P within P3 and P97

p41c4_	**Unit**	Mean(p)	p50(p)	min(p)	max(p)	sd(p)	sd(lp)	cv(p)	N(p)
Tea	KG	11.51375	10.8	5.94	19.23	3.605473	.3188294	.3131449	126
Edible oil	KG/LT	9.621965	9.07	5.69	16.2	2.37102	.2431566	.2464174	382
Oil cakes	KG	.4516434	.4	.06	1.5	.2593364	.6203459	.574206	283
Flour (wheat)	KG	2.577765	2.65	1.0884	3.795	.5373561	.2380541	.2084581	743
Bread (for metric unit only)	KG	4.328014	4	2.5	10	1.384864	.2798264	.2541508	727
Sugar	KG	4.562897	4.21595	2.5656	10.8411	1.704542	.2982124	.3735657	40
Liquor	LT	16.32336	16.8	10.5	20	1.696183	.1085016	.1039114	413
Beer	LT	5.957133	6.301515	3.08	12.9193	1.750648	.2992096	.2938742	158
Lemonade (soft drinks)	LT	4.221937	4.166667	3.125	5.22	.5415168	.1308305	.1282626	227
Cotton fabrics	SQM	6.74187	5.985	2.55	17.27	3.283965	.4517855	.4871001	292
Cotton yarn	KG	21.16431	19	12.44	51.8	7.691528	.3082716	.3634198	132
Nylon fabrics	SQM	8.455517	8.51	4.87	12.39	1.750792	.2187746	.2070592	58
Leather garment	SQF	10.70731	9.23	1.44	41	8.157958	.6218656	.7619057	81
Crust hides and wetblue hides	SQF	6.412759	5.8	.89	15	3.354631	.5404076	.5231183	80
Leather shoes and boots	PAIRS	61.65437	58.42	25	126.18	20.66206	.3365625	.3351272	486
Timber	CUB.M	1783.654	1778	495	3800	697.2754	.42268	.3909253	167
Gravel	CUB.M	95.90831	90	39.1	195	33.52443	.3483421	.3495467	290
Plastic footwear	PAIRS	8.242137	6.9	3.04	36	5.450559	.4667361	.6613041	498
Bricks of clay	PCS	.6915603	.6	.4	1.32	.2463302	.3308411	.3561948	109
Cement blocks	PCS	2.257217	2.1	1.25	4.37	.5879784	.2434398	.2604881	1316
Cement floor tiles	SQM	40.50493	37.44	7	166	21.72471	.5029547	.5363473	175
Cement	KG	.7016772	.65335	.435	1.4901	.2638925	.3170769	.3760882	46
Nails	KG	6.206165	5.77	3.93	11.98411	1.582849	.2413431	.2550446	65
Wires	KG	8.223145	7.985	2.46	12.94	2.215233	.2940674	.26939	60
Vaseline	KG	18.16026	17	7.829999	35.33	6.017519	.3174564	.3313564	81
Paraffin	KG/LT	27.66651	20.15	8.98	83.91	18.83157	.5407912	.6806629	287
Coffee (Milled)	KG	22.8061	24	8.17	33.6	7.230071	.3778923	.3170236	41

Note: Summary statistics for output price after taking out the top and bottom 3 percentiles of the price distribution used as a basis of product selection. However, regressions are estimated based on the entire observation s of selected products, including the top and bottom 3 percentiles, once products are selected..

Table A2. Revenue share of a product selected as major product among selected products

Product	mean	p50	sd	min	max	N
Tea	.7642337	.776008	.2181177	.1502504	1	45
Edible oil	.8450001	.9100978	.1677542	.3112822	1	298
Oil cakes	.5967218	.5877863	.0988283	.5102041	.7538735	5
Flour (wheat)	.9342096	1	.1643112	.0021914	1	583
Bread	.7515118	.9501183	.309753	.0081185	1	488
Sugar	.9304569	.9817675	.1243751	.5177934	1	31
Liquor	.5935034	.5999656	.2086854	.0076474	1	90
Beer	.8150789	.8723925	.1425953	.4872943	1	57
Lemonade (soft drinks)	.555601	.533848	.1061218	.2656777	1	59
Cotton fabrics	.5875103	.5187968	.2522806	.2029806	1	68
Cotton yarn	.5260595	.4967197	.2371481	.1522658	1	48
Nylon fabrics	.5298888	.5424613	.1068792	.3576697	.7146561	11
Leather garment	.2498415	.1038942	.2889866	.0004916	.9624314	26
Crust hides and	.2982448	.1665148	.2943526	.0012479	1	50
Leather shoes an	.7890972	.846727	.225266	.0249161	1	249
Timber	.9001228	1	.2424061	.0442101	1	123
Gravel	.6388954	.6026786	.2975923	.0901382	1	121
Plastic footwear	.5765909	.5234326	.3169391	.0032079	1	169
Bricks of clay	.9377542	1	.1442788	.3888889	1	59
Cement blocks	.6204691	.5831944	.2445371	.0067595	1	599
Cement floor tile	.5338686	.4990259	.2828305	.0427433	1	84
Cement	.9101429	1	.1437082	.5300261	1	39
Nails	.7790731	1	.3124588	.029105	1	67
Wires	.4207218	.2172211	.5090111	.0449441	1	3
Vaseline	.620885	.6158112	.2332482	.027773	1	30
Paraffin	.6190832	.5559087	.2478832	.2702311	1	82
Coffee (Milled)	.9689603	1	.0968267	.601117	1	31
Total	.7387405	.8448988	.2811175	.0004916	1	3515

Paper III

The Effects of Agglomeration and Competition on Prices and Productivity: Evidence for Ethiopia's Manufacturing Sector*

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Abstract

We use census panel data on Ethiopian manufacturing firms to analyze the effects of enterprise clustering on two key determinants of firm performance: physical productivity and output prices. We show that distinguishing between productivity and prices is important for understanding the effects of agglomeration and competition. We find a negative and statistically significant effect of agglomeration of firms on prices, suggesting that new entry leads to higher competitive pressure in the local economy. We also find a positive and statistically significant effect of agglomeration on physical productivity, consistent with the notion that clustering leads to positive externalities. The net effect of enterprise clustering on revenue-based measures of performance is small and not significantly different from zero. Our results thus highlight the importance of separating price from productivity effects in this type of analysis.

Keywords: Agglomeration economies, African manufacturing, Ethiopia, productivity, Prices.

JEL Classification: R10, R32, D24, O14, O55, L11

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1 Introduction

Starting with Marshall (1920), many economists have argued that geographical agglomeration, or clustering, of enterprises can be a source of improved firm performance.[1] The basic idea is that, by locating close to suppliers, customers and competitors, an enterprise may be able to benefit from information spillovers, obtain better access to (skilled) labor, face lower transaction costs, etc. Numerous studies (Glaeser et al., 1992, Henderson et al., 1995, Henderson, 1997, Combes, 2000, Blien et al., 2006) provide empirical evidence indicating that agglomeration economies have been an important source of employment growth in USA and European countries. Other studies (De Lucio et al., 2002) show that there are positive productivity effects. For less developed economies, little quantitative evidence on these mechanisms exists however, and for Sub-Saharan Africa – as far as we know - there is none.[2] In this paper, we use census panel data on Ethiopian manufacturing firms to empirically analyze the effects of enterprise clustering on firm performance. We will consider both the effect on physical productivity and the effects of increased competition (due to agglomeration) on the pricing behavior of firms.

The objective of this paper is thus to analyze whether agglomeration effects are economically important in Ethiopia, an economy where productivity gains in the non-farm sector are urgently needed. Our data are well suited for this purpose. Over our sampling period, 1996-2006, the enterprise landscape has changed quite dramatically. For example, the number of formal manufacturing firms grew by 83%, a number that in most cases will dwarf net entry rates in developed countries.[3] Such a big change to the structure of the market is useful from an empirical point of view. Moreover, access to census data implies that we can define agglomeration variables based on complete data on all members of the relevant economic cluster. We are therefore able to measure agglomeration variables more accurately than would be possible with survey datasets. The panel dimension in the data enables us to allow for time invariant unobserved heterogeneity in performance across firms. This is important, given that cluster characteristics and firm performance may be correlated for

[1] Sonobe and Otsuka (2006, p.4) define a cluster as "the geographical concentration or localization of enterprises producing similar or closely related goods in a small area". Porter (1990, p. 18) defines it as a "geographical concentration of interconnected companies and institutions in a particular field" Swann et al (1998, p 1) define it as "a large group of firms in related industries at a particular location". Schmitz and Nadvi (1999) simply define industrial cluster as "sectoral and spatial concentration of firms."

[2] See Sonobe and Otsuka (2011) for a case study of cluster-based industrial development in Africa and Asia, and Fafchamps and Söderbom (2011) for a descriptive study of the role of business networks for diffusion of new technology and business practices in Ethiopia and the Sudan. See Fafchamps and El Hamine (2004), and Fafchamps (2004), for an analysis of agglomeration economies in Moroccan manufacturing (Morocco, of course, is rather much more developed than most countries in Sub-Saharan Africa).

[3] Few African countries undertake industrial censuses. Sandefur (2008) reports that, for Ghana, the number of manufacturing firms with more than 10 workers grew by 23% between 1987 and 2003, thus implying a considerably more modest growth rate than for Ethiopia (see Table 2.1 in Sandefur, 2008).

many reasons, some of which may have nothing to do with agglomeration per se. The wide geographical coverage in the data is another unusual feature compared to other African firm-level datasets, and ensures there is plenty of variation in the cluster variables across firms. Since our main goal is to investigate the effects of agglomeration in clusters on firm performance, this is clearly of vital importance. Finally, the relatively broad coverage of industrial sub-sectors in the data enables us to investigate whether agglomeration effects are sector-specific or not. The findings will tell us whether sectoral composition matters for the performance of clusters.

The premise of the current study is that, in a poorly integrated economy, an increase in the density of producers in a given location may have two effects. First, entry into the local market may be associated with a reduction in the market power of incumbent firms. This would show up as a decrease in the output prices charged by firms following new entry. Second, entry may lead to higher productivity, either because competition provides a disciplinary device on firms or because the higher density of firms results in externalities. The current study accordingly investigates the impact of agglomeration on two key firm performance variables: physical productivity and output price. By treating output price and physical productivity separately, the current study makes a major contribution to the literature by addressing the methodological weakness of previous empirical work that have used revenue based productivity estimates to analyze the impact of competition and agglomeration. (Katayama et al. 2008, Melitz, 2000, and Foster et al., 2008)

We find a negative and statistically significant effect of agglomeration of firms on prices, suggesting that new entry leads to higher competitive pressure in the local economy. All else equal, this is positive for consumer welfare but negative for enterprise profitability. In addition, we find a positive and statistically significant effect of agglomeration on physical productivity, consistent with the notion that clustering leads to positive externalities. All else equal, this is positive both for consumer welfare and for enterprise profitability. We also show that the productivity and price effects on enterprise revenues by and large cancel each other out. For example, we find no significant effect of agglomeration on revenue-based measures of productivity, such as sales of output per employee or revenue based productivity measure though we find a significantly positive agglomeration effect on value added per employee net of factor inputs.

The rest of the paper is organized as follows: the next section reviews the relevant literature and section 3 discusses the data and variable construction of our key variables. Section 4 deals with the empirical strategy, while the main results are presented in section 5. Section 6 presents various robustness checks and section 7 concludes.

2 Previous Studies

This paper seeks to understand how agglomeration affects two dimensions of firm performance, namely physical productivity and pricing. We will relate to both the classical literature on the effects of agglomeration on productivity and a more recent literature that explicitly incorporates the effects of agglomeration on pricing behavior.

For the analysis of productivity effects it is the information spillover that is important. Firms located close to each other are well placed to learn from each other about new technologies, new ways of marketing, or new management techniques, for example. Such externalities can clearly enhance the technological capacity of firms. In countries with weak formal institutions, informal contract enforcement and cooperation are important for business and likely work better if the parties involved are located close to each other (McCormick, 1999). Physical proximity could also make firms better informed about which entrepreneurs can be trusted.

The analysis of the effects of information spillovers is complicated by the fact that we cannot directly observe flows of information. Therefore the literature has sought to relate productivity (and growth) effects to various cluster or agglomeration measures. Several authors have for example argued that agglomeration effects will depend on the sectoral composition of the cluster. Rosenthal and Strange (2003, p. 12) conclude from their literature review that "doubling city size seems to increase productivity by an amount that ranges from roughly 3-8%", suggesting that agglomeration effects are not sector-specific. Henderson et al. (1995) find that the presence of activities outside the own sector encourages growth particularly in high-tech industries in the U.S. However, Henderson (1997; 2003) and Desmot and Fafchamps (2005) find that generally, in the U.S., own-sector externalities are stronger than those generated by other sectors. So the evidence about the relative effects on performance of being located together with own sector firms or other firms is mixed.

The factors just described are measures of the size or level of activity of various types of firm clusters. The impact may however also vary along certain structural dimensions. One is diversity, that is having a wide variety of sectors in a region. A broad variety of producers may possibly generate a more comprehensive information set that can benefit producers. In a classical study Jacobs (1969) argued that particularly cross-sectoral effects are important, and that sectoral diversity raises productivity via the exchange of information and pecuniary externalities across sectors.

Apart from information externalities there is a wide range of agglomeration mechanisms that lower the operating costs of the firms. The cost of labor may fall as a result of agglomeration, since locating in a large local labor market makes it easier to find specialized labor (this is sometimes referred to as the thick labor market externality; Glaeser et al., 1992). A large local labor market also implies scope for specialization and division of labor among enterprises. The cost of fixed capital may be lower in locations where there is a functioning market for second hand capital (e.g. equipment) so that firms' investment decisions are reversible rather than irreversible (Dixit and Pindyck, 1994). Proximity to input suppliers and consumers and shared infrastructure lowers transportation and transaction costs. The review in Bun and El Makhlouf (2007) also indicates that diversity is generally correlated with economic development in advanced countries. Joint location may also facilitate sharing of indivisible goods and facilities. Clusters may also attract traders that make it easier for firms to market their goods.

The current study also relates to firm level studies of the effect of competition on firm performance.[4] Aghion et al. (2008) study the effect of low level product market competition on productivity growth in South Africa. Using price-cost margins as measure of competition, they find that a low level of competition has a negative impact on productivity growth in the South African manufacturing industry. They use fixed effect estimation where productivity growth is regressed on lagged price-cost margins and industry and year fixed effects where productivity growth is measured using Hall's (1990) decomposition and assuming constant returns to scale.

Increased competition has two effects on revenue based productivity measures: a decline in market share of existing firms and possibly their price; and pressure on firms to improve productivity to survive the competition. The two have opposing effects on revenue based TFP and the resulting effect of competition depends on the relative magnitude of the two effects. Moreover, Katayama et al. (2008) argue that findings that geographically clustered firms are relatively productive attributed to agglomeration economies may simply reflect high wages and rental costs in urban areas which translates into higher production costs and hence higher output prices.

At aggregate level, Syverson (2004a; 2004b; 2007) studies the effect of producer density on productivity and output price dispersions across producers of narrowly defined industries. The major premise in these studies is that consumers can easily switch between suppliers when producers are densely clustered in a market, making the market more competitive. Syverson (2004a & b) finds evidence that markets with high demand density and thus high producer density have higher lower-bound and average productivity levels and exhibit less productivity dispersion among their products as inefficient producers find it difficult to operate profitably. On the output price side, higher producer density implies lower prices due to lower optimal mark-ups in the case of homogenous product markets where firms have identical production costs. Syverson (2007) argues that if firms differ in their production costs, not only do average prices fall as density increases, but that upper-bound prices and price dispersion should also decline as high cost firms are forced to exit the market. Regressing various moments of log price at market level on producer density and local market demand controls, it is found that higher producer density reduces the upper-bound of prices firms charge. After adding controls

[4] See Syverson (2010) for a recent review of determinants of firm productivity

for input prices, it is still found that producer density negatively affects log prices implying that producers in dense-market have low costs not because factor prices are lower in dense markets but rather because they are more efficient.

Entry threat is another measure of competition often used in the IO literature. Aghion et al. (2009) study how firm entry threats, proxied by lagged actual entry rates; affect innovation incentives in incumbent firms in the UK. They find that the threat of technologically advanced entry spurs innovation incentives in sectors close to the technology frontier, where successful innovation allows incumbents to survive the threat. However, entry threat discourages innovation in lagging sectors, where the threat reduces incumbents' expected rents from innovating. Their result is robust to the use of foreign entry, domestic entry and entry through imports and controlling for average profitability of incumbent industries. Goolsbee and Syverson (2008), drawing on evidence from major US airlines, also find that incumbent, threatened by entry cut prices significantly.

Finally, our paper also relates to methodological papers on improving measures of firm productivity, output and inputs. Katayama et al. (2008) argue that productivity indices constructed using real sales revenues of output, depreciated capital spending and real input expenditures have little to do with technical efficiency, product quality or contributions to social welfare when applied to differentiated product industries. Assuming that firms' costs and revenues reflect Bertrand-Nash equilibrium in a differentiated product markets, and incorporating a demand system, they impute each firm's unobserved quantities, qualities, marginal costs and prices of each product from observed revenues and costs. Firm's contribution to consumer and producer surplus is used as an alternative welfare-based measure of productivity. When comparing their welfare-based measures of productivity with conventional productivity measures using panel data on Colombian paper producers, they find that the two are only weakly correlated. Melitz (2000) also demonstrates one way to incorporate consumer tastes into plant level performance measures when output price and quantity data are unavailable. He notes that the residuals from a revenue function can be used to infer a quality adjusted productivity index, which provides the basis for ranking firm's contributions to social output. The main limitations of this approach are that it forces identical markups on all firms and the presumption of availability of data on inputs in physical units.

The presence of firm level data on prices and physical quantities of output makes it possible to estimate physical output based productivity measures and to decompose the revenue based productivity measure into true efficiency and price effects. Using such an approach Foster et al. (2008) find that physical productivity is inversely related to price while revenue based productivity is positively related to price.

3 Data and Descriptive Statistics

3.1 Variable Construction

We use a census based panel dataset of Ethiopian large and medium scale manufacturing establishments for the period 1996-2006 collected by the Central Statistical Authority (CSA) of Ethiopia. The dataset includes information on quantity and unit prices of the firms' products, capital, labor, raw material and energy inputs as well as investment and other industrial costs for establishments employing at least 10 workers.

The number of firms in a local market or cluster is used as a measure of competition and agglomeration. The number of firms in a town at a given year is used as a measure of cluster size.[5] Using product information, our measure of cluster size is then disaggregated into: the number of own-cluster firms producing the same product as firm i ($NSAMEPROD_t$) and the number of own-cluster firms producing products different from firm i's products ($NDIFFPROD_t$).[6] The former captures competition between firms producing similar products, while the latter captures general agglomeration effects such as information spillovers, better access to skilled labor, lower transaction costs due to geographic clustering of firms producing different products. We further disaggregate the number of firms producing other products, $NDIFFPROD_t$, by sector in order to account for product distance between own product and other products. The idea is that products in the same sector are more similar than products belonging to different sectors. As a result, we generate three variables capturing agglomeration effects on firm performance: the number of own-cluster firms producing the same product, the number of own-cluster firms in own-sector producing different products and the number of own-cluster firms producing different products in a different sector.

How we constructed $NDIFFPROD_t$ deserves further explanation. Calculating $NDIFFPROD_t$ is straight forward when a cluster consists of single product firms only. In this case, $NDIFFPROD_t$ is the difference between number of firms in own-town and number of firms producing the same product as firm i. This is illustrated in panel A of table A0 in the appendix. All, *single product*, firms in the cluster will have equal number of firms in town; $NSAMEPROD_t$ and $NDIFFPROD_t$. This approach has, however, some limitation when applied to multi-product firms. A multi-product firm will not be counted in number of firms producing different products if it is already counted in $NSAMEPROD_t$. This is fine for our purpose, since we are mainly

[5] With the exception of firms with missing information on town and sector, we count all firms in our dataset including those firms with no product information. Throughout this paper, we use 'own-cluster firms' to refer to firms co-locating in same cluster at a given year.

[6] It is sometimes the case that firms report 'Other product' as their produce. Given the possibility that this product category can be used for various heterogeneous sets of products; we do not consider them when calculating the number of firms producing similar products in town. This also applies to firms with missing product information. Instead, firms with 'Other product' product categories and those with missing product information are counted among own-cluster firms producing different products ($NDIFFPRODt$).

interested in investigating agglomeration externalities from *other* firms in the cluster.[7] In clusters with multi-product firms, as in panel B of table A0 in the appendix: (i) we first, pick a product category j and count number of *firms* producing product j to get $NSAMEPROD_t$; (ii) we list all *other* products $i \neq j$ in one's own cluster; (iii) we then list firms in own-cluster that are producing these *other* products $i \neq j$; (iv) and finally we count firms in (iii), which are not already counted in (i).[8]

A census dataset covering all large and medium scale manufacturing firms is ideal for analyzing agglomeration effects because the number of firms is not an artifact of survey design but rather the actual number of firms in Ethiopian manufacturing sector as a whole. Annual census datasets are collected for all waves for the period 1996 -2006 except 2004/05. Unfortunately, CSA switched to a survey instead of census based data collection method for selected sectors, hence biasing the number of firms in a cluster for the 2004/05 wave. For this reason, we drop the survey year from our main regression analysis. Observations from the survey year are, however, used for robustness checks to our main regression results.

Another major advantage of this dataset is the availability of both price and quantity information of firms' products and this is what made this study possible. The product module of the dataset includes: the type of firms' products, their unit of measurement, price as well as quantity produced.[9] Ignoring a composite product category labeled 'other products', we have around 17, 000 product-year combinations in the period 1996-2006 belonging to 15 two-digit sectors.[10] A number of adjustments are made to generate comparable price and quantity information across different firms producing a given product. We converted various units of measurements firms use to a common unit of measurement such that all weights are measured in kilograms, volumes in liter, area in square meter or square feet depending on the product. . . etc. We then standardized all our price and quantity measures to the selected common unit of measurement.

3.2 On TFP calculation

We construct the conventional revenue based productivity ($TFPR$) using the following production function:

$$Y_i = A_i F(K_i, L_i, M_i, E_i) \tag{1}$$

[7] As an alternative, one can also control for $NDIFFPRODt$ by directly adding the number of firms in town along with $NSAMEPRODt$.

[8] Using this approach, we count firms only once, i.e., if there is one firm producing two other products in own-cluster, number of firms producing different products in this cluster is taken to be one. Thus a firm is either counted in $NSAMEPROD_t$ or $NDIFFPROD_t$ even if it is a multi-product firm.

[9] See table A1 in the appendix for list of products in the dataset

[10] Among these, 7800 product-year observations are selected as a set of homogenous products to check robustness of our regression results to quality variations within a product category.

where Y_i is firm i's output, A_i is measure of firms productivity, K_i is capital stock, L_i is labor input M_i is firm's raw material inputs and E_i is energy used in production. Expressing (1) in log terms :

$$\begin{aligned} \ln A_i &= \ln Y_i - \ln F(K_i, L_i, M_i, E_i) \qquad (2) \\ \text{where} \ln F(K_i, L_i, M_i, E_i) &= \alpha_k \ln K_i + \alpha_L \ln L_i + \alpha_M \ln M_i + \alpha_E \ln E_i \end{aligned}$$

Various measures of productivity differ in the way they measure output (lnY_i). Revenue based productivity measures ($TFPR$) use real revenue from the sales of output, whereas physical productivity measures ($TFPQ$) use physical quantities of output produced. Thus our $TFPR$ measure can be expressed as:

$$TFPR_i = \ln(\sum_k P_k Q_k) - \ln F(K_i, L_i, M_i, E_i) \tag{3}$$

where P_k and Q_k are output price and physical quantity of product k of firm i respectively. Physical productivity, on the other hand, uses physical quantity of firm's output as in (4). Estimating physical productivity of multi-product firm, however, faces a few aggregation problems. Since we measure physical output, we cannot sum up different physical units of different products to get an aggregate output of the firm. We avoid such aggregation issues by separately controlling for physical output and input usage as a proxy for physical productivity. The approach will be discussed further in empirical section..

$$TFPQ_i = \ln(\sum_k Q_k) - \ln F(K_i, L_i, M_i, E_i) \tag{4}$$

Instead of estimating productivity as a residual of a production function, we calculate the input component of (3) and (4) (second term on the right hand side) using sector average shares of the inputs calculated from our dataset. We use two digits ISIC classification to define sector. The factor shares of labor, raw material and energy inputs are calculated as the shares of the wage bill, raw material and energy expenditures in a firm's total output respectively. Assuming constant returns to scale, the share of capital is then calculated as the residual share after deducting the shares of labor, raw material and energy inputs from one.[11] Labor is measured as the number of workers, permanent and year equivalent number of seasonal workers. Deflated firm's expenditure on raw material and energy are used to measure raw materials and energy inputs using the GDP deflator. Deflated fixed capital stock at replacement value is used to measure firm's capital input.[12] Since we use the value instead

[11] The calculated input shares are reported in table 1 in parenthesis along with summary statistics of the inputs used.

[12] Capital stock is measured by the average of capital stock at the beginning and end of the year at replacement value. The average capital stock is then deflated using GDP deflator.

of physical quantities of capital, energy and raw material inputs, measures of productivity will be contaminated by input prices with firms facing higher input prices appearing to be less efficient. $TFPR$ additionally confounds output prices with true efficiency. The current study deals with the latter problem and contributes to the literature in disentangling output price effect from physical productivity.

4 Empirical Strategy

In this paper, we want to answer the following question: Are prices lower in areas characterized by high competition? And how does firm productivity respond to increased competition due to firm entry in the local market? The major contribution of this study is to disentangle the price and true physical productivity effects, which was not possible in previous studies using revenue based productivity measures. (5) presents our basic estimation strategy.

$$\begin{aligned} Y_{ijt} &= \alpha_0 + \alpha_1 NSAMEPROD_t + \alpha_2 NDIFFPROD_t + \sum_k \alpha_k X_{kit} \\ &\quad + \alpha_4 \ln sh_{ijt} + \eta_i + \rho_j + \sigma_t + \lambda_\tau + \varepsilon_{ijt} \end{aligned} \tag{5}$$

where Y_{ijt} includes a range of outcome variables of interest such as price, physical and value of output, and revenue based productivity measures. X_{kit} includes input k used in the production process. Alternatively, we use an aggregate measure of input usage: $tfp\_costSE_i = \alpha_K \ln K_i + \alpha_L \ln L_i + \alpha_M \ln M_i + \alpha_E \ln E_i$ where α_i is sector average income share of input i in total output, constructed under the assumption of constant returns to scale, i.e. $\alpha_K = 1 - \alpha_L - \alpha_M - \alpha_E$. Because we are using product level measures for the dependent variable while inputs are reported at firm level, we adjust for input usage of each product by controlling for the revenue share of each product of the total sales value of firm's output ($lnsh_{ijt}$).[13] The assumption here is that, the share of firm's total inputs allocated to the production of product j is equivalent to the revenue contribution of product j to firm i's total revenue from sales of all its products.[14] η_i, ρ_j and σ_t are firm, product and year fixed effects with ε_{ijt} being the error term. Additionally, we control for town fixed effects,λ_τ, to account for firms that switch location.

We construct a capital stock using perpetual inventory method where different depreciation rates are assumed for different category of capital. We used 5% for dwelling houses, non-residential buildings and construction works; 8% for machinery and equipment; and 10% for vehicles and furniture and other fixtures.

[13] Similar approach is used in Foster et al (2008), they divide firm's reported output by the product's revenue share.

[14] The limitation of such an approach is that, assuming inputs are used proportionately to each product's revenue share is the same as assuming that the use of inputs are perfectly separable across products. This may be a strong assumption to make; however, the bias is less important if firms are specializing in few products. Figure 1a shows that firms often specialize in 1-3 products. The median (mean) number of products firms produce is 1 (1.79) products.

The extent of competition is captured by the number of firms in own town producing similar product ($NSAMEPROD_t$). We also control for the number of firms in own town producing different products to analyze the impact of a more general agglomeration effects from firms producing different products ($NDIFFPROD_t$). $NDIFFPROD_t$ in (5) is further decomposed by sector, using two digits industry classification, to control for product distance between own product and other products in local market.

$$\begin{aligned} Y_{ijt} &= \alpha_0 + \alpha_1 NSAMEPROD_t + \alpha_2 NSAMESEC2_t + \alpha_3 NDIFFSEC_t \\ &\quad + \sum_k \alpha_k X_{kit} + \alpha_5 \ln sh_{ijt} + \eta_i + \rho_j + \sigma_t + \lambda_\tau + \varepsilon_{ijt} \end{aligned} \tag{6}$$

where $NSAMESEC2_t$ and $NDIFFSEC_t$ are number of firms producing other products in own and other sectors respectively. (5) and (6) are then estimated by firm fixed effects using panel dataset of the Ethiopian large and medium scale manufacturing sector firms for the period 1996-2006 except for 2004/05. The availability of both product price and quantity information enables us to analyze the price and physical productivity effects separately:

$$\begin{aligned} \ln Q_{ijt} &= \alpha_0 + \alpha_1 NSAMEPROD_t + \alpha_2 NSAMESEC2_t + \alpha_3 NDIFFSEC_t \\ &\quad + \sum_k \alpha_k X_{kit} + \alpha_5 \ln shA_{ijt} + \eta_i + \rho_j + \sigma_t + \lambda_\tau + \varepsilon_{ijt} \end{aligned} \tag{7}$$

where $ShA_{ijt} = \frac{(P_j Q_j)_{it}}{\left[\sum\limits_{z=1}^{n} P_z Q_z\right]_{it}}$

where Q_{ijt} is physical output per unit for product j of firm i at a given year t is used as a dependent variable in (7). We also control for inputs usage adjusted by revenue share of product j in firm i's total revenue from sales of all its products, $z = 1, 2, ..., n$, as well as firm, product, town and time fixed effects. Similarly, we estimate price effect of competition in (8), where we additionally control for physical productivity, since more productive firms are more likely to translate that into lower output prices.

$$\begin{aligned} \ln P_{ijt} &= \alpha_0 + \alpha_1 NSAMEPROD_t + \alpha_2 NSAMESEC2_t + \alpha_3 NDIFFSEC_t \\ &\quad + \alpha_4 TFPQ_i + \eta_i + \rho_j + \sigma_t + \lambda_\tau + \varepsilon_{ijt} \end{aligned} \tag{8}$$

Since we measure output using physical units, when using physical productivity, we cannot just sum up different physical units to come up with an aggregate output of the firm. Instead we separately control for individual components of productivity: output and input usage, in (9).

$$\begin{aligned} \ln P_{ijt} &= \alpha_0 + \alpha_1 NSAMEPROD_t + \alpha_2 NSAMESEC2_t + \alpha_3 NDIFFSEC_t \\ &\quad + \alpha_4 \ln Q_{ijt} + \sum_k \alpha_k X_{kit} + \alpha_6 \ln shB_{ijt} + \eta_i + \rho_j + \sigma_t + \lambda_\tau + \varepsilon_{ijt} \end{aligned} \tag{9}$$

where $ShB_{ijt} = \frac{Q_{ijt}}{\sum\limits_{z=1}^{n} \overline{P}_{zt} Q_{izt}}$

The revenue share of product j in total sales value of all firm i's output is used as input adjustment factor in the output regression in (7). For the price regression, on the other hand, the share of firm i's physical quantity of product j in firm i's total physical output is used to avoid inclusion of the dependent variable on the right hand side of (9). Total physical output, the denominator of the shB expression, is constructed as a weighted sum of physical quantities of firm i's products, $z = 1, 2, ..., n$, where the average prices of each product, $z = 1, 2, ..., n$, across all the firms producing the product at a given point in time ($\overline{P}_{zt}$) are used as weights. We expect that higher competition ($NSAMEPROD_t$) forces firms to improve productivity and hence decreases output price. In addition, competition has a direct effect on prices as firms compete for demand for their product for a given market share. Agglomeration of firms producing different products in own-cluster is expected to be beneficial to firm productivity due to technology spillover effects, better access to market information and cheaper inputs.

We test if the composition of a cluster matters to firm performance using equation 10:

$$\begin{aligned} Y_{ijt} &= \alpha_0 + \alpha_1 NSAMEPROD_t + \alpha_2 NDIFFPROD_t + \sum_k \alpha_k X_{kit} \\ &\quad + \alpha_4 \ln sh_{ijt} + \alpha_5 \Gamma_{t\tau} + \eta_i + \rho_j + \sigma_t + \lambda_\tau + \varepsilon_{ijt} \qquad (10) \end{aligned}$$

where $\Gamma_{t\tau}$ controls for time varying cluster characteristics such as number of employees, average firm age, share of new entrants; and share of exporters in own cluster, τ, at time t. Controlling for the number of employees in a cluster can additionally serve as a control for big city effects, since big cities are more likely to have lower prices due to economies of scale advantage of having a larger population size and market. Since we are using product level dependent variables, price and quantity of a product, (5)-(10) are estimated using our product module dataset in a product-year space. That is, if firm i produces five products at a given year t and we observe firm i in our dataset for ten years, firm i will have 50 product-year observations. As shown in data section and in table A0, $NSAMEPROD_t$ and $NDIFFPROD_t$ are constant within a product category at time t but vary across product groups in a cluster. Our dependent variable, on the other hand, varies even within a product category across different firms producing it. $\Gamma_{t\tau}$, which controls for time-varying cluster characteristics only varies across clusters, but not within.

Few econometric problems exist in our identification strategy discussed above. First, when estimating our physical output regression, we are comparing productivity of firms across different physical products and even within a product category; quality of a given product may vary across different firms producing it. Controlling for product fixed effect takes care of quality variation across different products, whereas focusing on selected homogenous products takes care of quality variations within a product between different firms. To this end, we select fairly homogenous products using a primary criterion that consumers should not differentiate between unlabeled products of firms producing the same product category. In addition, we included other set of products based on a secondary selection criterion that, in a cross-section of firms producing a given product the coefficient of variation of output price should not be more than 0.5 and the number of observation should be larger than 100.[15] As a result, we have chosen 27 products presented in table A2 in the appendix.

We follow a similar approach for price regressions as well in controlling for quality variation when counting number of firms producing same product, though this is less of a problem for monetary variables. We expect the second product selection rule to significantly reduce variation in price as a dependent variable, although output prices might still vary between firms, even after we control for quality variation, due to localization of markets and horizontal differentiations and long established customer-supplier relationships (Foster et al., 2008, p 406).

The second identification problem we face is firms' endogenous choice of location. New firms have an incentive to enter in locations with higher productivity as this might be associated with better investment climate in these local markets. By the same reasoning, existing firms also have an incentive to switch to more productive locations. It also pays for firms to locate themselves in markets, where they can secure higher prices for their products. Thus, our measure of competition and agglomeration are subject to endogenity bias. Endogenity of this kind is more serious to output than to price regressions. This is because, if indeed competition reduces output prices, this result works against the direction of the endogeneity bias, where firms endogenously choose locations which provide higher prices for their products. As regards the physical output regressions, larger productivity benefit due to competition and agglomeration may be alternatively interpreted as firms locating themselves in higher productivity markets, making it difficult to establish casualty. The use of town and firm fixed effects goes a long way towards controlling for time invariant differences in the investment climate of the local markets firms operate in, but time-varying unobserved local market characteristics are still uncontrolled. Besides, few firms change their location upon entry. We also use the one period lagged number of firms to analyze price and productivity effects of competition and agglomeration to mitigate the endogenity bias.

However, losing observations of the 2005/06 wave is more costly in regressions using lagged number of firms as the last wave of the dataset is the year with the largest number of firms operating in the Ethiopian large and medium scale manufacturing sector.[16] Instead of dropping the 2005/06 wave of our

[15] Note that products deemed to be homogenous according to the primary selection criterion do not necessarily have to satisfy the secondary selection criterion. See a companion paper Siba and Söderbom (2011) for detailed discussion on the product selection. A similar approach is also followed by Foster et al. (2008).

[16] There were 1140 firms in the last wave of our dataset, 2005/06, as opposed to 762 firms

dataset, as a result of biased lagged number of firms, we estimated the 'correct' number of firms in 2004/05 by using information in the years before and after the survey year to determine whether these firms operated in the market despite being excluded from the survey. We use the simple rule that if a firm was in the market both in the years before and after the survey period, then it is assumed to have been in the market during 2004/05. We then added the number of these firms, which we assume were left out of the survey, to the actual number of firms in our dataset for the year 2004/05. We made an exception, to this simple rule, for firms that are observed for the first time in the dataset in 2005/06. These firms are treated as genuine new entrants in 2005/06 and hence we do not adjust for them. However, using this approach we are not able to distinguish between firms exiting the market in the survey year and firms that were in the market but were left out of the survey. We are also unable to capture firms, which entered and exited the market in 2005/06. This is less of a concern, since it is less likely that firms enter and exit the market in the same year.As a result of this adjustment, we come up with 980 instead of 762 firms operating in the market in 2004/05.[17]

5 Results

We start our analysis by investigating the impact of competition and agglomeration on various revenue based measures of productivity in table 2. We use three alternative measures: value added per employee, sales value of output per employee as well as the revenue based productivity measure ($TFPR$) in logs at firm level. These are then regressed on number of own sector and non-own sector firms in town, as measures of competition and agglomeration; log of inputs and firm age using OLS (in column 1-6) and firm fixed effects (column 7-12). Controlling for year, town and sector fixed effects, number of firms in own sector and town is found to negatively affect log value added per employee in OLS specifications (column 1 and 2). When using firm fixed effect, on the other hand, we find a statistically weak positive effect on value added per employee (in column 7 and 8). However, we do not get any support for positive impact on productivity when using log sales value of output per employee and revenue based productivity measure ($TFPR$).

This study capitalizes on the major weakness of the revenue based output and productivity measures in confounding price and physical productivity, and estimates the two effects separately by using product level information on output price and quantity. Because the dependent variables are at product level, all the regressions below are estimated using the product module dataset,

in the 2004/05 survey year.

[17] Once we correct for the number of firms in the survey year, all the regression results are run based on the sample of firms in our actual dataset. In other words, the imputation is only used to correct for number of firms for firms already observed in the data but not to increase our number of observation. We also run all regressions using the actual dataset without any imputation to check the sensitivity of our results to the imputation. Results are even stronger and in line with the reported results in this study.

in a firm-product-year space. Competition is expected to have a negative impact on output price both through its effect of enhancing productivity and through its effect of reducing market share of incumbent firms. In Table 3, the number of firms producing same product in own-cluster has a robust negative effect on output price controlling for productivity and year, product, town and firm fixed effects in columns 1-4. Number of firms producing other products in own cluster, on the other hand, do not have any significant effect on price. This is not surprising since, agglomeration of firms producing other products is expected to decrease price only through productivity improvement, which is already controlled for. In line with the above results, we also find that firms that are the only firm in sector and town ($Monply\_st$) charge a significantly higher price as they face less competition in the product market.

How we control for productivity needs some explanation. We separately include individual components of physical productivity: physical output and inputs, into product price regressions and adjust for input usage of each product by the revenue share of each product as discussed in empirical strategy section. Thus, for a given units of inputs used, higher physical output (lnQ_{ijt}) leads to higher physical productivity, which in turn translates into a lower output price. In Table 3, we find a highly significant negative effect of physical output on output price. Similarly, for a given output, larger input usage leads to lower productivity due to increased production costs and hence higher price. Thus, we should expect a positive relationship between the level of input used and output price after adjusting for the share of inputs used in producing a given product ($lnsh\_new2$).

In columns 1-2, we add inputs separately and in columns 3-4, we use an aggregate measure of input usage, where inputs are aggregated by multiplying sector average income share of inputs by firm level capital, labor, and raw material and energy inputs. We find positive effects of level of inputs used on output price. The input adjustment variable ($lnsh\_new2$) itself is positive and highly significant implying that the larger the share of inputs used into the production of a given product, the higher its price. We find similar results in columns 3-4 when using an aggregate measure of inputs together with its adjustment factor.

The analysis of the effect of competition on physical output provides an explanation for why we did not find any productivity effect of competition using revenue based productivity measures or value of output. Controlling for inputs used; and year, product, town and firm fixed effects; we find a positive effect of number of own-cluster firms producing the same products on physical output in column 5-8 of table 3. An increase in number of firms producing same product by one, leads to an increase in physical output of about 0.9 %. This magnitude might look rather small, but it is only for one of firm's products and firms with more number of products have higher productivity advantage in total. This result is robust to the inclusion of alternative input measures as well as to controlling for lone firms in own sector and town. Firms with larger inputs also produce more output. The effect of an increase in the number of firms in own sector and town by one ($Monply\_st$), on output price is more robust than its effect on productivity.

An increase in the number of firms in own sector and town by one ($Monply\_st$) has stronger effect than the average effect of increasing number of firms producing same product by one unit ($NSAMEPROD_t$) indicating possible non-linear effects of cluster size on our variables of interest. In table 4, we investigate non-linear effects of number of firms in own sector and town by using dummies for having: only 1, 2, 3, 4, and atleast 5 firms in own sector and town. $Nsty\_2$, for instance, is a dummy equal to one if there are only two firms in own sector and town whereas $Nsty\_5$ is a dummy equal to one if there are at least 5 firms in own sector and town, zero otherwise. $Nsty\_1$, a dummy for being the only firm in own sector and town, is used as a base category. As before, an increase in the number of firms producing same product has a negative price and positive productivity effects with similar coefficient estimates to table 3. Moving from one to two firms in own sector and town decreases price by about 11% and increases productivity by 17% though the latter effects are significant at 10%. With the exception of $Nsty\_4$, an increase in number of firms by more than one firm seems to have larger price effect but no such pattern is observed for output effect.

In table 5, we address two major econometric issues in interpreting the above results as agglomeration effect on price and productivity. The first one involves causality. Firms may strategically locate themselves in high productivity locations and in locations where they can secure higher prices for their products making our agglomeration measures endogenous. As argued above, the results on output price are less prone to the bias as the negative effect on price works against the direction of the endogenity bias as a result of firms locating themselves in towns where they can secure higher price for their products. To mitigate the endogenity bias due to firms' strategic choice of locations, we run all the regressions above using lagged number of firms as our measure of competition and agglomeration using town and firm fixed effects to control for time invariant differences in the investment climate of the local markets firms operate in.[18] The price and productivity effect of competition still holds when using lagged number of firms with slightly lower coefficient estimates for price regressions in absolute terms. As before, more productive firms have lower output price whereas firms with larger share inputs allocated to production have higher prices. The output effect is similar to the above estimates using contemporary number of firms. The monopoly effect on price disappears with the use of lagged number of firms while being the only firm in own sector and cluster still have, large but statistically weak, productivity loss.

Secondly, one may wonder about the validity of grouping products, with potential quality variation across firms, into one product category. Although it makes sense to group a product such as concrete produced by different firms in a cluster, it may not be obvious to assume that different firms pro-

[18] as discussed above the number of firms is adjusted for the survey year 2004/05

ducing clothes produce a comparable quality of the same product. We create a dummy, selected, with a value equal to one for 27 selected homogenous products and zero otherwise and interact this dummy with our agglomeration variables to investigate the sensitivity of our results to quality variations. The absence of joint significance of the interaction variables is taken as an evidence for robustness of our results to quality variation. The use of product fixed effects also controls for quality variations across different products. In table 5, price dumping effect of competition loses significance, though we reject joint significance of the interaction effects (in column 3). This may be due to reduced variation in prices as we used lower variation in price across firms as one of the selection criteria for homogeneous products. The productivity effect, on the other hand, becomes stronger and highly significant (in column 6) while the interaction effects are jointly significant only at 10%.[19]

6 Robustness Checks

In this section we make a number of checks to see whether our cluster size measures are really capturing agglomeration effects rather than other effects such as population size, as big cities may have lower prices due to economies of scale of having a larger population and market size. In column 1 of table 6, we include number of employees in town and in own sector as proxies for population size.[20] It is interesting to see that our agglomeration variables remain significant with slightly lower coefficient estimates as some of the effects are taken away as population effect. Number of employees in own sector and town has a negative effect on output price and a positive effect on productivity. The latter is, however, significant only at 10%. We do not find such an effect for number of employees in town.

Another way of checking if our cluster size variables are capturing agglomeration effects is to control for firm entry and age. If our cluster size variables are indeed picking up agglomeration and competition effects, we would expect this to work through the mechanism of increased entry. Hence, we expect lower or no effect from cluster size variables when controlling for entry. Average firm age in the cluster in turn captures the resulting firm churning effects due to increased competition. In table 6, the cluster size variables become insignificant when share of entrants in own-town interacted with the cluster size variables is included in column 3 and 7, conforming to our reasoning that agglomeration effects are mainly driven by increased entry resulting in higher competitive pressure. $NDIFFPROD_t$ in levels has no significant effect though its interaction with share of entrants in the cluster is positive and significant for price regressions. Results are largely similar when doing the same analysis using

[19] When using interactions with contemporary measures of agglomeration, the effect of $NSAMEPROD_t$ is significant with the expected sign both for price and productivity effects. Results are presented up on request.

[20] Population census in Ethiopia is undertaken every 10 years which restricts our ability to come up with town level population size for our sample period.

share of entrants in own sector and town level in column 4 and 8.

The second robustness check concerns the underlying assumption we make that firms operate in localized market. If agglomeration effects work through the mechanism of new entry into a cluster creating competitive pressure and reducing market share of existing firms, this effect should be less important for firms that are not restricted to selling their products in local markets. We test this hypothesis, in table 7, using our cluster size variables interacted with share of exporters in a cluster and export dummy equal to one if firm i exports. When using share of exporters in a cluster, we find a significant positive interaction effect for price regressions in column 1 and 3 while the coefficient estimates for cluster size gets even larger in absolute terms. For output regressions, the interaction effect with $NDIFFPROD_t$ has the right sign, though not statistically significant, and we find a negative interaction effects with number of firms producing different products at 10%. This supports the hypothesis that agglomeration effects are stronger for firms operating in localized markets.[21] When using export dummy, on the other hand, we do not find empirical support for localized market argument in both for price and output regression. There is also positive correlation between productivity and exporting (column 5 and 6).

[21] Alternatively, one can control for distance to roads and markets

7 Conclusions

In this paper we have used census panel data on Ethiopian manufacturing firms to empirically analyze the effects of enterprise clustering on two key determinants of firm performance: physical productivity and output prices. We show that distinguishing between productivity and prices is crucial for understanding the effects of agglomeration. We find a negative and statistically significant effect of agglomeration of firms on prices, suggesting that new entry leads to higher competitive pressure in the local economy. All else equal, this is positive for consumer welfare but negative for enterprise profitability. In addition, we find a positive and statistically significant effect of agglomeration on physical productivity, consistent with the notion that clustering leads to positive externalities. All else equal, this is positive both for consumer welfare and for enterprise profitability. We also show that the productivity and price effects on enterprise revenues by and large cancel each other out. For example, we find no robustly significant effect of agglomeration on revenue-based measures of productivity, such as sales or value added net of factor input effects. Given that agglomeration has no effect on firm profitability, we hypothesize that agglomeration may not spur enterprise growth despite the positive effect on productivity. Analyzing Agglomeration effect on other firm perfomcance measures such as firm growth and investment is open for future research.

Taken together, our findings suggest there is a lot to be said for encouraging local competition and agglomeration of firms: individual firms will see their productivity rise and their profit margins reduced, and both effects benefit Ethiopian consumers. Cluster formation through creating industrial zones; and enhancing networking, technological learning as well as firm competition are key policy recommendations to boost enterprise productivity and cluster-based industrial development.

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Fig 1a. Number of products a firm produces

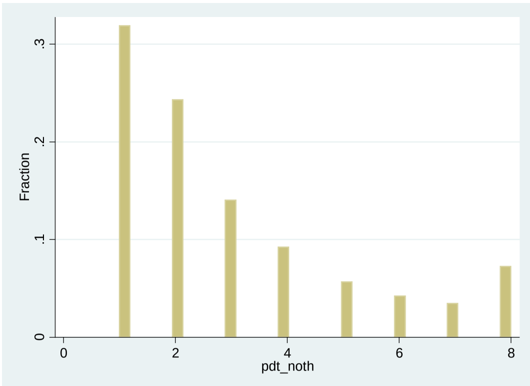

Fig 1b. Number of firms producing same product in a cluster

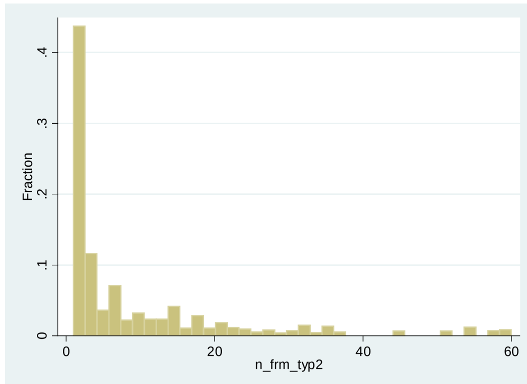

Table 1: Descriptive statistics of variables used

Variable	Descriptions	Mean	Median	sd
Dependent variables				
ln $(VA/L)_t$	Log value added per person	9,36	9,28	1,34
ln $(VOP/L)_t$	Log total sales value of output per person	10,14	10,14	1,42
TFPR	Log revenue based productivity	2,49	2,41	0,83
Log $price_t$	Log output price per unit of measurement	2,39	2,38	1,82
lnQ_{ijt}	Log physical output per unit of measurement	9,91	10,09	3,26
Explanatory Variables				
NSAMEPRODt	Number of firms producing same product in own town	2,4	1	5,57
NDIFFPRODt	Number of firms producing different products in own town	11,96	2	57,55
NSAMESEC2t	Number of own sector firms producing different products in own town	2,97	0	13,97
NDIFFSECt	Number of non-own sector firms in own town	11,73	2	57,05
nfirm_ty	Number of firms in own town	13	3	57,54
nfirm_sty	Number of firms in own town and own sector in a given year	4,1	1	13,97
nfirm_nsty	Number of firms in own town but different sector in a given year	11,73	2	57,07
Monply_sty	Dummy=1 if a firm is the only firm in own cluster and sector in a given year	52,12%		
TFPQE_slctU	Log of physical productivity using firm's major product	0,59	0,93	1,60
$lnK_t(\alpha_K)$	Log of capital stock (share of payment to capital in total income)	13,43 (0.17)	13,51(0.24)	2,60 (0.87)
$lnL_t(\alpha_L)$	Log of labor input=number of employees (share of wage bill in total income)	3,79 (0.22)	3,37 (0.13)	1,38 (0.65)
$lnM_t(\alpha_M)$	Log of material inputs expenditure (share of raw material expenditure in total income)	13,40 (0.56)	13,08(0.55)	2,28 (0.49)
$lnE_t(\alpha_E)$	Log of energy expenditure (share of energy expenditure in total income)	10,37 (0.05)	10,21(0.02)	2,38(0.11)
lnsh2	Log of revenue share of a product in firm's total sales value of output	-1,91	-1,61	1,66
lnsh_new2	Log of share of a product in firm's total average price weighted sales value of output	-4,59	-4,49	2,47
Firm age_t	Firm age	12,45	5,00	16,00
Selected	Dummy=1 if a product belongs to selected homogenous products	44,83%		

Table 2: Value added regression results using number of firms in own and non-own sector in town as measure of cluster size

	OLS						Firm fixed effect					
	Log value added per employee		**log sales value of output per employee**		**TFPR (revenue-based productivity)**		**Log value added per employee**		**log sales value of output per employee**		**TFPR (revenue-based productivity)**	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$nfirm\_sty_t$	-0.00233**	-0.00186*	-0.000358	-0.000197	-0.00118	-0.000610	0.00390*	0.00396*	-0.000341	-0.000356	-0.000635	-0.000635
	(0.00110)	(0.00111)	(0.000692)	(0.000696)	(0.000767)	(0.000768)	(0.00234)	(0.00232)	(0.00128)	(0.00129)	(0.00132)	(0.00135)
$nfirm\_nsty_t$	0.000126	0.000267	0.000404	0.000506	0.000288	0.000524	-0.000769	-0.000662	-4.04e-05	7.24e-05	-6.65e-05	9.14e-05
	(0.000589)	(0.000592)	(0.000348)	(0.000348)	(0.000380)	(0.000380)	(0.000701)	(0.000697)	(0.000420)	(0.000420)	(0.000446)	(0.000442)
lnK_t	0.177***	0.186***	0.00933	0.0137	-0.0317***	-0.0391***	0.000509	0.00654	0.0218	0.0260*	-0.138***	-0.132***
	(0.0194)	(0.0209)	(0.00843)	(0.00876)	(0.00899)	(0.00900)	(0.0146)	(0.0156)	(0.0139)	(0.0148)	(0.0188)	(0.0187)
lnL_t	0.0851**	0.0503	-0.857***	-0.881***			-0.266***	-0.279***	-0.845***	-0.855***		
	(0.0334)	(0.0388)	(0.0239)	(0.0262)			(0.0593)	(0.0592)	(0.0348)	(0.0352)		
lnM_t			0.760***	0.762***					0.709***	0.710***		
			(0.0205)	(0.0208)					(0.0257)	(0.0256)		
lnE_t			0.123***	0.124***					0.102***	0.101***		
			(0.0158)	(0.0157)					(0.0160)	(0.0160)		
Firm age_t		0.0143***		0.00228		0.0122***		0.0191		0.00559		0.0126*
		(0.00477)		(0.00285)		(0.00311)		(0.0129)		(0.00702)		(0.00754)
Firm age_t		-0.000218**		5.02e-06		-9.34e-05*		-0.000356		-0.000237**		-0.000390***
		(8.54e-05)		(4.67e-05)		(5.18e-05)		(0.000228)		(0.000108)		(0.000116)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Town	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector	Yes	Yes	Yes	Yes	Yes	Yes						
Firm							Yes	Yes	Yes	Yes	Yes	Yes
Observations	4863	4815	4923	4886	4925	4886	4863	4815	4923	4886	4925	4886
R-squared	0.382	0.385	0.791	0.793	0.404	0.417	0.030	0.031	0.533	0.534	0.039	0.044
Number of firm							1357	1317	1352	1325	1352	1325

Note: All regressions in col. 1-12 are estimated at firm level with one observation for each firm at a given year t. Clustered standard errors at firm level. Unreported constant included. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Effect on price and output using contemporary number of firms

	Price				Output			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$NSAMEPROD_t$	-0.00685***	-0.00685***	-0.00648***	-0.00648***	0.00837**	0.00836**	0.00922**	0.00920**
	(0.00220)	(0.00220)	(0.00221)	(0.00221)	(0.00390)	(0.00389)	(0.00396)	(0.00396)
$NSAMESEC2_t$	-0.000483	-0.000492	9.96e-05	9.32e-05	-0.000548	-0.000537	0.000968	0.000977
	(0.00131)	(0.00131)	(0.00131)	(0.00131)	(0.00224)	(0.00224)	(0.00225)	(0.00225)
$NDIFFSEC_t$	0.000171	0.000111	4.89e-05	-8.00e-06	-0.000124	-5.74e-05	-0.000472	-0.000393
	(0.000326)	(0.000325)	(0.000337)	(0.000337)	(0.000518)	(0.000520)	(0.000535)	(0.000537)
$Monply\_s_t$		0.111**		0.104**		-0.122		-0.143*
		(0.0517)		(0.0514)		(0.0811)		(0.0862)
lnQ_{ijt}	-0.285***	-0.285***	-0.277***	-0.277***				
	(0.0201)	(0.0201)	(0.0198)	(0.0198)				
lnK_t	0.00506	0.00478			0.0170	0.0173		
	(0.0127)	(0.0126)			(0.0226)	(0.0225)		
lnL_t	0.0543**	0.0553**			0.151***	0.150***		
	(0.0251)	(0.0248)			(0.0480)	(0.0479)		
lnM_t	0.221***	0.222***			0.676***	0.675***		
	(0.0177)	(0.0176)			(0.0277)	(0.0276)		
lnE_t	0.0115	0.0114			0.0819***	0.0821***		
	(0.00944)	(0.00942)			(0.0173)	(0.0173)		
tfp_costSE_t			0.334***	0.334***			1.084***	1.082***
			(0.0277)	(0.0276)			(0.0391)	(0.0390)
$lnsh\_new2_t$	0.152***	0.151***	0.144***	0.144***				
	(0.0181)	(0.0181)	(0.0178)	(0.0178)				
$lnsh2_t$					0.966***	0.966***	0.965***	0.965***
					(0.00845)	(0.00846)	(0.00846)	(0.00847)
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Town	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14344	14344	14344	14344	14344	14344	14344	14344
R-squared	0.666	0.666	0.665	0.665	0.843	0.843	0.840	0.840
Number of firm	1351	1351	1351	1351	1351	1351	1351	1351

Note: The dependent variable is log output price per unit in col 1-4 and log physical output in col 5-8. Results in col 1-8 are estimated at firm-product-year level with clustered standard errors at firm level. Unreported constant included.*** p<0.01, ** p<0.05, * p<0.1

Table 4: Effect of being Monopoly in own sector and town: Step-wise

	Price	Output
VARIABLES	(1)	(2)
$NSAMEPROD_t$	-0.00646***	0.00922**
	(0.00221)	(0.00396)
$NSAMESEC2_t$	0.000106	0.00100
	(0.00131)	(0.00226)
$NDIFFSEC_t$	-3.58e-05	-0.000452
	(0.000343)	(0.000558)
Nsty_2 (only 2 firms)$_t$	-0.0994**	0.155*
	(0.0500)	(0.0864)
Nsty_3 (only 3 firms)$_t$	-0.119*	0.103
	(0.0667)	(0.113)
Nsty_4 (only 4 firms)$_t$	-0.0945	0.170
	(0.0723)	(0.141)
Nsty_5 (>= 5 firms)$_t$	-0.128*	0.0990
	(0.0723)	(0.157)
lnQ_{ijt}	-0.277***	
	(0.0199)	
tfp_costSE$_t$	0.334***	1.082***
	(0.0277)	(0.0392)
lnsh_new2$_t$	0.144***	
	(0.0178)	
lnsh2$_t$		0.965***
		(0.00848)
Year	Yes	Yes
Product	Yes	Yes
Town	Yes	Yes
Firm	Yes	Yes
Observations	14344	14344
R-squared	0.665	0.840
Number of firm	1351	1351

Notes: dependent variable log output price in col: 1 and log physical output in col: 2. Dummy for only one firm in own sector and town (Nsty_1) is used as a base category whereas Nsty_5 is a dummy variable equal to 1 when there are 5 or more firms in own sector and town. All results are estimated at firm-product-year level with clustered standard errors in parenthesis. Unreported constant included. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Effect on price and output using lagged number of firms

	Price			Output		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$NSAMEPROD_{t-1}$	-0.00609**	-0.00545*	-0.00496	0.00850**	0.00869**	0.0120***
	(0.00305)	(0.00328)	(0.00382)	(0.00365)	(0.00385)	(0.00455)
$NDIFFPROD_{t-1}$	-0.000437			-0.000124		
	(0.000406)			(0.000528)		
Monply_s $_{t-1}$	0.00597			-0.112*		
	(0.0559)			(0.0608)		
$NSAMESEC2_{t-1}$		0.00205	0.00198		0.000178	-0.00333
		(0.00217)	(0.00300)		(0.00263)	(0.00363)
$NDIFFSEC_{t-1}$		-0.000663*	-0.000568		-0.000111	-0.000182
		(0.000364)	(0.000413)		(0.000509)	(0.000552)
$SAMEPROD_{t-1}$* Selected			-0.00255			-0.00882
			(0.00439)			(0.00538)
$SAMESEC_{t-1}$* Selected			-0.000327			0.00579**
			(0.00236)			(0.00282)
DIFFSEC $_{t-1}$* Selected			-0.000202			0.000105
			(0.000353)			(0.000421)
lnQijt	-0.218***	-0.218***	-0.218***			
	(0.0224)	(0.0224)	(0.0224)			
tfp_costSE $_t$	0.233***	0.235***	0.235***	1.086***	1.089***	1.089***
	(0.0300)	(0.0295)	(0.0295)	(0.0445)	(0.0444)	(0.0437)
lnsh_new2 $_t$	0.103***	0.103***	0.104***			
	(0.0203)	(0.0202)	(0.0203)			
lnsh2 $_t$				0.955***	0.955***	0.955***
				(0.00864)	(0.00864)	(0.00862)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Product	Yes	Yes	Yes	Yes	Yes	Yes
Town	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes	Yes	Yes
Selected			Yes			Yes
Observations	10792	10792	10792	10792	10792	10792
R-squared	0.609	0.609	0.610	0.851	0.850	0.851
Number of firm	901	901	901	901	901	901

Note: The dependent variable is log output price per unit in col 1-3 and log physical output in col 4-6. All results are estimated at firm-product-year level with clustered standard errors at firm level in parenthesis. Unreported constant included.*** p<0.01, ** p<0.05, * p<0.1

Table 6: Controlling for share of entrants, Average firm age and Number of employees in a cluster

	Price				Output			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$NSAMEPROD_t$	-0.00623***	-0.00635***	0.00506	-0.000902	0.00832**	0.00862**	-0.00274	0.00198
	(0.00213)	(0.00212)	(0.00324)	(0.00289)	(0.00351)	(0.00353)	(0.00525)	(0.00506)
$NDIFFPROD_t$	1.58e-05	-3.08e-05	-0.000263	-0.000289	-0.000228	-0.000110	-0.000111	5.76e-05
	(0.000301)	(0.000300)	(0.000324)	(0.000306)	(0.000534)	(0.000541)	(0.000559)	(0.000539)
Mean firm age in own $town_t$	-0.00304	-0.00352	-0.00314	-0.000916	0.00389	0.00512	0.00446	0.00123
	(0.00469)	(0.00469)	(0.00474)	(0.00431)	(0.00742)	(0.00747)	(0.00742)	(0.00691)
Share of entrants in own $town_t$	-0.0913	-0.158**	0.00401		0.0538	0.223*	-0.0557	
	(0.0644)	(0.0684)	(0.0678)		(0.100)	(0.120)	(0.104)	
NSAMEPROD* Share of entrants in own $town_t$			-0.0626***				0.0612***	
			(0.0137)				(0.0202)	
NDIFFPROD* Share of entrants in own $town_t$			0.00139**				-0.000348	
			(0.000588)				(0.000961)	
Share of entrants in own sector & $town_t$		0.0753		0.0268		-0.191*		-0.164*
		(0.0512)		(0.0506)		(0.104)		(0.0936)
NSAMEPROD* Share of entrants in own sector & $town_t$				-0.0267***				0.0309**
				(0.00967)				(0.0148)
NDIFFPROD* Share of entrants in own sector & $town_t$				0.00143***				-0.000741
				(0.000465)				(0.000689)
Log number of employees in sector & $town_t$	-0.0861**	-0.0879**	-0.0804**	-0.0863**	0.0915*	0.0962*	0.0823	0.0908*
	(0.0352)	(0.0350)	(0.0355)	(0.0350)	(0.0537)	(0.0537)	(0.0538)	(0.0534)
Log number of employees in $town_t$	0.0340	0.0392	0.0275	0.0342	0.0249	0.0115	0.0393	0.0227
	(0.0357)	(0.0359)	(0.0357)	(0.0356)	(0.0604)	(0.0618)	(0.0599)	(0.0611)
lnQ_{ijt}	-0.276***	-0.276***	-0.272***	-0.275***				
	(0.0197)	(0.0198)	(0.0194)	(0.0197)				
tfp_costSE_t	0.342***	0.343***	0.337***	0.340***	1.074***	1.072***	1.075***	1.072***
	(0.0279)	(0.0280)	(0.0276)	(0.0278)	(0.0392)	(0.0394)	(0.0389)	(0.0391)
$lnsh\_new2_t$	0.143***	0.143***	0.139***	0.142***				
	(0.0177)	(0.0178)	(0.0175)	(0.0176)				
$lnsh2_t$					0.965***	0.965***	0.965***	0.965***
					(0.00850)	(0.00848)	(0.00849)	(0.00848)
Observations	14297	14297	14297	14297	14297	14297	14297	14297
R-squared	0.665	0.665	0.667	0.666	0.840	0.840	0.841	0.841
Number of firm	1347	1347	1347	1347	1347	1347	1347	1347

Notes: dependent variable is log output price in col: 1-4 and log physical output in col. 5-8. All results are estimated at firm-product-year level with clustered standard errors in parenthesis. Unreported constant, year, product, firm and town fixed effects included.*** p<0.01, ** p<0.05, * p<0.1

Table 7: Controlling for share of exporting firms in a cluster

	Price			Output		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
$NSAMEPROD_t$	-0.0139***	-0.00626***	-0.0140***	0.0140**	0.00852**	0.0142**
	(0.00400)	(0.00213)	(0.00402)	(0.00664)	(0.00351)	(0.00660)
$NDIFFPROD_t$	4.25e-05	-2.70e-05	-1.66e-05	0.000712	-0.000112	0.000832
	(0.000362)	(0.000304)	(0.000361)	(0.000632)	(0.000542)	(0.000642)
Share of exporters in own $town_t$	-0.298	0.0834	-0.183	0.158	-0.343	-0.131
	(0.205)	(0.183)	(0.222)	(0.303)	(0.301)	(0.357)
NSAMEPROD*Share of exporters in own $town_t$	0.253**		0.256**	-0.177		-0.177
	(0.116)		(0.117)	(0.207)		(0.207)
NDIFFPROD*Share of exporters in own $town_t$	-0.00312		-0.00314	-0.0183*		-0.0185*
	(0.00561)		(0.00564)	(0.00984)		(0.00983)
Export_D (Dummy=1 if firm i $\text{exports})_t$		-0.123	-0.124		0.322**	0.321**
		(0.0777)	(0.0777)		(0.147)	(0.147)
NSAMEPROD* $Export\_D_t$		-0.00216	-0.00393		-0.00746	-0.00563
		(0.00663)	(0.00674)		(0.00639)	(0.00657)
NDIFFPROD* $Export\_D_t$		0.000237	0.000277		-0.000284	-0.000302
		(0.000232)	(0.000235)		(0.000353)	(0.000353)
Log number of employees in sector & $town_t$	-0.0858**	-0.0851**	-0.0849**	0.0815	0.0902*	0.0800
	(0.0356)	(0.0352)	(0.0356)	(0.0536)	(0.0535)	(0.0534)
Log number of employees in $town_t$	0.0337	0.0316	0.0330	0.0210	0.0256	0.0223
	(0.0351)	(0.0350)	(0.0350)	(0.0597)	(0.0591)	(0.0593)
Mean firm age in own $town_t$	-0.000523	-0.00107	-0.00104	0.00344	0.00412	0.00466
	(0.00432)	(0.00430)	(0.00432)	(0.00700)	(0.00722)	(0.00719)
lnQ_{ijt}	-0.277***	-0.276***	-0.276***			
	(0.0197)	(0.0197)	(0.0196)			
tfp_costSE_t	0.340***	0.342***	0.341***	1.077***	1.071***	1.074***
	(0.0279)	(0.0278)	(0.0278)	(0.0390)	(0.0391)	(0.0389)
$lnsh\_new2_t$	0.143***	0.143***	0.143***			
	(0.0177)	(0.0176)	(0.0177)			
$lnsh2_t$				0.965***	0.965***	0.965***
				(0.00847)	(0.00851)	(0.00848)
Observations	14297	14297	14297	14297	14297	14297
R-squared	0.665	0.665	0.666	0.841	0.840	0.841
Number of firm	1347	1347	1347	1347	1347	1347

Notes: dependent variable is log output price in col. 1-3 and log physical output in col. 4-6. All results are estimated at firm-product-year level with clustered standard errors in parenthesis. Unreported constant, year, product, firm and town fixed effects are included. *** p<0.01, ** p<0.05, * p<0.1.

Appendix

Table A0: Cluster Size Calculations

A. Cluster with Single Product firms only

Town	Product	Firm	No. of firms in Town	NSAMEPROD	NDIFFPROD
1	1	1	3	1	2
1	2	2	3	1	2
1	3	3	3	1	2

B. Cluster with Multi-product firms

Town	Product	Firm	No. of firms in Town	NSAMEPROD	NDIFFPROD
2	1	1	4	3	1
2	1	2	4	3	1
2	1	3	4	3	1
2	2	1	4	2	2
2	2	2	4	2	2
2	3	1	4	1	3
2	4	4	4	1	3

Table A1: Products in the Dataset

Acrylic (yarn)	Electric wires	Milk pasterurized	Tomato paste
Alchohol (non-drink)	Embroidery thread	Mineral water	Tubes
Animal feed	Fafa, dube, edget,metin	Molasses	Tyres
Antibiotics	Flour (other)	Motor vehicles spring	Varnishes and lacquers
Ballpen	Flour (wheat)	Nails	Vasilin
Bed sheet	Foam	Nylon fabrics	Vegetable soup
Beer	Galleta	Oil cakes	Wearing apparel (excl. leather)
Biscuts and cakes (excl. galleta)	Glass bottles	Ointment	Wearing apparel (leather)
Blankets	Glasses	Orange juce	Wine
Boxing paper	Gravel	Oxygen	Wires
Bread	Gunny bags	Paints	Zign and shiro wet (minchet abish)
Bricks of clay	Hosieries	Palstic crate	
Butter and ghee	Injection of 100A	Paper	
Candles	Iron bars	Paraffine	
Canvas and rubber shoes	Iron sheets	Particle board	
Capsules	Jano thread	Plastic footwear	
Carbon dioxide	Leather garment	Plastic sole	
Carpets	Leather shoes and boots	Polyethylene products	
Cement	Leather sole	Raw cotton	
Cement blocks	Leather upper and lining	Semiprocessed skins	
Cement floor tiles	Lemonade (soft drinks)	Sewing thread	
Cement tubes	Lime	Shirts	
Cheese	Liquor	Soap	
Cigarettes	Macaroni and pasta	Sugar	
Coffe (Milled)	Malt	Sweater	
Cotton fabrics	Marble	Sweets (candy)	
Cotton yarn	Marmalade	Syrup	
Crown cork	Meat	Tablets	
Crust hides and wetblue hides	Metalic door	Tea	
Edible oil	Metalic window	Timber	

Table A2. Summary of unit output price for selected products

Product	**Unit**	Mean(p)	p50(p)	min(p)	max(p)	sd(p)	sd(lp)	cv(p)	N(p)
Tea	KG	11.51375	10.8	5.94	19.23	3.605473	.3188294	.3131449	126
Edible oil	KG/LT	9.621965	9.07	5.69	16.2	2.37102	.2431566	.2464174	382
Oil cakes	KG	.4516434	.4	.06	1.5	.2593364	.6203459	.574206	283
Flour (wheat)	KG	2.577765	2.65	1.0884	3.795	.5373561	.2380541	.2084581	743
Bread (for metric unit only)	KG	4.328014	4	2.5	10	1.384864	.2798264	.2541508	727
Sugar	KG	4.562897	4.21595	2.5656	10.8411	1.704542	.2982124	.3735657	40
Liquor	LT	16.32336	16.8	10.5	20	1.696183	.1085016	.1039114	413
Beer	LT	5.957133	6.301515	3.08	12.9193	1.750648	.2992096	.2938742	158
Lemonade (soft drinks)	LT	4.221937	4.166667	3.125	5.22	.5415168	.1308305	.1282626	227
Cotton fabrics	SQM	6.74187	5.985	2.55	17.27	3.283965	.4517855	.4871001	292
Cotton yarn	KG	21.16431	19	12.44	51.8	7.691528	.3082716	.3634198	132
Nylon fabrics	SQM	8.455517	8.51	4.87	12.39	1.750792	.2187746	.2070592	58
Leather garment	SQF	10.70731	9.23	1.44	41	8.157958	.6218656	.7619057	81
Crust hides and wetblue hides	SQF	6.412759	5.8	.89	15	3.354631	.5404076	.5231183	80
Leather shoes and boots	PAIRS	61.65437	58.42	25	126.18	20.66206	.3365625	.3351272	486
Timber	CUB.M	1783.654	1778	495	3800	697.2754	.42268	.3909253	167
Gravel	CUB.M	95.90831	90	39.1	195	33.52443	.3483421	.3495467	290
Plastic footwear	PAIRS	8.242137	6.9	3.04	36	5.450559	.4667361	.6613041	498
Bricks of clay	PCS	.6915603	.6	.4	1.32	.2463302	.3308411	.3561948	109
Cement blocks	PCS	2.257217	2.1	1.25	4.37	.5879784	.2434398	.2604881	1316
Cement floor tiles	SQM	40.50493	37.44	7	166	21.72471	.5029547	.5363473	175
Cement	KG	.7016772	.65335	.435	1.4901	.2638925	.3170769	.3760882	46
Nails	KG	6.206165	5.77	3.93	11.98411	1.582849	.2413431	.2550446	65
Wires	KG	8.223145	7.985	2.46	12.94	2.215233	.2940674	.26939	60
Vaseline	KG	18.16026	17	7.829999	35.33	6.017519	.3174564	.3313564	81
Paraffin	KG/LT	27.66651	20.15	8.98	83.91	18.83157	.5407912	.6806629	287
Coffee (Milled)	KG	22.8061	24	8.17	33.6	7.230071	.3778923	.3170236	41

Note: Summary statistics for output price after taking out the top and bottom 3 percentiles of the price distribution used as a basis of product selection. However, regressions are estimated based on the entire observation s of selected products, including the top and bottom 3 percentiles, once products are selected..

Paper IV

Ethnic Cleansing or Resource Struggle in Darfur? An Empirical Analysis

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Abstract

The conflict in Darfur has been described both as an ethnic cleansing campaign, carried out by the Sudanese government and its allied militias, and as a local struggle over dwindling natural resources between African farmers and Arab herders. In this paper, we use a previously unexploited data set to analyze the determinants of Janjaweed attacks on 530 civilian villages in Southwestern Darfur during the campaign that started in 2003. Our results clearly indicate that attacks have been targeted at villages dominated by the major rebel tribes, resulting in a massive displacement of those populations. Resource variables, capturing access to water and land quality, also appear to have played an important role. These patterns suggest that attacks in the area were motivated by both ethnic cleansing and resource capture, although the ethnic variables consistently have a larger impact.

Key words: Ethnic cleansing, resource struggle, Darfur
JEL Classification codes: P16, O41

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1 Introduction

The conflict in Darfur is one of the worst humanitarian disasters in the world. Since the onset of hostilities in 2003, it is estimated that some 300,000 people have died and that 2.7 million people have fled their homes (BBC, 2008). In a statement before the US Congress, State Secretary Colin Powell referred to the conflict as a genocide already in September, 2004.[1] The war has led to a massive international aid operation as well as the deployment of a large UN-backed peace-keeping force. On July 12, 2010, the prosecutor of the International Criminal Court (ICC) in the Hague extended the previous warrant of arrest for Sudan's incumbent president Omar al-Bashir to also include genocide, in addition to war crimes and crimes against humanity in Darfur (ICC, 2009, 2010).

In this article, we use a previously unexploited data set to analyze the determinants of attacks on 530 civilian villages in Southwestern Darfur. Our data was collected by an international organization working in the area and covers attacks perpetrated during the campaign that was initiated by the government and the Janjaweed militia in 2003.[2] The data set is unique in the sense that it includes detailed information about the ethnic composition in villages before and after the onset of the conflict and comprises all known rural villages in the area. On the basis of our reading of the literature, we propose two main hypotheses that we bring to the data: The probability and intensity of attacks on villages should increase with (i) the proportion of rebel tribes in the village population and (ii) with the level of appropriable natural resources.

The first of these hypotheses - stipulating a targeting of certain ethnic groups by the government and its loyal militias - receives very strong support in our empirical investigation. Regardless of our choice of resource variables, control variables, samples, and levels of aggregation, we consistently find that the proportion of Fur, Masalit, and Zaghawa (rebel tribes) households in the village population before conflict is our strongest determinant of the probability and intensity of attacks. We further show that about 59,000 rebel tribe households have been displaced from our area of study and that 329 villages out of 530 in our sample have been completely abandoned during the conflict. We argue that our results are clear indications of an ethnic cleansing campaign and of serious violations of international law.

This finding conforms broadly with the general view of the ICC and the international community. In the most recent version of the warrant of arrest against Sudan's president, the ICC briefly refers to "acts of murder and extermination" being perpe-

[1] In Powell's own words: "When we reviewed the evidence compiled by our team, along with other information available to the State Department, we concluded that genocide has been committed in Darfur and that the Government of Sudan and the jinjaweid bear responsibility – and genocide may still be occurring." (America.Gov, 2004). It is further interesting to note that the investigation commissioned by the UN Security Council found evidence of crimes against humanity but not of genocide (United Nations, 2005).

[2] Given the current security situation in Darfur, we have agreed not to disclose the identity of the organization(s) that have provided the data that our study builds upon. Until the situation in the area improves, more details about the data will only be communicated through personal correspondence with the authors.

trated against the Fur, Masalit, and Zaghawa groups in certain localities in West Darfur (ICC, 2010, p 6). The arrest order specifies three potential cases of genocide in the region. Among very few studies on Darfur in the wider social science literature, Hagan and Rymond-Richmond (2008) analyze 932 individual interviews collected by the American Bar Foundation among refugees in Chad and identify the Sudanese government's "racial dehumanization"-campaign against the three rebel tribes as key for understanding the acceptance among local Arabs to participate in ethnic cleansing against the civilian population of the targeted groups. Similar conclusions have been drawn by Kevane and Gray (2008) and Prunier (2007).[3]

Compared to these investigations, our study covers information from a much larger part of the Darfur population (530 villages that host approximately 792,000 individuals) and is the only study with village-specific information on ethnic composition before and after conflict.

Our second main hypothesis - that an important determinant of attacks was the level of appropriable natural resources in the villages - also receive some support. On the basis of GIS data, we create a number of proxy variables for appropriable natural resources; the density of vegetation, access to alluvials soils, and distance to surface water. We also create measures for related variables such as distances to roads and administrative centers and control for neighborhood spillover effects, altitude, population size, regional effects, etc. Our regression analysis shows that when we hold all other variables constant, villages that are located close to alluvial soils and to roads tend to suffer from a higher probability and intensity of attacks. The marginal impacts are however smaller than for the ethnic variables.

The official view held by the GoS is that the hostilities in Darfur are primarily a local struggle over dwindling natural resources between farmers and herders with no government involvement and that the conflict probably has not taken more than 10,000 lives. The importance of land degradation and a deteriorating climate for understanding Darfur has also been emphasized by UNEP (2007) and Ki-Moon (2007). Among scholars, Sachs (2006) makes a similar argument and supports his line of argumentation on the finding that decreased rainfall has been shown to have an indirect effect on conflict risk in Africa via poor economic growth (Miguel et al, 2004). Using annual data on rainfall in Darfur, Kevane and Gray (2008) fail to find any clear link between rainfall and conflict onset.

As far as we can tell, the only other quantitative study on the role of natural resources in Darfur is Vanrooyen et al (2008) who use interview data from refugees in Chad in order to analyze in detail the nature of attacks and the scope of human and resource losses in three villages. Olsson (2011) uses the same data as we do but focuses exclusively on land reallocation issues and implications for post-conflict reconstruction.[4]

[3] The government of Sudan (GoS) however denies any links to the Janjaweed and to the conflict (Prunier, 2007).

[4] In a recent study based on satellite imagery, Schimmer (2008), claims that the large population and livestock displacements have recently resulted in a resurge of vegetation in the area. Further empirical studies of the conflict in Darfur include Depoortere et al (2004), who provide estimates of mortality during

The empirical study in this paper is related to a large volume of articles studying the general determinants of civil war and social conflict using cross-country data (Collier and Hoeffler, 1998, 2004; Fearon and Laitin, 2003; Miguel et al, 2004; Azam and Hoeffler, 2002). The specific role of environmental stress and scarcities is given particular attention in Homer-Dixon (1994), Diamond (2005), and Schubert et al (2008), but more formal statistical analyses have generally not found any strong effect of environmental stress on conflict risk (Nordås and Gleditsch, 2007). The analysis in this paper is one of rather few other attempts at analyzing the determinants of violence at micro level.[5] What makes our study unique compared to existing analyses is primarily the detailed village level data on the ethnic composition before and after the onset of the conflict. Also, unlike any of the papers surveyed, we find robust evidence of aggression primarily targeted at certain ethnic groups.

Although we believe our empirical analysis is the main contribution of our paper, we also offer a basic theoretical framework for understanding how ethnic cleansing might emerge as an equilibrium outcome in a conflict between competing groups.[6] We postulate that the capture and possession of rival natural resources is always a motivating factor for a representative individual of a militia. The militia is further loosely allied to the government who has a goal of displacing certain rebel groups from the area. During normal times, the militia will be constrained from predating on other groups due to direct opportunity costs (losing production from normal work) and indirect social costs (psychic or legal costs or costs from loss of future cooperation). A key insight from our model is that attacks by the militia on villages hosting other ethnic groups, will only take place (i) if the direct opportunity cost of predation is low due to poor normal production potential, (ii) if the government has supported the militia so that they are militarily dominant in relative terms, and (iii) if the perceived social costs of attacking certain ethnic groups have decreased due to government propaganda aimed at making the groups in question legitimate targets of attack. Ethnic cleansing by a local militia is basically modelled as an externality (purposefully generated by the government) from an interethnic struggle over

the first year of the crisis. Bloodhound, a Denmark-based NGO, has independently compiled a large number of witness accounts of attacks (Petersen and Tullin (2006a).

[5] Buhaug and Röd (2006) study the determinants of civil war in Africa by using grid cells with a resolution of 100x100 km as the basic unit of analysis. In a study of more than 5,000 villages in Aceh, Indonesia, Czaika and Kis-Katos (2007) find that ethnicity does not seem to matter much for (forced) migration patterns and that general socioeconomic variables matter more. Other studies with conflict intensity as the dependent variable include Murshed and Gates (2005) and Do and Iyer (2007) (on 75 districts in Nepal) and Bellows and Miguel (2006) (on 152 chiefdoms in Sierra Leone). See also André and Platteau (1998) and Verwimp (2005) who both study individual-level data from Rwanda and show that land stress appears to have played a key role for the conflict outbreak in 1994. Blattman and Miguel (2008) provide a recent overview of the literature on civil war.

[6] Our model is related to the work of Azam and Hoeffler (2002) and a recent paper by Esteban et al (2010). The former paper models a government's choice of terrorizing and displacing a rebel population as a conscious military strategy aimed at weakening the rebel group. In the latter paper, the authors imagine a tradeoff for a group in power between on the one hand exterminating a rebel population and keeping all government revenue for themselves, or on the other hand to let the rebels live and squeeze tax revenues out of them. Our model differs from both these attempts since we consider the choice of a local militia who is an imperfectly monitored agent of the government and who has an agenda of its own.

resources.[7] Based on our model, we identify the increase in government military support and its strategy of dehumanizing its opponents, as the likely reasons for why the major conflict erupted in 2003, despite decades of a environmental deterioration.

Our article is structured as follows: In section 2, we provide a general background to the conflict in Darfur and discuss the nature of ethnic cleansing and the specific context of our study. In section 3, we outline a conflict theoretical framework in order to clarify the key causal linkages. The data, the empirical strategy, and the regression analysis are presented in section 4, whereas section 5 concludes.

2 Background[8]

2.1 The Darfur conflict

Darfur is Sudan's westernmost province, sharing an extensive border with Chad in the west and with an area of roughly 500,000 sq km (approximately the size of Spain). Its northern parts are largely uninhabited desert areas, whereas the central and southern parts belong to the African Sahel belt.

Darfur is believed to host about 6.5 million inhabitants belonging to a multitude of ethnic groups. The population is often subdivided into "African" and "Arab" tribes, although the distinction between the two is not always clear. The African tribes are usually sedentary agriculturists and include some of the largest and traditionally most influential groups such as the Fur tribe, which has given the region its name.[9] The Arab tribes are typically either cattle or camel herders and practice a nomadic lifestyle with seasonal migrations across farmer lands. Both the African and Arab tribes are Muslim and Arabic serves as a lingua franca in the region.

The recent conflict in Darfur is generally regarded to have started in February 2003 when the rebel groups JEM (Justice and Equality Movement) and the SLA (Sudanese Liberation Army) announced their programs in opposition to the government in Khartoum. The SLA group consisted mainly of Fur and Masalit tribesmen, whereas JEM was dominated by the African (yet nomadic) Zaghawa tribe. Both groups claimed that the basic reason for their rebellion was the consistent marginalization of Darfur in a national context. Figure 1 gives schematic overview of the sequence of events. After some successful initial attacks on government outposts, which appeared to catch the GoS by surprise, Khartoum started to mobilize loyal Arab tribes in Darfur to fight SLA and JEM (stage 2

[7] We adhere to the definition of ethnic cleansing provided by Petrovic (1994, p 351), claiming that "...ethnic cleansing is a well-defined policy of a particular group of persons to systematically eliminate another group from a given territory on the basis of religious, ethnic or national origin." As such, ethnic cleansing typically involves violence on a large scale and a series of specific crimes against humanity such as murder, mass rape, torture, and forced displacement of populations (Bell-Fialkoff, 1993; Petrovic, 1994). See Hagan and Rymond-Richmond (2008) for a related (informal) model or Horowitz (2000) for a general overview of ethnic conflict.

[8] The general information in this section builds mainly upon Prunier (2007) and Flint and de Waal (2008).

[9] "Darfur" means literally "the land of the Fur".

in Figure 1) (Prunier, 2007; Flint and de Waal, 2008; ICC, 2009). The Sudanese army was still engaged in the south to secure the emerging peace process with the SPLA rebels. To date, the GoS still denies that it has played any role in the mobilization and subsequent actions of the Janjaweed.

A massive military campaign was then launched during the second half of 2003 (stage 3 in Figure 1). Supported by government intelligence, coordination, and aircraft, the Arab militias - referred to locally as the Janjaweed - attacked hundreds of civilian African villages throughout Darfur during late 2003 and early 2004 (stage 3a). The typical pattern was an initial bombing by Antonov airplanes or helicopter gunships, whereupon the Janjaweed would move in, mounted on camels or small pickup trucks, and kill many civilians, rape women and girls, destroy as much equipment as possible, poison the wells, and eventually set the whole village ablaze (Prunier, 2007; Hagan and Rymond-Richmond, 2008; Vanrooyen et al, 2008). The horses, camels, and cattle in the village were usually either driven out into the desert or were stolen and loaded onto trucks (Vanrooyen et a, 2008). The villages tended to be unprotected since the rebel fighters in JEM and SLA were typically hiding elsewhere. Many villages were totally abandoned after such attacks and the surviving population fled to refugee camps near the larger towns or just west of the Chadian border. Similar attacks have repeatedly occurred also after the most intense campaigns in winter 2004. By winter 2008, it was estimated that the crisis has resulted in some 300,000 deaths and about 2.7 million refugees (BBC, 2008).

On the basis of a large number of interviews of refugees, Hagan and Rymond-Richmond (2008) attempt to reconstruct the "sociology" of these attacks. In particular, the authors document how racial and dehumanizing epithets such as "All the people in the village are slaves; you make this area dirty; we are here to clean the area" were very common. According to Hagan and Rymond-Richmond's model and terminology, this "racial dehumanization" of the African groups (in particular the Fur, Masalit and Zaghawa) was primarily instigated by locally-organized "ethnopolitical entrepreneurs" who sought to mobilize local Arab populations into collective violent action. These local militia leaders were in turn agents of the GoS who for a long time had held an Arab supremacist ideology and who were responsible for a general collective framing process that differentiated between Arabs and Africans.

Apart from attacking civilian villages, the Janjaweed also fought the actual rebels in regular military battles (stage 3b). Compared to the campaign against civilian villages, these activities had a relatively small impact on the flow of refugees.

But if the GoS indeed mobilized the Janjaweed to pursue a counter-insurgency campaign, why should it let them attack civilian villages rather than the actual rebel fighters? One suggested explanation is that the attacks against villages should simply be regarded as a counter-insurgency campaign that went out of hand and unintentionally resulted in a humanitarian disaster (Prunier, 2007). A more cynical explanation is that the government and the Janjaweed very consciously had come to the conclusion that a terror campaign against the rebel fighters' home villages would be a more effective military strategy than trying to fight the rebels hiding somewhere in the Sahel.[10] The result of this strategy was a massive "cleansing" of civilian rebel tribe populations from the area.

It has been argued that the conflict in Darfur has at least two key dimensions.[11] The most obvious one is the cultural and economic tension between an Arab center of the country in Khartoum and a marginalized African population in the periphery. Darfur was not included into the British colony until 1916 and had previously been an autonomous sultanate for hundreds of years with an own sense of identity. The colonial government, as well as the governments of independent Sudan, had in common a lack of interest in developing Darfur. The Arabization ideology embraced by Omar al-Bashir's government certainly did not contribute to improving the situation for Sudan's African groups. Eventually a rebellion arose in early 2003.

The current conflict in Darfur also has deep roots within the social fabric of Darfur itself. It represents a rapid escalation of a conflict that has long divided different groups in Darfur over land use and competition for scarce natural resources, particularly water.[12] According to the customary land tenure system in Darfur, most of the land has been controlled by the biggest ethnic groups indigenous to the area – the Fur and the Masalit. The communal leaders of these tribes, the *sultans, omdas* and *sheiks*, were responsible for the administration of their respective areas (*dars*). It was they who gave permission to outsiders to reside in villages and grazing rights to herders. As a result, there is a clear social stratification among Darfurians in relation to access to land into two groups: *dar owners* - the indigenous people and cattle nomads and *non-dar owners,* including Arabic camel nomads and newcomers who migrated from Chad and northern Darfur due to drought of the 1970s and 80s.[13] Essentially, the new African arrivals were well integrated with the dar owners but occupied a lower social and economic status.[14]

The traditional system of managing resources facilitated relatively peaceful coexistence between nomads and farmers. The Arab nomads (particularly the camel nomads) had no dar of their own. Instead, they made seasonal movements, south and north, in search of water and pasture for their herds. In the past, this had been done without too much friction as land was abundant. During the farming season, nomadic movements were restricted to certain annually-marked migration routes. After the harvesting season, the nomads were allowed to use all of the grazing land, except for the fenced vegetable/fruit gardens. Conflicts and disputes among tribes and individuals were settled by the traditional authorities (O'Fahey and Tubiana, 2009; Abdul-Jalil, 2006).

The *dar*-system was formally abolished by the central GoS in 1970, without being re-

[10] See for instance Azam and Hoeffler (2002) for a model of such a choice situation or Mann (2005) for a review of similar events throughout history.

[11] See Brosché (2008) and Prunier (2007) for an in-depth analysis of the multicausal nature of the Darfuri conflict.

[12] See Olsson (2011) for an analysis of the role of land tenure institutions in the current conflict.

[13] Such as the Tama, Gimier, Mararit, Eringa, Kajaksa, Borgo, Mesiria Jabal, Mimi, Singar, Dajo and Falatta tribes.

[14] Anecdotal evidence also indicates that when the conflict erupted in August 2003, many of the 'new' African tribes chose not to side with the traditional African tribes of the area which made them considered by the other African groups as 'collaborators'.

placed with mechanisms that would facilitate the relationship between nomads and farmers. The consequence was the disappearance of the various *native courts* and much of the expertise on land tenure and the resolution of inter-ethnic conflicts. However, the abolition was never complete though the old system was severely weakened. It remained as a parallel authority structure embedded in the state making a number of land tenure systems co-exist in Darfur (O'Fahey and Tubiana, 2009; Abdul-Jalil, 2006).

The issue of land became more critical following the growing pressures on natural resources as a result of land degradation and desertification, combined with expanding rain fed and wadi cultivation to meet the demands of increased population. Expansion of agricultural land triggered the blocking of animal migration routes and decreased access to water sources for animals, which has been one of the common causes of grassroots conflicts in Darfur (Abdul-Jalil, 2006). According to this view then, the conflict should primarily be seen as a struggle over natural resources.

2.2 Ethnic cleansing

As discussed in the introduction, ethnic cleansing is most often described as a sustained attempt by one group to remove another group - defined in ethnic, religious, or political terms - from a given territory. In this sense, ethnic cleansing can be distinguished from the related term "genocide" by the notion that whereas the former features an intent to *remove* a population, the latter aims at *destroying* a population, in whole or in part (Petrovic, 1994). It might thus be argued that genocide is also an act of ethnic cleansing, but the reverse needs not to be true.[15]

A further difference is that while genocide is described by a specific UN convention from 1948, ethnic cleansing is not defined by international law.[16] Rather, ethnic cleansing can be understood as an overarching term for a series of crimes against humanity such as massive deportation, torture, large scale rape and sexual assaults, for war crimes such as attacking civilian targets with military, as well as for other crimes such as robbery, destruction of homes and livelihoods, destruction of cultural and religious monuments, verbal harassments, and the use racist propaganda, all with the aim of removing a particular group from a territory (Petrovic, 1994).

Though the term ethnic cleansing did not become commonly used until the early 1990s during the conflict in former Yugoslavia, the phenomenon is far from new. Bell-Fialkoff (1993) traces incidents of ethnic cleansing at least back to antiquity. During the Middle Ages, various religious groups were often violently expelled from countries, for instance Jews (from Spain, England, France, and other countries), and Protestant Huguenots were famously expelled from France in the late 1680s. The Armenian holocaust in 1915, when

[15] Mann (2005) uses the term "murderous ethnic cleansing" to describe all kinds of activities involving extreme violence on a massive scale aimed at a certain population. According to this definition, genocide is therefore the most extreme form of murderous ethnic cleansing.

[16] It is, however, mentioned in a Security Council Resolution from 2006, stating that member countries should assume the responsibility "...to protect populations from genocide, war crimes, ethnic cleansing and crimes against humanity." (Security Council, 2006, p 2)

an estimated 1.5 million Armenians succumbed in the Ottoman empire, and the Holocaust during World War II, both involved massive ethnic cleansing campaigns alongside outright exterminations. The most well-known example of ethnic cleansing during recent years is undoubtedly the war in Bosnia-Herzegovina in the early 1990s.

In 2004, a Security Council resolution requested that an investigation should be carried out on the situation in Darfur concerning alleged violations of international law. The investigation was also commissioned to determine whether acts of genocide had occurred. Their conclusion, reported in 2005, was that although there were strong indications of that the GoS/Janjaweed forces had committed serious crimes against humanity throughout Darfur, the investigators could not find evidence of a policy aimed at exterminating a specific subpopulation. A similar conclusion was initially drawn by the International Criminal Court, which nonetheless issued a warrant of arrest against Omar al-Bashir on charges of war crimes and crimes against humanity (ICC, 2009).

However, in July 2010, the ICC extended its warrant of arrest to also include genocide. More specifically, the extended charges included three counts of genocide and found reasonable grounds to believe that Omar al-Bashir was responsible as an indirect perpetrator for trying to "...destroy in part the Fur, Masalit and Zaghawa ethnic groups" by "...deliberately inflicting conditions of life calculated to bring about physical destruction..." (ICC, 2010, p 8). The arrest order also states that "...as part of the GoS's unlawful attack on the above-mentioned part of the civilian population of Darfur...GoS forces subjected, throughout the Darfur region...hundreds of thousands of civilians, belonging primarily to the Fur, Masalit, and Zaghawa groups, to acts of forcible transfer." (ICC, 2010, p 6).

2.3 Context of the study

As discussed above, the causes of the conflict in Darfur are complex and multifaceted. In this study, we will focus on one particular geographical area - Southwestern Darfur - and one particular dimension of the conflict; the campaign that started in 2003 in which the government-supported Janjaweed militia attacked civilian villages (stage 3a in Figure 1).

The choice of area is mainly dictated by data availability, as discussed further below. The fact that we restrict our analysis to the campaign against civilian villages is similarly primarily explained by our access to village-level data. Our study will therefore *not* be concerned with rebel fighters' (from JEM or SLA) direct military encounters with Janjaweed or government forces (stage 3b in Figure 1), which is another central aspect of the conflict. Neither will we study the actions of other groups in the area like NGOs, UN peacekeepers, etc. However, it is generally recognized that the government-supported Janjaweed attacks on civilian villages that we study here are by far the most important factor behind the current refugee crisis and what has caused the ICC to indict Sudan's incumbent president for war crimes and genocide.

The main issue that we analyze is to what extent the probability and intensity of attacks against civilian villages can be explained by ethnic variables, as suggested by the hypothesis of a government-led ethnic cleansing campaign, and to what extent they can be explained by resource-related variables, as suggested by the GoS.

3 A Model

In the model below, we propose a framework for understanding how ethnic cleansing might become an equilibrium outcome in a local conflict between groups. The basic scenario is an environment with several ethnic groups who compete over limited resources.

More specifically, we assume a conflict that has reached the equivalent of stage 3a in Figure 1, i.e. a rebellion has previously occurred (stage 1), a militia has been mobilized with or without government assistance (stage 2), and the militia has decided that the most promising strategy for obtaining its goals is to attack civilian villages rather than the rebel forces.[17] The main aim of the militia is to capture resources. The government is a political ally of the militia and its support can take two forms; it can provide military assistance that increases the militia's fighting power, and/or it can grant exemption from punishment and moral support for any attacks that the militia makes on the government's enemies. Normally, the social costs of trying to steal a competing group's resources are too high for predation to occur. But if the government ensures that the attacking group is militarily strong and that its members will not be punished, an equilibrium with a predatory aggression against the government's political enemies might arise. A result of such aggression is that people flee from the attacked villages. Ethnic cleansing in this way becomes an indirect consequence of a struggle for resources.[18]

3.1 Basic assumptions

Let us imagine an environment with a total population consisting of three distinct ethnic groups.[19] For the purpose of concreteness, let us refer to these groups as *Arabs*, *New Africans*, and *Rebel tribes*. *Arabs* are politically allied to the government whereas *Rebel tribes* are political enemies of the government. The latter have even initiated a rebellion against the government. *New Africans* are politically neutral.

The focus of our model is a campaign that starts when an Arab militia has been mobilized. The militia is an agent of the government and is provided with certain kinds of support, but the government can only imperfectly monitor the militia's activities. The militia can choose between either doing their normal economic activities or to attack civilian villages in the area in order to loot or steal productive resources. Their choice depends on the type and level of support provided by the government.

[17] Azam and Hoeffler (2002) explicitly model the choice between fighting rebels or terrorizing the rebels' home villages in order to decrease their fighting strength.

[18] Although we think that this approach to modelling the ethnic cleansing mechanism might be applied for understanding several historical conflicts apart from Darfur (for instance to Rwanda in 1994), we would not claim that it is universally applicable. More research is needed into the motivations and constraints faced by agents in other ethnic cleansing episodes.

[19] In reality, there are also other African groups in Darfur but with a very small share of the total population.

The model therefore has two main types of collective agents; the Arab militia (the *Janjaweed*) consisting of $N > 0$ potential attackers on the one side, and a number of civilian villages ($i = 1, 2, ...I$) whose populations $L_i > 0$ will potentially be preyed upon, on the other.[20] We assume that the N members of the militia do not live in the civilian villages but that other Arabs do so. The government is not a strategic player in the model but influences (exogenously) the cost and effectiveness of the militia's operations. The key decision in the model is the militia's independent choice whether to attack some village i or not. If the militia is purely resource-motivated, they might even predate on Arab villages.

The time frame of the model is $t \in \{1, 2, ...T\}$ where $T > I$. An attack on one village takes one unit of time (perhaps a week or a couple of days). Since $T > I$, there is time for attacking every village in the area. The time discount rate is zero. The militia can reach all villages without incurring any transportation costs. They consider every village a potential target of attack and their decision whether to attack or not is made on an individual basis for each village and is independent of the choices made for other villages.[21]

We assume that the militiamen at each point in time t gain material utility U from two potential sources: From consuming their own (peaceful) normal production of size Q or from the consumption of looted or captured resources from some other village Z_i. Total available effort from the militia during some t is normalized to unity. Effort devoted to predation on village i is $z_i \geq 0$ whereas normal productive effort during the period is $1 - z_i$. If effort is devoted to predation, this activity will entail a social cost C which could include many factors such as risk of punishment by a court, psychic costs of committing crimes against neighbors, or loss of future collaboration with the attacked villagers. Total utility for the militia during any time period is given by

$$W = U\left(Z\left(z_i\right), Q\left(1 - z_i\right)\right) - C\left(z_i\right). \tag{1}$$

We assume that the marginal utilities are $\partial W / \partial Z = U_Z > 0$ and $\partial W / \partial Q = U_Q > 0$. Consumption from predation Z increases with z such that $Z_z > 0$. However, efforts devoted to predation mean that normal production is crowded out since less effort is available for production ($Q_z < 0$). In addition, predatory activities give rise to a marginal social cost $C_z > 0$ that will be explained further below. Hence, predation has a direct opportunity cost in terms of forgone production, but also an indirect social cost.[22] These marginal benefits and costs of predation will determine whether any predation is undertaken.

The usual first-order conditions for maximum imply that optimal predatory effort on village i should be set such that

$$U_Z \cdot Z_{z_i} = C_{z_i} - U_Q \cdot Q_{z_i}.$$

[20] We do not explain in this model how this militia has been formed or how it has solved collective action problems, etc.

[21] In the empirical analysis, we will control for neighborhood spillover effects.

[22] For simplicity, we assume away all other direct monetary costs of waging wars.

The expression simply shows that the marginal utility of predation should in optimum equal the sum of its marginal direct and indirect costs. The normal situation in most societies throughout history is that $U_Z \cdot Z_{z_i} < C_{z_i} - U_Q \cdot Q_{z_i}$ at all $z_i \leq 1$ and for all i. In that case, no predatory aggression will occur. Such a scenario is likely if the marginal product of normal activity Q_{z_i} and the marginal cost of predation C_{z_i} are high. This is typically the case in developed economies characterized by rule of law but does not necessarily apply to regions like Darfur.

3.2 Functional forms

By using the general functions above, we cannot derive any explicit solutions for the optimal level of effort z_i. Neither can we say anything about the role of resources or ethnicity. We therefore make some specific assumptions about functional forms:

$$U = Z + Q \tag{2}$$

$$Z = \alpha \rho (z_i) R_i = \frac{\theta N z_i}{\theta N z_i + L_i} \cdot \alpha R_i \tag{3}$$

$$Q = A (1 - z_i) \tag{4}$$

$$C = \omega(z_i) L_i c_i = \gamma \rho (z_i) L_i s ((1 - \lambda) f_i + n_i + (1 + \lambda)(1 - f_i - n_i)) \tag{5}$$

Starting from above, we make the extreme simplification that Z and Q are perfect substitutes. In (3), we assume that the total success of predation on village i will depend on the level of appropriable resources R_i. This variable potentially includes non-lootable resources like better-quality land and strategic access to water, as well as readily appropriable resources such as livestock, stored harvests, or village equipment and property. $\alpha > 0$ is a parameter indicating how easily these resources can be transformed into consumption and utility. A fraction $\rho (z_i) \in [0, 1)$ of all resources are captured or looted.

$\rho (z_i)$ is given by a standard contest success function $\theta N z_i / (\theta N z_i + L_i)$. In this expression, $N z_i$ is made up of the share of total available effort devoted to attacking village i, z_i, multiplied by the number of militiamen N. The whole village population L_i defends the village. The parameter θ describes the relative strength of the militia. $\theta > 1$ means that the militiamen are more effective on the margin than the defenders, and vice versa with $\theta < 1$.[23] In this model, θ is a parameter capturing the indirect military support from the government to the Janjaweed. It is easily shown that $\rho (0) = 0$, $\rho (1) = (1 + L_i/\theta N)^{-1} < 1$, $\rho' (z_i) > 0$ and $\rho'' (z_i) < 0$.

Peaceful normal production is given in (4) by a linear function $Q = A (1 - z_i)$ where $A > 0$ is a labor productivity parameter capturing for instance climate and institutional quality.[24] This parameter is invariant of i since it involves productivity in the militia's own home environment. Production is the normal activity even for the militia.

In case of an attack, the social costs of predation are given by C. We assume that after

[23] See Grossman and Kim (1995) and Olsson and Congdon Fors (2004) for a similar assumption.

[24] A might equivalently be thought of as a general opportunity cost of violence.

the realization of the fighting between the militia and the village population, a fraction $\omega(z_i) \leq 1$ of the total village population L_i, regardless of race, is killed or abandon the village as a consequence of the attack. For simplicity, we suggest that ω is linearly related to the extent of looting so that $\omega(z_i) = \gamma\rho(z_i)$ where we assume that $\gamma > 1$.

There are at least two rationales for our specification of $\omega(z_i)$. First, one might view population displacement as an external and unintended effect of an attack that is aimed at capturing resources. Second, it might alternatively be argued that resource capture and population displacement have strong complementarities; in order to secure a longer-term possession of a village and its resources, it might be necessary to also displace the local population. Hence, displacement could be intentional and serve both the predatory militia and the government.

Note that since γ is larger than unity, there might exist a level $z_i = \tilde{z}_i$ such that $\omega(\tilde{z}_i) = \gamma\rho(\tilde{z}_i) = 1$. When this is the case, the whole village is abandoned. Some algebra shows that $\tilde{z}_i = L_i/\theta N(\gamma - 1)$.

The militia's social costs of predation are given by

$$c(f_i, \lambda) = s \cdot ((1 - \lambda) f_i + n_i + (1 + \lambda)(1 - f_i - n_i))$$

where f_i is the share of the rebel tribe population in the village (Fur, Masalit, and Zaghawa), n_i is the share of New African populations, and the residual $(1 - f_i - n_i)$ is the share of the militia's own people (Arabs) in the village. It is an empirical fact that rebel tribe farming populations and Arab herding populations tend to live in a segregated manner.[25] Hence, an increase in f_i is usually associated with a lower fraction of nomadic Arabs as in the expression above.

$s > 0$ is a general indicator of the social cost of any person fleeing and $\lambda \geq 0$ is a parameter reflecting differences in the marginal social cost of fleeing between groups. In a society with a benevolent and impartial government that honors human rights and the rule of law, we would have that $\lambda = 0$ and that general costs s are at a sufficiently high level to discourage potential predation. In societies with a culture of impunity, the costs of predation are low in general. In some countries - such apartheid South Africa - the government actively supports some groups in society against others and even encourages attacks on certain populations. In Darfur, we argue that the government's racial dehumanization of rebel tribe groups, as documented by Vanrooyen et al (2008), should imply that $\lambda > 0$ so that the marginal cost of a rebel tribe individual fleeing is lower than that of a New African fleeing, which in turn is lower than the cost of an Arab fleeing. It might even be argued that $\lambda \geq 1$ so that the social costs of attacking populations with rebel tribes might be zero or negative, i.e. the militia is rewarded for attacking rebel tribe villages. We will discuss this further below. The partial derivatives of c_i are $c_{f_i} = -2s\lambda < 0$ and $c_\lambda = s(1 - 2f_i - n_i) < 0$ if $(1 - n_i)/2 < f_i$. The latter derivative shows that social costs decrease with the level of racial discrimination against the rebel tribes λ if their proportion

[25] The correlation coefficient between the share of rebel tribe and Arab populations in the sample is -0.71.

in the village population f_i is high.

Given all these functional forms, the utility function of the militia can be written as

$$W(z_i) = A(1 - z_i) + \frac{\theta N z_i}{\theta N z_i + L_i} \cdot (\alpha R_i - \gamma L_i c(f_i, \lambda)).$$

The optimization problem is to find the value $z_i^* \in [0,1]$ that maximizes utility. The marginal utility of predatory effort z_i is $W_{z_i} = \rho'(z_i) \cdot (\alpha R_i - \gamma L_i c(f_i, \lambda)) - A$. The different solutions for z_i^* are characterized in (6):

$$z_i^* : \begin{cases} = 0 \ \text{ iff } \ \theta N (\alpha R_i - \gamma L_i c(f_i, \lambda)) < A L_i \\ = z_i^{\max} = \frac{L_i}{\theta N}\left(\sqrt{\frac{\theta N(\alpha R_i - \gamma L_i c(f_i,\lambda))}{A L_i}} - 1\right) \ \text{ iff } z_i^{\max} \in (0,1) \\ = 1 \ \text{ iff } z_i^{\max} \geq 1 \end{cases} \tag{6}$$

As mentioned above, the historically most common situation in Darfur and in most other societies is that W_{z_i} is negative at all $z_i \leq 1$, implying that the marginal utility of effort in peaceful production exceeds the marginal utility of predation at all possible levels of predation. In that case, optimal predatory effort is simply $z_i^* = 0$.

If there exists some z_i in the range $(0,1)$ where W_{z_i} is positive, then $z_i^* > 0$ and there will be an attack on village i. The necessary condition for a positive z_i^* to exist is that the value of z_i where the utility function reaches its maximum, $z_i^{\max}$, is larger than zero, implying that $\theta N (\alpha R_i - \gamma L_i c_i(f_i, \lambda)) > A L_i$. To start with, it is noteworthy that the probability of attack will increase with θN and decrease with A. This is certainly in line with intuition: All else equal, predatory aggression should be more likely the greater the number N and relative military strength θ of the attackers and the lower the marginal product of peaceful activities A.[26] It is further only natural that an attack is more likely if there are plenty of resources R_i and if the social cost of attacking $c_i(f_i, \lambda)$ is low. If $\theta N (\alpha R_i - \gamma L_i c_i(f_i, \lambda)) / A L_i$ is very high, then it might be the case that the maximum is attained beyond the feasible range of z_i, implying that all effort is optimally devoted to predation; $z_i^* = 1$.

The equilibrium value of the contest success function can be found by inserting the different values of z_i^* into $\rho(z_i^*)$. In the cases of $z_i^* = 0$ and $z_i^* = 1$, the solutions are simply $\rho(0) = 0$ and $\rho(1) = (1 + L_i/\theta N)^{-1} > 0$, as mentioned above. If $z_i^* = z_i^{\max}$, the equilibrium proportion is:

$$\rho(z_i^{\max}) = \frac{\theta N z_i^{\max}}{\theta N z_i^{\max} + L_i} = 1 - \sqrt{\frac{A L_i}{\theta N (\alpha R_i - \gamma L_i c(f_i, \lambda))}} \tag{7}$$

This expression shows the equilibrium percentage of appropriable resources that are conquered or looted from the village.

The share of the population that is displaced is one of the main variables in the em-

[26] Similar results have been derived in many other conflict models, for instance Olsson and Congdon Fors (2004).

pirical section. Recall that this share is given by $\omega(\tilde{z}_i) = \gamma\rho(\tilde{z}_i)$ and that the critical level of $\tilde{z}_i$, beyond which the whole population abandon the village, was $\tilde{z}_i = L_i/\theta N(\gamma - 1)$. Total abandonment will thus happen if $\tilde{z}_i^{\max} \geq \tilde{z}_i$. A formal comparison of these two levels defines a threshold function:

$$z_i^{\max} - \tilde{z}_i = \frac{L_i}{\theta N}\left(\sqrt{\frac{\theta N(\alpha R_i - \gamma L_i c(f_i, \lambda))}{AL_i}} - \frac{\gamma}{\gamma - 1}\right) = y^*(R_i, c(f_i, \lambda)) \tag{8}$$

The village is abandoned if $y^*(R_i, c(f_i, \lambda)) \geq 0$. Inspection of this expression makes it clear that the probability of total abandonment increases with R_i and with f_i (since y^* decreases with $c(f_i, \lambda)$ which in turn decreases with f_i). Hence, abandonment is more likely if there are plenty of appropriable resources and if the proportion of the targeted tribes is large.

Another outcome variable of interest in the empirical section is the total size of the village population that is displaced as a result of a potential attack. This number equals $\gamma\rho(z_i)L_i = \bar{L}_i$. From the results above, we can solve for the equilibrium level of population displacement:

$$\bar{L}_i : \begin{cases} = 0 \ \text{ iff } z_i^* = 0 \\ = \gamma\left(1 - \sqrt{\frac{AL_i}{\theta N(\alpha R_i - \gamma L_i c(f_i,\lambda))}}\right) L_i \in (0, L_i) \ \text{ iff } z_i^* = z_i^{\max} < \tilde{z}_i \\ = L_i \ \text{ iff } z_i^* = z_i^{\max} \geq \tilde{z}_i \end{cases} \tag{9}$$

There are thus three possible outcomes: (i) The village is not attacked at all and that nobody flees. (ii) An attack occurs that results in the displacement of a certain part of the population. (iii) The village is completely abandoned by the whole population. The key sources of variation across villages among these determinants of attacks (except the size of the village population L_i) are resources R_i and the proportion of rebel tribes f_i. Also the expression in (9) shows that the intensity of attacks increases with f_i and with R_i.

In Figure 2, we show a simulation of the relationship between $\bar{L}_i$ and f_i at varying social costs of displacing particular groups, using (9) and assuming a total village population of $L_i = 500$.[27] The dashed, flat line shows the case when $\lambda = 0$ so that no discrimination is made between the groups. In this case, the size of the population fleeing is unresponsive to f_i and about 2/3 of the population is displaced regardless of the ethnic composition. The dotted concave line assumes $\lambda = 0.1$, whereas the thick solid concave line assumes $\lambda = 0.2$. In the last case, the village will only be attacked when the proportion of rebel tribes in the village is $f_i \geq 0.283$ and the whole village will be abandoned ($\bar{L}_i = L_i = 500$) at $f_i \geq 0.768$.[28]

[27] See the figure note for the assumed parameter values. A similar model has not been simulated in the literature before and the choice of parameter values is therefore necessarily arbitrary.

[28] The associated equilibrium level of predatory effort is $z_i^* = 0.667$.

In the area as a whole, the total size of the displaced population is

$$\sum_{i=1}^{I} \bar{L}_i = D(\theta, \lambda) \tag{10}$$

where the total level of displacement D is a function of the government's choice of parameter levels θ and λ. Clearly, the level of displacement increases in general with the militia's relative military strength, θ. To what extent attacks will be targeted on rebel tribes depends on the level of λ. It can be shown that for a given level of θ, the size of population displacement will increase with λ if f_i is high on average in the villages.

An extended model might have included a first stage of the conflict when the government chose parameter levels θ and λ that maximized a government utility function with D as an argument.[29] We leave that for future work.

3.3 Interpretation and empirical predictions

What does our model have to say about the potential reasons behind the militia's attacks on villages? To start with, there are many indications of a very low level of labor productivity A at the time, mainly due to a sustained period of drought since the 1970s (Kevane and Grey, 2008; Olsson, 2009). Furthermore, the ideology and propaganda of Arabization, practiced by the government in Khartoum and its local agents, presumably implied that the Janjaweed forces considered the social costs of attacking villages with rebel tribe populations to be very low, i.e. λ was relatively high at the time. From summer 2003, there was further a sudden increase in θ, resulting from the government's policy to assist the militia with fighter airplanes, helicopters, and army intelligence. In terms of our model, this should have led to a general boost in optimal levels of fighting effort (see eq. (6). Without this active ideological and military government support, it is highly unlikely that the Janjaweed fighters would have been able to carry out violence on such a massive scale.

However, these factors are constant across villages and do not explain why individual villages were attacked. The main dependent variable in the empirical section is a binary variable for whether villages are abandoned or not. In our theoretical framework, the choice is determined by the sign of $y^*(R_i, c(f_i, \lambda))$ in (8), which we consider to be a latent variable that we try to estimate in the empirical section. According to our model, the main motivating factor for the militia is the possibility of capturing appropriable resources. It is easy to show that

$$\frac{\partial y^*(R_i, c(f_i, \lambda))}{\partial R_i} = \frac{\alpha \cdot \sqrt{L_i}}{\sqrt{4\theta NA(\alpha R_i - \gamma L_i c(f_i, \lambda))}} > 0,$$

implying that the militia is more likely to predate on more resourceful villages, holding ethnic composition constant, and that the level of the marginal effect will depend on α, the parameter indicating how resource capture translates into utility.

[29] See for instance Azam and Hoeffler (2002) or Esteban et al (2010) for models that take this route.

Our central hypothesis is that for a given level of resources, the militia should specifically target villages with a large proportion of rebel tribes, f_i. The marginal impact of f_i is

$$\frac{\partial y^*\left(R_i, c\left(f_i, \lambda\right)\right)}{\partial f_i} = \frac{\gamma s \lambda L^{3/2}}{\sqrt{\theta N A\left(\alpha R_i - \gamma L_i c\left(f_i, \lambda\right)\right)}} > 0. \tag{11}$$

In our empirical analysis, the regression coefficient for f_i is thus expected to be positive across villages and should give an indication of λ, the underlying discrimination in the social costs of violence against rebel tribe populations, which is the root of ethnic cleansing. Given two villages with the same level of resources, the militia will attack that with the highest proportion of rebel tribes since the costs of attacking such villages are lower. Note that if $\lambda = 0$, then the derivative in (11) is zero and the ethnic composition will not matter for the choice of attacking. The expression in (11) also shows that the cross-derivative is $\partial\left(y^*\right)^2 / \partial R_i \partial f_i < 0$, implying that the marginal impact of rebel tribes should decrease with the level of resources.

Attacks should thus in particular be directed towards villages with a great level of resources (R_i) and with a high fraction of population from the three rebel tribes Fur, Masalit, and Zaghawa (f_i). These are the main hypotheses that we test in the empirical section.

4 Empirical analysis

4.1 Data

The main data source to our empirical analysis comes from international organizations operating in the area.[30] In 2004/2005, while participating in provision of emergency assistance and protection interventions, these organizations undertook a return-oriented profiling exercise in Southwestern Darfur to help understand the complex picture of displacement that the 2003 crisis had created and to support war affected communities, sustain voluntary return and prepare the ground for an eventual voluntary return of a large number of IDP's and refugees to their villages of origin. An important objective of the data collection was to provide reliable GIS-based intelligence to emergency organizations working in the area. The profiling was designed to obtain a comprehensive picture of both the current and pre-conflict situations. Pre-conflict situations refer to the situation by early 2003, whereas the latest information about the current situation has November 30, 2005 as the oldest date and June 2008 as the most recent date (the median village had its latest visit in October, 2007). The organizations were *not* motivated by attempts at assisting the ICC trials on war crimes.

The data collection covered eight administrative units with a total area of approxi-

[30] Given the current security situation in Darfur, we have agreed not to disclose the identity of the organization(s) that have provided the data that our study builds upon. Until the situation in the area improves, more details about the data will only be communicated through personal correspondence with the authors.

mately 25,000 sq km (almost equivalent to the size of Belgium or Vermont and roughly 5 percent of Darfur's total territory). We inferred from correspondence with the data collecting staff that their intention has consistently been to gather information from all villages in the area except in limited cases of exclusion of villages due to lack of roads or a security situation which did not allow the team to be aware of the very existence of some settlements. Some secondary towns like Forobaranga and Habila are also included, whereas major towns like Garsila and Zalingei are not included. Figure 3 gives a general overview of the area and shows the geographical distribution of surveyed settlements. All in all, our base sample consists of 530 settlements[31] with a total population of approximately 792,000 people before the conflict.[32]

Visiting the villages, the team collected information on the location and general situation of the place, the typology of settlements, and, most importantly, a retrospective assessment of the size of population and composition of ethnicities before and after the crisis. There were also different specific sections covering health, education, vulnerable persons in the community, shelter, accessibility, security, economic situation, and land ownership. In addition to speaking with sheiks and other traditional and administrative authorities, the teams were instructed to verify the information they gathered with people in the market and other ordinary residents of each village. Where a location had an international presence, the team also crosschecked information with that organization. Upon return from each mission, the team had three-day debriefing sessions with other staff to compile the data and identify the main issues and trends that emerged from the information gathered. This was followed by a one-day debriefing with two staff members from another organization in the area.

The data source referred to above unfortunately contains few useful proxies for resources, which is a key variable in our model. Ideally, we would have liked to have data on lootable resources like the total size of each village's livestock, as well as non-lootable resources like access to water. Since we do not have data on village-specific lootable resources, we create a number of geographical variables capturing the quality of the village's natural resource environment, which should be strongly correlated with lootable resources. Water availability, for instance, is obviously a key determinant of the quality of land and of the ability to maintain herds of camels and cattle. We have assembled data on geographical distance (in meters) from each village to the nearest major wadi from USAID (2010). Wadis are seasonally dry rivers where water is usually available beneath the ground. In Darfur, as well as in many other parts of the Sahel, access to the wadis are important both for cultivators and for livestock herders (UNEP, 2007).

[31] The sample originally contained 562 villages. 20 villages in the original sample had an inconsistent share of inhabitants. Their ethnic compositions fail to add up to one and no logical explanation is provided for why it is so. As ethnic composition is our primary source of information for identifying African and Arab predominated villages, we excluded these villages from our analysis. 12 other villages had no population before the conflict. The final sample size that our study bases on thus contains 530 villages.

[32] We have reached this figure by multiplying the total number of households 143,938 with an assumed average size of 5.5 individuals, which was the average household size in a survey on the region collected by Deporteere et al (2004). The area sampled has roughly 12 percent of the total population in Darfur.

We have also collected detailed data from USAID (2010) on density of vegetation (NDVI) for the whole region. The data was distilled from satellite images with a resolution of 500 by 500 meters that were taken in June 2003, i.e. a few weeks before the initiation of the counter-insurgency campaign. Furthermore, we have obtained measures of distance to nearest alluvial soils and distance to nearest road. Alluvial soils are usually found near wadis and offer good pasture and fertile fields. Access to roads should imply a better access to markets but also an easier access for roaming militias. These measures should be highly correlated with the true level of R_i. Figure 3 shows the geographical distribution of villages, wadis, and roads in our sample region. Figure A1 in the Appendix shows alluvial soils and elevation in an area that was particularly hit by destructive violence.

The rural population is also dependent on health care and education which is typically provided in local administrative centers. For each village, we have therefore calculated the geographical distance to its administrative center. We imagine that the closer a village is to an administrative center, the better its access to public goods like health and schools but also to police and courts. On the one hand, access to public goods should make the village a more attractive prize for predators. On the other hand, villages far away from the center are more likely to be attacked because of a weaker rule of law in the periphery and a smaller likelihood of attention from media and human rights watchdogs. The hypothesized direction of the net effect is unclear. Among the geographical control variables is altitude above sea level, which we have gathered for each village from satellite maps in Google Earth, as well as village coordinates and dummies for administrative units.

In order to control for the influence of the situation in each village's nearest neighborhood, we have further divided the region into 0.1 latitude degree by 0.1 longitude degree grid cells. In either north-south or east-west direction, a 0.1 degree distance is equivalent to about 10-11 kms so that each grid cell represents an artificially constructed neighborhood of 100-121 sq km.[33] We found in total 151 populated grid cells and then estimated the number of abandoned villages, the total population, the total number and proportion of people fleeing, and the ethnic proportions in each cell. For each of the 530 individual villages, there is thus both an observation of, for instance, total population in the village, as well as the total population in the grid cell to which the village belongs. Figure A1 shows some grid cell neighborhoods that were particularly affected by violence.

4.2 Descriptive statistics

Figure 4 shows the ethnic composition in our sample before and after the crisis. The dominant rebel tribes (mainly Fur and Masalit) made up about 2/3 of the population before the crisis. After the conflict, 58,989 rebel tribe households had been displaced from their home villages. The other two main population groups did not experience any losses and the number of Arab households even increased by about 7,000. All in all, the total population decreased by almost 1/3.

[33] A similar grid cell methodology is used in Buhaug and Röd (2006) where 100 km by 100 km cells in Africa are the basic unit of observation.

Table 1 shows the descriptive statistics of the data used in the empirical analysis. Our main outcome variable in the empirical analysis is *abandon*, which is a binary variable taking the value 1 if all inhabitants have abandoned the village. 329 villages (about 62 percent) were abandoned and 201 were not. Figure 3 shows the geographical distribution of abandoned and non-abandoned villages.

Apart from *abandon*, we also use a binary variable *attack* and the number of households fleeing (*peoplefled*) in logs as dependent variables. The dummy *attack* equals 1 if any people have fled from the village and 0 otherwise. 400 villages were attacked. A noteworthy feature is that out of an average population of 270 households before the conflict (*popsize*), as many as 198 (or around 73 percent) would typically flee.

The proportion of civilian Fur, Masalit, and Zaghawa households in the village population before conflict (*rebeltribes*) is one of our main explanatory variables. The average proportion is 0.61, but due to residential segregation the most common situation is that the proportion is either 0 or 1, as illustrated in Figure 5.[34] The figure also shows the proportional distribution of New Africans and Arabs before conflict in abandoned and non-abandoned villages. Whereas New Africans are relatively dispersed, Arab populations rarely mix with the other groups. The distributions of rebel tribes and Arabs across abandoned and non-abandoned villages further suggest a very clear pattern of attacks being targeted at rebel tribe villages whereas hardly any Arab village was abandoned. A second ethnic variable is *rebeldummy*, taking a value of 1 if the village's population consisted of rebel tribes only. The sample contains 275 such villages, 258 of which were ultimately abandoned.

Among the resource variables, the mean of the (ndvi) index of *vegetation* is 3,467 whereas the average distance to a major wadi (*dist_ wadi*) is about 4,360 meters. The mean distance to alluvial soils (*dist_ alluvial*) is shorter than that and several villages are even located right on such soils and thus score 0. The average distance to a road (*dist_ road*) is about 5 km and the mean distance to an administrative center (*dist_ admin*) is 26.5 kilometers.

Popsize measures population size (number of households) whereas *n_ popsize* is the size of the population in the neighborhood and should be thought of as population density. The average grid cell population of 1510 households implies that the average population density, given that the area is populated, is about 80 people per sq km.[35] Some of these neighborhoods are ethnically homogenous (*n_ rebels*=1). The average village in the sample is further located at an *altitude* of about 700 meters above sea level.

Table 2 shows the means of selected variables in abandoned and non-abandoned villages. The table provides concrete numbers of the patterns revealed in Figure 5 of an overwhelming predominance of *rebeltribes* in the villages that were abandoned (88 percent). The mean for *rebeltribes* in non-abandoned villages, on the other hand, is only

[34] 162 villages in the area had a share of *rebeltribes* lower than 5 percent whereas 277 villages had a share larger than 95 percent.

[35] 1510 times household size 5.5 divided by grid cell size 100 sq km.

about 0.18. A standard t-test in the third column shows that this difference is indeed highly significant. Abandoned villages further have a significantly more dense vegetation and are typically located closer to major wadis, alluvial soils and to roads. This is well in line with our hypothesis that resourceful villages should be important targets for attacks.

4.3 Empirical strategy

Although several strong correlations are already evident, we need a regression analysis to estimate the impact of each variable when holding the others constant. The main dependent variable in our empirical analysis is a binary variable y for whether villages are abandoned or not. The key predictions of our theoretical model emerge from (8) where it is shown that the village will be abandoned if $y^* > 0$. In line with the argument there, we will regard A, θ, N and λ as deep parameters which influenced the general decision by the Janjaweed to take up arms but which do not display any local variation and thereby do not determine what village to attack within our sampled region. The primary sources of local variation are instead the proportion of rebel tribes f_i and resources R_i.

More formally, we employ a probability model

$$\Pr(y = 1 | x) = \Pr(y^* > 0 | x) \tag{12}$$

where x is a vector of explanatory variables and where y^* is a latent, unobserved variable that we estimate by making the simplified assumption that

$$y^* = \beta_0 + \beta_1 f_i + \beta_2 R_i + \mathbf{C}' \boldsymbol{\beta}_3 + \epsilon. \tag{13}$$

The dependent discrete variable y is *abandon.* f_i is the proportion of rebel tribes before hostilities, R_i is a vector that includes our resource proxies *vegetation, dist_wadi,* and *dist_ alluvial*, $\mathbf{C}$ is a vector of other relevant control variables, and ϵ_i is a normally distributed error term. In line with the comparative static in (11), we interpret the size of β_1 to reflect the militia's bias against rebel tribes, λ. A β_1 significantly larger than zero should thus imply that $\lambda > 0$, as illustrated in Figure 2. It would also imply that we can reject the hypothesis that the conflict is merely over local resources. Equivalently, we would expect to find that $\beta_2 > 0$, supporting the local resource struggle hypothesis.

$\mathbf{C}$ generally includes village size in number of households before the conflict *popsize* (the equivalent of L_i in our model), *dist_ road*, *dist_ admin*, and other geographical covariates. It also includes proxies for conflict intensity in the neighbourhood to control for local spillover effects, controls for administrative units, and interaction terms between f_i and R_i.

We further estimate a variant of equation (13) by using the number of households fleeing in each village, *peoplefled*, as a dependent variable (capturing the level of $\bar{L}_i$ in (9) of our model). Since 25 percent of our villages have zero number of household fleeing, we employ a corner solution tobit model where we use similar explanatory variables as in (13). Alternatively, we use a "hurdle model" to allow for heterogeneous impacts of the explanatory variables on the following two decisions: (i) Whether any household flee from a given village and, (ii) if so, how many households fled as a result of the conflict.[36] A hurdle model for a corner solution variable involves two key equations (14)-(15). The probability of a positive outcome is estimated using a probit model whereas conditional OLS is employed to estimate (15), using log number of households as a dependent variable which follows a log normal distribution with mean $x\psi$ and variance σ^2, conditional on $\bar{L}_i > 0$ and our explanatory variables x.

$$\begin{aligned} \Pr(\bar{L}_i > 0 | x) &= \Phi(x\eta) \qquad (14) \\ \log \bar{L}_i | (\bar{L}_i > 0, x) &\sim N(x\psi, \sigma^2) \qquad (15) \end{aligned}$$

In these expressions, η is vector of probit coefficient estimates using a dependent variable ($attack$) equal to one if $\bar{L}_i > 0$ and zero if $\bar{L}_i = 0$. If our dependent variable in eq. (15) is log normally distributed for the sub-sample of villages with a positive number of households fleeing, we can consistently estimate ψ as coefficient estimates of the explanatory variables using OLS (Wooldridge, 2002, p 536). The resulting expression for expected value, unconditional on $\bar{L}_i$, which the hurdle model uses to calculate marginal effects, is given by:[37]

$$E(\bar{L}_i | x) = \Phi(x\eta) \cdot \exp\left(x\psi + \frac{1}{2}\sigma^2\right). \qquad (16)$$

A few remarks are in order. Firstly, while we are fairly confident that f_i is measured with some precision, we recognize that the lack of village-specific data on readily lootable resources such as livestock means that our econometric strategy potentially suffers from omitted variable bias. However, we argue that the included resource proxies should be highly correlated with lootable wealth. For instance, villages located close to a wadi should typically have good access to water and fodder for animals.

Secondly, it might be the case that f_i and R_i are structurally related in the sense that the dominant Fur, Masalit, and Zaghawa could have obtained possession of the most fertile lands since they were historically the first settlers. If this is the case, then f_i and R_i will be positively correlated and the interpretation of β_1 will be problematic. We will deal specifically with this issue in the robustness section.

Thirdly, in micro studies like these, it is inevitable to discuss potential problems of sample selection bias. There are at least three possible sources of selection bias: (i) The

[36] The tobit model, on the other hand, assumes that a single mechanism determines the choice between $peoplefled = 0$ versus $peoplefled > 0$. We informally investigate the validity of this assumption in the results section.

[37] The second term on the RHS of eq (16) captures the expected value in eq (15) converted into levels. The marginal effect of an explanatory variable x_k on the number of households fleeing is given by $\frac{\partial E(\bar{L}_i | x)}{\partial x_k} = \left[(\eta_k \phi(x\eta) + \psi_k \Phi(x\eta)) \exp\left(x\psi + \frac{1}{2}\sigma^2\right)\right]$ where $\phi(x\eta)$ and $\Phi(x\eta)$ are the probability and cumulative density function of the probit model and η_k and ψ_k are probit and OLS coefficient estimates of the explanatory variable x_k respectively.

data collection might focus on villages which are potentially returnable places for displaced people, (ii) on villages affected by the conflict, and (iii) on predominately African villages. However, since it was an explicit aim of the data collectors to visit *every* village in this sub-region of west Darfur, we do not believe this to be a major problem. In addition, both African villages and nomadic settlements, predominated by Arabic nomads, are covered in the data collection with the intention of understanding both affected villages and the needs of the nomadic population.

A fourth potential issue is spatial autocorrelation, i.e. that conflict intensity in village i does not only depend on village specific characteristics but also on local spillover effects. We argue that our 10 by 10 km grid level analysis checks the sensitivity of our results to the unit of analysis used.

4.4 Regression results

The baseline set of regression results are shown in table 3 where we report the marginal effects of the main covariates used with *abandon* as the dependent variable. We use a linear (OLS) probability model in column (1) and a probit estimator in all the other columns.

The first main result is that the estimate for *rebeltribes* is positive and significant. The reported marginal effects in table 3 typically vary around 1. Based on the probit results in column 3, an increase from *rebeltribes*=0 to *rebeltribes*=1 implies a 91.8 percent higher predicted risk of that village being abandoned. The basic tendency remains intact when we use *rebeldummy* in column 6 instead and when we include interaction terms with the resource variables in column 7. In column 4, only 350 villages with no Arab populations are included and *rebeltribes* is still significant. The interpretation is that the attacking militia was capable of careful discrimination also between different African groups.

The second main result concerns our resource proxies. Out of these, *vegetation* and *log dist_wadi* are never significant and even shift signs. When included, *log dist_alluvial* is however always significant and with the expected sign. All else equal, villages near alluvial soils are thus more likely to be abandoned, but the effect is smaller than for *rebeltribes*. On the basis of column 3, we can calculate that an increase in *log dist_alluvial* from its minimum to its maximum value would imply a 34 percent lower risk of abandonment. When interaction terms are included in column 7, *log dist_alluvial*rebeltribes* is positive, indicating that the impact of *rebeltribes* is weaker in areas close to alluvial soils. Note that this kind of effect was predicted by the model in eq. (11).[38]

Distance to nearest road, *dist_road*, is always negative and significant, suggesting that villages close to roads are particularly adversely affected by raids from motorized militias. Distance from administrative center, *dist_admin*, is always positive and most often significant. This appears to suggest that the Janjaweed preferred to attack more remote villages, possibly to avoid interference with local authorities or eventual police

[38] An equivalent interpretation is that the marginal effect of *dist_alluvial* is weaker in areas with a large proportion of rebel tribes. In terms of our model, it would appear that the lower social cost of attacking rebel villages diverts the militia from attacking resourceful villages.

forces in the centers.

The estimate for the size of the population, *popsize*, is negative in all columns and mostly significant. Local population density, *n_popsize*, has the opposite effect according to the estimates. Thus, all else equal, the attacking militias are more destructive in smaller villages. The results further weakly indicate that villages at lower altitudes and in the northern part of the area are more likely to be abandoned.

In table 4, we analyze the determinants of the two other outcome variables in eq. (9); whether villages are attacked or not, and if an attack happens, how many households flee. We start our estimation with pooled OLS that is used as a baseline where the number of households fleeing (*peoplefled*) is our dependent variable. In column 1, we find that villages with a larger share of rebel tribes and with larger population size both in and in the vicinity of a village before the conflict, have significantly higher numbers of households displaced. Whereas all our resource variables are insignificant, villages closer to their administrative center have a higher number of households fleeing at a 10 percent level of significance. This may be the case as people usually flee to the nearest administrative center when displaced although villages far away from the centers are more likely to be attacked.

Column (2) in table 4 presents the estimates of the tobit model where the dependent variable is *peoplefled*. The share of rebel tribes continues to be a highly significant predictor of the number of households displaced, and so does the total number of households before the conflict (*popsize*). It is also worth noting that villages closer to alluvial soils have significantly (at 10 percent) larger number of households fleeing. When calculating average marginal effects conditional on $peoplefled > 0$ in column 5, we find that an increase from 0 to 1 in the share of rebel tribes results in an increase of 203 displaced households. A one percent increase in distance to alluvial soil is associated with an additional 4 households displaced.

Comparison of estimates of the tobit model (column 2) to that of the probit model (column 3) can be used as an informal test of the single mechanism-assumption underlying the tobit model. We find that distances to major road and to administrative centers are significant determinants of probability of $attack = 1$ ($peoplefled > 0$) but not in the tobit model where the dependent variable is *peoplefled*. On the other hand, village population size before the conflict is a significant determinant of $peoplefled$ in column 2 but not a significant determinant of likelihood of $attack = 1$ in column 3. Thus we allow for heterogeneous impacts of the explanatory variables by using a hurdle model.

Estimation of the hurdle model makes use of the probit estimation results of column 3 as well as conditional OLS estimations where the dependent variable is log of *peoplefled* (column 4). The latter uses a restricted sample of villages where $peoplefled > 0$. The average marginal effects from the hurdle model are presented in column 7. Villages with larger share of rebel tribes and larger population size before the conflict are found to have significantly higher number of people fled. More resourceful villages, in terms of a closer distance to alluvial soils, have a higher number of households fleeing. Villages closer to major roads also have a higher displaced number of households which probably indicates ease of transportation to flee from the attacked villages.

4.5 Robustness checks

In this section, we analyze the robustness of the main results obtained so far. A potential problem referred to above would be if f_i and R_i were systematically related so that, for instance, rebel tribes tended to own the best lands. In that case, β_1 could be biased upwards since it would partly be picking up the indirect effect of resources in addition to the direct effect from the share of rebel tribes.

In order to address this issue, we compare the means of selected variables in homogenous rebel tribe villages (where *rebeldummy*=1) with non-homogenous rebel tribe villages (*rebeldummy*=0) as in table 5. From the table it appears that homogenous rebel tribe villages typically have a more dense vegetation, a shorter distance to wadis, and a greater population. For the other displayed variables, there is no clear difference. When we estimate a probit regression in the last column with *rebeldummy* as the dependent variable, it actually appears that homogenous rebel tribe locations also have a longer distance to alluvial soils and to administrative centers.[39]

In table 6, we take this analysis one step further. Using a p-score analysis, we screen observations to obtain a more balanced sample where our resource variables somewhat equally predict the probability of *rebeldummy*=1 or *rebeldummy*=0. More specifically, we consider for a moment *rebeldummy* to be a binary treatment variable and estimate a probability score for *rebeldummy*=1 on the basis of the probit regression in the last column of table 5. In table 6, we then exclude observations with a very high or very low p-score, as in Angrist and Pischke (2009, p 90). In this case, *rebeltribes* should be capturing ethnicity but not resource effects. The standard set of covariates from the previous tables are used as regressors, including *rebeltribes*. In columns 1-3, the included 337 observations have a p-score between 0.3-0.7. In columns 4-6, the score ranges between 0.4-0.6 and only 193 observations are used.[40] Throughout the table, *rebeltribes* remains positive and significant, as well as some of the resource variables.

A second robustness check concerns our level of sample aggregation. Does the same pattern of a positive and significant *rebeltribes*-estimate remain when our observations are neighborhoods rather than individual villages? In table 7, we run regressions at neighborhood level, using the 148 artificially constructed 10 km by 10 km grid cells as our unit of analysis. We use two dependent variables: A dummy for when all villages in the neighborhood have been abandoned (*n_ abandon*) and the log of the number of households fleeing from the neighborhood (*log n_ peoplefled*). The main explanatory variable, *n_ rebels*, is consistently positive and significant as before and the average distance to alluvial soils in

[39] The Pearson correlation coefficients between *rebeltribes* and the resource variables are: *vegetation* (0.24), *dist_ wadi* (-0.215), and *dist_ alluvial* (-0.10).

[40] The main purpose is of course to discard observations where resource variables might have exerted an influence on our "treatment" variable *rebeldummy*. We recognize that the extent of homogenous rebel tribe villages is not a proper treatment variable in the conventional sense. See Greiner and Rubin (2010) for a recent discussion regarding the use of "immutable characteristics" such as race as treatment variables.

the neighborhood (*log n_ dist_ alluvial*) is negative and significant when included. Also in this table, it appears that the militia prefer peripheral neighborhoods far from administrative centers (*log n_ dist_ admin*).[41] *log dist_ road* is negative for intensity of attack in line with our previous results though it has a positive effect on probability of attack, which is counter to what we found earlier.

A third level of aggregation is the eight administrative units. In table A2 in the Appendix, we run a t-test to check for differences in means in *rebeltribes* in abandoned and non-abandoned villages. In all eight administrative units, abandoned villages had a significantly higher mean level of rebel tribes. In Garsila alone, with 107 villages in total, as many as 71 homogenous rebel tribe villages were abandoned.[42]

As a last robustness check, we try a battery of alternative variables in table A3.[43] Among the resource variables, we use an alternative index of vegetational intensity (*evi*) as well as two alternative measures of distance to surface water (*log dist_ river* and *log d_ wadi*). The last of these turn out to be negative and significant in column 4. A crude proxy for temperature in six climate zones within the area (*temperature*) also has some predictive power whereas an indicator for *rainfall* in the same six areas does not. We also include distance measures to the capital cities in Darfur (*d_ nyala, d_ elgen*, and *d_ elfash*) and an ethnic fractionalization index for each village (*ethnicfrac*). In all cases, the marginal effects for *rebeltribes* remain positive and significant. In the last column, we use a different dependent variable: a binary dummy *destroyed*=1 if the village (according to the data collectors) was physically destroyed. The estimate for *rebeltribes* is at a similar level as before but the coefficient for vegetation is now significant at a p-level lower than 1 percent.

In summary, our results indicate, as predicted, that the militia has been prone to attack villages that are relatively resourceful. More specifically, villages close to alluvial soils appear to have been strong targets for attacks, as well as villages close to roads and far from administrative centers. Our most robust result, however, is that we have consistently been able to reject the hypothesis that ethnicity did not play any role in the conflict. In all our specifications, the proportion of rebel tribes in the population was the strongest determinant of attacks, even when controlling for numerous other variables, different samples, and different levels of aggregation.

5 Conclusions

The main question addressed in this article is whether the military campaign on civilian villages by the government-supported Janjaweed forces was primarily an ethnic cleansing

[41] Explanatory notes and descriptive statistics for the variables in this table are presented in table A1 in the Appendix.

[42] We also ran separate probit regressions for each administrative unit, but in several cases the model could not be estimated due to a significant reduction in the number of observations. In the administrative units where the model could be run, *rebeltribes* had more or less the same sign and level of significance as before. Results are available upon request.

[43] Explanatory notes and descriptive statistics are given in table A1 in the Appendix.

campaign or a struggle over natural resources. Both are a priori plausible and often proposed reasons for the conflict. As a framework for the empirical study, we outline a theoretical model for understanding how ethnic cleansing might become an equilibrium outcome in a local struggle that is primarily driven by limited natural resources.

Our empirical analysis, based on a sample of 530 villages in the southwestern part of the region, clearly demonstrates that the proportion of the rebel tribes Fur, Masalit, and Zaghawa in the population is a robust determinant of the probability and intensity of Janjaweed attacks. The militia also appear to have targeted villages that are close to alluvial soils and to roads. The evidence might thus be described as being largely consistent with both of the major hypotheses, although the results regarding natural resources have smaller marginal effects. Since our model as well as our results suggest important interdependencies between the ethnic and resource variables, it is most likely impossible to discriminate completely between the two.

We believe our study has left several issues that remain to be explored. For instance, an intuitive extension of our model would be to also endogenize the strategic actions of the government. The question of under what conditions a government chooses to exterminate an oppositional group rather than trying to accommodate its demands, appears to be an interesting line of future research. Our data further indicate that a massive reallocation of land has occurred throughout Darfur as a result of the conflict. We believe the future implications of this process will be an important area for research in years to come.

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Figure 1: Approximate sequence of events in the Darfur conflict

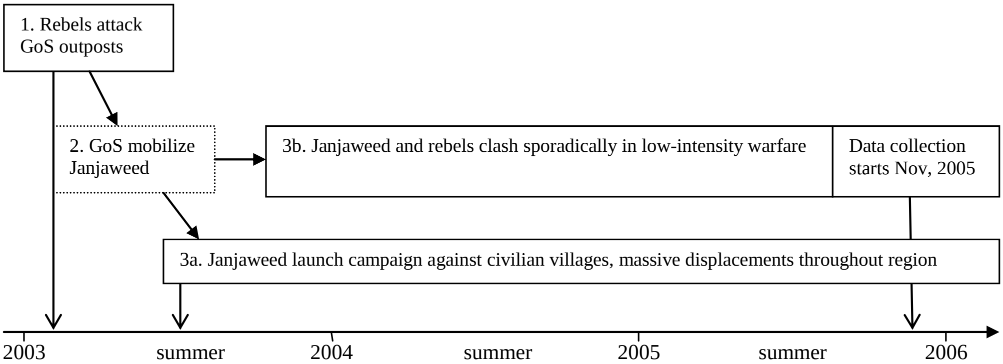
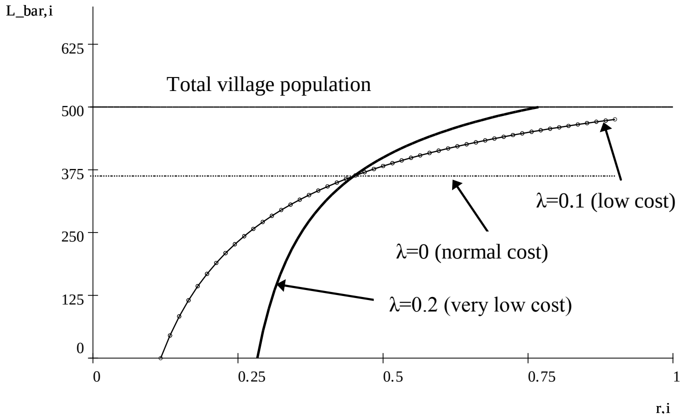


Figure 2: Simulated relationship between the equilibrium number of village individuals fleeing $\bar{L}_i$ and the share of rebel tribes f_i at three different social costs of displacing rebel tribes (λ).



Note: The figure plots $\bar{L}_i$ based on equation (8) at varying social costs of rebel tribe displacement. We assume L_i=500, $A/\theta N$=60/1500, αR_i=900, γ=3/2, s=1.1, and n_i=0.1 throughout. The range of f_i is 0-0.9. The dashed flat line illustrates no differences in the social costs of displacing ethnic groups (λ=0). The dotted curve shows lower costs of attacking rebel tribes (λ=0.1) whereas the thick black line shows an even stronger bias against rebel tribes (λ=0.2). This line is discontinuous at (L_i=500) when the whole village is abandoned ($\bar{L}_i$=500). The associated proportion of rebel tribes is f_i=0.768.

Figure 3: Map of abandoned and non-abandoned villages in the sampled region

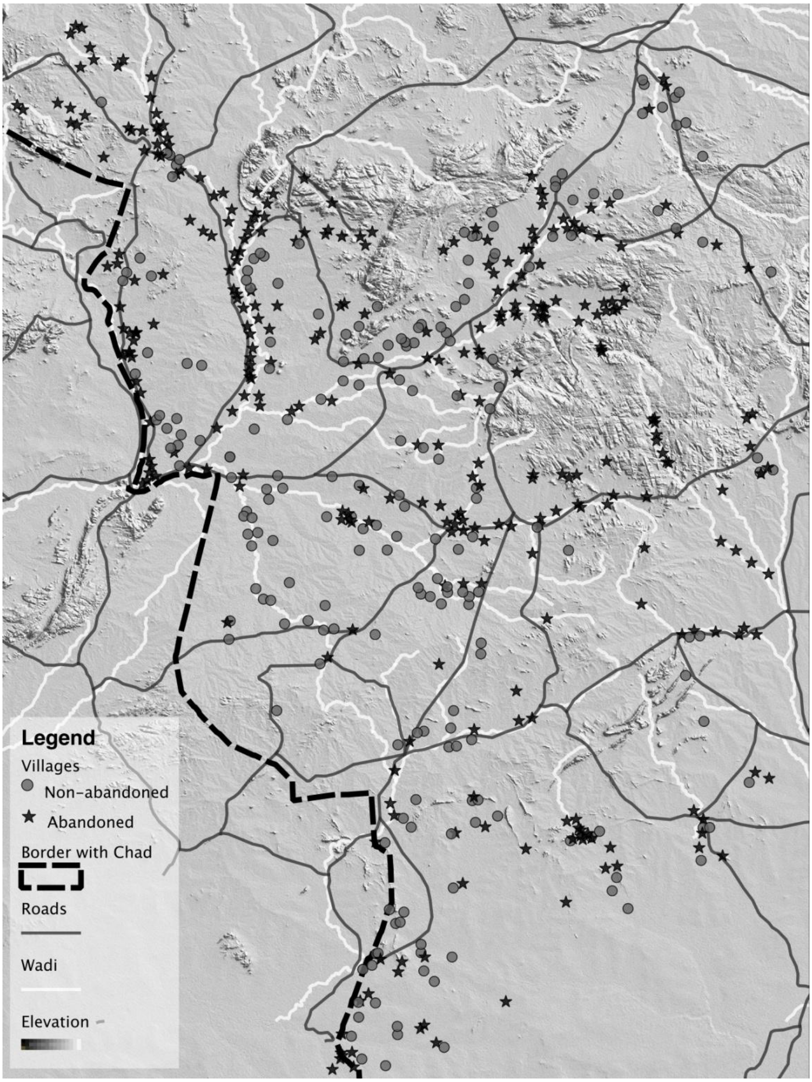


Figure 4: Number of households in the three major population groups before and after conflict.

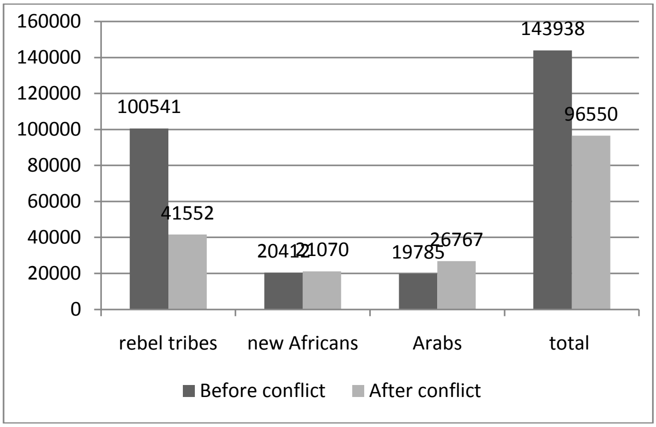
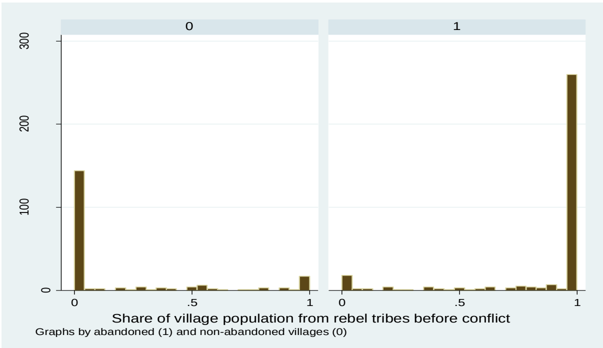
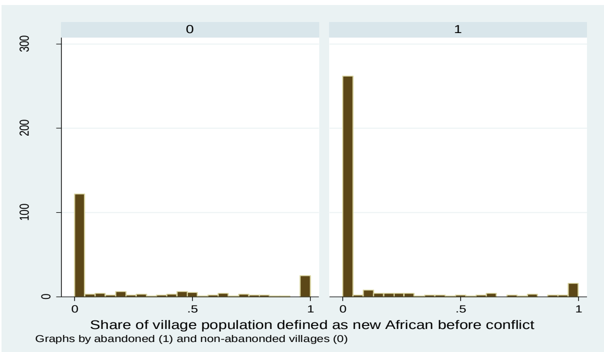


Figure 5: Distribution of major population group proportions before conflict in villages that were not abandoned (0) or abandoned (1) after conflict.

Rebel tribes:



New Africans:



Arabs:

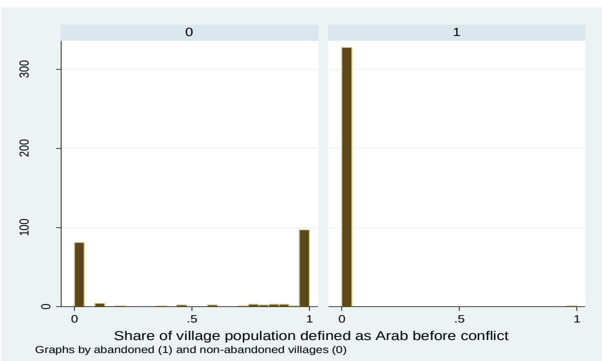


Table 1: Descriptive statistics of main variables used in the empirical analysis

Variable	**Description**	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
Dependent variables						
abandon	Binary dummy for village abandoned by the whole population (peoplefled=popsize)	530	.621	.486	0	1
attack	Binary dummy for village attacked (peoplefled>0)	530	.754	.431	0	1
peoplefled	No. of households fleeing from village	530	198.42	433.54	0	7200
Ethnic variables (independent)						
rebeltribes	Proportion of Fur, Masalit, and Zaghawa households before conflict in village	530	.615	.454	0	1
rebeldummy	Binary dummy for village where rebeltribes=1	530 530	.519	.500	0	1
Resource variables (independent)						
vegetation	NDVI index as of June 2003	530	3467.6	758.2	1916	6013
dist_wadi	Distance to nearest wadi (meters)	530	4358.7	5112.7	1.4	33250
dist_alluvial	Distance to nearest alluvial soil (meters)	442	1575.6	3342.3	0	24060
Geographical and other variables (independent)						
dist_road	Distance to nearest road (meters)	530	5074.2	4931.2	5.6	26079
dist_admin	Distance from village to center of administrative unit (meters)	530	26798	17261	0	80118
popsize	No. of households before conflict in village	530	269.6	536.3	11	7200
n_popsize	Total no. of households in 10 km by 10 km neighbourhood (grid cell)	530	1510	1795	18	8917
n_rebels	Proportion of Fur, Masalit, and Zaghawa in 10 km by 10 km neighbourhood (grid cell)	530	.660	.331	0	1
altitude	Altitude above sea level (meters)	530	697.5	128.8	502	1290
latitude	Latitude degree	530	12.08	.50	10.86	12.95
longitude	Longitude degree	530	23.01	0.36	22.24	23.75
admin unit	Dummies for 7 administrative units (Zalingei is reference unit)	530			0	1

Sources: All variables are taken or constructed from data collected by international organizations in the area except *vegetation*, *dist_wadi*, *dist_alluvial*, and *dist_road* (based on GIS-data from USAID, 2010) and *altitude* (Google Earth). The geographical distances from each village to their relevant administrative center *dist_admin* were calculated using latitude and longitude coordinates in the great circle formula.

Table 2: Means for selected variables in non-abandoned and abandoned villages

	abandoned		non-abandoned		total	
Variable	Obs	Mean	Obs	Mean	Obs	Difference
rebeltribes	329	.881	201	.179	530	.702***
		(.015)		(.023)		(.027)
vegetation	329	3.58	201	3.28	530	.299***
		(.045)		(.043)		(.065)
log dist_wadi	329	7.37	201	7.98	530	-.610***
		(.082)		(.083)		(.121)
log dist_alluvial	283	4.11	159	5.53	442	-1.415***
		(.200)		(.247)		(.325)
log dist_road	329	7.77	201	8.10	530	-.324***
		(.080)		(.085)		(.122)
log dist_admin	329	9.91	201	9.78	530	.131
		(.051)		(.122)		(.116)
log popsize	329	4.99	201	4.83	530	.163
		(.06)		(.08)		(.097)

Note: Standard errors in parenthesis. In the third column, we carry out a t-test of differences in means. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3: Probability of a village being abandoned

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable				abandon			
Sample	full	full	full	no Arabs	full	full	full
	OLS	probit	probit	probit	probit	probit	probit
rebeltribes	0.819***	1.091***	1.126***	0.421***	1.314***		0.950*
	(0.0330)	(0.0845)	(0.0957)	(0.0702)	(0.122)		(0.537)
rebeldummy						0.746***	
						(0.0381)	
vegetation	0.0255	0.0450	-0.000484	-0.00887	0.0240	0.0449	-0.0684
	(0.0203)	(0.0369)	(0.0360)	(0.0190)	(0.0423)	(0.0365)	(0.0605)
log dist_wadi	-0.0142	-0.0206	0.00948	0.0108	0.0128	-0.0344	0.0425
	(0.0105)	(0.0212)	(0.0240)	(0.0123)	(0.0281)	(0.0258)	(0.0465)
log dist_alluvial			-0.0450***	-0.0216***	-0.0390***	-0.0493***	-0.0759***
			(0.0115)	(0.00628)	(0.0122)	(0.0116)	(0.0198)
log dist_road	-0.0335***	-0.0712***	-0.0868***	-0.0395***	-0.0592**	-0.0676***	-0.0918***
	(0.0106)	(0.0226)	(0.0239)	(0.0125)	(0.0266)	(0.0208)	(0.0256)
log dist_admin	0.0490***	0.0685***	0.0489***	0.0144	0.0443**	0.0149	0.0465**
	(0.0120)	(0.0213)	(0.0185)	(0.0104)	(0.0195)	(0.0204)	(0.0192)
log popsize	-0.0468***	-0.110***	-0.148***	-0.0841***	-0.150***	-0.0235	-0.157***
	(0.0134)	(0.0282)	(0.0336)	(0.0193)	(0.0361)	(0.0280)	(0.0362)
log n_popsize	0.0125	0.0259	0.0272	0.0121	0.0518	-0.0268	0.0294
	(0.0116)	(0.0303)	(0.0323)	(0.0161)	(0.0372)	(0.0275)	(0.0366)
altitude	-0.000598***	-0.00118***	-0.000428	-5.96e-05	0.000146	-0.000574	-0.000734
	(0.000182)	(0.000406)	(0.000447)	(0.000250)	(0.000380)	(0.000475)	(0.000471)
n_rebels	-0.0135	-0.0464	0.0203	0.00401			
	(0.0541)	(0.121)	(0.136)	(0.0883)			
latitude	0.169***	0.321***	0.382***	0.232***		0.396***	0.455***
	(0.0525)	(0.116)	(0.137)	(0.0793)		(0.121)	(0.145)
longitude	0.0476	0.135	0.00665	0.0896		-0.0290	0.113
	(0.0594)	(0.130)	(0.147)	(0.0825)		(0.159)	(0.161)
vegetation* rebeltribes							0.112 (0.0827)
log dist_wadi* rebeltribes							-0.0548 (0.0592)
log dist_alluvial* rebeltribes							0.0551** (0.0257)
Adm. unit dummies	no	no	no	no	yes	no	no
Observations	530	530	442	350	442	442	442
R^2	0.613						
Pseudo R^2		0.552	0.615	0.428	0.683	0.560	0.625

Note: The estimator is OLS in column (1) and binomial probit in (2)-(7). The probit coefficients in (2)-(7) are marginal effects. Only villages without any Arab populations are included in column (4). A constant with unreported coefficients has been included in each specification. Administrative unit controls include dummies for 7 units with Zalingei as the excluded reference category. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Determinants of attack and of people fleeing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. variable	peoplefled	peoplefled	attack	log peoplefled	Average marginal effects		
Sample	full	full	full	peoplefled >0	peoplefled >0	peoplefled >0	full
	OLS	tobit	probit	OLS	tobit	OLS	hurdle
rebeltribes	63.10**	446.3***	4.745***	0.689***	203.12***	178.4158***	167.5486***
	(26.65)	(131.5)	(0.693)	(0.141)	(45.94)	(36.298)	(35.2164)
vegetation	-14.52	-1.289	-0.0415	0.0183	-0.586426	4.736475	3.471091
	(17.76)	(18.57)	(0.170)	(0.0244)	(8.435)	(6.347)	(5.360)
log dist_wadi	-0.407	-4.852	-0.0892	0.0193	-2.2080	4.990134	3.391568
	(8.521)	(11.54)	(0.126)	(0.0204)	(5.208)	(5.276)	(4.022)
log dist_alluvial	0.488	-9.453*	-0.118**	-0.0231**	-4.3018*	-5.99143**	-5.38393***
	(6.312)	(5.443)	(0.0486)	(0.00945)	(2.601)	(2.392)	(1.980)
log dist_road	-0.551	-13.92	-0.230**	-0.0464**	-6.3342	-12.0087**	-10.756***
	(12.19)	(16.54)	(0.102)	(0.0190)	(7.160)	(5.096)	(3.627)
log dist_admin	-47.14*	-31.32	0.162**	-0.00386	-14.255	-1.0001	0.1638092
	(28.40)	(31.99)	(0.0800)	(0.0209)	(15.342)	(5.417)	(5.132)
log popsize	242.9***	305.0***	0.127	0.914***	138.79***	236.689***	186.2842***
	(54.55)	(70.85)	(0.140)	(0.0293)	(23.083)	(17.28)	(24.552)
log n_popsize	18.84*	21.45	0.252	0.0248	9.7631	6.42146	6.506416
	(11.27)	(15.69)	(0.179)	(0.0172)	(6.876)	(4.424)	(4.441)
Controls	yes	yes	yes	yes	yes	yes	yes
sigma		390.9***					
		(126.0)					
Observations	442	442	442	337			
R^2	0.427			0.854			
Pseudo R^2		0.063	0.760				

Notes: Robust standard errors in parentheses in all columns except in column (7). Unreported constant included but not reported. Controls include: altitude, latitude and longitude. Marginal effects for the tobit model are average marginal effects conditional on *attack*=1 (i.e. *peoplefled*>0) using the specification in column (2). Average marginal effects of the conditional OLS model in column (6) are converted to number of households fled in levels. Robust standard errors using delta method is used for average marginal effects of the tobit and conditional OLS models. Bootstrapped standard errors, where the probit estimation of column (3) was possible to estimate with none of the explanatory variables being dropped in 100 replications, are reported for the average marginal effect of the hurdle model. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Analysis of selected variables' influence on *rebeldummy*

	rebeldummy=1		rebeldummy=0		total		Probit regression
Variable	Obs	Mean	Obs	Mean	Obs	Difference	rebeldummy
vegetation	275	3.62	255	3.31	530	.309***	0.363***
		(.048)		(.042)		(.065)	(0.0795)
log dist_wadi	275	7.46	255	7.77	530	-.312**	-0.142***
		(.095)		(.077)		(.123)	(0.0536)
log dist_alluvial	232	4.79	210	4.43	442	.356	0.0581***
		(.213)		(.239)		(.319)	(0.0215)
log dist_road	275	7.91	255	7.89	530	.021	-0.00526
		(.086)		(.081)		(.119)	(0.0473)
log dist_admin	275	9.94	255	9.77	530	.165	0.111**
		(.045)		(.106)		(.113)	(0.0436)
log popsize	275	5.04	255	4.81	530	.228***	0.219***
		(.060)		(.072)		(.094)	(0.0598)
Observations							442
Pseudo R^2 ¤							0.078

Note: Standard errors in parenthesis. In the third column, we carry out a t-test of differences in means. In the fourth column, we estimate a probit regression with *rebeldummy* as the dependent variable. A constant with unreported coefficients has been included.*** p<0.01, ** p<0.05, * p<0.

Table 6: Regressions using samples prescreened on probability score for *rebeldummy*

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable	abandon	abandon	logpfled	abandon	abandon	logpfled
Sample		pscore: 0.3-0.7			pscore: 0.4-0.6	
	OLS	probit	OLS	OLS	probit	OLS
rebeltribes	0.822***	1.184***	3.217***	0.835***	1.206***	3.377***
	(0.0351)	(0.0977)	(0.174)	(0.0457)	(0.130)	(0.242)
vegetation	0.00204	-0.0403	0.112	0.0312	-0.0249	0.00979
	(0.0289)	(0.0530)	(0.102)	(0.0540)	(0.115)	(0.216)
log dist_wadi	0.00840	0.0490	-0.00337	0.00935	0.0733	0.106
	(0.0152)	(0.0341)	(0.0531)	(0.0270)	(0.0666)	(0.0956)
log dist_alluvial	-0.0216***	-0.0515***	-0.0927***	-0.0160	-0.0507*	-0.105**
	(0.00667)	(0.0149)	(0.0259)	(0.0124)	(0.0279)	(0.0475)
log dist_road	-0.0420***	-0.104***	-0.178***	-0.0431***	-0.110***	-0.163***
	(0.0139)	(0.0295)	(0.0477)	(0.0156)	(0.0393)	(0.0596)
log dist_admin	0.0355**	0.0376*	0.0503	0.0337	0.0227	0.0358
	(0.0156)	(0.0220)	(0.0387)	(0.0239)	(0.0498)	(0.0859)
Standard controls	yes	yes	yes	yes	yes	yes
Observations	337	337	337	193	193	193
R^2	0.645		0.787	0.685		0.761
Pseudo R^2		0.623			0.659	

Note: The estimator is OLS in columns (1), (3), (4), and (6) and binomial probit in (2) and (5). The probit coefficients in (2) and (5) are marginal effects. A probability score-equation identical to the last column of table 5 was estimated for the purpose of pre-screening observations. In columns (1)-(3), only observations with a p-score in the range of 0.3-0.7 are included. In columns (4)-(6), the equivalent range for inclusion is 0.4-0.6. Standard controls includes *log popsize, log n_popsize, altitude, latitude*, and *longitude*. A constant with unreported coefficients has been included in each specification. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Regressions on grid cell level of aggregation

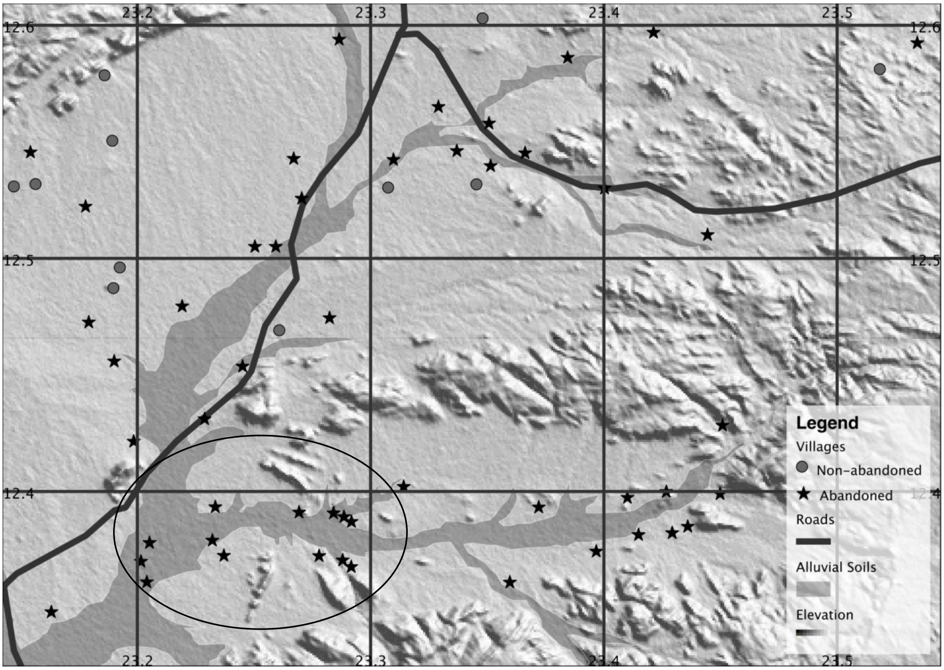
	(1)	(2)	(3)	(4)	(5)
Dep. variable	n_abandon	n_abandon	n_abandon	log n_peoplefled	log n_peoplefled
	OLS	probit	probit	OLS	OLS
n_rebels	0.704***	1.130***	1.500***	3.407***	3.271***
	(0.0850)	(0.165)	(0.253)	(0.377)	(0.438)
n_vegetation	0.0833	0.0885	0.0417	-0.220	-0.200
	(0.0535)	(0.0899)	(0.103)	(0.140)	(0.145)
log n_dist_wadi	-0.0455*	-0.0696*	0.00176	0.0122	0.0490
	(0.0242)	(0.0364)	(0.0455)	(0.0496)	(0.0557)
log n_dist_alluvial			-0.124***		-0.0706*
			(0.0347)		(0.0366)
log n_dist_road	0.0613**	0.0899**	0.130**	-0.121**	-0.0993*
	(0.0244)	(0.0404)	(0.0556)	(0.0549)	(0.0544)
log n_dist_admin	0.0830**	0.224***	0.101	0.205**	0.113
	(0.0364)	(0.0706)	(0.0824)	(0.0816)	(0.0689)
Controls	yes	yes	yes	yes	yes
Observations	148	148	121	148	121
R^2	0.504			0.832	0.864
Pseudo R^2		0.521	0.606		

Note: The probit coefficients in (2)-(3) are marginal effects. The set of controls includes *log n_popsize, n_altitude, n_latitude,* and *n_longitude*. A constant with unreported coefficients has been included in each specification. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix

(not for publication)

Figure A1: Map of abandoned and non-abandoned villages in a heavily affected area



Note: Each grid square constitutes one of our constructed neighborhoods. The circled area shows the most adversely affected neighborhood in the sample with 13 abandoned villages, all of them located right on or very close to alluvial soils.

Table A1: Descriptive statistics of additional variables used in tables 7 and A3.

Variable	Description	Obs	Mean	Std. dev.	Min	Max
Dependent variables						
n_abandon	Binary dummy =1 when all villages in neighborhood have been abandoned	148	.365	.483	0	1
n_peoplefled	No. of households fleeing in neighborhood	148	707.2	1203.6	0	8917
destroyed	Binary dummy for a village being destroyed	530	.479	.500	0	1
Ethnic variables (independent)						
n_rebels	Proportion of Fur, Masalit, and Zaghawa households before conflict in neighborhood	148	.641	.369	0	1
ethnicfrac	Ethnic fractionalization index in village	530	.168	.265	0	.851
Resource variables (independent)						
n_vegetation	Average NDVI index in neighborhood as of June 2003	148	3.53	.67	1.92	5.53
log n_dist_wadi	Log of average distance to nearest wadi in neighborhood (meters)	148	7.70	1.33	2.90	10.41
log n_dist_alluvial	Log of average distance to nearest alluvial soil in neighborhood (meters)	121	4.91	2.91	0	10.09
evi	Enhanced vegetation index	530	2562.5	568.8	1275	4564
log dist_river	Log of alternative measure of distance to wadi	530	7.63	1.34	.80	10.26
log d_wadi	Log of alternative measure of distance to wadi	530	7.79	1.59	2.30	10.58
temperature	Annual mean temperature in village's climate zone (Celsius degrees)	530	25.3	.52	23	26.8
rainfall	Average annual rainfall in village's climate zone (mms)	530	704.9	63.1	500	730
Geographical and other variables (independent)						
log n_dist_road	Log of average distance to nearest road in neighborhood (meters)	148	7.97	1.16	4.65	10.17
log n_dist_admin	Log of average distance from village to center of administrative unit in neighborhood (meters)	148	10.03	.87	5.86	11.26
n_popsize	Total number of households in neighborhood	148	962.2	1353.6	18	8917
n_altitude	Average altitude above sea level in neighborhood (meters)	148	711.1	142.3	519.3	1290
n_latitude	Latitude degree of neighborhood	148	11.98	0.51	10.8	12.9
n_longitude	Longitude degree of neighborhood	148	23.02	0.38	22.2	23.7
d_elgen	Distance from village to El Geneina (kms)	530	167.8	56.5	55.35	291.4
d_nyala	Distance from village to Nyala (kms)	530	211.5	39.0	124.0	300.1
d_elfash	Distance from village to El Fasher (kms)	530	310.9	40.6	213.5	408.4

Note: Variables with 148 or less observations on grid cell level are used in table 7. Variables with more than 148 observations are used in table A2. All variables are taken or constructed from data collected by international organizations in the area except *n_vegetation*, *n_dist_wadi*, *n_dist_alluvial*, *evi*, *dist_river*, and *n_dist_road* (based on GIS-data from USAID, 2010), *d_wadi* and *altitude* (Google Earth), and *temperature* and *rainfall* (FAO, 1998).

Table A2: Means for *rebeltribes* in non-abandoned and abandoned villages in eight administrative units

	abandoned		non-abandoned		total	
Administrative unit	Obs	Mean	Obs	Mean	Obs	Difference
Bindisi	24	.88	39	.24	63	.649***
		(.05)		(.05)		(.074)
Forobaranga	38	.49	13	.023	51	.464***
		(.07)		(.02)		(.124)
Garsila	71	1	36	.17	107	.833***
		(0)		(.06)		(.045)
Habila	49	.89	9	.33	58	.567***
		(.04)		(.14)		(.100)
Mukjar	49	.97	16	.06	65	.904***
		(.01)		(.05)		(.037)
Um-Dukhun	52	.89	51	.21	103	.677***
		(.04)		(.05)		(.067)
Um-Kher	43	.90	32	.16	75	.743***
		(.04)		(.05)		(.061)
Zalingei	3	1	5	.12	8	.884***
		(0)		(.12)		(.155)
All	329	.881	201	.179	530	.702***
		(.015)		(.023)		(.027)

Note: Standard errors in parenthesis. In the third column, we carry out a t-test of differences in means. *** p<0.01, ** p<0.05, * p<0

Table A3: Probit regressions with additional variables

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable	abandon	abandon	abandon	abandon	abandon	destroyed
rebeltribes	1.120***	1.080***	1.105***	1.103***	1.190***	0.919***
	(0.0966)	(0.100)	(0.0853)	(0.0870)	(0.101)	(0.0952)
vegetation	0.00151	-0.00189				0.129***
	(0.0364)	(0.0373)				(0.0434)
log dist_wadi	0.0120	0.00839				0.0372
	(0.0240)	(0.0252)				(0.0245)
log dist_alluvial	-0.0457***	-0.0484***				-0.0219*
	(0.0116)	(0.0121)				(0.0117)
log dist_road	-0.0935***	-0.0882***	-0.0753***	-0.0649***	-0.0845***	-0.00138
	(0.0246)	(0.0236)	(0.0224)	(0.0228)	(0.0223)	(0.0232)
log dist_admin	0.0523***	0.0480***	0.0662***	0.0763***	0.0666***	0.0697**
	(0.0185)	(0.0181)	(0.0214)	(0.0229)	(0.0219)	(0.0276)
d_nyala	-0.00946					
	(0.00633)					
d_elgen	-0.00823**					
	(0.00410)					
d_elfash	0.00754					
	(0.00577)					
ethnicfrac		-0.349***				
		(0.134)				
evi			4.36e-05			
			(4.96e-05)			
log dist_river			0.00408			
			(0.0202)			
log d_wadi				-0.0507**		
				(0.0210)		
temperature					0.333***	
					(0.0861)	
rainfall					-0.000760	
					(0.000829)	
Controls	yes	yes	yes	yes	yes	yes
Observations	442	442	530	530	530	442
Pseudo R^2	0.614	0.626	0.550	0.558	0.571	0.408

Note: The estimator is binomial probit in all columns and the dependent variable is *abandon* in all columns except column (6) where *destroyed* is the dependent variable. The probit coefficients in all columns are marginal effects. The set of controls includes *log popsize, log n_popsize, n_rebels, altitude, latitude*,and *longitude*. A constant with unreported coefficients has been included in each specification. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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