# Achieving Scale Collectively*

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**Abstract**

Technology is often embodied in expensive and indivisible capital goods, such as production machines. As a result, the small scale of firms in developing countries could hinder investment and productivity. This paper argues that market interactions between small firms substantially attenuate this concern, by allowing them to achieve scale collectively. We design a firm-level survey to measure production processes in three prominent manufacturing sectors in urban Uganda. We document the emergence of an active rental market for machines among small firms, and we build and estimate an equilibrium model of firm behavior to quantify its importance. Our results show that the rental market almost doubles the share of firms using machines, and increases labor productivity by 8%, relative to a counterfactual economy where renting is not possible. We show that the rental market leads to significant gains in our context because it mitigates substantial imperfections in the labor, output, and financial markets.

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# 1 Introduction

Technological progress plays a key role for economic development. Understanding the barriers to technology adoption for firms is thus important to narrow the productivity gaps that still persist between rich and poor countries (Hall and Jones, 1999; Caselli, 2005; Bloom et al., 2010).

Technology is often embodied in expensive capital goods, such as production machines.[1] Their indivisible nature may hinder technology adoption for firms in developing countries, which typically operate at small scale due to a multitude of factors, such as frictions in the output, financial and labor markets, as well as limits to delegation.[2] In line with this view, policy-makers around the world engage in extensive efforts to help small firms grow.[3]

While small, firms in developing countries tend to operate near each other in informal clusters.[4] Figure 1 shows that the geographical proximity of firms is a systematic feature of production also in Uganda, especially in sectors where firms are small. In this paper, we show that market interactions between small Ugandan firms allow them to overcome barriers to the adoption of large capital equipment: while machines are indivisible, their capacity is divisible and can be shared by many firms through a rental market.

To do so, we design and implement a novel firm-level survey, and we interpret the evidence through an equilibrium model of firm behavior. The data provides direct evidence of economies of scale driven by the indivisibility and large capacity of modern machines, but also reveals that an active rental market for such machines has emerged between small firms. The model allows us to quantify the aggregate and distributional effects of the rental market on technology adoption and productivity, and to discuss how these effects depend on the size of other frictions that keep firms small.

We surveyed a representative sample of over 1,000 firms in three manufacturing sectors that employ a large share of workers in Uganda: carpentry, metal fabrication and grain milling. The key innovation of our survey is that it collects detailed information on production processes for pre-specified products that are common in these sectors. We collect information on: (i) which production steps firms follow; (ii) the combination of capital and labor used in each step; and (iii) prices, quantity and quality of output. To measure the capital input in each step, we collect data at the machine level, such as whether the machine is owned or rented, its price, hours used, and multiple proxies of its quality. To measure the labor input we gather information on time allocation, on the skills of employees, and on the managerial ability of firm owners.

[1]See, for instance, Solow (1960); Griliches (1997); Janes et al. (2019); and Caunedo and Keller (2019).

[2]See Hsieh and Olken (2014) for evidence on the prevalence of small firms, and Jensen and Miller (2018), De Mel et al. (2008), Banerjee and Duflo (2014), Hardy and McCasland (2017), and Akcigit et al. (2020) for examples of constraints to firm expansion.

[3]For instance, in 2018 the International Finance Corporation had a lending portfolio of $21.1 billion committed to Micro, Small and Medium Enterprises specifically (IFC, 2019).

[4]For instance, Atkin et al. (2017) study clusters of soccer ball producers in Pakistan; Rabellotti (1995) describes clusters of footwear enterprises in Mexico; Shapiro et al. (2020) study clusters of carpenters in Kenya.

We use this data to present key facts on production in these sectors. Firms are spatially concentrated in informal clusters and produce similar products, but do so at different capital intensity: some rely mostly on labor, while others use modern, electrically-powered machines. These machines have clear productivity benefits: performing a production step is substantially faster, and mechanized firms sell more output, charge higher prices, and produce higher quality goods. At the same time, machines are very expensive and have high capacity relative to the size of the typical firm, thus leading to economies of scale. One salient example is the thickness planer: this is a central machine in the production process for carpentry and costs $4,000 on average, or about *18 times* average monthly profits ($220).

The high cost and indivisibility of machines is overcome, at least partly, by the presence of active inter-firm rental markets. Back to the example, we document that while 60% of firms use a thickness planer, less than 10% own one. The rental market improves the allocation of capital and increases capacity utilization, but is hampered by transaction costs: most firms access rented machines at the premises of the machine owner, requiring them to move intermediate inputs between locations, which leads to sizable transportation costs and wait times for machine access. To measure transaction costs and quantify the extent to which the rental market allows firms to collectively reap the benefits of scale, we introduce a model.

The model is built and estimated for the carpentry sector, as that is the sector where we document the largest economies of scale, and where the rental market is more developed.[5] In the model, individuals draw a managerial ability and decide whether to produce a differentiated carpentry good or to work as employees. Managers[6] decide how much and how to produce, given their ability and their cost of capital. Specifically, they choose: (i) whether to mechanize the production process; (ii) quantities of output, and of the capital and labor input; and (iii) whether to purchase machines or rent them from other firms. Additionally, if they purchase machines, they decide how many hours of their machine's capacity to rent out to the market. All managers hire workers subject to a firm-specific increasing cost of labor which captures labor market frictions in reduced form. The rental market for machines is also subject to a reduced form friction: for every dollar earned by a machine lender, the renter pays $1 + \tau$ dollars, where $\tau$ is an exogenous transaction cost, or the rental market wedge. The rental market for machines and the output market are in equilibrium.

We characterize the solution analytically, focusing on the role of the rental market. If the rental market is frictionless – i.e. $\tau = 0$ – the choice to mechanize and invest are given by two separate cutoffs: managers with high ability mechanize, and those with a low cost of financing invest and rent out their machines. Frictions in the rental market tie together the two choices

[5]Machines are less expensive in metal fabrication. In grain milling, they have lower capacity relative to the average firm size, hence they are used more intensively by each firm.

[6]In our sample, firm owners also actively manage the firm operations in most cases. So in this paper we use the terms "firm owners" and "managers" interchangeably.

to mechanize and invest since they make the marginal cost of capital lower for firms that own machines. Overall, a well-functioning rental market has two benefits: (i) providing access to capital to firms that would not otherwise afford it; and (ii) improving the allocation of capital, by leading managers with low cost to buy capital, and those with high returns to use it.

We estimate the model using our data from the carpentry sector. Two features of the data are both unique and essential: for each machine, we observe whether it is rented or owned, and for each production step, we know the combination of machine and labor time used. Given the structural equations, this information exactly identifies the rental market wedge in the data. If the wedge is positive, machine renters should operate at a lower capital-labor ratio since they face a higher marginal cost of capital.[7] We find the wedge to be equal to 40 cents for each dollar spent in the rental market. Evidence on time-use for rental market transactions shows that almost two thirds of this amount can be directly accounted for by transportation and opportunity costs. The richness of the data, together with the structure of the model, identifies all the other parameters of interest. We estimate the model parameters by simulated method of moments, and show that it offers a good fit of the data.

We then quantify the aggregate and distributional effects of the rental market. A frictionless rental market, with $\tau = 0$, increases mechanization by 174%, labor productivity by 15%, and output by 28% relative to an economy where renting is not possible. The benchmark economy, with $\tau = 0.40$, attains more than half of the possible gains. The existing rental market is thus quite effective, and allows carpentry firms in urban Uganda to *achieve scale collectively.* We structurally decompose these aggregate results into direct and indirect (or equilibrium) effects. In our context, equilibrium effects cannot be ignored: the productivity gain that could be estimated by a partial equilibrium randomized experiment eliminating the rental market friction for a small number of firms is almost *three times* larger than the aggregate effect of a country-wide change. Finally, we show that the rental market redistributes market share from high to low ability entrepreneurs and reduces the dispersion in labor productivity.

Accounting for rental markets is important to understand productivity in the carpentry sector in urban Uganda. Beyond Uganda, should development economists and policy makers pay more attention to rental markets? We use the estimated model to discuss the settings in which we expect rental markets to matter most. First, they are effective in sectors with many small firms and with potential for economies of scale. In our context, a thick rental market has emerged in carpentry which has expensive and high capacity machines for technological reasons. We would expect rental markets to emerge in other contexts that share these features. Second, the rental market is more effective when the economy is plagued by other imperfections: improving financial markets, or reducing frictions in the labor and output markets, makes the

[7] For machine owners, the marginal cost of capital is the opportunity cost of not renting out the machine in the market, hence the rental price; for machine renters, it is the rental price times the rental market wedge.

rental market less important for aggregate productivity. Third, rental markets matter for policy targeting: policy-makers wishing to improve the mechanization of small firms might want to subsidize credit for larger firms, which are better able to sustain the capital investment, and have the benefits trickle down through the rental market.

**Related literature.** Our work makes three contributions to the literature on the role of scale for development. First, a classic literature studies the importance of fixed costs and financial frictions for technology adoption and poverty traps in developing countries, focusing primarily on micro-entrepreneurs (Greenwood and Jovanovic, 1990; Banerjee and Duflo, 2005; Kaboski and Townsend, 2011; Buera et al., 2011, 2017).[8] We provide two new insights relative to this literature: (i) we show direct evidence that scale economies are driven by the large capacity of machines; (ii) we document the presence of an active inter-firm rental market, and we analyze its ability to help firms overcome poverty traps and to attenuate financial frictions.[9]

Second, the development literature has long been concerned with the evaluation of policies aimed at helping small firms grow.[10] Our results highlight that in contexts where firm clusters are important, focusing on the size of individual firms as the key policy outcome of interest can be partly misleading, since the productivity of individual firms depends on market interactions with other firms. We argue that more attention should be given to the functioning of firm clusters, and to the potential of leveraging such firm to firm interactions to increase productivity.

Third, we are not the first to highlight that clusters of firms might be an efficient way to exploit the potential benefits of coordination such as specialization of the production process, outsourcing of production steps to suppliers, or knowledge transfers. In fact, this idea goes back at least to Marshall (1920). A relatively recent literature in economics and sociology has examined the role of firm clusters along some of these dimensions (Rabellotti, 1995; Schmitz, 1995). The focus has however been primarily on case studies with small samples in successful industrial districts in Europe. Our contribution is to provide the first quantitative assessment – at least to our knowledge – of this type of firm-to-firm interactions in determining the cost of production and access to modern technology.[11]

[8] More recently, Balboni et al. (2019), Banerjee et al. (2019) and Janes et al. (2019) find evidence consistent with micro-entrepreneurs facing substantial fixed costs. Our study is also closely related to Foster and Rosenzweig (2017) who study economies of scale in farming.

[9] Foster and Rosenzweig (2017) note (i) as a promising channel. However, they do not have data on time use and capacity for most machines and thus cannot validate the hypothesis in general. Although it is not their main focus, Jensen and Miller (2018) also provide evidence on economies of scale at the firm level. In particular, they show that labor is more specialized in large firms which is consistent with our findings. Their results also suggest that larger firms use capital more effectively, but they do not show direct evidence of this.

[10] For recent reviews, see Quinn and Woodruff (2019) and Jayachandran (2020).

[11] Our work is also related to the literature on technology adoption in agriculture, which emphasizes the importance of rental markets for land and agricultural equipment (see, for instance, Binswanger and Rosenzweig (1986) and Olmstead and Rhode (2001)). Other work in progress on the importance of rental markets includes: Rampini and Townsend (2016) who uncover an important role for rental markets among households in Thailand,

More broadly, we contribute to an established literature on the causes of industrial agglomeration (Duranton and Puga, 2004; Rosenthal and Strange, 2004; Ellison et al., 2010), by highlighting the sharing of indivisible capital equipment as a potential source of agglomeration for small firms. Finally, our results show that well-functioning rental markets for capital effectively reduce the costs of small scale and the incentives to consolidate, thus adding new insights to a classic literature on the boundary of the firm (Coase, 1937; Gibbons and Roberts, 2013).

The rest of the paper is organized as follows. Section 2 discusses the sampling strategy and survey design. In Section 3 we present descriptive evidence on the organization of production and the rental market for machines. The model is developed in Section 4, and Section 5 discusses our approach to identification and estimation of the model. Section 6 quantifies the aggregate and distributional effects of the rental market, and Section 7 discusses the broader implications of our results beyond Uganda.

# 2 The Survey

In this Section we describe the survey. This took place in late 2018 and early 2019, and was implemented by our partner NGO, BRAC Uganda, in partnership with the Ministry of Trade. We present key elements of the sampling strategy and the survey instrument in turn. Further details can be found in Supplemental Appendix C.[12]

## 2.1 Sampling

Our survey targeted firms in manufacturing, where output is easier to measure and where both capital and labor are relevant inputs. Within manufacturing, we focused on three prominent sectors: carpentry, metal fabrication and grain milling. As revealed by the Census of Business Establishments for Uganda,[13] these are sectors that: (i) employ a large share of workers and (ii) are not dominated by micro-enterprises. The first criterion implies we target sectors that are important for policy, whereas the second criterion allows us to focus on sectors where both smaller and larger firms co-exist. By focusing on more than one sector we can exploit heterogeneity across sectors, something that we do later in the paper.

The survey was implemented in a representative sample of urban and semi-urban areas across three of the four macro-regions of Uganda: Central, Western, and Eastern regions. A sample of 52 sub-counties was randomly extracted, stratifying by population and by whether the sub-county is in the broader Kampala area.[14] We conducted a listing of all the firms in

and Caunedo et al. (2020), who study the organization of rental markets for agricultural equipment in India.

[12]Supplemental appendix materials can be found on the authors' websites.

[13]We use the latest firm census, conducted by the Uganda Bureau of Statistics in 2010.

[14]Appendix Figure S2 shows the final sample of sub-counties. Figures and Tables labeled with "S" can be found in the Supplemental Appendix.

our three sectors in the sampled areas, identifying close to 3,000 firms. We then randomly extracted about 1,000 firms from our listing to be included in the survey, oversampling firms with five or more employees. In firms selected for the survey, we interviewed the owner and all the employees working on our pre-defined core products, which are discussed below. Across the three sectors we interviewed 1,115 firms and 2,883 employees.[15] Finally, as described in detail in Supplemental Appendix C, all our results are weighted to reflect our sampling strategy.

## 2.2 Survey Design

Our objective was to zoom inside the firm, and paint a complete picture of how these firms combine capital and labor inputs to produce output. Following existing firm surveys, we collected a wide range of firm-level information such as revenues, profits, wages, owner and employees' characteristics (e.g. age, education, experience, and vocational training received), and management skills of the owner (that are measured using similar questions to De Mel et al. (2018)).

We then went beyond related studies and collected information on the entire production process for key products. This allows us to improve on the measurement of capital and labor, and how they are combined. We worked with the Uganda Industrial Research Institute to identify for each sector one "core product" made by most firms. These are: two-panel doors in carpentry, two-shutter sliding windows in metal fabrication, and maize flour No. 1 in grain milling. We then broke down their production process into a series of steps that firms typically engage in, and collected information on: (i) whether firms produce the pre-specified core product; (ii) whether they perform the pre-specified production steps; and (iii) the combination of capital and labor used in each step. That is, for each step we know: (i) which modern electrically powered machines or manual tools are used; (ii) which employees work on it and for how many hours; and, (iii) the time taken by the employee (or team of employees) to complete it.[16]

We link this information to a detailed employee and machine roster. We collected details of each machine, such as hours used per week, whether it is owned or rented, purchase (or rental) cost, country of production, age, current value, and expected remaining life. Finally, for our core products we collected information on: quantities produced and sold, prices, and multiple proxies of quality collected through direct observation by our enumerators.[17] In the next Section we use this rich data to describe the production process in these sectors, with a specific focus on how capital and labor inputs are combined.[18]

[15]Compliance with the survey was very high at over 90% (see Supplemental Appendix C for details).

[16]As an example, Appendix Table S3 shows the production steps for carpentry, with examples of typical machines and tools. The Supplemental Appendix also includes pictures of a two-panel door and typical machines.

[17]As shown in the next section, the majority of our firms produce the pre-specified core product. For firms that do not produce it, all questions about the core product refer to their main type of product within the same category (e.g. in carpentry this would be the main type of door produced), or to the main product of the firm overall if the firm does not produce the same product category. See Supplemental Appendix C for more details.

[18]Some of the descriptive evidence on rental markets presented later in the paper was captured in short

# 3 Descriptives on the Organization of Production

We now present a number of key facts on the organization of production. We document the role of capital and labor in production and the sources of economies of scale. We present the results for carpentry in detail, and highlight when results are similar and when they differ across sectors. We also discuss how such heterogeneity contributes to our evidence on whether there are economies of scale that seem to be un(der)exploited.

## 3.1 Basic Firm Descriptives

Appendix Table A1 reports descriptive statistics for the 1,115 firms in our sample, their owners, and their employees. The average firm is small, employing about five workers. Average monthly revenues and profits are $1,437 and $237, respectively. To put these numbers into perspective, per capita GDP in Uganda was $60 per month in 2018. This shows that the average firm is highly profitable, and operates beyond subsistence level. In addition, these are established and regular activities: the average firm has been in business for 10 years, and the great majority of firms are registered with the local authority. The average owner works 9 hours per day for the firm, so this is the primary job for the majority of them. The average employee has 3.5 years of tenure, works 9.9 hours per day for the firm, and makes about $70 per month. This shows these are stable, regular, and well-paying jobs by Ugandan standards. Taken together, this evidence shows that our sample is composed of established and profitable firms that employ well-paid workers. There is no substantial heterogeneity across sectors.

## 3.2 Distribution of Economic Activity

We now describe the distribution of production activities across firms and space that emerge from our survey. We have already discussed that the average firm is small, and the fact that we identified close to 3,000 firms in the listing shows these are sectors with many firms. Figure 2a reports the distribution of the types of output produced by carpentry firms in our sample and shows that production is concentrated around some key products. For instance, 68%-75% of the firms produce beds and doors. Figure 2b shows that among door producers, around 65% produce the two-panel door, which is our core product.[19] Figure 2c then shows that not only do carpentry firms produce similar products, but they do so using very similar production steps. Indeed, the great majority of firms engage in most of the pre-specified production steps for door production.[20] Taken together, this evidence shows that the market is populated by many small

follow-up surveys conducted with our sample of firms in the months after the initial survey was completed. Supplemental Appendix C discusses this additional data collection in detail.

[19] The pattern for metal fabrication and grain milling reported in Appendix Figure S5 shows similar results.

[20] As shown in Appendix Figure S7, this is valid also in the other two sectors.

firms producing similar products using similar production steps. In other words, we do not find evidence of specialization of economic activity across firms.

We then use the initial firm listing to study the spatial concentration of firms in our data. Firms are concentrated in clusters. One way to see this is to calculate the median number of firms falling within a 500 meter radius from each firm in our data. These are: 11 firms in carpentry, 5 in metal fabrication and 2 in grain milling, thus suggesting that the degree of spatial concentration is substantial, especially in carpentry. The clustered nature of economic activity can be appreciated visually in Appendix Figure S3, which maps the distribution of firms from the listing in one of our sampled sub-counties. Indeed, we see that firms tend to cluster together around major roads..

### 3.3 Economies of Scale Due to Indivisibility of Machines

We now turn to the role of the capital input in production, and show how we uncover the presence of substantial economies of scale driven by the indivisibility of large production machines.

**Importance of modern machines.** The main productive capital in these sectors are machines and tools. There is a sharp contrast between modern machines that are electrically powered, and hand tools that are human powered. For example, in carpentry a modern machine would be a thickness planer, while a hand tool would be a hand planer. These largely perform the same production steps, but vary in their efficiency, accuracy, capacity and cost as explained in more detail below. We first note that while firms produce similar products using similar production steps, there is substantial variation in the extent to which these steps are performed using modern machines as opposed to hand tools. To show this, for each step we identify the firms with the largest number of different modern machine types used in that production step.[21] For each firm we then compute their "machine utilization rate" for that step, defined as the number of different machine types they use, divided by the number of different machine types used for that step by the most mechanized firms in the data. Appendix Figure S9 shows that indeed there is substantial variation in machine utilization rates across firms for most steps, especially in carpentry and metal fabrication.[22]

We document a significant association between usage of modern machines and productive efficiency. We asked the employees performing any given step what would be the minimum time they could take to perform that step, with the equipment typically used by their firm. We can then compute the average minimum time taken to perform a step, by whether it is mechanized

[21] These are the firms at the 95% or above of the distribution of machine types used in production of the step.

[22] This conclusion is not affected significantly by the specific definition of machine utilization. We also note that in 93% of cases firms only use one machine of each type, so looking at the number of machine types or the number of machines as a measure of machine utilization makes little difference.

or not, after controlling for a large set of firm and worker characteristics.[23] Figure 2d reports the results for carpentry, and shows substantial efficiency gains from mechanization for most steps. For example, thicknessing for a door typically takes around 70 minutes if done with hand planers, but this is cut down by *more than half* if a thickness planer is used instead.

There are clearly other potential gains from mechanization in addition to efficiency/time-saving: machines may be better suited for more complex operations, leading to higher quality output. Indeed, we notice from Figure 2d that the Design and Finishing steps in door production take *longer* in firms that use machines, which is in line with firms using machines to engage in more complex designs and finishing operations. Table 1 further shows that the machine utilization rate is strongly correlated with: (i) total revenues per worker (columns 1-2), (ii) revenues per worker from the sale of doors (columns 3-4); (iii) selling price of doors (column 5-6); and (iv) a standardized index of the quality of doors produced (columns 7-8).[24] In addition, note that the coefficient in the regression of log revenues per worker from the sale of doors on mechanization (columns 3-4) is roughly twice as large as the coefficient from a regression of log door price on mechanization (columns 5-6). This implies that the higher revenue productivity of mechanized firms is due both to higher prices and to higher quantity sold, with these two channels contributing roughly in similar ways. These correlations are robust to controlling for a measure of managerial ability and other firm controls, and so do not just capture the fact that higher ability entrepreneurs are better able to use machines or have easier access to capital. While not causal, this evidence is all in line with modern machines playing a key role in production, both in terms of efficiency and in terms of output quality.[25]

**Machine capacity and economies of scale.** Figure 3 shows the percentage of firms using different types of machines in production of the core product, together with their average price.[26] Focusing on Panel (a) for carpentry, we note that most machines are expensive. For example, thickness planers cost $4,000 on average – about 18 times average monthly profits ($220). Machines also tend to have a capacity that is too high for a single firm. The average (median) machine is used by a firm for only about 21 (18) hours per week, across *all* products. Average weekly employee hours are close to 60 in carpentry, and so this shows the average firm uses machines for only about *one third* of the time that the firm is open. Machines are instead substantially less expensive in metal fabrication, as shown by Panel (b) of Figure 3, and they

[23] For this analysis we define a step as mechanized if at least one modern machine is used, but again our results are not sensitive to the specific definition of mechanization.

[24] Details on the construction of the output quality index are reported in Supplemental Appendix D.

[25] Figure S10 and Tables S4 and S5 in the Supplemental Appendix show that these conclusions on the importance of machines in the production process broadly hold in the other sectors as well.

[26] Most machines are imported. For instance, 92% of the machines used in the production of doors in carpentry in our data are made abroad.

are used closer to full capacity in grain milling.[27]

These results uncover the presence of large economies of scale driven by the capital input in carpentry, as modern machines increase productivity, but also have a high fixed cost. Since capacity is much larger than the needs of any single firm, this creates a concern that economies of scale might go largely un(der)exploited in this economy, as individual firms might be too small to justify investing in such large machines. Our data shows that the potential for unexploited economies of scale is lower in metal fabrication and grain milling –in metal fabrication, because machines are not very expensive; in grain milling, because even though machines are expensive, they are utilized heavily by each firm.

## 3.4 Rental Market for Machines

A natural market solution to the presence of indivisibilities in the capital input would be to organize a rental market for machines. We use our machine-level data to study whether a rental market has emerged. Given the discussion above, we would expect this to be larger in carpentry. Figure 3 shows the break-down of the percentage of firms that use a machine between those that own the machine, and those that rent it. The figure reveals that in carpentry most machines are *rented*. For instance, Panel (a) shows that while 60% of firms use a thickness planer, less than 10% own one. The rental market is instead more limited in metal fabrication and almost entirely absent in grain milling (Panel (b) and (c)), which is in line with our expectations. Our data further confirms that the rental market increases capacity utilization substantially in carpentry: while the average firm uses the typical machine for 21 hours per week, the average machine is used by the market for 35 hours per week, that is, market-level capacity utilization almost *doubles* thanks to the rental market.[28]

Our data for carpentry further reveals that the rental market is primarily across firms in the same cluster: in at least 60% of cases, firms report renting the machine from another carpenter nearby.[29] As most of these machines are heavy, the rental market is operationalized by workers carrying intermediate inputs to the firm where the machine is located, and paying the firm owner a fee to let them perform the required production step with their machine. There are significant transportation and time costs associated with the rental market. As shown in Appendix Table A2, renters typically visit machine owners 15 times per month, and every time they go: (i) they spend around 50 minutes traveling (and do so using motorcycle taxis); (ii) they spend almost

[27]The average (median) machine is used for at least 45 (48) hours per week in grain milling. For grain milling, we know the hours that a machine is used for the main product only, which provides a lower bound to the overall firm-level capacity utilization. See Supplemental Appendix C for more details.

[28]To calculate market-level capacity utilization we use data for machine owners, who were asked how many hours per week their machines are used in total (both for own production and for renting out to other firms).

[29]In the rest of the cases, firms report renting from specialized rental workshops. We return to this point in the structural model, where we explicitly model specialized workshops.

three hours at the premises of machine owners and about half of this time is spent idle, waiting for machine access. In line with wait times being important, 70% of machine owners report avoiding wait times as a primary reason for owning instead of renting. These wait times can in part be explained by congestion: almost a third of renters report visiting machine owners in the early morning, as shown in Appendix Table S7.[30]

The rental market is more common for large and expensive machines (Appendix Figure S11). While the rental market allows small firms to access machines, it also benefits machine owners, who can rent out their excess capacity: Appendix Figure A1 plots average machine prices against average annual income from renting out these machines in carpentry, and shows that machine owners can recover the cost of the typical machine with about one year of revenues from the rental market. This is in line with evidence presented in Section 5 that the cost of capital faced by managers is high on average.

While the rental market generates substantial revenues for machine owners, we provide three pieces of evidence which suggest that it operates competitively (though subject to frictions). First, if machine owners have market power we would expect rental prices to be relatively higher for more expensive machines, as there is a higher entry cost in supplying them. Appendix Figure A1 shows however that revenues from renting out machines are relatively higher for the *cheapest* ones, which suggests instead that an important component of rental prices are costs that do not depend on the value of machines, such as the costs of finding renters or monitoring costs.[31] Second, the concentration of machines is limited: Appendix Figure S12 shows for the three most commonly rented machines in carpentry that there are typically a number of machine owners in each sub-county, which likely creates competition and limits the monopoly power of machine owners. Finally, Appendix Table A3 regresses hourly rental prices on the number of machine owners in the sub-county. If machine owners have market power, we would expect prices to decrease as the number of machine owners increases (due to higher competition). Instead, we fail to find a negative coefficient in any of the specifications. While this evidence is purely descriptive, it supports the conclusion that rental markets operate competitively.

### 3.5 An Efficient Sharing Economy?

We have provided direct evidence of economies of scale driven by the large capacity of machines. Especially in carpentry, machines are too large for the typical firm. This could in principle prevent small firms from adopting technology and hinder their productivity. However, we have also shown that an inter-firm rental market for machines has emerged in carpentry, allowing

[30]This descriptive evidence on the nature of the rental market was collected in a short follow-up survey of our sample of carpenters conducted in three of our sampled sub-counties about 4 months after the end of the main survey. See Appendix C for more details.

[31]In fact, monitoring costs are likely larger for smaller machines like drills that can be easily moved around or stolen. This can further explain why smaller machines have relatively higher rental prices.

small firms to access machines that they might otherwise find unprofitable to purchase.

The data alone is, however, not enough to quantify which fraction of the potential gains from scale are reaped collectively through the rental market. To answer this question, we need to measure the costs or frictions associated with the inter-firm transactions that we have documented, and we need to take into consideration equilibrium effects. In the next section we develop a model that will help us along both dimensions.

Finally, we note that the presence of large economies of scale in the capital input indicates that there should be large returns from consolidation. So the puzzle remains of why more profitable firms do not take over smaller and less productive firms, and instead engage in a rental relationship with them. There could be many constraints leading to this, such as contracting frictions or limited span of control (Bloom et al., 2010; Akcigit et al., 2020). While our survey (and our model) is not designed to answer these important questions, we note that the existence of a rental market for machines *reduces* the inefficiencies from lack of consolidation, thus limiting the impact of any such constraints on productive efficiency.

## 3.6 Additional Descriptive Results

Before turning to the model, we present two additional descriptive results that inform our modeling choices. First, we find evidence of *diseconomies* of scale in labor, due to substantial labor market frictions. This justifies introducing a convex cost of labor in the model. Second, we uncover substantial product differentiation and limited direct competition in the output market. Congruently, we assume that managers produce differentiated products and that they compete monopolistically.

**Lack of economies of scale in the labor input.** Our data allows us to look for direct evidence of economies of scale in labor. We study how labor specialization, teamwork and hours worked vary across the size distribution. Appendix Figure A2 reports the results for our three sectors. Focusing on carpentry, Panel (a) shows that: (i) while we do see some evidence that specialization increases with firm size, this is not strong: the average employee works on half of the production steps even in large firms, which is far from full specialization; (ii) there is little evidence that team-work increases with the size of the firm, except at the very top of the distribution; and, (iii) we do not find that larger firms use the labor input more intensively: workers spend close to three hours per day idle, and this does not vary much by firm size.[32] In short, a more efficient organization of labor or a more intense use of labor are unlikely to drive economies of scale in labor.

We further show that firms operate in a labor market with significant frictions. Appendix Table A4 shows that: (i) most workers are hired through referrals, which is a recruitment

[32]Figures A2b and A2c in the Appendix show similar results for metal fabrication and grain milling.

method difficult to scale up and symptomatic of labor market frictions; (ii) in about a third of cases, the owner would be willing to raise the worker's wages if they threatened to leave; and, (iii) turnover is very low despite the absence of any firing or hiring laws. In short, our data shows labor market frictions are substantial, which in turn suggests the presence of *diseconomies* of scale in labor.[33] For instance, since networks are such an important recruitment channel, we can expect the cost of recruitment to increase exponentially as the manager needs to extend beyond their network of contacts in order to hire more employees (Chandrasekar et al., 2020).

**Demand and competition.** As described above, the rental market takes place within clusters of firms in the same sector. That is, firms rent out their machines to other firms they are potentially competing with. Since an active rental market exists, we must infer that any loss of revenues for machine owners from the increased productivity of surrounding firms must be more than offset by the profits from renting out their machines. Limited competition in the output market would explain the sustainability of this arrangement. We provide two pieces of evidence that suggest that competition is low: (i) firms produce differentiated products; (ii) there are sizable frictions in the output market.

On product differentiation, Appendix Figure S13 shows that there is substantial variation in both prices and quality for 2-panel doors even *within* sub-counties.[34] This confirms that there is substantial differentiation even within narrowly defined products. On output market frictions, Appendix Table A5 shows that: (i) the majority of customers are from within the parish; (ii) firm owners engage in extensive interactions with customers (e.g. they try to persuade customers of the quality of their products, and there is price variation across customers for the same product driven by bargaining); (iii) firms have few customers and cite lack of demand as a very serious problem. This evidence suggests that demand is geographically segmented and that relationships with customers are important, which are both factors that can lower competition.[35] In line with limited competition due to product differentiation and output market frictions, we estimate markups that range between 21%-24% (Appendix Table A1).[36]

# 4 Model

We develop a model consistent with the stylized facts documented in Section 3. The main objective is to characterize and quantify the aggregate and distributional effects of the rental

[33] This result is in line with a number of recent studies highlighting the importance of labor market frictions in developing countries. See, for instance, Alfonsi et al. (2019); Bassi and Nansamba (2019); Abebe et al. (2018); Abel et al. (2019) and Carranza et al. (2019).

[34] For instance, the ratio of the 75th to the 25th percentile of the quality distribution is more than 2.

[35] Another potential reason for limited competition in firm clusters would be collusive behavior on prices. Brooks et al. (2018) document the importance of this channel in Chinese manufacturing.

[36] For more details on the estimation of markups, see Appendix B.2.

market. We build the most parsimonious model that allows us to address this question in the context of our data. The model is intended primarily for the carpentry sector.

This section introduces the economic environment and characterizes its main properties. Section 5 will bring the model to the data, and Section 6 will use the estimated model to unpack the role of the rental market.

## 4.1 Economic Environment

Time is discrete, and the economy is static: we abstract from consumption/savings decisions, and from asset accumulation. This choice is driven by the nature of our data, which is made of only one cross-section.

**Agents.** The economy is inhabited by two types of individuals: workers, and carpentry managers. Workers have a collective yearly income equal to $\Psi$. We do not model their individual behavior, but consider them as consumers and suppliers of labor for the carpentry sector. Carpentry managers, in mass 1, are each identified by a unique index $\omega \in \Omega$. They differ along two dimensions: (i) the shadow cost of capital, $\rho(\omega)$, which captures the fact that some individuals might have more assets for self-financing and/or easier access to credit; (ii) a skill term, $\zeta(\omega)$, which affects both the quality of the manager's products and his[37] productivity, with relative strength modulated by a parameter $\gamma$. To keep the notation light, we omit the index $\omega$, unless necessary, throughout the the model. The cost of capital and managerial skills are jointly distributed across managers with the density $g(\rho, \zeta)$.

**Preferences.** Individuals consume two goods: a general consumption good $Y$, and a composite carpentry good $Y_C$. The utility function is

$$U(Y, Y_C) = \left[(1-\lambda) Y^{1-\iota} + \lambda Y_C^{1-\iota}\right]^{\frac{1}{1-\iota}}$$

where

$$Y_C = \left[\int_{\omega \in \hat{\Omega}} q(\omega) y(\omega)^{1-\eta} d\omega\right]^{\frac{1}{1-\eta}}$$

and $\hat{\Omega} \subseteq \Omega$ is the set of active managers in the economy[38], $q(\omega)$ is a manager-specific quality that depends on his ability $\zeta(\omega)$ and whether he mechanizes, and $y(\omega)$ is quantity produced.

[37]Almost all the managers and workers in our sectors are males, as shown in Table A1.

[38]Not all carpentry managers start a firm in equilibrium, some take an outside option.

**The consumers' problem.** The representative household chooses how much to consume of each good to maximize utility subject to the budget constraint

$$\begin{array}{ll} & \max_{\{y(\omega)\}_{\omega\in\Omega},Y} \left[(1-\lambda)\, Y^{1-\iota} + \lambda Y_C^{1-\iota}\right]^{\frac{1}{1-\iota}} \\ \text{s.t.} & \int_{\omega\in\Omega} p\,(\omega)\, y(\omega) d\omega + Y \leq \Psi \end{array},$$

where the outside good $Y$ is the numeraire. The assumption of CES demand, see Melitz (2003), implies that the price of the variety produced by manager $\omega$ is

$$p\,(\omega) \;=\; \left(\frac{\lambda}{1-\lambda}\right) q\,(\omega) \left(\frac{y\,(\omega)}{Y_C}\right)^{-\eta} \left(\frac{Y_C}{Y}\right)^{-\iota}.$$

As usual, the price is increasing in the goods' quality and decreasing in the quantity produced. To ease the exposition, we define $P \equiv \left(\frac{\lambda}{1-\lambda}\right) Y_C^{\eta-\iota} Y^{\iota}$ so that the price faced by manager $\omega$ is $p\,(\omega) = q\,(\omega)\, y\,(\omega)^{-\eta}\, P$.

**Production function.** Each manager $\omega$ has access to two production processes to produce the good $y\,(\omega)$: a non-mechanized one, that uses only labor, and a mechanized one that uses a combination of labor and capital. For tractability, we do not model the different production steps. This assumption is justified by the fact that firms do not substitute across steps, and that, as we document below, the capital labor ratio is similar across production steps.

If the firm uses the non-mechanized process, output is produced according to

$$y\,(\omega) = \zeta\,(\omega)^{1-\gamma} A_L L\,(\omega)$$

where $L$ is labor and $A_L$ is a productivity term, identical for all managers. If the firm uses the mechanized process, output is produced according to

$$y\,(\omega) = \zeta\,(\omega)^{1-\gamma} A_M K\,(\omega)^{\alpha} L\,(\omega)^{1-\alpha}$$

where $K$ is capital, $A_M$ is productivity, and $\alpha$ is the capital share in production.

The two production processes provide goods of different quality, which in turn affect their prices, as noted. The quality of a good produced by manager $\omega$ is equal to $q\,(\omega) = \zeta\,(\omega)^{\gamma}$ if the manager chooses the non-mechanized process and to $q\,(\omega) = \mu\zeta\,(\omega)^{\gamma}$, with $\mu \geq 1$, if the manager chooses the mechanized process. The outside good $Y$ is in fixed supply.

**Machines and capital market.** Capital is supplied by machines. We assume that there is only one type of machine in the market, which should be interpreted as an aggregate of the different machines documented in the previous section. Machines can be purchased at price $p_b$, where the subscript $b$ is for buying. Machines depreciate at rate $\delta$ and have a convex operating cost given by $\chi(C)$, where $C \leq 1$ is the total machine capacity utilization. Each machine supplies 1 unit of time of production capacity,[39] and machines are indivisible.

Consistent with the empirical evidence, each firm can purchase at most one machine. Firms can purchase machines irrespective on whether they decide to use capital for production or not.

**Rental market for machines.** A manager $\omega$ that purchases a machine, operates it at capacity $C(\omega)$, and uses $K(\omega)$ units of capital in production has excess capacity equal to $C(\omega) - K(\omega) \geq 0$.[40]

Excess machine capacity is rented out to other firms in a competitive market at equilibrium price $p_r$. The market is subject to a transaction iceberg cost $\tau$, or rental market wedge, that firms have to pay for each unit of machine used. The total effective price paid by a renter to use one unit of machine time is $(1+\tau)\,p_r$, while the lender receives the price $p_r$. The wedge $\tau$ captures the cost of moving inputs to the workshop where the machine is located, or the cost of waiting to use the machine.[41] All costs are expressed in units of output.

**Labor market.** Labor is hired in a partial equilibrium market subject to frictions. We model frictions in reduced form as a convex cost of labor: manager $\omega$ hiring labor $L(\omega)$ faces total labor cost equal to $WL(\omega)^{1+\nu}$ where $W$ is the wage level and $\nu \geq 0$ modulates the extent of the frictions. If $\nu = 0$, each manager can hire as much labor as he wishes at the equilibrium wage. Instead, if $\nu$ is positive, the manager faces an increasing labor supply curve and needs to pay a higher wage to grow the firm size. As a result, there is wage dispersion across firms, and a size-wage premium – as in frictional labor models such as Burdett and Mortensen (1998).

**The managers' problem.** Each manager $\omega$ makes several choices. First, before observing his cost of capital $\rho$, he decides whether to enter the market and start producing or take an outside value. The manager ex-ante profits are given by

$$\Pi(\omega) = \max\left\{ \underbrace{\pi_X(\zeta(\omega))}_{\text{Outside Option}} ; E_\rho \underbrace{\left[\pi(\rho(\omega), \zeta(\omega))\right]}_{\text{Production Profits}} \right\},$$

where $\pi_X(\zeta)$ is the exogenous outside option, which we will estimate in the data, and $\pi(\rho, \zeta)$ is the profit of a manager with traits $(\rho, \zeta)$. $E_\rho[\cdot]$ is the expectation taken with respect to the distribution of the random variable $\rho$ conditional on the managerial ability $\zeta$. We use this

[39] In the data, we observe weekly machine hours. We map one unit of time into a full week's worth of utilization, at 10 hours per day for 6 working days (average weekly working hours in carpentry are close to 60).

[40] Managers can either buy or rent in capital, but not both.

[41] In principle, it could also capture departures from perfect competition in the machine market. However, we have shown evidence in the empirical section supporting the idea that the machine market is competitive.

notation throughout the model. The expected profits do not depend on the identity of the manager, or its name $\omega$, but only on its characteristics $(\rho, \zeta)$. Therefore, we omit $\omega$.

If the manager enters the market, he observes his cost of capital $\rho$ and faces two discrete choices. He has to decide whether to mechanize – i.e. use some capital in production – and whether to invest – i.e. buy the machine. As a result, the manager profits are given by

$$\underbrace{\pi(\rho,\zeta)}_{\text{Overall Profits}} = \max \left\{ \underbrace{\pi_L(\zeta)}_{\text{No Mech, No Inv}} \;;\; \underbrace{\pi_{M,r}(\zeta)}_{\text{Mech, No Inv}} \;;\; \underbrace{\pi_{L,b}(\rho,\zeta)}_{\text{No Mech, Inv}} ; \underbrace{\pi_{M,b}(\rho,\zeta)}_{\text{Mech, Inv}} \right\},$$

and we next describe each component in the right hand side.

A manager that does not invest nor mechanize solves

$$\begin{aligned} \pi_L(\zeta) &= \max_L p(\zeta, y)\, y - w(L)\, L \\ s.t. \quad & y = \zeta^{1-\gamma} A_L L \text{ and } p(\zeta, y) = \zeta^{\gamma} y^{-\eta} P \end{aligned}$$

where, as described, $w(L) = WL^{1+\nu}$ and $p(\zeta, y)$ comes from the demand structure.

A manager that does not invest, but mechanizes and rents capital solves

$$\begin{aligned} \pi_{M,r}(\zeta) &= \max_{L,K} p(\zeta, y)\, y - w(L)\, L - p_r(1+\tau)\, K \\ s.t. \quad & y = \zeta^{1-\gamma} A_M K^{\alpha} L^{1-\alpha} \text{ and } p(\zeta, y) = \mu \zeta^{\gamma} y^{-\eta} P. \end{aligned}$$

Relative to the previous case, the manager faces a different production function and a quality improvement due to mechanization, which shows up in the price. Also, the manager has to pay a rental price $p_r$ and a transaction cost $\tau p_r$ for each unit of rented capital. The rental price is paid to the machine lenders, while the transaction cost is a net loss.

A manager that invests has to choose not only his production inputs, but also the total machine capacity to use. For the managers that invest but do not mechanize, the two problems are kept distinct:

$$\begin{aligned} \pi_{L,b}(\rho,\zeta) &= \max_L p(\zeta, y)\, y - w(L)\, L + \max_C p_r C - \chi(C) - (\rho+\delta)\, p_b \\ s.t. \quad & y = \zeta^{1-\gamma} A_L L \text{ and } p(\zeta, y) = \zeta^{\gamma} y^{-\eta} P. \end{aligned}$$

Recall that $\chi(C)$ is a physical operating cost in units of output, which we parametrize as $\chi(C) = \frac{\chi}{1+\xi} C^{1+\xi}$ with $\xi > 1$, and $(\rho+\delta)\, p_b$ is the user cost of machines. We assume, consistent with evidence, that machines are produced and directly sourced abroad, hence the machine price $p_b$ is essentially a net loss from both an individual and an aggregate perspective.

Finally, for a manager that invests and mechanizes, the input decision and capacity utilization are intertwined:

$$\begin{aligned}\pi_{M,b}(\rho,\zeta) &= \max_{L,K,C} p(\zeta,y)\, y - w(L)\, L + p_r (C-K) - \chi(C) - (\rho+\delta)\, p_b \\ s.t. &\qquad y = \zeta^{1-\gamma} A_M K^{\alpha} L^{1-\alpha},\;\; p(\zeta,y) = \mu\zeta^{\gamma} y^{-\eta} P, \text{ and } K \leq C\end{aligned}$$

The two problems are tied together by the fact that the owner can use only as much capital as is supplied by his machine.[42]

The solution to the manager's problem gives the choice of whether to enter, $\mathbb{I}_X(\omega) = 1$ if and only if $\pi_X < \pi(\rho,\zeta)$, as well as the optimal capital, labor, capacity, and output produced - which we label $K(\omega)$, $L(\omega)$, $C(\omega)$, and $y(\omega)$ respectively. The entry choice $\mathbb{I}_X(\omega) = 1$ determines the set of active managers: $\hat{\Omega} \equiv \{\omega \in \Omega \text{ s.t. } \mathbb{I}_X(\omega) = 1\}$. Finally, notice that $K(\omega) = 0$ if manager $\omega$ chooses to not mechanize and $C(\omega) = 0$ if manager $\omega$ chooses to not invest in the machine. We can thus use dummies $\mathbb{I}_K(\omega)$ and $\mathbb{I}_C(\omega)$, which are equal to 1 if $K(\omega)$ and $C(\omega)$ are strictly positive, to keep track of whether a given manager $\omega$ decides to mechanize and/or invest. If a manager $\omega$ does not enter, he has $K(\omega) = C(\omega) = 0$.

## 4.2 Equilibrium

In equilibrium, managers maximize profits, consumers maximize utility, the goods' markets clear, and the rental market for machines clears. The labor market is in partial equilibrium.

**Goods' markets clearing.** It requires two distinct conditions: (i) the relative demand and supply for each internal good $\omega$ must be equal; (ii) the overall demand for the outside good must be equal to the fixed supply $Y$. The first condition pins down the relative price between any two differentiated types of carpentry goods, $\frac{p(\omega')}{p(\omega)}$ . The second one pins down the price level relative to the numeraire, $P$.

**Machines' rental market clearing.** Supply of machine capacity is given by the sum of the machines' capacity chosen by all the managers that decide to invest. It increases in the rental price, due to (i) machine owners' capacity choice; (ii) the share of managers that, conditional on mechanizing, decide to buy rather than rent. Demand for machine capacity is given by the

[42]We are implicitly assuming that managers cannot both use their own machine and rent in additional capital. This assumption is done to avoid keeping track of the possibility that managers are both owners and renters. It does not affect the aggregate results quantitatively since, in the calibration and consistent with the evidence, the majority of managers lease out a positive amount of capital. Further, relaxing this assumption would not alter the theoretical conclusions either. The two problems would still be intertwined as the manager's marginal cost of capital is affected by the capacity choice.

sum of capital utilization of all the managers. It decreases in the rental price because (i) the higher the rental price the fewer managers decide to mechanize; (ii) the higher the rental price the lower the amount of capital that each manager chooses to use, conditional on mechanizing. The equilibrium rental price, $p_r$, is such that demand and supply are equal

$$\int\limits_{\omega\in\Omega} C(\omega)\,d\omega \;=\; \int\limits_{\omega\in\Omega} K(\omega)\,d\omega.$$

To conclude the section, we define the competitive equilibrium.

**Definition of the competitive equilibrium.** *The competitive equilibrium is given by firm capital, labor, capacity and output* $\{K(\omega), L(\omega), C(\omega), y(\omega)\}_{\omega\in\Omega}$*; rental price for machines* $p_r$*, and output price for each active manager* $\{p(\omega)\}_{\omega\in\hat{\Omega}}$ *such that (i) the rental market clears; (ii) the goods' markets clear; (iii) each potential manager maximizes profits; and (iv) the representative consumer maximizes utility.*

## 4.3 Characterization

We next characterize some key properties of the solution to shed light on how the rental market shapes economic activity and productivity within the sector. All the results are proved in Appendix A. To ease exposition and simplify, we show a series of results that hold under an empirically motivated assumption. This assumption is not imposed when solving and estimating the quantitative model in the next section.

**Parametric assumption.** *We assume that the constraint* $C(\omega) \geq K(\omega)$ *is slack for all managers.*

The assumption is motivated by two empirical observations. First of all, the firm-level capital usage is smaller than the market-level capital utilization, suggesting that machine owners have excess capacity to rent out to the market. Second, the great majority of firms own only one machine of each type, which again reinforces the idea that firms have often excess capacity for each machine. In practice, the assumption guarantees that machine buyers are also renting out part of their machine time. This implication is consistent with our data, where we see that over 70% of carpenters who own machines also rent out their machines to others.

When the constraint $C(\omega) \geq K(\omega)$ is not binding, capacity utilization is pinned down by the market value of machine time, the interest rate $p_r$. As a result, each machine is used with similar overall capacity $C = \chi^{-\frac{1}{\xi}} p_r^{\frac{1}{\xi}}$ and higher ability managers, since they produce more, use a larger share of the total machine capacity for their own production. Furthermore, the rental profits for a manager that leases out all the capacity are

$$\tilde{m}(\rho) = \left(\frac{\xi}{1+\xi}\right) p_r C - (\delta + \rho) p_b.$$

**Lemma 1.** *A manager $(\zeta, \rho)$ has overall production and rentals profits given by*

$$\begin{aligned} \pi_L(\zeta) &= \tilde{A}_L \zeta^{\tilde{\gamma}_L} \\ \pi_{L,b}(\zeta,\rho) &= \tilde{A}_L \zeta^{\tilde{\gamma}_L} + \tilde{m}(\rho) \\ \pi_{M,r}(\zeta) &= \tilde{A}_{M,r} \zeta^{\tilde{\gamma}_M} \\ \pi_{M,b}(\zeta,\rho) &= \tilde{A}_{M,b} \zeta^{\tilde{\gamma}_M} + \tilde{m}(\rho) \end{aligned}$$

*where $\tilde{\gamma}_M > \tilde{\gamma}_L$, $\tilde{A}_{M,b} \geq \tilde{A}_{M,r}$, and all the tilde-variables are explicit functions of primitive parameters included in the Appendix.*

Lemma 1 shows that the mechanized production process is more sensitive to managerial skills, as captured by the fact that profits are more convex in managerial ability $\zeta$ for managers that decide to mechanize.[43] It implies that the $(\zeta, \rho)$ state-space is partitioned into compact regions with different production choices. The shape of the partitioning depends on the rental market wedge $\tau$, as is formalized in Proposition 1.

**Proposition 1.** *The solution of the manager's problem yields policy functions $\mathbb{I}_C(\omega)$ and $\mathbb{I}_K(\omega)$ that satisfy the following properties:*

- *if $\tau = 0$, there exists values $\hat{\rho}_1$ and $\hat{\zeta}_1$ such that: (i) $\mathbb{I}_C(\omega) = 1$ if and only if $\rho(\omega) \leq \hat{\rho}_1$; and (ii) $\mathbb{I}_K(\omega) = 1$ if and only if $\zeta(\omega) \geq \hat{\zeta}_1$;*
- *if $\tau \in (0, \infty)$, there exists values $\hat{\rho}_2$, $\hat{\zeta}_{2,a}$, and $\hat{\zeta}_{2,b}$ and a strictly increasing function $\tilde{\rho}_2(\zeta)$ such that: (i) $\mathbb{I}_C(\omega) = 1$ if and only if $\rho(\omega) \leq \hat{\rho}_2$ or $\zeta(\omega) \geq \hat{\zeta}_{2,a}$ and $\rho(\omega) \leq \tilde{\rho}_2(\zeta)$; and (ii) $\mathbb{I}_K(\omega) = 1$ if and only if $\zeta(\omega) \geq \hat{\zeta}_{2,a}$ and $\rho(\omega) \leq \tilde{\rho}_2(\zeta)$ or $\zeta(\omega) \geq \hat{\zeta}_{2,b}$.*
- *if $\tau \to \infty$, there exists a value $\hat{\zeta}_3$ and a function $\tilde{\rho}_3(\zeta)$ such that: (i) $\mathbb{I}_C(\omega) = 1$ if and only if $\zeta(\omega) \geq \hat{\zeta}_3$ and $\rho(\omega) \leq \tilde{\rho}_3(\zeta)$; and (ii) $\mathbb{I}_K(\omega) = 1$ if and only if $\zeta(\omega) \geq \hat{\zeta}_3$ and $\rho(\omega) \leq \tilde{\rho}_3(\zeta)$.*

*Given a set of active managers $\hat{\Omega}$ and an aggregate output price $P$, the equilibrium rental price $p_r$ is decreasing in $\tau$, but $p_r(1+\tau)$ is increasing in $\tau$. Also, $\hat{\zeta}_3 \leq \hat{\zeta}_{2,a} \leq \hat{\zeta}_1 \leq \hat{\zeta}_{2,b}$; $\hat{\zeta}_{2,a}$ is decreasing in $\tau$; $\hat{\zeta}_{2,b}$ is increasing in $\tau$; $\hat{\rho}_2 \leq \hat{\rho}_1$; and $\hat{\rho}_2$ is decreasing in $\tau$.*

[43]This is because the cost of labor is convex while the cost of capital is linear. Intuitively, it is costlier to scale up using labor only. We could obtain the same result by assuming that non-mechanized firms produce according to $y(\omega) = \zeta(\omega)^{1-\gamma} A_L L(\omega)^{\beta}$, with $\beta < 1$.

Figure 4 helps to visualize Proposition 1: it illustrates the partitions of the $(\rho, \zeta)$ space in the three cases.[44] When the rental market is frictionless – i.e. $\tau = 0$ – the choice to invest in machines and to mechanize are separate. The first one depends on the manager's cost of capital $\rho$, while the second one on the manager's productivity $\zeta$. When $\tau > 0$, the choice to invest and mechanize are, instead, endogenously correlated. Managers that purchase the machine face a lower marginal cost of capital, and are thus more likely to mechanize as well. In the extreme case when $\tau \to \infty$, mechanization is possible only through investment in machines, and as a result the two choices are perfectly intertwined.[45]

We conclude that a well-functioning rental market (i.e. a rental market with low $\tau$) has two benefits: (i) allows more firms to access machines ; (ii) provides an efficient allocation of machine ownership and utilization across firms. When $\tau$ is small, only firms with the lowest cost of capital purchase the machine, and only the firms with the highest returns from using capital decide to mechanize.

# 5 Estimation

Next, we estimate the model. First, we describe how we make the model amenable to empirical analysis. Then, we show how we can leverage our unique data to pin down the parameter $\tau$ that modulates the strength of the rental market frictions. Finally, we discuss how all the other parameters are jointly identified and estimated using the structure of the model.

## 5.1 Bringing the Model to the Data

We make two small changes to the model described in the previous section: (i) we introduce extreme value shocks to smooth out the discrete choice of managers of whether to enter, mechanize, and invest in machines; (ii) we introduce an external sector that specializes in renting out machines, and that supplies a calibrated share of overall market capacity.

Each manager $\omega$ draws two vectors of preference shocks: (i) $\{\varepsilon_X; \varepsilon_N\}$ where $\varepsilon_X$ is for exit, and $\varepsilon_N$ for entry; (ii) $\{\varepsilon_n(\omega)\}_{n \in \mathbb{N}}$, where $\mathbb{N}$ is the set of four possible production methods, or the combination of the investment and mechanization choices.[46] The shocks are distributed

[44] The comparative statics as a function of $\tau$ hold for a given set of managers active in the sector. In general, a change in $\tau$ also affects the entry decision and may change the relationship between the cutoffs for managerial ability and the cost of capital. Nonetheless, the general features of the solution are unaffected by managers' entry. In fact, Figure S16 in the Appendix shows that Proposition 1 holds in the estimated model.

[45] When $\tau \to \infty$ there is essentially no rental market, since the marginal cost of capital for renters is infinite.

[46] In practice, managers that invest can also choose capacity equal to zero and not pay the investment cost. In this way, we guarantee that managers only invest if it is profitable to do so. More details are in Appendix A.

according to independent Type I Extreme Value Distribution with shape parameters $\frac{1}{\bar{\theta}}$ and $\frac{1}{\theta}$ respectively.

Given the realization of the first vector of shocks, the manager decides whether to enter, taking into account the expected value of production which depends on the realization of the second vector of shocks:

$$\Pi(\omega) = \max\left\{\varepsilon_X(\omega)\,\pi_X(\omega)\,;\varepsilon_N(\omega)\,\pi_N(\omega)\right\}$$

where

$$\pi_N(\omega) = \mathrm{E}_{\rho,\varepsilon}\left[\max_{n\in\mathbb{N}}\varepsilon_n(\omega)\,\pi_n(\rho(\omega),\zeta(\omega))\right].$$

Specialized machine lenders do not produce carpentry good themselves, but own capital that they rent out to carpenters. As described below, our data shows that this sector is quantitatively important. There is a fixed mass $\phi$ of machine lenders. They face the same cost of capacity utilization as carpentry firms. We do not need to take a stand on their interest rate $\rho$ because they are in fixed supply and their profits are not included in the sector GDP. Each machine lender solves the capacity maximization problem

$$\max_{C} p_r C - \chi(C).$$

The solution to the problem yields an additional supply of capital in the market equal to $\phi\chi^{-\frac{1}{\xi}}p_r^{\frac{1}{\xi}}$, where $\chi$ and $\xi$ are the same parameters as in the carpentry problem, and $p_r$ is the equilibrium market price of rented capital. The two changes only marginally affect the definition of the equilibrium; we include the new definition in Appendix A.

A few results, proved and expanded in Appendix A, provide useful structural restrictions. Frechet-distributed taste shocks smooth out discrete choices and provide analytical expressions for the probability that each option is chosen. The parameter $\theta$ modulates the relative roles of shocks and individual characteristics in determining production choices. The higher is $\theta$, the closer the equilibrium resembles the partitions shown in Figure 4. If $\theta \to 0$, all managers are equally likely to adopt any production method, irrespective of their skills and cost of capital.

The presence of the taste shocks does not affect the optimal input choices for each production method. As a result, the estimation can leverage the analytical tractability of Cobb-Douglas production and CES demand. The ratio of capital to labor expenditure pins down the capital share in production for the managers that mechanize. The profit share of revenues is decreasing in the elasticity of substitution $\frac{1}{\eta}$ and increasing in the curvature of the cost of labor $\nu$ since firms are not price takers in the labor market. Also, firm price decreases in *quantity* and increases in *quality* which implies that higher ability managers (i.e. managers with higher $\zeta$)

may charge a higher or lower price depending on the value of $\gamma$.[47] Finally, but most importantly, the framework offers a relationship between observable variables that can be used to pin down the rental wedge $\tau$ in the data.

**Lemma 2.** *Consider a manager $\omega$ that chooses a mechanized production process. His log capital stock is given by*

$$\log K(\omega) = \hat{\alpha} + \log L(\omega) + \log w(\omega) - \log p_r - \mathbb{I}_{M,r}(\omega) \log(1+\tau) \tag{1}$$

*where $\hat{\alpha}$ is a constant term, $w(\omega) = WL(\omega)^{1+\nu}$ is the average wage paid by manager $\omega$, and all other terms are as previously defined.*

Lemma 2 follows from comparing the optimal capital labor ratio of owners and renters. The relative capital intensity of production $(\log K(\omega) - \log L(\omega))$ depends, as usual, on relative prices. For machine owners, the marginal cost of capital is the opportunity cost of renting out, $p_r$. Machine renters instead face a higher effective cost of capital, since they have to pay a wedge $\tau$ on top of the direct rental fee. The wedge $\tau$ distorts the capital labor ratio of renters compared to owners: renters use relatively more labor.

Next, we describe our overall estimation strategy. We parametrize the value of the outside option as follows

$$\pi_X(\omega) = \tilde{\pi}_X (E_\omega [\pi_N(\omega)])^{1-\psi} (\pi_N(\omega))^{\psi}$$

where $\tilde{\pi}_X$ captures the relative return of the outside option, while $\psi$ captures how sensitive this is to managers' ability. When $\psi = 1$ and $\tilde{\pi}_X = 1$, the outside option is identical to the expected profit from entry, and thus managers are going to be randomly selected. When $\psi = 0$, the outside option is identical for everyone, thus leading to positive selection of managers. We also parameterize the joint distribution of $(\rho, \zeta)$ as two correlated log-normals, yielding five free parameters: $\{\mathrm{E}(\rho), \mathrm{Var}(\rho), \mathrm{E}(\zeta), \mathrm{Var}(\zeta), \mathrm{Cov}(\rho, \zeta)\}$. Finally, we normalize $A_L = 1$.

We need to pin down a vector of 24 parameters, which are shown in Table 3. We pin down $\tau$ in the data using the empirical specification provided by Lemma 2. We then calibrate the six parameters that have direct empirical counterparts outside of the model. We jointly estimate by simulated method of moments the remaining 17 parameters to match the 23 moments included in Table 4. We next describe the calibration/estimation of each parameter in detail.

## 5.2 Estimating the Rental Market Wedge $\tau$

Lemma 2 provides an estimating equation to pin down $\tau$ in the data. The core of Lemma 2 is that firms who rent machines use relatively more labor than capital to perform the same

[47] Recall that $\gamma$ modulates the effect of $\zeta$ on output quality and productivity.

task. To bring this to the data, we focus on production steps - that are clearly defined tasks in our case - and approximate equation 1 by regressing a step-level measure of capital utilization on the share of capital in that step that is rented, controlling for the step-specific labor cost. Specifically, we create a dataset where each observation is a production step $s$ in a firm $j$, and run the following regression on the pooled sample of firms and production steps:

$$\log(K_{sj}) = \beta_0 + \beta_1 Rent_{sj} + \beta_2 \log(w_j \times L_{sj}) + \vartheta_s + \gamma X_j + \delta Z_{sj} + \epsilon_{sj} \tag{2}$$

where $\log(K_{sj})$ is the log of total monthly machine hours used by firm $j$ in production step $s$;[48] $Rent_{sj}$ is the share of the machines used by firm $j$ in step $s$ that are rented; $w_j$ is the predicted average hourly wage of the employees in firm $j$;[49] $L_{sj}$ is the monthly labor hours used by firm $j$ in step $s$; $\vartheta_s$ are step fixed effects (e.g. dummies for planing, thicknessing etc).

Our key independent variable of interest is $Rent_{sj}$. Equation 1 shows that the coefficient $\beta_1$ is directly related to the rental market wedge $\tau$ as follows: $\beta_1 = -\log(1+\tau)$. The inclusion of $\log(w_j \times L_{sj})$ accounts for the labor cost, that is $\log L(\omega) + \log w(\omega)$ in equation 1. Identification of $\beta_1$ requires that renters and owners face the same rental cost $p_r$, and so we control for sub-county fixed effects, in order to compare firms in the same local rental market.

In our preferred specification we also control for additional firm-level characteristics ($X_j$) and for characteristics of the machines used in step $s$ by firm $j$ ($Z_{sj}$) to account for potential sources of heterogeneity not included in the model but that might be relevant in the data. For instance, one concern is that lower ability managers (and their employees) are less skilled in using machines, and so are more likely to rely on labor and to rent rather than own machines. As shown in Appendix Table S6, lack of skills is not a primary reason why managers report not using certain machines. Still, to account for this possibility, we control for our measure of manager ability as well as quantity and quality of doors produced. A different concern relates to the nature of the capital input: if machines that are rented out tend to be of lower quality, that might induce renters to rely more on labor and less on capital in production. Again, firms do not report this as an important reason for owning rather than renting (Appendix Table A2). Nevertheless, our data allows us to control for a wide range of machine characteristics such as machine value and expected remaining life. To run regressions at the step-level, we control for the step-level averages of such machine characteristics.

Since most firms operate machines in multiple steps, we can estimate an alternative specification with firm fixed effects, which compares the utilization of rented and owned machines across steps *within* the same firm. This approach has the advantage that it perfectly controls for unobserved firm and product characteristics. However, it only exploits variation coming

[48] In Appendix B.1 we describe how we assign machines to steps.

[49] We prefer to control for predicted wages (rather than actual wages) to alleviate endogeneity concerns. See the footnotes to Appendix Table A12 for more details on how predicted wages are computed.

from firms that partly own and partly rent machines, and the share of such firms is 44%.

Table 2 reports the results of OLS estimation of equation 2. The sample is restricted to door producers in carpentry, and to the seven steps that are most common across firms, that is steps 3-9, as shown in Figure S3. Column 1 reports our preferred estimate of $\beta_1$. This is $-0.34$, significant at the 1% level. This means that in steps where machines are rented (as opposed to owned), machine utilization is 34% lower. Column 2 shows that the results are very similar when firm fixed effects are included ($\hat{\beta}_1 = -0.39$). To gauge the importance of including control variables, in column 3 we drop all controls apart from step and sub-county fixed effects and in column 4 we add back only the labor cost control at the step level. We note that the estimate of $\beta_1$ becomes more negative. This result is in line with the model prediction that smaller and less productive firms are more likely to rent, and so highlights the importance of including controls. We implement two further robustness checks. First, Appendix Table A6 shows that estimating equation 2 separately for each step yields mostly negative $\hat{\beta}_1$. This justifies our pooled specification in Table 2. Second, we run the same specifications as in columns 1 and 2 of Table 2 but at the machine level rather than at the step level: the results, in columns 5 and 6 of Table 2, are remarkably similar.[50]

Our preferred specification in column 1 implies an estimate of $\tau = e^{0.34} - 1 = 0.404$. This indicates that the rental market wedge is approximately 40% of the direct machine rental price: transportation and coordination costs in the rental market, while significant, are not prohibitively large. To validate the estimated wedge, we compare its magnitude to direct information on transportation and time costs of using the rental market. In Appendix Table A2, we compute for each renter: (i) their monthly value of time spent traveling to the machine owners' premises and waiting for machine access; (ii) their direct monthly transportation costs from using motorcycle taxis. Comparing the sum of (i) and (ii) with the monthly expenditures on machine rentals shows that transportation and time costs represent \$45.5/\$180.1 = 24.4% of direct expenditures on rentals. That is, we are able to explain almost 2/3 of the estimated rental market wedge through direct transportation and time costs. This reassures us about the validity of our estimated wedge. There are clearly other transaction costs that we are not able to measure in our data (e.g. the risk of missing a sale if customers visit while the manager is at the premises of the machine owner), which can account for the remaining difference.

## 5.3 Estimating the Other Parameters

Equipped with an estimate for the rental market friction $\tau$, we turn to the other parameters.

[50]We do not have information on the assignment of labor hours to specific machines, and so in column 5 the labor cost variable is calculated at the firm level (i.e. summing across production steps). This variable varies at the firm level and so is not included in column 6 which controls for firm fixed effects.

**Calibrated parameters.** Panel B in Table 3 includes the six calibrated parameters, which we next briefly discuss, their values and references to the Appendix tables where we compute them and show robustness. More details can be found in Appendix B.1.

Due to the Cobb-Douglas production, the capital share $\alpha$ is pinned down by the ratio of the capital and labor expenditures. Our data allows us to compute the capital-labor ratio within each production step for those firms that mechanize. We focus on machine owners since their marginal cost of capital is not affected by the rental market friction. We compute the total capital expenditure as the monthly hours of machine time used by the firm, priced at their average rental rates in the data. We compute the labor expenditure as the monthly labor hours used by the firm, priced at the predicted firm-specific average hourly wage.[51] The capital labor ratios are very similar across steps. We compute the average, weighted by the share of labor expenditures in each step, and find $\alpha = 0.50$: mechanized firms spend roughly equal amounts on labor and capital inputs.

As mentioned, in our model there is only one representative machine. We therefore aggregate the rental and purchase prices, $p_r$ and $p_b$, of all the machines in our dataset using a weighted average of the reported ones. The weights are given by the overall number of hours that each type of machine is used in our data. The representative machine costs \$776.2 and is rented at \$0.514 cents per hour.

To calculate machine depreciation, we first compare the price of new machines to the value and age of the currently owned ones. Prices and values are self-reported by managers. We then aggregate across machine types using the same weights as for prices. The representative machine depreciates at an yearly rate of 6.9%.

Using the same aggregation described above, we calculate the share of total machine capacity supplied from specialized lenders. We find that this share is 49.4% , which leads to $\phi = 0.976$ when we normalize the mass of active managers to be equal to 1.[52]

The elasticity of substitution for the composite carpentry good, which is $\frac{1}{\iota}$ in the model, does not affect the estimation but is necessary to compute general equilibrium counterfactuals. We are not aware of any estimate for Uganda. We thus use results from Broda and Weinstein (2006), which estimate the elasticities of substitution for 3 digit industries using U.S. data. The median value across all industries is 2.2 and the mean is 4. The estimates for the categories that most closely correspond to our industry are: 2.18 for "Wood Manufactures, N.E.S." and 2.53 for "Furniture and parts thereof.". In view of this evidence, we use 2.2 as our benchmark value (so that $\iota = 0.45$), and we consider 1 and 4 for robustness.

[51] Firm specific average hourly wages are predicted in exactly the same way as for the creation of the labor cost control in Section 5.2.

[52] This normalization is without loss of generality: only the share of capacity supplied from outside lenders matters for the equilibrium outcomes.

**Jointly identified parameters.** Panel C in Table 3 shows the 17 parameters that are jointly estimated. We target 23 moments computed from our data. These are shown in Table 4, which also indicates the Appendix tables where the moments are constructed. We leave to Appendix B.2 a detailed description of how the moments are computed and of robustness checks.

Our estimation approach is standard: we run the same regressions using both our survey data and the model-generated data, and all parameters are jointly estimated through simulated method of moments. Here we provide a heuristic identification argument for how the targeted moments pin down the parameters of interest. We explicitly link each parameter to one or more moments, but note that they are all connected through general equilibrium interactions.

First, we describe the parameters broadly related to mechanization and managers' productivity. $A_M$ is the relative productivity of the mechanized process and targets the mechanization rate (row 1 in Table 4): the higher $A_M$, the more managers decide to mechanize. In the model, the mechanization rate is the share of firms that mechanize the production process. In the data, we have multiple types of machines, and thus we compute the mechanization rate as the share, properly weighted, of all the different types of machines used by the firm.

$\mu$ is the relative quality of goods produced with the mechanized process. It targets the relationship between mechanization and price (row 9). If $\mu$ is large, mechanized goods are of higher quality and thus cost more. Similarly, the role of managerial ability in determining quality rather than quantity, modulated by $\gamma$, is pinned down by the empirical relationship between price and managerial ability (row 10).

$\frac{1}{\theta}$ is the variance of the shocks that guide the choice of production process. If $\theta$ is low, the mechanization choice is mostly driven by the random shocks rather than by manager characteristics. The relationship between mechanization rate and managerial ability $\zeta$, properly normalized, pins down $\theta$ (row 7): it is steep if $\theta$ is high. As a proxy of managerial ability $\zeta$ we use our standardized index of managerial ability described in Section 3. The index is normalized with mean 0 and standard deviation 1. We normalize $\log \zeta$, in the same vein, before running the regressions with the model-generated data.

$E[\log \zeta]$ is the average ability of managers. Given the price of the representative machine, the larger is the average ability, the more capital managers would like to use. To pin down $E[\log \zeta]$, we target the average firm-level capacity utilization (row 3), which is the machine hours that a firm uses on average, divided by the maximum machine capacity that is assumed to be 60 hours per week. $Std(\log \zeta)$, instead, impacts the variance of profits. We pin it down by targeting the relationship between log revenues and normalized managerial ability (row 6). The larger is $\text{Std}(\log \zeta)$, the bigger the profit gap between relatively high and low skilled managers.

Second, we describe the parameters related to the investment choice and machine capacity utilization. The rental and purchase prices , $p_r$ and $p_b$, and the depreciation rate $\delta$ are computed in the data, as discussed above. We also observe the average number of hours that each machine is used in the market (by both the machine owner and firms that rent out the machine), which we use to compute the capacity utilization of the representative machine, again assuming 60 hours per week as full capacity (row 4). The cost of machine capacity is given by $\frac{\chi}{1+\xi}C^{1+\xi}$, and the optimal capacity and lending profits, are $C = \chi^{-\frac{1}{\xi}} p_r^{\frac{1}{\xi}}$ and $\left(\frac{\xi}{1+\xi}\right) p_r C - (\delta + \rho)\, p_b$. As expected, the more expensive the cost of capacity utilization $\chi$, the lower the capacity. Also, the larger is $\xi$, the higher the profitability of machine lending, hence the more managers choose to invest. We can thus pin down $\xi$ using the market clearing conditions.

The investment decision depends also on the distribution of the cost of capital $\rho$. The lower is $\mathrm{E}(\log\rho)$, the more managers will invest. High ability managers have larger incentives to invest, implying that the correlation between the cost of capital $\rho$ and the manager ability $\zeta$ impacts the overall share of managers investing, or the investment rate. If $\mathrm{Cov}(\log\rho, \log\zeta)$ is negative and large, the probability of investing would increase steeply with managerial ability. We pin down $\mathrm{E}(\log\rho)$, $Std(\log\rho)$, and $Cov(\log\rho, \log\zeta)$ targeting the average investment rate (row 2), the relationship between investment rate and managerial ability (row 8), and the mean and standard deviation of the interest rate among managers who borrow (rows 22 and 23).[53]

Third, we describe the parameters determining the extent of competition in the markets for output and labor. As discussed, the lower the elasticity of substitution across varieties – i.e. the higher is $\eta$ – the larger the markup, which we target (row 21). The stronger are labor market frictions – i.e. the larger is $\nu$ – the more wages are increasing with firm size. The model also implies that firm size is increasing in managerial ability and that the larger are labor market frictions, the more high ability managers will rely on capital rather than labor to scale up . Therefore, we target the relationship of wages with firm size (row 20) and of wages, capital, and labor with managerial ability (rows 19, 11, and 12).[54] Finally, the average wage level $W$ is pinned down by the average hourly wage rate (row 18).

Fourth and last, we describe the parameters that modulate the decision to become a manager. We parameterize the outside option such that $\tilde{\pi}_X$ captures its value relative to becoming a manager, and $\psi$ captures how sensitive it is to managers' ability. The size of $\tilde{\pi}_X$ is directly related to the share of individuals that choose to be managers (row 13). A low $\psi$ implies that skills are less relevant if individuals choose not to become managers. Our data suggests that, for most managers, the outside option is to be a worker in the same industry.[55] We thus discipline $\psi$ by targeting the relative income inequality of managers and workers (row 15). Of course, $\psi$, together with the variance of the taste shock for entry $\frac{1}{\theta}$, determines also how selected on ability

[53] In the data, we only observe the interest rate for managers with an outstanding loan. In the model, we compute the statistics on $\rho$ for managers that invest. In Appendix B.2 we provide more details on this. In particular, we show that managers that invest face lower cost of capital, which is consistent with the model.

[54] The wage of a firm of size $L$ is given by $WL^{\nu+1}$. As a result, a regression of log wage on log size exactly identifies $\nu$. Nonetheless, we choose to target a bundle of moments rather than rely uniquely on the regression of wage on size, which might suffer from omitted variable bias, as we further discuss in Appendix B.2.

[55] 86% of managers report having worked as employees at some point in the past.

managers are. The distribution of ability among managers and workers impacts their relative income inequality as well. For these reasons, we target the average ability gap between workers and managers (row 14), and their relative within group ability dispersion (row 16). Finally, we target the relationship between the decision to become a manager and the rank of managerial ability (row 17). This last moment captures managers' selection without being affected by the distribution of ability, $Std(\log \zeta)$. It helps to achieve a tighter identification of $\frac{1}{\theta}$.

**Simulated method of moments and model fit.** We solve for the set of parameters $\varphi$ that satisfies $\varphi^* = \arg\min_{\varphi \in \mathbb{F}} \mathcal{L}(\varphi)$, where $\mathcal{L}(\varphi) \equiv \sum_x \left[ (m_x(\varphi) - \hat{m}_x)^2 \right]$, $m_x(\varphi)$ is the value of moment $x$ in our model given parameters $\varphi$, and $\hat{m}_x$ is the properly normalized vector of moments computed in the data.[56] The empirical targets $\hat{m}_x$ and the model computed moments $m_x(\varphi^*)$ are shown in Table 4. The model fits the data well, which is not surprising given that we have 17 free parameters to target 23 moments. Most importantly, we show in Appendix E that the likelihood function $\mathcal{L}(\varphi)$ is single peaked around the estimated value $\varphi^*$, thus suggesting that the model is tightly identified, at least locally.

The estimated parameters are shown in Table 3. A few comments are in order. Rows (8) and (9) show that mechanization increases both physical productivity and product quality, consistent with the evidence shown in Table 1 and discussed in Section 3. Row (19) shows that there are moderate decreasing returns to scale coming from product differentiation. The elasticity of substitution across doors is roughly 12, consistent with the fact that we are looking at a narrow sector, where product differentiation is present, but limited.[57] Row (20) shows that the estimated size of the labor market friction $\nu$ is almost identical to what would be pinned down from a regression of wage on size, although several other moments help us to identify $\nu$ in the estimation. The labor frictions are sizable, consistent with the direct evidence in Appendix Table A4. One way to interpret the size of $\nu$ is to notice that the markup, which is inversely related to firm size, would decrease by approximately 50% in the absence of labor market frictions. Rows (16), (17) and (18) show that the cost of capital is high, varies widely across individuals and is negatively correlated with managers' ability. This result is consistent with evidence in the literature (see Banerjee (2003)) and from our context, as we discuss in Appendix B.2. Last, the variance of the production choice shocks is notably larger than the one of the entry choice shocks – i.e. $\frac{1}{\theta} > \frac{1}{\theta}$. As a result, individual characteristics are a stronger determinant of the decision to become a manager than of the decision to mechanize. This results likely captures the fact that switching across production methods has smaller associated fixed costs than starting a firm.

[56] In Supplemental Appendix E we describe the estimation procedure, which is standard.

[57] In this setting, the parameter $\eta$ may also capture frictions in the output market.

# 6 Quantifying the Importance of the Rental Market

We use the estimated model to study the role of the rental market in shaping economic activity in the carpentry sector. The results are specific to our context, but they clarify the mechanism through which a well-functioning rental market can affect the organization of production. Section 7 further discusses the external validity and general lessons from our results.

## 6.1 Aggregate Effects on Output, Employment and Productivity

We compute the equilibrium of an economy that keeps all primitive parameters constant at their estimated values but varies the level of frictions in the rental market – i.e. the rental market wedge $\tau$.This exercise essentially computes the long-run impact of a country-wide policy that affects $\tau$. In the long run, the change in $\tau$ possibly leads managers to switch their entry decisions and their production methods. A country-wide policy would affect the rental price of machines and the price of the composite carpentry good. Our model takes all these effects into account.

Figure 5 shows the main results. We consider values of the rental market wedge $\tau \in [0, \bar{\tau}]$. $\tau = 0$ represents a frictionless economy. $\bar{\tau}$ is a value sufficiently large to shut down the rental market. We plot four statistics of interest, normalized relative to an economy with no rental markets, as a function $\tau$. We also consider 1 and 4 as alternative values of $\frac{1}{\iota}$ (2.2. is the benchmark value, as explained before). We highlight the estimated value of $\tau = 0.404$ with a dashed red line.

The first three panels show that the rental market has a large effect on aggregate output, labor productivity and mechanization. Going from an economy without a rental market to one with a frictionless rental market increases aggregate output by 28%, average labor productivity by 15%, and the share of firms that are mechanized by 174%. Importantly, our benchmark economy with $\tau = 0.404$ achieves more than half of the total possible gain. In this sense, the rental market in urban Uganda is a key determinant of aggregate productivity and allows firms to reap a large share of the benefits of scale or to *achieve scale collectively.*

The last panel shows the impact of the rental market on aggregate employment. This is driven by the interaction of two forces. On one side, a lower $\tau$ increases productivity, thus allowing the sector to grow and hire more labor. On the other , a lower $\tau$ decreases the marginal cost of capital, thus leading firms to substitute labor for capital. If $\iota$ is large, the scope for the carpentry sector to expand is limited and thus the latter force dominates.

## 6.2 Equilibrium Effects

Next, we shed light on the mechanisms behind the aggregate effects and highlight the importance of equilibrium effects. To do so, we reduce the rental market friction to zero while shutting down different channels in the model. To ease interpretation, we connect the results to the impacts of randomized control trials targeting different groups of firms.

Table 5 shows the results. Column 1 shows the effect when all channels are allowed to operate. As previously discussed, reducing the rental wedge increases aggregate output, employment, labor productivity, and mechanization. It also reallocates capital from owners to renters and increases the mass of active managers, as more individuals find it optimal to enter the sector. Prices are also affected: row (7) shows that the rental market price increases as the lower $\tau$ leads to increased demand for capital, and row (9) shows that the output price decreases as the sector expands. These results correspond to the aggregate effect of a a country-wide and permanent intervention that successfully reduces $\tau$ to zero. This case serves as a benchmark.

In column 2, we keep constant the aggregate price of the carpentry good, and the entry choice.[58] The effects on output and productivity are similar to column 1, but slightly smaller. Preventing firm entry reduces the number of active managers, which mechanically reduces output, and the supply of capital in the economy. While the demand for capital is also lower, the net effect is a relative increase in the rental price of capital which leads fewer managers to mechanize, and the ones that do to operate at lower capital intensity. This exercise corresponds to a clustered RCT, which reduces the rental market friction for all the firms operating within a cluster constituting a closed rental market, but which is too small to affect aggregate output price and entry decisions. In order to make the results comparable with column 1, we create the aggregate effects in column 2 by assigning to all firms in the economy the average treatment effects from this clustered RCT.

In column 3, we also keep constant the rental price of machines. The effects are in the same direction as the ones of column 1, but much larger. The increase in both output and labor productivity are almost four times as large. In the model, three types of equilibrium effects dampen the aggregate results: a reduction in the rental market friction (i) leads marginal, lower ability managers to enter, (ii) increases the price of machines in the rental market and (iii) decreases the price of output. Mirroring the previous case, the results in column 3 correspond to the average treatment effect (assigned to all firms in the economy) of an intervention that targets a small number of individual firms rather than clusters, so that none of these three channels is operating to dampen the effects.[59]

Finally, in column 4 we also keep the production method constant and do not allow firms to change their mechanization choice. This aggregate effect would correspond to the average treatment effect of an intervention that *temporarily* reduces $\tau$ for a small number of individual firms, thus not leading managers to change their mechanization choices in response. Relative to column 3, the effect on employment is larger and the one on labor productivity smaller. In

[58]For this reason rows (8) and (9) are left blank in column 2. This same logic applies to the other empty cells.

[59]That is, we assume that the intervention targets a small enough share of firms in the market that prices of inputs or outputs are not affected.

this case, the effects are purely driven by an increase in capital utilization due to a reduction in its effective marginal price. No other mechanism is at play here. When firms are allowed to change production methods, many are induced to mechanize, thus substituting capital for labor, and increasing productivity.

Overall, this analysis shows the importance of taking into account equilibrium effects when estimating the gains from the the rental market. Such equilibrium effects are large in this setting. More broadly, our results highlight the challenge of extrapolating from partial equilibrium reduced form estimates to aggregate predictions (Bergquist et al., 2019; Egger et al., 2019).

## 6.3 Distribution of Economic Activity

The aggregate effects of the rental market hide substantial heterogeneity: while everyone benefits, the rental market favors relatively unproductive entrepreneurs, as Figure 6 shows.

The left panel shows that decreasing $\tau$ has a larger effect on labor productivity, or revenues per worker, for the low ability managers. A decrease in $\tau$ increases labor productivity through two margins: (i) capital intensity of renters increases since the marginal cost of capital is lower, and (ii) more individuals mechanize as this becomes more profitable due to the lower effective cost of capital. Both effects are, in our estimated economy,[60] larger for lower productivity managers. The reason is that these managers are more likely to be renters since: (i) they operate at smaller scale, which makes it relatively more expensive to pay the fixed cost to purchase a machine; and (ii) given the estimated negative correlation between $\rho$ and $\zeta$, they have, on average, a higher cost of capital.

The middle panel, instead, highlights one channel through which high ability managers benefit relatively more from a well-functioning rental market: they are more likely to invest, as we discuss below, and thus more positively affected from the higher revenues generated in the rental market.[61]

The third panel shows that, overall, relatively low ability managers benefit more. Reducing the rental wedge, by allowing low productivity entrepreneurs to mechanize without the need to pay the investment cost, leads more of them to enter and gain market share.

## 6.4 Efficiency of Investment and Mechanization Choices

To conclude this section, we discuss the role that the rental market plays in allocating capital and machines efficiently across managers. Managers differ along two dimensions, the interest rate $\rho$ and ability $\zeta$, which determine their cost of capital and the return from using it. In a first

[60] Theoretically, the effect does not have to be monotonic since the very low productivity managers might not be sufficiently productive to mechanize even with lower $\tau$.

[61] The effect is non-monotonic because very high ability managers rent out a smaller fraction of the machine capacity since they use more capital for themselves.

best world, managers with the lowest cost of capital would buy the machines, and those with the highest returns would use them. Without a rental market, the first best allocation could only be replicated if returns and cost are perfectly negatively correlated. A well functioning rental market, as we showed in the Section 4, facilitates the first best allocation through trading of capital across firms.

In practice, how important is the rental market in achieving an efficient distribution of resources in our estimated economy? The answer depends on the empirical correlation between $\rho$ and $\zeta$, and the size of the preference shocks. In Appendix Figure A4 we compare mechanization and investment in the benchmark economy with two alternatives with $\tau = 0$ and $\tau = \infty$. Decreasing the rental wedge leads many more managers to mechanize, especially among the lower ability ones, thus making the relationship between mechanization and managerial ability *flatter*. At the same time, it does concentrate investment towards managers with the lowest interest rate, but the effect is quantitatively small: even in a frictionless economy high ability managers are more likely to invest due to the strong negative correlation between $\rho$ and $\zeta$.

Overall, the results show that, given our estimates, the purely allocative effect of the rental market is dominated by the direct effect of allowing many more firms to access capital.

# 7 Beyond Uganda

We have shown that taking into account the rental market is important to understand the organization of production and aggregate productivity in the carpentry sector in urban Uganda. However, our results so far have been silent on whether, beyond our setting, academics and policy makers should pay more attention to rental markets. In this section, we discuss when we expect rental markets to be important and argue that they are likely to be more prevalent and more relevant in developing countries, as they attenuate the negative effects of other market imperfections.

**Prevalence.** We do not expect rental markets to be ubiquitous. In fact, already among our three sectors there are differences: the rental market is essential in carpentry, present but minor in metal fabrication, and mostly absent in grain-milling. In Section 3, we show that while the average firm size is similar in the three sectors, in carpentry there is more potential for economies of scale, due to expensive and high capacity machines. The rental market emerged where most needed. More broadly, we expect rental markets to be present in sectors and countries with many and geographically concentrated small firms and with potential for economies of scale to be reaped collectively, which requires that either firms produce similar products, or that products need similar machines.

Unsurprisingly, we expect rental markets to be important where firms can achieve scale collectively. Less evidently, we next illustrate using our model that rental markets are likely to be more prevalent in settings plagued by other market imperfections. In Figure 7a, we recompute the model as we vary three parameters that capture the extent of frictions in the financial, labor, and output markets. The left panel shows that the rental market becomes less prevalent as the dispersion of the cost of capital is reduced.[62] The rental market facilitates the reallocation of capital across firms and thus it shrinks if banks can do that task. The middle panel shows that fewer managers need to rely on the rental market if we reduce labor market frictions. Labor market frictions keep firms small, thus preventing them to reach sufficient scale for investing. Lastly, the third panel shows that increasing the elasticity of substitution across managers reduces the mass of renters in equilibrium.[63] When $\eta$ is large, many low ability managers enter the market, operate at a small scale, and rely on the rental market to mechanize.

Overall, these results show that we expect rental markets to become less relevant as countries develop, the average firm size increases, and market imperfections vanish.[64]

**Relevance.** The presence of rental markets does not by itself imply that they are relevant for aggregate output and productivity. For example, in an economy where most output is produced by only a few firms, the rental market would not matter for the aggregate as long as large firms can invest. To highlight some of these differences, Figure 7b shows the aggregate gains, in terms of output, of reducing the rental market wedge from an economy with no rental market to one with a frictionless one. As before, we show how these gains depend on imperfections in the financial, labor, and output markets.

As expected, the aggregate output gains from an efficient rental market are smaller when fewer managers rely on it. However, there are differences across the three cases. The largest gains are obtained when the elasticity of substitution across firms is small, hence when $\eta$ is large. In this case, firms face strong decreasing returns to scale and thus aggregate output is produced by many small firms. An efficient rental market is thus very valuable, since achieving scale collectively is the only way to make indivisible investments profitable. Changing the variance of the cost of capital, instead, does not affect the firm size distribution. As a result, varying the frictions in the financial market has a smaller impact on the gains from the rental market.

Overall, we learn that the efficiency of rental markets is a more important determinant of aggregate output when production is not concentrated.

[62]While reducing the dispersion of $\rho$, we also change its mean to keep constant the interest rate of the 20th percentile (which is approximately the median manager that invests in our benchmark estimated model).

[63]While a high $\eta$ may be due to product differentiation, it also likely captures imperfections in the output market, as discussed in Section 3.

[64]For example, using data from Hornbeck and Rotemberg (2019) and from the 2017 County Business Patterns of the US Census respectively, we document that the average size of carpentry firms in the US increased from 7.5 in 1860 to 25.4 in 2017.

**Policy.** The rental market does not create any apparent externality and thus its presence does not justify policy intervention. At the same time, the existence of the rental market has simple and sharp implications for the effectiveness and optimal targeting of development policies. For example, consider a development agency that wishes to stimulate mechanization of the small and less productive firms. In the presence of a rental market, subsidizing capital for the most productive firms could be more effective than directly targeting the small ones with credit. In fact, the most productive firms are more able to sustain the new capital investment, while the benefits of having additional machines trickle down to other firms through the rental market.

# 8 Conclusion

This paper studies the role of small firm scale as a barrier to technology adoption and productivity in developing countries. To this purpose, we collected new survey data that allow us to shed light on how output is produced in three prominent sectors in urban Uganda. The data uncovers large economies of scale due to the important role that indivisible capital inputs have in determining firm productivity. We might expect the presence of economies of scale to imply large aggregate costs due to the small size and low capacity utilization of most firms. However, we document that a thick rental market has emerged that overcomes the indivisibility: while a machine is indivisible, its capacity is divisible and can be shared by many firms.

We build and estimate a structural model to quantify the aggregate and distributional effects of the rental market. Our counterfactuals show that a perfectly efficient rental market has large aggregate effects on the usage of machines, labor productivity and output. We estimate that rental markets in urban Uganda are quite efficient, and achieve more than half of these possible benefits. Further, we show that all firms benefit from the rental market: relatively small firms can access machines that would be too expensive for them to buy; relatively large firms can profit by renting out the excess capacity of their machines.

Overall, we learn two broad lessons. First, focusing on the size of individuals firms can be misleading, and more attention should be directed towards the study of firm-to-firm interactions and firm clusters if we wish to understand technology adoption and productivity in developing countries. Second, a well-functioning rental market can be a powerful mechanism to attenuate the aggregate productivity costs of imperfections in the financial, labor or output markets.

Much work remains to be done to gauge the importance of rental markets for economic development. Three questions that, for us, are still open: Are rental markets prevalent and relevant empirically in other settings? How can policies improve the way they function? And finally, to what extent is the rental market a stepping stone in the development path of industries in the long run?

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# Tables

Table 1: Relationship between mechanization and product-level outcomes in carpentry

| | Log Rev PW | | Log Rev Doors PW | | Log Price Doors | | Quality Index Doors | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Machine Utilization Rate (0-1) | 1.185*** | 0.125*** | 1.059*** | 0.959*** | 0.479*** | 0.447*** | 1.446** | 1.462** |
| | (0.216) | (0.226) | (0.235) | (0.249) | (0.124) | (0.111) | (0.584) | (0.599) |
| Subcounty FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm Controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Adjusted $R^2$ | 0.446 | 0.456 | 0.408 | 0.422 | 0.499 | 0.639 | 0.305 | 0.299 |
| Observations | 378 | 378 | 333 | 333 | 348 | 348 | 109 | 109 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, robust standard errors in parentheses. Regressions are weighted using firm weights. The sample includes only firms that produced doors in the last three months. The dependent variable in columns 1-2 is the log of average monthly revenues per worker from the sale of all products in the last three months; in columns 3-4 it is the log of average monthly revenues per worker from the sale of doors in the last three months; in columns 5-6 it is the log of the average selling price of the main type of door sold to local final customers in the last three months; in columns 7-8 it is a standardized index of door quality based on multiple survey questions where enumerators were asked to score a number of product characteristics by direct observation of finished doors at the firm premises. For the construction of the output quality index see Appendix B. This variable is missing for those firms that did not have a finished door on display at the time of the survey. If the firm produced two-panel doors, the outcomes in columns 5-8 refer to two-panel doors; otherwise these refer to the main type of door produced in the last three months. The survey asked firm owners to indicate which of 23 different types of machines they use in the production of their main product. To construct the Machine Utilization Rate we compute the share of all such machine types used by the firm, relative to the firms in the data at the 95th percentile of the distribution of machine usage. All regressions further control for sub-county fixed effects. Regressions in columns 2, 4, 6 and 8 further control for a standardized index of managerial ability based on multiple survey questions, dummies for the most common type of door produced in the last three months and a dummy for whether the firm produced the core product of the two-panel door in the last three months. For the construction of the managerial ability index see Appendix B. The mean of a dependent variable is the weighted mean using firm weights. Figures in columns 1-6 are reported in nominal US dollars, converted from Ugandan shillings (UGX).

Table 2: Estimates of wedges in rental market for machines in carpentry

Dependent variable: Log Monthly Machine Hours

| | Step-Level | | | | Machine-Level | |
|---|---|---|---|---|---|---|
| | Baseline | Firm FE | No Controls | Only Labor Controls | Baseline | Firm FE |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Share of Rented Machines (0-1) | -0.339*** | -0.385*** | -0.655*** | -0.530*** | | |
| | (0.092) | (0.089) | (0.110) | (0.094) | | |
| Machine is Rented (0/1) | | | | | -0.364*** | -0.298*** |
| | | | | | (0.079) | (0.090) |
| Labor Cost Control | Yes | Yes | No | Yes | Yes | No |
| Machine Controls | Yes | Yes | No | No | Yes | Yes |
| Firm Controls | Yes | No | No | No | Yes | No |
| Machine Type FE | No | No | No | No | Yes | Yes |
| Step FE | Yes | Yes | Yes | Yes | No | No |
| Firm FE | No | Yes | No | No | No | Yes |
| Subcounty FE | Yes | No | Yes | Yes | Yes | No |
| Adjusted $R^2$ | 0.374 | 0.608 | 0.277 | 0.308 | 0.429 | 0.728 |
| Observations | 1,536 | 1,536 | 1,536 | 1,536 | 1,728 | 1,728 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, standard errors in parentheses, bootstrapped in columns 1, 2, 4 and 5 (with 1,000 replications and resampling by firm) and clustered by firm in the other columns. The sample includes door producers in carpentry. We use data on machines used in steps 3-9 of the production process for the main type of door. Firm weights are used. In columns 1-4 an observation is a production step in a firm. The dependent variable in columns 1-4 is the log monthly machine hours used in a production step. Our data includes information on: (i) which production steps each machine is used for and (ii) how many hours the machine is used. For those machines used in more than one step, we assign machine time to steps proportionally to the distribution of machines across steps in the data. The Share of Rented Machines is the average of dummies for whether the machines used in a step are rented, weighted by the share of total machine hours in a given step accounted for by each machine type in the data. The Labor Cost control is the log monthly wage bill used in the production step, calculated as the monthly labor hours in the step, multiplied by the within-firm average predicted hourly wages, where hourly wages are predicted from the regression in column 3 of Appendix Table A16. Machine controls include: log average value; average age; average expected remaining life; share made abroad. These averages are weighted similarly to the Share of Rented Machines. Firm Controls are: log quantity of doors produced; an index of door quality (see Appendix B for details); dummies for the most common type of door produced and a dummy for whether the firm produces two-panel doors. In columns 5-6 the dataset is at the machine level. The dependent variable is the log monthly machine hours used. The Labor Cost control is defined similarly to columns 1-4, but is summed across all production steps. Machine controls are at the machine level. If a firm uses more than one machine of each type, then our data contains one observation for each type of machine per firm, and in this case: monthly machine hours refer to the average machine; current value refers to the total of all machines; age refers to the average machine; expected remaining life refers to the machine in the best condition; the made abroad dummy takes value one if any of the machines are made abroad. Firms use more than one machine of each type in less than 7% of cases. To account for this, we always control for the number of machines of a given type used by the firm.

Table 3: Estimated parameters

| | Parameter | Value | Source |
|---|---|---|---|
| | *Panel A: Rental Market Friction* | | |
| | Parameter | Value | Source |
| (1) | $\tau$ | 0.404 | Table 2, column 1 |
| | *Panel B: Calibrated Parameters* | | |
| | Parameter | Value | Source |
| (2) | $\alpha$ | 0.50 | Table A7, column 8 |
| (3) | $p_b$ | 776.2 | Table A8, column 1 |
| (4) | $p_r$ | 0.514 | Table A8, column 1 |
| (5) | $\delta$ | 0.069 | Table A8, column 1 |
| (6) | $\iota$ | 0.450 | Broda and Weinstein (2006) |
| (7) | $\phi$ | 0.976 | Table A8, column 1 |
| | *Panel C: Jointly Estimated Parameters* | | |
| | Parameter | Value | Source |
| (8) | $A_M$ | 1.431 | |
| (9) | $\mu$ | 1.589 | |
| (10) | $\gamma$ | 0.939 | |
| (11) | $\theta$ | 0.524 | |
| (12) | $E(\log \zeta)$ | - 0.934 | |
| (13) | $Std(\log \zeta)$ | 0.052 | |
| (14) | $\chi$ | 0.762 | |
| (15) | $\xi$ | 0.717 | |
| (16) | $E(\log \rho)$ | 2.021 | Jointly Estimated |
| (17) | $Std(\log \rho)$ | 2.118 | |
| (18) | $Cov(\log \rho, \log \zeta)$ | -0.330 | |
| (19) | $\eta$ | 0.075 | |
| (20) | $\nu$ | 0.162 | |
| (21) | $W$ | 0.311 | |
| (22) | $\tilde{\pi}_X$ | 1.464 | |
| (23) | $\psi$ | 0.851 | |
| (24) | $\tilde{\theta}$ | 3.431 | |

Notes: This table reports the estimated parameters. See the respective source tables for more details. The parameters in Panel C are jointly estimated using simulated method of moments.

Table 4: Targeted moments and model fit

| | Moment | Source for Data | Data | Model | Key Parameter |
|---|---|---|---|---|---|
| (1) | Mechanization Rate | Table A8, column 1 | 0.381 | 0.355 | $A_M$ |
| (2) | Investment Rate | Table A8, column 1 | 0.139 | 0.180 | $\mathrm{E}[\log\rho]$ |
| (3) | Average Firm-Level Capacity Utilization | Table A8, column 1 | 0.356 | 0.318 | $\mathrm{E}[\log\zeta]$ |
| (4) | Average Market-Level Capacity Utilization | Table A8, column 1 | 0.585 | 0.585 | $\chi$ |
| (5) | Median Hourly Machine Rental Price | Table A8, column 1 | 0.514 | 0.514 | $\xi$ |
| (6) | Reg of Log Revenues on Managerial Ability | Table A9, column 1 | 0.288 | 0.272 | $Std[\log\zeta]$ |
| (7) | Reg of Mechanization Choice on Managerial Ability | Table A9, column 3 | 0.025 | 0.021 | $\theta$ |
| (8) | Reg of Investment Choice on Managerial Ability | Table A9, column 5 | 0.048 | 0.055 | $Cov\,[\log\rho, \log\zeta]$ |
| (9) | Reg of Log Price on Mechanization Choice | Table A9, column 7 | 0.559 | 0.560 | $\mu$ |
| (10) | Reg of Log Price on Managerial Ability | Table A9, column 7 | 0.042 | 0.026 | $\gamma$ |
| (11) | Reg of Log Capital Used on Managerial Ability | Table A13, column 4 | 0.398 | 0.398 | $\nu$, $\eta$ |
| (12) | Reg of Log Labor Used on Managerial Ability | Table A13, column 8 | 0.135 | 0.200 | $\nu$, $\eta$ |
| (13) | Ratio of Managers to Workers | Table A1, column 2 | 0.222 | 0.210 | $\pi_X$, $\tilde{\theta}$ |
| (14) | Workers-Managers Managerial Ability Gap | Table A14, column 1 | -0.285 | - 0.320 | $\psi$, $\tilde{\theta}$ |
| (15) | Ratio of Workers-Managers Std of Income | Table A15, column 1 | 0.898 | 0.854 | $\psi$, $\tilde{\theta}$ |
| (16) | Ratio of Workers-Managers Std of Managerial Ability | Table A15, column 1 | 0.970 | 1.009 | $\psi$, $\tilde{\theta}$ |
| (17) | Reg of Entry Choice on Managerial Ability (Normalized) | Table A14, column 4 | 0.275 | 0.234 | $\tilde{\theta}$ |
| (18) | Hourly Worker Wage Rate | Table A1, column 2 | 0.333 | 0.327 | W |
| (19) | Reg of Log Hourly Wage on Managerial Ability | Table A12, column 3 | 0.060 | 0.036 | $\nu$ |
| (20) | Reg of Log Hourly Wage on Labor Used | Table A12, column 6 | 0.146 | 0.162 | $\nu$ |
| (21) | Average Markup | Table A1, column 2 | 0.229 | 0.227 | $\eta$ |
| (22) | Average Interest Rate | Table A10, column 1 | 0.329 | 0.340 | $\mathrm{E}[\log\rho]$ |
| (23) | Std of Interest Rate | Table A10, column 1 | 0.281 | 0.263 | $\mathrm{Std}[\log\rho]$ |

Notes: The table reports the moments used in the estimation, and compares them with the same moments calculated from the estimated model. The moments used in the estimation are generated with our survey data, as indicated in the third column. See the respective data sources for more details. The model parameters are estimated by simulated method of moments.

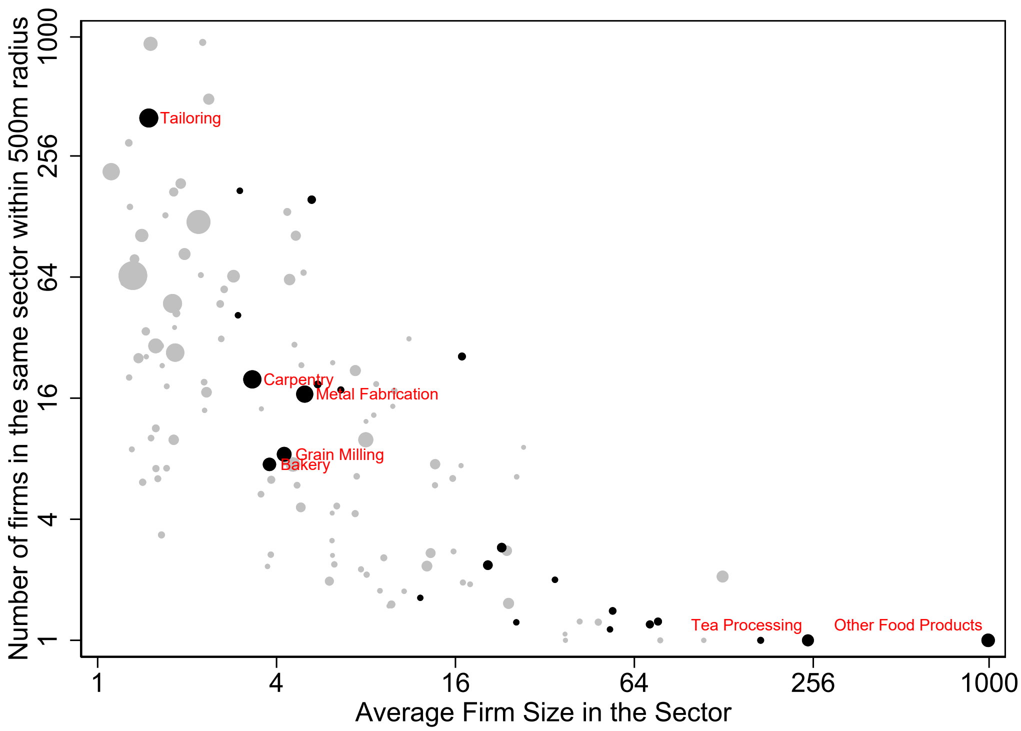
Table 5: Impacts of eliminating the rental market friction: importance of equilibrium effects

| | Level of intervention: | Country-wide, permanent (1) | Cluster of firms, permanent (2) | Individual firms, permanent (3) | Individual firms, temporary (4) |
|---|---|---|---|---|---|
| (1) | Aggregate Output | + 8.6 % | + 5.0 % | + 29.8 % | + 25.5 % |
| (2) | Aggregate Employment | + 1.4 % | - 0.23 % | + 8.1 % | + 12.7 % |
| (3) | Aggregate Labor Productivity | + 7.1 % | + 5.3 % | + 20.0 % | + 11.3 % |
| (4) | Average Mechanization | + 15.6 % | + 14.8 % | + 31.5 % | - |
| (5) | Market-level Machine Capacity Utilization Rate | + 31.8 % | + 35.9 % | - | - |
| (6) | Share of Total Used Capital that is Rented | + 83.8 % | + 81.0 % | - | - |
| (7) | Rental Market Price | + 13.8 % | + 17.4 % | - | - |
| (8) | # of Managers | + 16.4 % | - | - | - |
| (9) | Output Price | - 3.1 % | - | - | - |

Notes: Each cell shows the average treatment effect of setting $\tau = 0$, relative to the benchmark economy with $\tau = 0.405$. Impacts are expressed as percentage differences for the average firm in the group. The columns correspond to different potential interventions, as described in the main text. In particular, column 1 corresponds to a country-side and permanent intervention. Column 2 corresponds to a clustered RCT, which reduces the rental market friction for all the firms operating within a cluster constituting a closed rental market, but which is too small to affect aggregate output price and entry decisions. In order to make the results comparable with column 1, we create the aggregate effects in column 2 by assigning to all firms in the economy the average treatment effects from this clustered RCT. Column 3 corresponds to a permanent intervention that targets a small number of individual firms rather than clusters. Again, to compare the aggregate effects to column 1, in column 3 we assign the average treatment effect from this RCT to all firms in the economy. Finally, column 4 reports the average treatment effect from an intervention that temporarily targets a small number of individual firms (again with this average treatment effect assigned to all firms in the economy). We leave empty the cells that are not affected by the definition of the exercise. For example, if we reduce $\tau$ only for few individual firms, this cannot have an impact on the share of managers in the economy, hence row (8) in column 2 is left empty.

# Figures

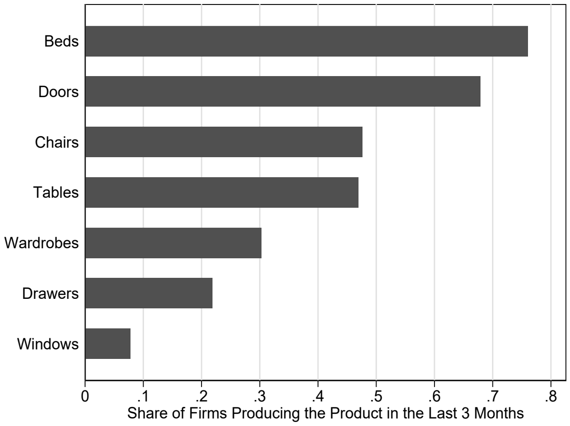
Figure 1: Spatial concentration of firms across sectors in Uganda



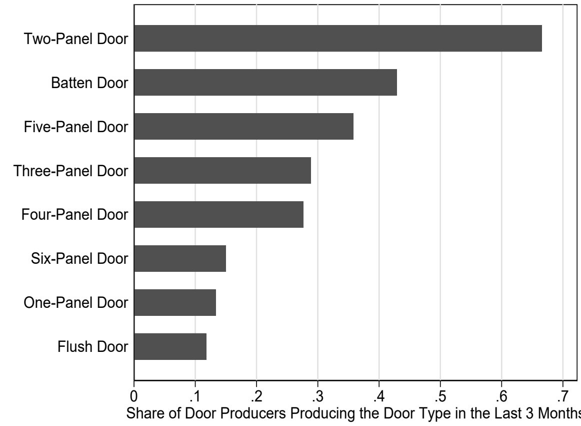

Notes: The figure uses data from the Census of Business Establishments for Uganda for 2010 (the latest available). For each firm in the census, we compute the number of other firms in the same 3 digit industry that are located at a distance below 500 meters. We then calculate the average for each industry, and plot it as a function of the average firm size in the sector. Each dot represents a 3-digit industry and is weighted by the number of workers employed in the sector. Black dots are industries in manufacturing. We drop sectors that employ less than 1,000 individuals across the whole Uganda. We label the manufacturing sectors that employ more than 5,000 workers. Finally, we omit one sector, "Retail sale via stalls & markets of second hand clothes, textiles, shoes", that has more than 2,000 firms within a 500 meters radius and so is a clear outlier.

Figure 2: Descriptives on product varieties and production steps in carpentry

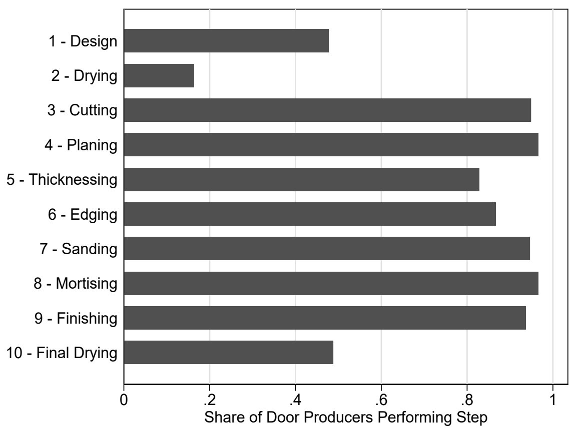
(a) Prevalence of product types



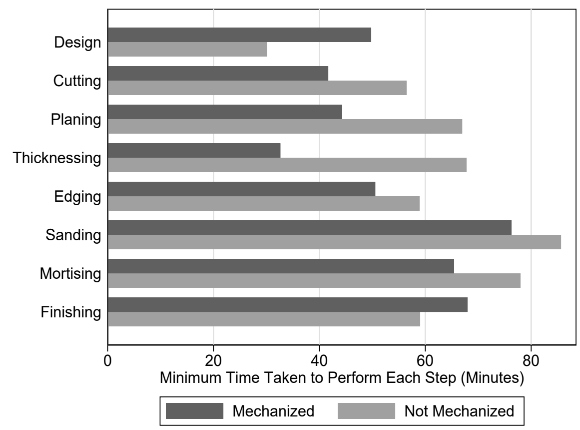

(b) Prevalence of door types




(c) Prevalence of production steps



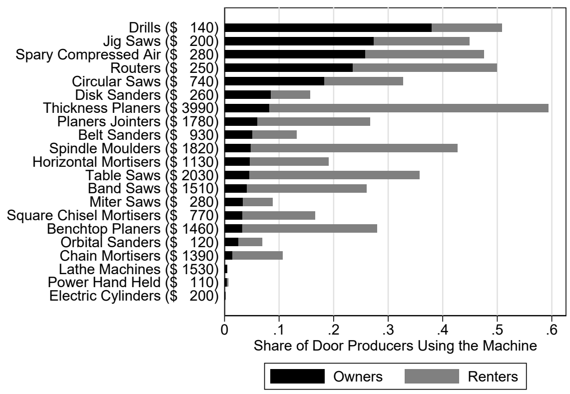

(d) Productivity gains from mechanization



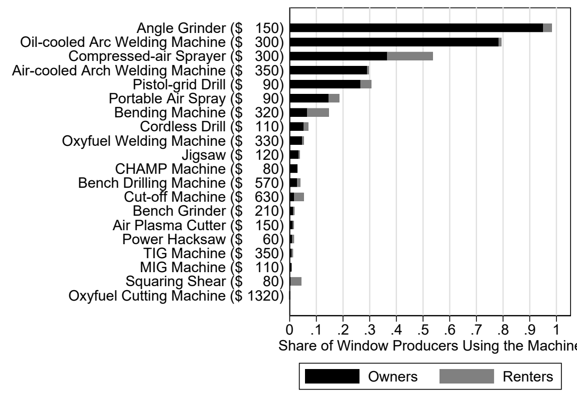

Notes: Figure 2a reports the share of firms in the carpentry sector which produced the types of products listed on the y-axis in the 3 months preceding the survey. The list of products firms were asked about was pre-specified. Figure 2b reports the share of door producers who produced the types of door listed on the y-axis in the 3 months preceding the survey. The list of door types firms were asked about was pre-specified. Figure 2c reports the share of carpentry firms that perform the production steps listed on the y-axis in the production of doors. The list of production steps door producers were asked about was pre-specified. The bars in Figure 2d represent the average minimum time which the employees could take to perform each step when it is either mechanized or not, predicted from an employee-level regression controlling for whether the employee works alone or in team with other employees, the total number of employees in the firm, the managerial ability score of the owner, as well as the following employee-level covariates: years of schooling, age, tenure in the firm, average hours worked per day, and vocational training status. Each step is defined as mechanized if at least one modern machine is used. The sample is restricted to firms producing doors. Regressions are weighted using firm weights. The figure only considers steps for which the mechanization rate depicted in Figure S9 is greater than 10% and smaller than 90%. For the definition of the managerial ability score see Appendix D.

Figure 3: Usage of modern machines by ownership vs rental

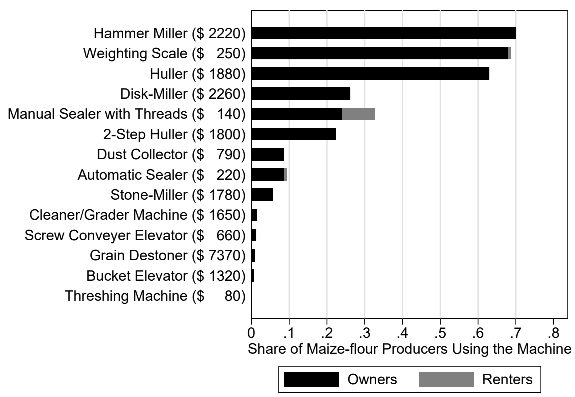
(a) Carpentry




(b) Metal Fabrication



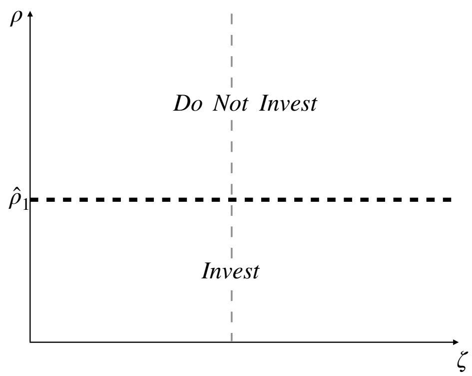

(c) Grain Milling



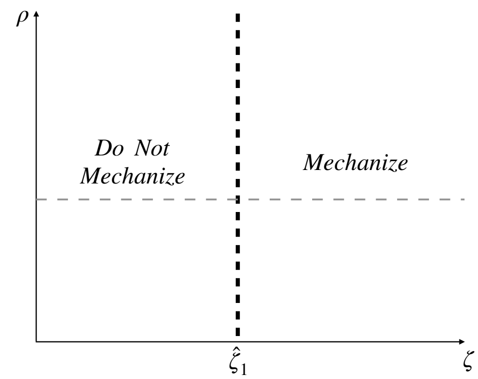

Notes: These figures decompose the share of firms that use a machine in carpentry (Figure 3a), metal fabrication (Figure 3b) and grain milling (Figure 3c) sectors among those firms that own the machine (black) and those that rent it (grey). Machines used in the production of the core products in the various sectors (e.g. 2-panel doors in the case of carpentry) are listed on the y-axis, whereas the share of firms using these machines is displayed on the x-axis. The sample for carpentry is restricted to firms producing doors, for metal fabrication it is restricted to firms producing windows, and for grain milling it is restricted to firms producing maize flour.

Figure 4: Equilibrium investment and mechanization choices when $\theta \to \infty$

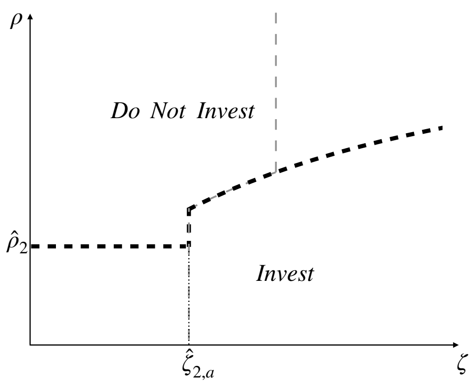
(a) Investment, $\tau = 0$



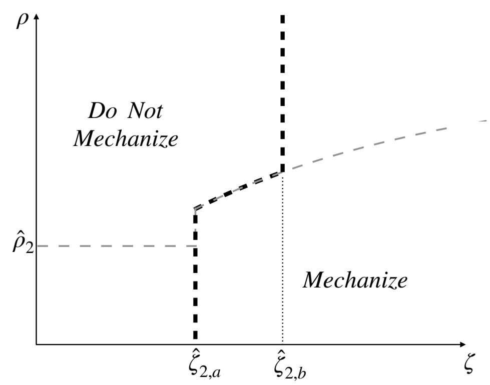

(b) Mechanization, $\tau = 0$



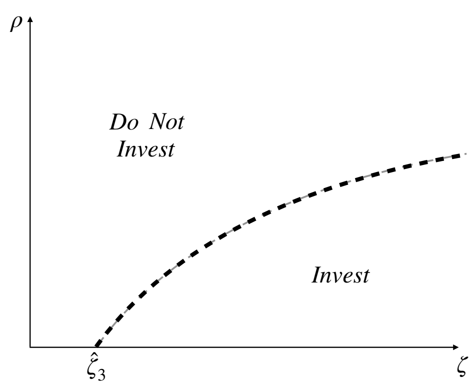

(c) Investment, $\tau \in (0, \infty)$



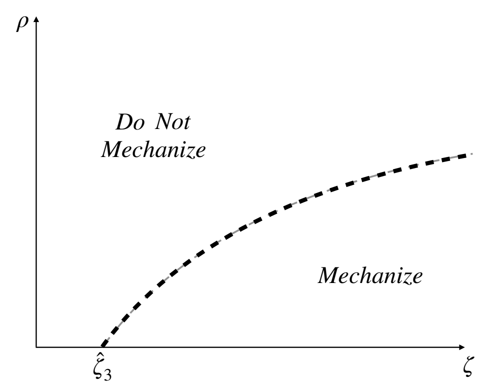

(d) Mechanization, $\tau \in (0, \infty)$




(e) Investment, $\tau \to \infty$

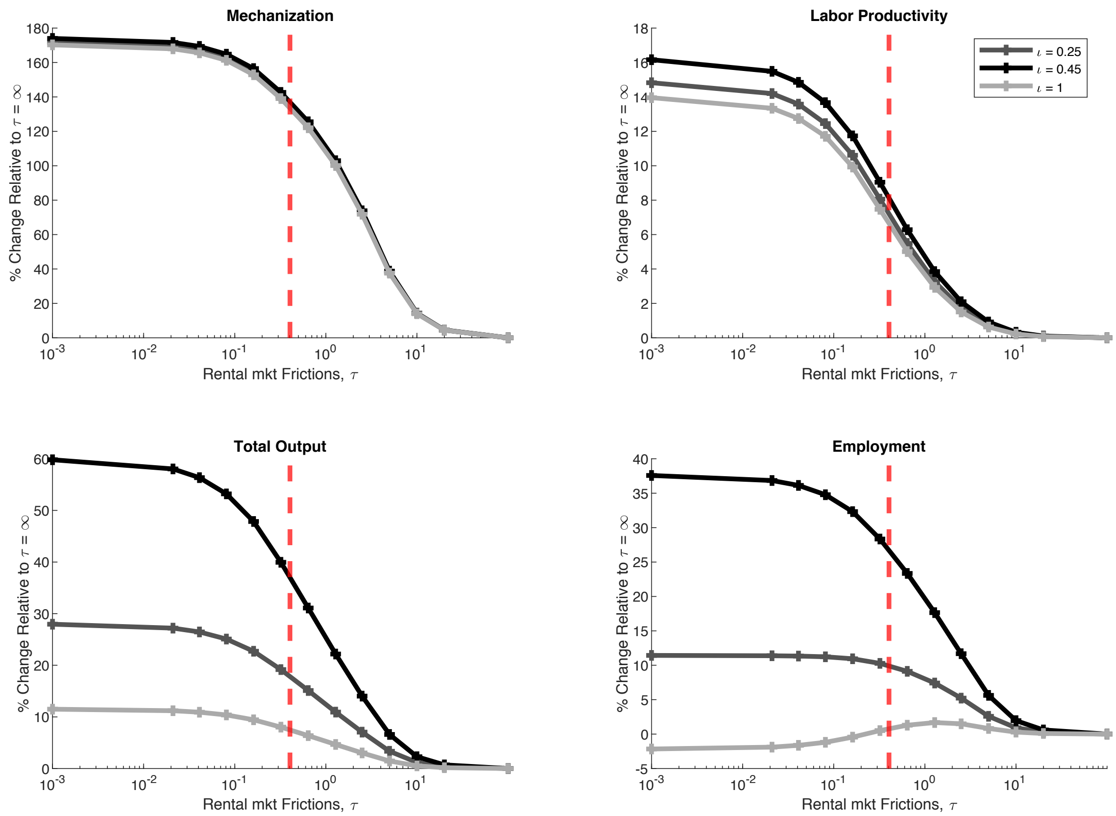



(f) Mechanization, $\tau \to \infty$



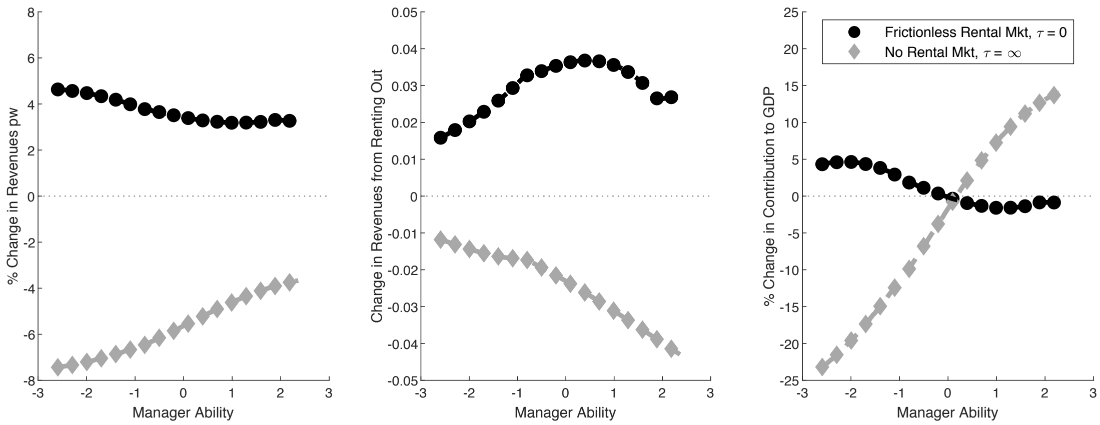

Notes: The Figure shows the partitions of the $(\rho, \zeta)$ space into regions where managers decide to invest and mechanize, for different values of rental market wedge. Frictionless rental market in the first row, no rental market in the third row, and an intermediate case in the second row. The left panels show the investment choice, while the right ones show the mechanization choice. In the mechanization panels, the black lines represent the mechanization choices and the light gray lines represent the investment choices (and vice-versa).

Figure 5: Aggregate effects of changing the rental market frictions




Notes: the Figure shows the impact of changing the rental market wedge $\tau$ on aggregate outcomes. Each panel, shows, for a different statistic of interest, the percentage change relative to an economy without a rental market. The red dotted line highlights the level of rental market frictions estimated in our data. We show the results for three values of the elasticity of substitution between aggregate GDP and the carpentry composite good.

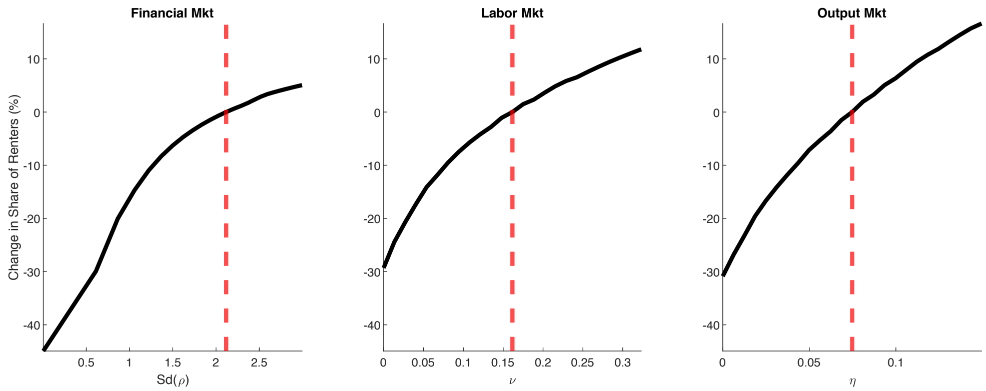
Figure 6: Distributional effects of changing the rental market frictions



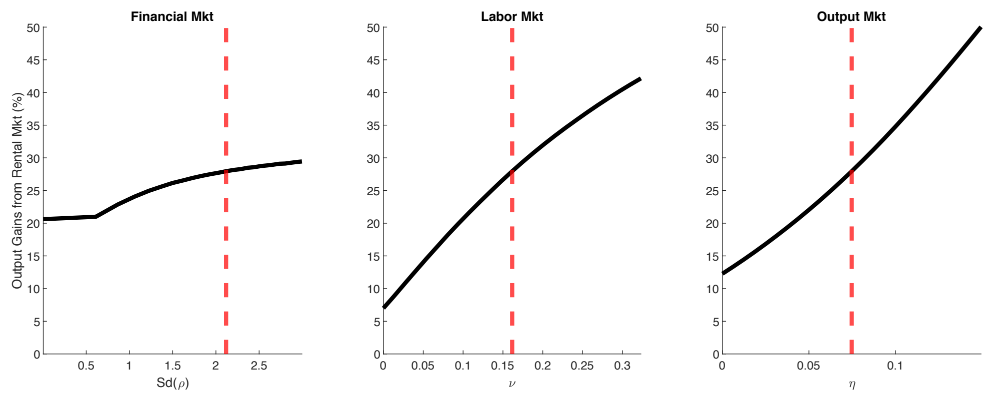

Notes: the Figure compares the benchmark economy with a frictionless economy ($\tau = 0$) and with an economy without rental markets ($\tau = \infty$). The black circles are for the economy with $\tau = 0$ and the gray diamonds for one with $\tau = \infty$. All panels have potential managerial ability on the x-axis. The left panel shows the change in the average revenue per workers. The middle panel shows the change (not in percentage) in revenues from renting out machine capacity. We do not consider percentage change because in the economy with $\tau = \infty$ there are, by definition, no revenues from renting out, hence that line would simply be -100%, and thus provide no additional information. The right panel shows the change in the contribution to total GDP, which is defined as the ratio between the output produced by all the active managers of a given ability type and the total output produced overall in the sector.

Figure 7: Role of the rental market in different economies

(a) Prevalence of Rental Markets




(b) Relevance of Rental Markets




Notes: The Figure shows outcomes from solving the model as we vary the imperfections in the financial, labor and output markets. The left panels consider changes in the dispersion of the cost of capital across managers, $Sd\,(\rho)$. The middle panels consider changes in the frictions in the labor market, $\nu$. The right panels consider changes in the decreasing returns to scale at the firm level, $\eta$, which are driven by elasticity of substitution across varieties. The red dotted line highlights the level of each parameter in the benchmark economy. The top panels (Figure 7a) shows the share of mechanized managers in the economy that access capital through the rental market. The bottom panels (Figure 7b) shows the output gains of going from an economy without a rental market ( $\tau \rightarrow \infty$) to one with a frictionless rental market ($\tau = 0$).

# Online Appendix

The Online Appendix is divided in two sections: Appendix A includes proofs and details on the model solution. In Appendix B, we describe the computation of the calibrated parameters and of the moments used in the estimation.

Additional supplemental material not intended for publication can be found on the authors' websites, in a document labeled Supplemental Material. In particular: additional survey details can be found in Supplemental Appendix C. Supplemental Appendix D describes the construction of the managerial ability and output quality indices used in the paper. More details on the model estimation can be found in Supplemental Appendix E. Finally, the Supplemental Material document also includes all figures and tables mentioned in the main paper and not already reported in the Online Appendix.

# A Proofs and Details on Model Solution

In this section, we include proofs of the theoretical results of Section 4 and further details on the quantitative model of Section 5

## A.1 Analytical Solution

We solve the model backward. We first solve the optimal choice for each manager conditional on production method choice. We then solve the production method choice. Last, we solve for the entry choice.

### A.1.1 Optimal Output and Input Mixes for Each Production Methods

There are four production methods. We solve each one in turn.

**Managers that Do not Invest nor Mechanize.** Replacing the constraint $y = A_L L$, the equation for price, and the one for wage, we get that he solves the problem

$$\pi_L(\zeta) = \max_L \zeta^\gamma P \left(\zeta^{1-\gamma} A_L L\right)^{1-\eta} - \frac{W}{1+\nu} L^{1+\nu}$$

which yields price and profits given by

$$\begin{aligned} p_L(\zeta) &= \zeta^{\gamma - \frac{\eta}{\eta+\nu}(1+\nu(1-\gamma))} \left[(1-\eta)\frac{A_L^{1+\nu} P}{W}\right]^{-\frac{\eta}{\eta+\nu}}. \\ \pi_L(\zeta) &= \left[\zeta^{1-\eta(1-\gamma)} A_L^{1-\eta} P W^{-\frac{1-\eta}{1+\nu}} (1-\eta)^{\frac{1-\eta}{1+\nu}}\right]^{\frac{1+\nu}{\eta+\nu}} \left(\frac{v+\eta}{1+\nu}\right). \end{aligned}$$

**Managers that Mechanize but Do not Invest.** As before, replace the constraints into the equation to get

$$\pi_{M,r}(\zeta) \quad = \quad \max_{L,K} \mu\zeta^{\gamma} P \left(\zeta^{1-\gamma} A_M K^{\alpha} L^{1-\alpha}\right)^{1-\eta} - \frac{W}{1+\nu} L^{1+\nu} - (1+\tau)\, p_r K$$

which, using the fact that $y = \zeta^{1-\gamma} A_M K^{\alpha} L^{1-\alpha}$, gives

$$\begin{aligned} L &= \left[ A_M^{-1} \zeta^{-(1-\gamma)} \left[ \left(\frac{\alpha}{1-\alpha}\right) \left(\frac{W}{(1+\tau)\, p_r}\right) \right]^{-\alpha} y \right]^{\frac{1}{1+\nu\alpha}} \\ K &= \left[ A_M^{-1} \zeta^{-(1-\gamma)} \left[ \left(\frac{\alpha}{1-\alpha}\right) \left(\frac{W}{(1+\tau)\, p_r}\right) \right]^{\frac{1-\alpha}{1+\nu}} y \right]^{\frac{1+\nu}{1+\nu\alpha}} . \end{aligned}$$

Replacing $L$ and $K$ into the profit maximization problem and solving for $y$ we get

$$y_{M,r}(\zeta) \quad = \quad \left[ \frac{A_M^{1+\nu} \left[(1-\eta)\, \mu P\right]^{1+\nu\alpha} \zeta^{1+\nu-\gamma\nu(1-\alpha)}}{\left((1+\tau) \frac{p_r}{\alpha}\right)^{\alpha(1+\nu)} \left(\frac{W}{1-\alpha}\right)^{(1-\alpha)}} \right]^{\frac{1}{\nu+\eta-(1-\eta)\nu\alpha}} .$$

Through a few more lines of algebra we can then find price and profits

$$\begin{aligned} p_{M,r}(\zeta) &= \zeta^{\gamma-\eta\frac{1+\nu-\gamma v(1-\alpha)}{v+\eta-(1-\eta)v\alpha}} (\mu P)^{\frac{v(1-\alpha)}{v+\eta-(1-\eta)v\alpha}} \left[ \frac{A_M^{1+\nu} (1-\eta)^{1+\nu\alpha}}{\left((1+\tau) \frac{p_r}{\alpha}\right)^{\alpha(1+\nu)} \left(\frac{W}{1-\alpha}\right)^{(1-\alpha)}} \right]^{-\frac{\eta}{\nu+\eta-(1-\eta)\nu\alpha}} \\ \pi_{M,r}(\zeta) &= \left(\frac{\nu+\eta-(1-\eta)\, v\alpha}{1+\nu}\right) \left[ \frac{A_M^{1-\eta} \mu P \zeta^{(1-\eta(1-\gamma))} (1-\eta)^{(1-\eta)\left(\frac{1+\nu\alpha}{1+\nu}\right)}}{\left((1+\tau) \frac{p_r}{\alpha}\right)^{\alpha(1-\eta)} \left(\frac{W}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\eta)}{1+\nu}}} \right]^{\frac{1+\nu}{v+\eta-(1-\eta)v\alpha}} . \end{aligned}$$

**Managers that Invest but do not Mechanize.** He solves the problem

$$\pi_{L,b}(\rho,\zeta) = \max_{L} \zeta^{\gamma} P \left(\zeta^{1-\gamma} A_L L\right)^{1-\eta} - \frac{W}{1+\nu} L^{1+\nu} + \max_{C} p_r C - \chi(C) - (\rho+\delta)\, p_b.$$

The output and capacity choices are separate. As a result, the output and labor input choices are identical to the ones of a manager that does not invest. Therefore, we will not repeat them here. Replacing the cost of capacity $\chi(C) = \frac{\chi}{1+\xi} C^{1+\xi}$ and taking the first order condition we get

$$C = p_r^{-\frac{1}{\xi}} \chi^{\frac{1}{\xi}}$$

which then gives profits from renting out the machines equal to

$$\tilde{m}(\rho) \equiv p_r^{\frac{\xi+1}{\xi}} \chi^{-\frac{1}{\xi}} \left(\frac{\xi}{1+\xi}\right) - (\rho+\delta)\, p_b.$$

**Managers that Invest and Mechanize.** After the usual substitutions, the manager's problem becomes

$$\begin{aligned}\pi_{M,b}(\rho,\zeta) &= \max_{L,K,C} \mu\zeta^{\gamma}P\left(\zeta^{1-\gamma}A_M K^{\alpha}L^{1-\alpha}\right)^{1-\eta} - \frac{W}{1+\nu}L^{1+\nu} - (1+\tau)\,p_r K + p_r(C-K) \\ &\quad -\frac{\chi}{1+\xi}C^{1+\xi} - (\rho+\delta)\,p_b \\ s.t. &\quad K \leq C.\end{aligned}$$

First, we solve the problem under the parametric assumption that assumes that the constraint $K \leq C$ is slack. In this case, the optimal capacity and output choices are, again, separate. As a result, the output, capital, and labor choices are the same as in the case for a manager that does not invest, but replacing $\tau = 0$. For brevity, we don't repeat them. Also, the capacity choice is the same as the case of a manager that does not mechanize, again, due to the separability of the two problems. Overall, this shows that the profits are given by

$$\pi^1_{M,r}(\rho,\zeta) = \left(\frac{\nu+\eta-(1-\eta)\,v\alpha}{1+\nu}\right)\left[\frac{A_M^{1-\eta}\mu P\zeta^{(1-\eta(1-\gamma))}\,(1-\eta)^{(1-\eta)\left(\frac{1+\nu\alpha}{1+\nu}\right)}}{\left(\frac{p_r}{\alpha}\right)^{\alpha(1-\eta)}\left(\frac{W}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\eta)}{1+\nu}}}\right]^{\frac{1+\nu}{v+\eta-(1-\eta)v\alpha}} + \tilde{m}(\rho),$$

where we keep the superscript 1 to distinguish this from the case when $K \leq C$ is binding, which we solve below.

It is simple to see that the results so far have proved Lemma 1, where

$$\begin{aligned}\tilde{\gamma}_L &= \frac{(1+\nu)(1-\eta(1-\gamma))}{\nu+\eta} \\ \tilde{\gamma}_M &= \frac{(1+\nu)(1-\eta(1-\gamma))}{\nu+\eta-(1-\eta)\,v\alpha} \\ \tilde{A}_L &= \left[A_L^{1-\eta}PW^{-\frac{1-\eta}{1+\nu}}(1-\eta)^{\frac{1-\eta}{1+\nu}}\right]^{\frac{1+\nu}{\eta+\nu}}\left(\frac{v+\eta}{1+\nu}\right) \\ \tilde{A}_{M,r} &= \left(\frac{v+\eta-(1-\eta)\,v\alpha}{1+\nu}\right)\left[\frac{A_M^{1-\eta}\mu P(1-\eta)^{(1-\eta)\left(\frac{1+\nu\alpha}{1+\nu}\right)}}{\left((1+\tau)\frac{p_r}{\alpha}\right)^{\alpha(1-\eta)}\left(\frac{W}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\eta)}{1+\nu}}}\right]^{\frac{1+\nu}{v+\eta-(1-\eta)v\alpha}} \\ \tilde{A}_{M,b} &= (1+\tau)^{\frac{\alpha(1-\eta)(1+\nu)}{v+\eta-(1-\eta)v\alpha}}\tilde{A}_{M,r}.\end{aligned}$$

Next, we solve the problem for the case when $K \leq C$ is binding. This second case, requires to solve for the optimal capital and labor when the marginal cost of capital is given by the capacity cost, hence, replacing the constraint $K = C$. The problem now reads as

$$\pi^2_{M,b}(z,r) = \max_{L,K}\frac{\mu z^{\gamma}}{P}\left(z^{1-\gamma}A_M K^{\alpha}L^{1-\alpha}\right)^{1-\eta} - \frac{W}{1+\nu}L^{1+\nu} - \frac{\chi}{1+\xi}K^{1+\xi} - (r+\delta)\,p_b.$$

Solving for the optimal level of capital and labor shows that profits are given by

$$\pi_{M,b}^{2}(z,r) = \left(\left[\frac{(1-\eta)^{\frac{(1-\eta)(1+\xi-\alpha(\xi-\nu))}{(1+\nu)(1+\xi)}}\mu z^{1-\eta(1-\gamma)}A_M^{1-\eta}P}{\left(\frac{W}{1-\alpha}\right)^{\frac{(1-\alpha)(1-\eta)}{(1+\nu)}}\left(\frac{\chi}{\alpha}\right)^{\frac{\alpha(1-\eta)}{(1+\xi)}}}\right]^{\frac{(1+\nu)(1+\xi)}{(\nu+\eta)(1+\xi)+\alpha(\xi-\nu)(1-\eta)}} \times \left[\frac{(\nu+\eta)(1+\xi)+\alpha(\xi-\nu)(1-\eta)}{(1+\nu)(1+\xi)}\right]\right) - (r+\delta)\,p_b.$$

Since capital increases in managerial ability, there is a cutoff value $\zeta^*$ such that the constraint $K \leq C$ is binding if and only $\zeta > \zeta^*$. As a result, we get that the manager's profits are

$$\pi_{M,b}(\zeta,\rho) = \begin{cases} \pi_{M,b}^{1}(\zeta,\rho) & \zeta \leq \zeta^* \\ \pi_{M,b}^{2}(\zeta,\rho) & \zeta > \zeta^* \end{cases}.$$

While we don't use this result to prove the theoretical results, it is useful in the computation where we allow managers to not rent out any machine capacity.

### A.1.2 Production Method Choice (Investment/Mechanization)

We next study the choices of invest and mechanize. A manager makes the production choice to maximize profits, that is

$$\pi(\zeta,\rho) = \max\left\{\pi_L(\zeta), \pi_{L,b}(\zeta,\rho), \pi_{M,r}(\zeta), \pi_{M,b}(\zeta,\rho)\right\}.$$

We first notice, using the previously derived expressions, that $\pi_L(\zeta)$ and $\pi_{M,r}(\zeta)$ are increasing in $\zeta$, but do not depend on $\rho$, while $\pi_{L,b}(\zeta,\rho)$, and $\pi_{M,b}(\zeta,\rho)$ are increasing functions of $\zeta$ and decreasing functions of $\rho$. Next, we show that both the choices to invest and mechanize are given by cutoffs policies, and we characterize how the cutoffs are affected by $\tau$.

**Investment.** Consider managers that do not mechanize. Since $\pi_{L,b}(\zeta,\rho)$ decreases in $\rho$, there will be a cutoff $\hat{\rho}$ such that if and only if $\rho < \hat{\rho}$ the manager invests. Moreover, notice that

$$\pi_{L,b}(\zeta,\rho) = \pi_L(\zeta) + \tilde{m}(\rho),$$

implying that, if a manager $\zeta$ does not mechanize, the investment cutoff does not depend on $\zeta$, and it is in fact given by $\hat{\rho}$ such that $\tilde{m}(\hat{\rho}) = 0$:

$$\hat{\rho} = \frac{p_r^{\frac{\xi+1}{\xi}}}{p_b}\chi^{-\frac{1}{\xi}}\left(\frac{\xi}{1+\xi}\right) - \delta.$$

Next, consider a manager that invests. He invests if and only if $\pi_{M,b}(\zeta,\rho) \geq \pi_{M,r}(\zeta)$. Noticing that

$$\pi_{M,b}(\zeta,\rho) \quad = \quad (1+\tau)^{\frac{\alpha(1-\eta)(1+\nu)}{v+\eta-(1-\eta)v\alpha}} \pi_{M,r}(\zeta) + \tilde{m}(\rho),$$

we find that a manager that mechanizes invests if and only if

$$\rho \quad \leq \quad \tilde{\rho}(\zeta) \equiv \left((1+\tau)^{\frac{\alpha(1-\eta)(1+\nu)}{v+\eta-(1-\eta)v\alpha}} - 1\right) \frac{\pi_{M,r}(\zeta)}{p_b} + \frac{p_r^{\frac{\xi+1}{\xi}}}{p_b} \chi^{-\frac{1}{\xi}} \left(\frac{\xi}{1+\xi}\right) - \delta$$

where $\tilde{\rho}(\zeta)$ is an increasing function of $\zeta$ as long as $\tau > 0$. Also, notice that $\tilde{\rho}(\zeta) \geq \hat{\rho}$ and that if and only if $\tau = 0$, then $\tilde{\rho}(\zeta) = \hat{\rho}$.

**Mechanization.** Consider managers that do not invest. They mechanize if and only if $\pi_{M,r}(\zeta) \geq \pi_L(\zeta)$. Since $\pi_{M,r}(\zeta)$ is more convex in $\zeta$ (because $\tilde{\gamma}_M > \tilde{\gamma}_L$), we know that there must be exist a value $\hat{\zeta}_a$ such that if and only if $\zeta \geq \hat{\zeta}_a$, then the manager mechanizes. We can use the closed form solutions for $\pi_L(\zeta)$ and $\pi_{M,r}(\zeta)$ to solve for $\hat{\zeta}_a$, but it is sufficient to notice, to prove our results, how $\hat{\zeta}_a$ depends on $(1+\tau)p_r$: the larger the marginal cost of capital – i.e. the larger $(1+\tau)p_r$ – the higher is $\hat{\zeta}_a$, since it is less profitable to mechanize.

Next, consider managers that invest. They mechanize if and only if

$$\begin{aligned} \pi_{M,b}(\rho,\zeta) &\geq \pi_{L,b}(\rho,\zeta) \\ (1+\tau)^{\frac{\alpha(1-\eta)(1+\nu)}{v+\eta-(1-\eta)v\alpha}} \pi_{M,r}(\zeta) + \tilde{m}(\rho) &\geq \pi_L(\zeta) + \tilde{m}(\rho) \\ (1+\tau)^{\frac{\alpha(1-\eta)(1+\nu)}{v+\eta-(1-\eta)v\alpha}} \pi_{M,r}(\zeta) &\geq \pi_L(\zeta). \end{aligned}$$

Therefore, even among managers that invest, the choice to mechanize does not depend on $\rho$ and it is given by a cutoff $\hat{\zeta}_b$ such that a manager mechanizes if and only if $\zeta \geq \hat{\zeta}_b$. Importantly, we notice that the cutoff $\hat{\zeta}_b$ does not depend on $\tau$, but it is increasing in the marginal cost of capital for managers that invest, which is given by the opportunity cost of capital, $p_r$. Also, notice that $\hat{\zeta}_b \geq \hat{\zeta}_a$, with $\hat{\zeta}_b = \hat{\zeta}_a$ if and only if $\tau = 0$, and that since, as we prove below, $p_r$ decreases in $\tau$, the difference $\hat{\zeta}_b - \hat{\zeta}_a$ increases in $\tau$.

Assuming, we prove it below, that $(1+\tau)p_r$ increases in $\tau$ and $p_r$ decreases in $\tau$, and putting together the cutoffs for the choice to invest and mechanize and their comparative statics with respect to $\tau$, yields Proposition 1.

### A.1.3 Comparative Statics of Rental Price with Respect to $\tau$

We prove that, for fixed distribution of managers $\hat{\Omega}$ and aggregate output price $P$ , $p_r$ is decreasing in $\tau$ and $(1+\tau)\,p_r$ is increasing in $\tau$.

First, consider the demand for machines' capacity. The overall demand for machine capital, both rented and owned, is given by

$$\int_{\hat{\Omega}} K(\omega)\, d\omega,$$

where $K(\omega)$ is the capital used by manager $\omega$, and $K(\omega) = 0$ if $\omega$ does not mechanize.[65]

Keeping $p_r$ constant, the aggregate demand for capital decreases in $\tau$ for two reasons: i) conditional on production choices, $K(\omega)$ is weakly decreasing in $\tau$ for each $\omega$, and strictly so for renters; ii) the share of managers that decide to mechanize is decreasing in $\tau$ since $\pi_{M,r}(\rho,\zeta)$ decreases in $\tau$, and $\pi_{M,b}(\rho,\zeta)$, $\pi_{L,b}(\rho,\zeta)$, and $\pi_L(\zeta)$ are not affected by it.

The aggregate supply of machines' capacity is given by

$$\int_{\hat{\Omega}} C(\omega)\, \mathbb{I}_C(\omega)\, d\omega.$$

where, $C(\omega)$ is the capacity chosen by manager $\omega$, and $C(\omega) = 0$ if $\omega$ does not invest.

The aggregate supply of machines' capacity increases in $\tau$ since, for investors, $C(\omega)$ is not affected by $\tau$, and the mass of investors increases in $\tau$ since $\pi_{M,r}(\rho,\zeta)$ decreases in $\tau$, and $\pi_{M,b}(\rho,\zeta)$, $\pi_{L,b}(\rho,\zeta)$, and $\pi_L(\zeta)$ are not affected by it. As a result, without a change in $p_r$, the rental market cannot be in equilibrium due to the excess supply of machine capacity.

Next, notice that the aggregate supply of machines' capacity is decreasing in $p_r$ for two reasons: i) $C(\omega)$ is decreasing in $p_r$; ii) the share of firms investing is also decreasing in $p_r$ since profits from leasing decrease in $p_r$, hence the lower is $p_r$ the more firms would access capital through rental market rather than investing – everything else equal.

As a result, in order for the rental market to be in equilibrium, the price $p_r$ has to decrease as we increase $\tau$.

Finally, notice that $p_r(1+\tau)$ must be increasing in $\tau$ – i.e. the change in $p_r$ must be smaller than the change in $\tau$. If this is not the case, the demand for capital would increase, but then the price $p_r$ should increase to restore equilibrium, thus reaching a contradiction.

### A.1.4 Entry Choice

Since the labor market is in partial equilibrium, the choice to enter into the sector and become a manager can be solved last. Managers decide to enter before observing their cost of capital

[65] Recall that $\omega$ is the manager identity. Every manager has ability $\zeta(\omega)$ and cost of capital $\rho(\omega)$.

$\rho$. They enter if the expected choice of production is higher than the outside option. Without specifying the outside option we can't provide any further characterization. However, we notice that the managers' expected profits increase in their managerial ability $\zeta$. As a result, if everyone has similar outside option, the solution will yield positive selection of managers into the sector, as usual.

## A.2 Quantitative Extension

Next, we turn to the extended model of Section 5.

The definition of the competitive equilibrium is almost identical to the one of the model in Section 4. The differences are that we have to take into account the sector of specialized machine renters, that the rental market clears with the supply coming both from managers and from the specialized renters, and that the profit maximization takes into account the realization of the Frechet shocks.

**Definition of Competitive Equilibrium.** *The competitive equilibrium is given by firm capital, labor, capacity and output* $\{K(\omega), L(\omega), C(\omega), y(\omega)\}_{\omega\in\Omega}$*, total capacity supplied by specialized machine renters* $\tilde{C}$*, rental price for machines* $p_r$*, and output price for each active manager* $\{p(\omega)\}_{\omega\in\hat{\Omega}}$ *such that (i) the rental market clears; (ii) the goods market clears; (iii) each potential manager maximizes profits; (iv) the specialized machine renters maximize profits; and (v) the representative consumer maximizes utility.*

We next summarize in a lemma, and prove, the results mentioned in the main test.

**Lemma 3.** *The share of managers of type* $\zeta$ *that enter is given by*

$$\frac{\pi_N(\zeta)^{\tilde{\theta}}}{\pi_X(\zeta)^{\tilde{\theta}} + \pi_N(\zeta)^{\tilde{\theta}}}$$

*where*

$$\pi_N(\zeta) = \frac{1}{\int g(\rho,\zeta)\, d\rho} \int \left[\pi_L(\zeta)^{\theta} + \pi_{L,b}(\rho,\zeta)^{\theta} + \pi_{M,r}(\zeta)^{\theta} + \pi_{M,b}(\rho,\zeta)^{\theta}\right]^{\frac{1}{\theta}} g(\rho,\zeta)\, d\rho$$

*and the probability that a realized type* $(\rho,\zeta)$ *chooses production method* $n$ *is given by*

$$\nu_n(\rho,\zeta) = \frac{\pi_n(\rho,\zeta)^{\theta}}{\pi_L(\zeta)^{\theta} + \pi_{L,b}(\rho,\zeta)^{\theta} + \pi_{M,r}(\zeta)^{\theta} + \pi_{M,b}(\rho,\zeta)^{\theta}}.$$

*The ratio of capital to labor expenditures pins down the capital share in production*

$$\frac{K(1+\tau)p_r}{Lw(L)} = \frac{\alpha}{1-\alpha}. \tag{3}$$

*For any manager $\omega$, the ratio of firm profits to total revenues is equal to*

$$\frac{\pi_L(\omega)}{p_L(\omega)\,y_L(\omega)} = \frac{\nu+\eta}{1+\nu} \tag{4}$$

$$\frac{\pi_M(\omega)}{p_M(\omega)\,y_M(\omega)} = \frac{\nu+\eta-(1-\eta)\,\nu\alpha}{1+\nu}. \tag{5}$$

*The price of output $p(\omega)$: (i) decreases in $A_M$ and $A_L$; (ii) increases in $\mu$; and (iii) there exists a value $\hat{\gamma} \in (0,1)$ such that if and only if $\gamma > \hat{\gamma}$ , then the price of output increases in $\zeta$.*

The properties of the type II extreme value distribution (or Frechet) generate the results in Lemma 3. These results are not new, and are, in fact, widely used in economics (e.g. Allen and Arkolakis (2014); Caliendo et al. (2019)).

Once managers draw the Frechet shocks, and make the discrete production method choice, the solution is identical to the one of the model in Section 4. In fact, the multiplicative Frechet shocks do not affect the output and input choices within production methods. As a result, the capital-labor ratios of a manager $\omega$ is given, as we have shown in A.1, by

$$\frac{K(\omega)}{L(\omega)} = \frac{\alpha w(L(\omega))}{(1-\alpha)(1+\tau(1-\mathbb{I}_C(\omega)))\,p_r}$$

where, $\mathbb{I}_C(\omega)$ is a dummy equal to 1 if manager $\omega$ invests. Taking logs on both side of the equation yields the specification in Lemma 2.

Once the Frechet shocks are realized and managers have decided their production method, prices are also given by the same formula shown in A.1. Given the price equations, the results in Lemma 3 yields directly. In particular, the values $\hat{\gamma}$ depends on whether the managers mechanize, and are

$$\hat{\gamma}_L = \frac{\eta(1+\nu)}{\eta(1+\nu)+\nu}$$

$$\hat{\gamma}_M = \frac{\eta(1+\nu)}{\eta(1+\nu)+\nu-\alpha\nu}$$

respectively, for the case of a manager that does not ($\hat{\gamma}_L$) or does ($\hat{\gamma}_M$) mechanize. Finally, equations (3), (4) and (5) are trivial manipulations of the analytical results shown in A.1.

# B Computation of Calibrated Parameters and Moments

## B.1 Calibrated Parameters

**Capital share ($\alpha$).** Appendix Table A7 reports details of how we compute $\alpha$. As shown in equation 3, $\alpha$ is pinned down by the capital labor ratio. To compute the numerator, we calculate the total hours of machine time used in a given step per month.[66] We price these at the average hourly rental rate for each machine type, computed using information on all machines rented in our data. For the denominator, we calculate the total monthly labor hours used in a given step. These are priced at the within-firm average predicted hourly wages, predicted from the same regression as in column 3 of Appendix Table A12. We take the ratio of monthly capital to labor expenditure for each step, and report the median value for machine owners in column 3 (Appendix Table A7). Column 8 shows that the implied value of $\alpha$ does not vary substantially across steps ($\alpha$ is always between 0.42 and 0.61). This justifies our approach of taking the average across steps. This is shown in the last row, where each step is weighted by the median labor expenditure of owners on that step, as a share of labor expenditures across all steps (column 5).[67]

In column 4 we report the capital labor ratios for *renters*. Comparing columns 3 and 4 we note that the production process of renters is less capital intensive, which is consistent with the rental market wedge estimated in Table 2. Finally, comparing columns 5 and 6 we note instead that the labor expenditure shares of owners and renters across steps are very similar. This is consistent with the production function being the same for renters and owners, and so validates an important modeling assumption.

**Machine price ($p_b$), rental price ($p_r$), and depreciation rate ($\delta$).** These are reported in Panel A of Appendix Table A8. To compute the machine purchase ($p_b$) and rental prices ($p_r$) we use our machine-level data, where firms were asked to report the price paid for each machine (if they own the machine) and the hourly rental rate they pay to use the machine (if they rent it). We take the median across machines for both these prices. To construct $p_r$, we additionally subtract from the median hourly rental rate the median cost of labor incurred by machine owners, as we are interested in isolating the share of the rental cost that captures payment to capital. This is estimated using the following procedure. Our data shows that:

[66] To be precise, we have data on: (i) which production steps each machine is used for and (ii) how many hours the machine is used. For those machines used in more than one step, we assign machine time to steps proportionally to the distribution of machine usage across steps in the data. As shown in Appendix Table S8, machines are rarely used in more than one step and the concentration of machine time across steps is high. For instance, the average machine is used in 1.2 steps, and is used on the most common step for 86% of the time.

[67] As a robustness check, in column 7 we show an alternative computation of the capital labor ratio for owners, where we first compute the average of the numerator across firms and the average of the denominator across firms, and we then compute their ratio. Reassuringly, the results in columns 3 and 7 are similar.

in 65.5% of cases the employees of machine owners perform all operations on machines that are rented out to other firms; in 19.9% of cases the employees of machine owners supervise the employees of firms who are renting the machine; and, in 14.6% of cases machine owners let the employees of other firms use their machines without supervision. Median hourly wages in our sample of carpenters are \$0.26, so we subtract from the median hourly rental rate: $\$0.20 = (0.655 \times 0.26) - (0.199 \times 0.5 \times 0.26)$. That is, when the employees of machine owners perform the operations themselves, we remove from the rental price their hourly wage. For similar reasons, we remove half of the hourly wage when the employees of machine owners supervise the employees of machine renters.[68]

The depreciation rate $\delta$ is computed as: $1-(V/P)^{1/A}$, where $V$ is the current machine value, $P$ is the purchase price of the machine and $A$ is the age of the machine in years. We report the average depreciation rate in row 3 of Panel A.

In column 1 machines are aggregated by weighting each machine type by the share of total machine time it accounts for in the data, so that machine types used more intensively get a higher weight.[69] Column 2 shows that our results are robust to aggregating without weights. We note that machine purchase prices are significantly larger in column 1 than column 2. This is in line with more expensive machines being used more heavily by firms.[70]

**Share of machine capacity rented from specialized lenders ($\frac{\phi}{1-\phi}$).** This is reported in Panel A of Appendix Table A8, and is defined as $(HR_i - HR_o)/HR_i$ , where $HR_i$ are weekly total hours of machine usage reported by machine renters, and $HR_o$ are weekly total hours of machine time that machine owners report supplying to renters. Since we have a random sample of firms, this ratio would be zero if machine renters were only renting from other machine owners. However, Appendix Table A8 shows that the machine time used by renters is about twice as large as what machine owners report renting out. This indicates that about 50% of the rented machine time originates from other providers that are not themselves carpentry firms. Our data further shows that such providers are mostly workshops that specialize in renting out machines: machine renters were asked where they rent their machines from, and around 39% of door producers report renting from intermediary retailers (while 58% report renting from other carpentry firms in the same area, and 3% from other sources such as family and friends).[71]

[68] This information on supervision of renters by machine owners was collected in a short follow-up phone survey conducted about 3 months after the end of the main survey. See Supplemental Appendix C for details.

[69] The information on machine usage at the firm level was collected in a short follow-up phone survey conducted about 7 months after the end of the main survey. See Supplemental Appendix C for details.

[70] If a firm uses more than one machine of each type (i.e. more than one thickness planer), then our data contains one observation for each type of machine, and in this case the machine purchase price refers to the last machine purchased by the firm, the current value refers to the average machine, the age to the average machine, and the hourly rental rate refers to the typical machine of that type rented by the firm. Firms use more than one machine of each type in less than 7% of cases.

[71] Specialized lenders likely have higher machine capacity available for rent (since they do not use the machines themselves) and so this can explain why the share of rented machine time accounted for by specialized lenders

As described above, in column 1 machines are aggregated weighting each machine type by the share of total machine time it accounts for in the data. In column 2 we show that our results are robust to aggregating without weights.

## B.2 Moments

This section describes the computation and estimation of moments, and should be read in conjunction with Table 3. In each paragraph, we refer to the rows of Table 3 that include the computed moments. Two rows are missing: row 5 includes $p_r$, already computed above; row 18 includes the average wage from Table A1.

**Mechanization rate, investment rate, and capacity utilization (Rows 1-4)** These moments are shown in Panel B of Appendix Table A8. We construct the mechanization rate as the share of all 23 machine types used by a firm in the production of doors. The investment rate is computed similarly, but counting only machine types that are owned.

To compute the averagefirm-level capacity utilization, firms were asked how many hours per week they use each machine for the production of *all* their products. We set full capacity at 60 hours per week. To compute the average market-level capacity utilization, we use information from machine owners, who were asked how many hours per week they use their machines for their own products, and how many hours they rent them out to other firms. We consider as total demand the total time that the machine is operated per week (for both own use and for renting out), and as total supply 60 hours per owned machine.

As indicated above, in column 1 machines are aggregated by weighting each machine type using the share of total machine time it accounts for in the data.[72] In column 2 we show that our results are robust to aggregating machines without using weights. We note that the mechanization rate is higher in column 1 than column 2. This shows that mechanization is more common in key steps where machines are used intensively, such as thicknessing.

**Manager's productivity, mechanization and investment choices (Rows 6-10).** Appendix Table A9 shows the computation of moments related to a manager's productivity, mechanization and investment choices. We limit the sample to door producers, as the machines that firms were asked about are specific to doors. Columns 1-6 report the results of OLS regressions of log monthly firm revenues (columns 1-2), mechanization rate (columns 3-4) and investment rate (columns 5-6) on our standardized index of managerial ability and sub-county fixed effects. The mechanization rate and investment rate are the same variables defined in the previous

(50%) is higher than the share of renters using specialized lenders (39%).

[72] The information on machine usage at the firm level was collected in a short follow-up phone survey conducted about 7 months after the end of the main survey. See Supplemental Appendix C for details.

paragraph. Columns 7-8 regress log average price from the sale of doors on both the managerial ability index and the mechanization rate.[73] In our preferred specifications in the odd columns we weight observations using firm weights, as discussed in Supplemental Appendix C. For robustness, even columns show the results weighting by both firm and sub-county weights.

The results of our preferred specifications show that an increase of one standard deviation in managerial ability is associated with: (i) a 29% increase in revenues; (ii) an increase in the mechanization rate of 0.033; (iii) an increase in the investment rate of 0.054; and (iv) an increase of 3.8% in output price. In addition, column 7 shows that going from no mechanization to full mechanization is associated with an increase in price of 54%. Reassuringly, the alternative specifications in the even columns show similar results.

**Cost of capital (Rows 22-23).** Firm owners who reported borrowing for the business at the time of the survey were asked about the interest rate faced. Column 1 of Table A10 shows that the mean interest rate is 33%, with standard deviation of 28%. However, we note that only 29 carpentry firms reported to be borrowing in the survey and provided a value for the interest rate.

To provide more evidence on the cost of capital, in column 2 we report the mean and standard deviation of the *hypothetical* interest rate that firms expect to face if they had to borrow to cover an unforeseen expense.[74] This information is available only for firms that would need to borrow to cover it (as opposed to using own savings).[75] First, we note that 39% of firms reported that they would need to borrow. This shows that about 60% of entrepreneurs have substantial savings, and so likely have a low cost of capital. Second, column 2 reports the mean and standard deviation of the interest rate that firms would expect to face. Comparing columns 1 and 2 suggests that those managers who borrow face a lower interest rate than those who do not have substantial savings and do not currently borrow. Taken together, this evidence shows that there is substantial variation in the cost of capital across firms.

In Appendix Table A11 we verify that higher ability managers and firms that invest in machines face a lower cost of capital. Columns 1-2 show that there is a positive correlation between managerial ability and whether the manager reports being able to cover an unforeseen

[73] The regressions in columns 7-8 further control for dummies for the most common type of door produced in the last three months, and a dummy for whether the firm produced the core product of the two-panel door in the last three months.

[74] Specifically, we first asked if firm owners would be able to cover a UGX 1 Million (USD 263) expense, either through borrowing or through own savings. If they said No, then we asked if they could cover a UGX 500,000 expense (USD 132). If they said No, we asked about UGX 300,000 (USD 79). For those that said Yes to any of these questions, we then asked if they would be able to cover the expense by borrowing or through savings. To those that reported that they would need to borrow, we then asked the interest rate they would expect to face. This information was collected in a short follow-up phone survey conducted about 7 months after the initial survey. See Supplemental Appendix C for details.

[75] This information is missing also for firm owners who would not be able to cover the expense at all (neither with a loan nor with own savings), but we note that only 2 firms reported not being able to cover it.

expense of UGX 1M (with either own savings or a loan). Columns 5-6 show that, conditional on being able to cover an unforeseen expense, there is a negative association between managerial ability and the probability that the manager would need to borrow to cover the expense (so that higher ability managers are more likely to cover the expense through savings), though this result is imprecisely estimated. Columns 3-4 and 7-8 show that firm owners who own a higher share of machines face easier access to capital and have more liquidity available through savings. These results are in line with the model estimates that higher ability managers face a lower cost of capital, and that managers with lower cost of capital are more likely to invest.

**Labor market frictions (Rows 11-12, 19-20).** Appendix Table A12 shows the results of Mincerian regressions of worker monthly earnings in carpentry. In columns 1-3 the key independent variable is our index of managerial ability; in columns 4-6 it is the log of firm size. All regressions control for monthly hours worked and sub-county fixed effects. In columns 2 and 5 we additionally control for worker education, age, tenure and a dummy for whether the worker received vocational training. Columns 3 and 6 additionally control for cognitive skills and non-cognitive skills, and so are our preferred specifications. The estimates in column 6 show that a 1% increase in firm size (as measured by the number of employees) is associated with a 0.15% increase in wages, a result significant at the 5% level.

The main identification concern in these regressions is sorting on unobservables: if more able workers are more likely to sort into higher ability/larger firms, then the coefficient on our key independent variables of interest would be upward biased. The inclusion of sub-county fixed effects limits concerns related to sorting across locations. Our rich set of controls for worker skills also limit concerns related to sorting on unobserved ability. To assess the importance of any remaining selection on unobservables, we follow Oster (2019) and calculate bounds on our coefficients of interest by making assumptions on the relative importance of selection on observables and unobservables. Using the assumptions recommended in that paper, we still find a lower bound of 0.117 for the coefficient on log firm size.[76] This highlights the robustness of the estimated correlation between wages and firm size.

To be conservative, for the identification of the labor market friction parameter $\nu$ we prefer to target the bundle of moments described in Section 5, rather than relying exclusively on the direct estimates of $\nu$ from Table A12. In particular, we also target: (a) the relationship between

[76] Oster (2019) extends the methods in Altonji et al. (2005) and shows that movements in the coefficients of interest and in the R-squared when additional controls are included are informative of selection on unobservables, once assumptions on the relative importance of selection on observables and unobservables are made. To use this method, we need to make assumptions on: (i) the degrees of proportionality between selection on observables and unobservables ($\delta$), and (ii) the maximum R-squared ($R_{max}$) from a regression that would include the full set of regressors (both observed and unobserved). We follow the author's recommendation and set $\delta = 1$ (so that selection on observables and unobservables are equally important), and $R_{max} = 1.3 \times \tilde{R}$ where $\tilde{R}$ is the R-squared from the specification with the full sets of controls in column 6 of Appendix Table A12. We recover a lower bound on the correlation between firm size and worker wages under these assumptions.

wages and managerial ability shown in column 3 of Table A12, and (b) the correlation between managerial ability and (i) capital stock and (ii) firm size, reported in Appendix Table A13. The results from part (a) indicate that an increase in managerial ability of one standard deviation is associated with a 6% increase in earnings (significant at the 10% level). For part (b), in Appendix Table A13 we regress the log value of the capital stock used (including both owned and rented capital) and log firm size on our standardized index of managerial quality. The Table shows that these correlations are robust to: (i) using either the full sample of carpentry firms or the restricted sample of door producers, and (ii) including additional product controls. Our preferred specifications are those that limit the sample to door producers and control for additional product characteristics (i.e. columns 4 and 8). These show that a one standard deviation increase in managerial ability is associated with a 40% increase in capital and a 14% increase in labor.

**Markups (Row 21).** We calculate markups as revenues over variable cost (measured as revenues minus profits), minus 1. This approach recovers markups under the assumption that profit measures in the survey correspond to variable profits (i.e. managers do not take into account fixed costs when reporting monthly profits). We believe this to be the case given how the profit question was worded. Estimates of markups using this procedure are reported in Appendix Table A1. For robustness, we also calculate markups exploiting a series of hypothetical questions specifically designed to measure markups. Managers were asked how much revenues they could generate from UGX 250,000 (approximately USD 66) of intermediate inputs for the core product. They were then asked how much of these revenues would: (i) be used to cover wages; (ii) be used to cover other variable costs such as machines/buildings/electricity/fuel; (iii) be left as variable profits. We compute markups as the ratio of the stated revenue amount over the sum of intermediate input costs, wage costs and other operating costs. This alternative procedure yields markups that are very similar to those reported in Table A1.

**Outside option and entry choice Rows (13-17).** We are interested in the relationship between managerial ability and the decision to become a manager (relative to the outside option of being a worker in the same industry, as suggested by our data). However, managerial ability is available only for managers, and so is predicted by running a regression of our standardized index of managerial ability on a set of individual characteristics available for both managers and workers.[77] In columns 1-3 of Appendix Table A14 we regress predicted managerial ability (standardized) on a dummy for being a worker. The sample includes all workers and managers in the carpentry sector. Columns 1-3 show that workers score about 0.24-0.29 of a standard deviation lower on the predicted measure of managerial ability, a result significant at the 1%

[77] These are: years of schooling, age, age squared, a dummy for whether attended vocational training, the score on a 4-item Raven matrices test, and the Big five traits, measured through a 10-item Big five test.

level. This result is robust to alternative weighting (column 2) and to excluding sub-county fixed effects (column 3).

In columns 4-6 we regress a dummy for being a manager on the rank of the individual on the same measure of predicted managerial ability described above. To construct the rank, we weight observations so that the weighted sample includes an equal share of managers and workers.We report both standard errors clustered by firm and bootstrap standard errors (with resampling by firm) as the independent variable is constructed using a generated regressor. The results show that an increase in the rank of 10pp is associated with an increase in the probability of being a manager of about 0.2-0.28. This result is imprecisely estimated once we account for the generated regressor in the estimation through bootstrap standard errors.

Finally, Appendix Table A15 reports the ratios of the standard deviations of workers to managers for: (i) Income (row 1) and (ii) Predicted managerial ability (row 2), predicted as described above. Column 1 reports our preferred specification where observations are weighted using firm weights, and the standard deviations are calculated netting out sub-county fixed effects. As a robustness check, column 2 shows the ratios without controlling for sub-county fixed effects and when both firm and sub-county weights are used. These are similar.

# Appendix Tables and Figures

Table A1: Basic descriptives

| | All sectors<br>(1) | Carpentry<br>(2) | Metal fabrication<br>(3) | Grain milling<br>(4) |
|---|---|---|---|---|
| Number of firms | 1,115 | 522 | 433 | 160 |
| *Panel A: Firm characteristics* | | | | |
| Number of employees | 4.8 | 4.5 | 4.9 | 6.0 |
| Monthly revenues (USD) | 1,437.4 | 1,221.7 | 1,548.5 | 1,916.0 |
| Monthly profits (USD) | 236.9 | 219.5 | 257.2 | 244.9 |
| Monthly profits per worker (USD) | 42.6 | 42.3 | 46.7 | 32.6 |
| Markup | 0.22 | 0.23 | 0.21 | 0.24 |
| Firm age (years) | 10.1 | 10.4 | 8.9 | 12.0 |
| Firm has trading license (%) | 82.2 | 76.4 | 85.7 | 91.3 |
| *Panel B: Owner characteristics* | | | | |
| Owner is male (%) | 96.3 | 97.9 | 99.2 | 83.0 |
| Owner age (years) | 40.2 | 39.2 | 37.9 | 50.1 |
| Owner years of education | 10.0 | 9.8 | 10.0 | 10.9 |
| Hours usually worked per day for the firm | 9.1 | 9.8 | 9.3 | 6.7 |
| *Panel C: Employee characteristics* | | | | |
| Employee is male (%) | 98.0 | 97.7 | 99.5 | 95.2 |
| Employee age (years) | 28.4 | 29.0 | 26.6 | 30.7 |
| Employee years of education | 9.3 | 8.9 | 10.2 | 7.9 |
| Employee tenure (years) | 3.5 | 3.5 | 3.3 | 3.9 |
| Hours usually worked per day for the firm | 9.9 | 9.7 | 10.0 | 10.0 |
| Employee monthly wage (USD) | 69.6 | 73.8 | 71.6 | 52.3 |
| Employee hourly wage (USD) | 0.29 | 0.33 | 0.29 | 0.19 |

Notes: The table reports basic descriptive statistics for the three sectors across a range of firm, owner and employee characteristics in Panels A, B and C respectively. The statistics reported are calculated for the average firm, and are weighted using firm and subcounty weights. Monthly revenues and profits are measured through survey questions that asked managers to report their total revenues and profits in each of the last three months prior to the survey. We report averages of these variables in the last three months. Markups are defined as average monthly revenues minus average monthly total cost, divided by average monthly total cost (where average monthly total cost is calculated as average monthly revenues minus average monthly profits). Figures reported in US dollars are in nominal terms, and were converted from Ugandan shillings (UGX) to US dollars (USD) using an exchange rate of 3,800 UGX/USD. Number of employees, monthly revenues, profits, profits per worker and markups are trimmed at the 99th percentile. The size distributions for the three sectors are shown in the Supplemental Appendix.

Table A2: Descriptives on costs of renting in carpentry

| | |
|---|---|
| *Panel A: Reasons for owning rather than renting machines* | |
| Cheaper or more profitable | 79.1% |
| To avoid waiting times | 69.8% |
| To increase production capacity | 72.1% |
| To make money from renting machines out | 32.6% |
| Do not know where to rent | 0 |
| Rented machines are not reliable | 7.0% |
| Rented machines are of lower quality | 0 |
| Other | 4.7% |
| *Panel B.1: Descriptive statistics on rental market transactions* | |
| Number of different rental places the firm goes to | 1.7 |
| Number of machines rented from each rental place on average | 5.4 |
| Total number of visits per month to all rental places the firm goes to | 15.6 |
| Share of renters staying at the premises of rental place while machine is operated | 61.3% |
| Time from arrival to rental place to job completion for average visit (minutes) | 162.7 |
| Time spent idle at premises of rental place for average visit (minutes) | 73.3 |
| Total travel time for the average completed visit to the rental place (minutes) | 48.1 |
| Share of renters traveling to the rental place by motorcycle taxi | 53.1% |
| Share of managers who travel themselves to rental place | 56.5% |
| *Panel B.2: Calculated monthly costs for renters* | |
| Value of time to access machines (USD, valued at average wage) | 10.5 |
| Value of time to access machines (USD, valued at average opportunity cost, A) | 23.3 |
| Direct transportation cost (USD, B) | 22.1 |
| Total cost of time and transportation (USD, A+B) | 45.5 |
| Total direct expenditure on machine rentals (USD) | 180.1 |

Notes: Data is for the carpentry sector. Panel A shows the share of machine owners reporting each reason as relevant for buying certain machines instead of renting them. Multiple responses were allowed for this question. Panel B.1 shows average statistics regarding rental market transactions. The total number of visits is defined as the number of separate times the firm reports going to all rental places to use their machines per month. The first four rows of Panel B.2 show the average monthly costs for renters calculated from Panel B.1. The first value of time is calculated as the sum of the total travel time and the total time spent idle at the premises of the rental place, valued at the average wage (taken from Appendix Table A1). The second value of time is the same total time, valued reflecting the average income of managers and employees, respectively. That is, when workers travel to the rental place, we value their time at the average wage; instead, when managers are the ones who go, we value their time at the average hourly profit (taken from Appendix Table A1). If renters travel by motorcycle taxis, we compute their direct transportation cost using typical motorcycle fares (per minute of travel) that we collected in Kampala. The direct transportation cost is set to zero if renters report walking or using a bicycle. In 22% of cases, renters report to mainly use other means of transport such as buses, cars, or vans. We value those at zero direct cost, since we do not have reliable information on the cost of such means of transport per trip. The final row in Panel B.2 reports the total direct expenditure on machine rentals at the firm level, valued at median machine prices (taken from Appendix Table A8). All statistics apart from the last row of Panel B.2 come from a short follow-up survey of our sample of carpenters conducted in three sub-counties about 4 months after the end of the main survey. The information on machine usage at the firm level used to create the statistic reported in the last row of Panel B.2 was collected in a short follow-up phone survey conducted about 7 months after the end of the main survey. See Supplemental Appendix C for details.

Table A3: Relationship between rental market price and machine concentration in carpentry

| | Dependent variable: Log Hourly Rental Price | | | | | |
|---|---|---|---|---|---|---|
| | Baseline | No Subcounty FE | Exclude Drills | Only Large Machines | Baseline | Baseline |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Number of Machine Owners | 0.000933 | 0.00324*** | -0.000213 | -0.0107 | | |
| | (0.00101) | (0.00111) | (0.00153) | (0.0108) | | |
| Number of Machines Owned | | | | | 0.00115 | |
| | | | | | (0.000846) | |
| Number of Machine Owners (no weight) | | | | | | 0.00185 |
| | | | | | | (0.0100) |
| Machine FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Subcounty FE | Yes | No | Yes | Yes | Yes | Yes |
| Number of Subcounties | 29 | 43 | 28 | 20 | 29 | 29 |
| Adjusted $R^2$ | 0.343 | 0.064 | 0.309 | 0.501 | 0.346 | 0.341 |
| Observations | 192 | 192 | 176 | 67 | 192 | 192 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, robust standard errors in parentheses. Regressions are at the level of machine-types in each subcounty, and utilize the sample of door producers in the carpentry sector. The dependent variable in Columns 1-6 is the log of hourly rental prices reported by machine renters. Column 1 shows the baseline specification, which includes controls for the number of machine owners in a subcounty (i.e. the number of carpentry firms who own machines), machine fixed effects, and subcounty fixed effects. The number of machine owners in each subcounty is calculated from our sample using firm-level weights. Columns 2-6 all report variants of the specification reported in Column 1. In column 2 we omit controls for subcounty fixed effects. Column 3 includes subcounty fixed effects but excludes drills from the sample. Column 4 also reports the baseline specification in Column 1, while restricting the sample to only large machine types such as thickness planers, spindle moulders, table saws, horizontal mortisers, chain mortisers, lathe machines and band saws. In Column 5 the dependent variable is replaced with the number of machines owned in each subcounty (also extrapolated from the sample using firm weights). Column 6 repeats the baseline specification but only for the number of machine owners in each subcounty that are represented in our sample.

Table A4: Labor market frictions

| | Carpentry (1) | Metal fabrication (2) | Grain milling (3) |
|---|---|---|---|
| Lack of employees with the right skills is a serious problem | 26% | 21% | 24% |
| Finding workers with the right skills is a serious problem | 30% | 26% | 26% |
| Screening workers at recruitment is a serious problem | 33% | 36% | 33% |
| Number of employees who left in the last six months | 57% | 56% | 66% |
| Share of firms with no workers leaving in the last six months | 75% | 73% | 78% |
| Share of workers hired through referrals | 57% | 63% | 43% |
| Would offer wage rise to keep current workers from leaving | 33% | 34% | 28% |

Notes: The Table provides summary statistics which suggest the presence of sizable frictions in labor markets across the three sectors in our sample. Each row corresponds to a different question asked to firm owners/managers. Rows 1-5 report averages across firms which are weighted using firm-level weights. These rows highlight the prevalence of frictions related to worker skills, search, screening, and turnover respectively. Rows 6 and 7, instead, report weighted averages across all employees, since the manager answered the associated questions separately for each employee in the firm.

Table A5: Descriptives on demand in carpentry

| | |
|---|---|
| *Panel A: Location of customers* | |
| % of firms reporting that most customers come from within the LC1 | 20.1% |
| % of firms reporting that most customers come from outside the LC1 but within the parish | 34.0% |
| *Panel B: Location of transactions* | |
| Share of sales to final customers | 94.8% |
| % of firms that sold to final customers at the business premises | 96.9% |
| % of firms that sold to final customers through shipping in Uganda | 15.6% |
| % of firms that sold to final customers through shipping outside Uganda | 0.6% |
| % of firms where orders are placed in person through walk-ins | 79.6% |
| *Panel C: Customer relations* | |
| Average number of customers coming to the business per day | 3.4 |
| Average ratio of highest to lowest selling price for the same product to final customers | 1.43 |
| % firms citing Bargaining as main reason for price variation for the same product | 43.2% |
| % of firms that communicate the quality of their products by directly talking to customers | 55.5% |
| % if firms citing being close to customers as main reason for locating the business premises | 28.5% |
| % of firms indicating lack of demand as a main constraint to growth | 54.3% |

Notes: The table reports basic descriptive statistics on demand in the carpentry sector. Panel A shows the share of firms reporting that most customers come from within the LC1 or within the parish. The share of other customer originations is reported in Supplemental Table S9. Panel B shows the share of sales in the last three months to final customers, the location of deliveries and the share of customers placing orders at the firm premises. Sales to final customers exclude sales to subsidiaries, wholesalers, and government agencies. The share of sales to these other types of customers is reported in Supplemental Table S10. The share of other routes through which orders are placed is reported in Supplemental Table S11. Panel C shows the descriptives on customer relations. The distribution of the ratio of highest to lowest selling price is displayed in detail in Supplemental Figure S14. The share of firms citing other reasons as main reason for price variation is reported in Supplemental Table S12. The share of firms that communicate the quality of their products through other means is reported in Supplemental Table S13. The share of firms that cite other reasons as main reason for locating the business premises is reported in Supplemental Table S14. Finally, the share of firms that indicate other reasons as a main constraint to growth is reported in Supplemental Table S15. All statistics are weighted using firm and sub-county weights.

Table A6: Estimates of wedges in rental market for machines in carpentry - Step level

| | Dependent variable: Log Monthly Machine Hours in Step | | | | | | |
|---|---|---|---|---|---|---|---|
| | Step 3<br>(1) | Step 4<br>(2) | Step 5<br>(3) | Step 6<br>(4) | Step 7<br>(5) | Step 8<br>(6) | Step 9<br>(7) |
| Share of Rented Machines (0-1) | -0.647*** | -0.442* | -0.138 | -0.490** | -0.476 | 0.046 | 0.365 |
| | (0.182) | (0.253) | (0.312) | (0.223) | (0.408) | (0.265) | (0.248) |
| Labor Cost Control | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Machine Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | No | No | No | No | No | No | No |
| Subcounty FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted $R^2$ | 0.447 | 0.390 | 0.358 | 0.279 | 0.382 | 0.347 | 0.432 |
| Observations | 264 | 267 | 234 | 258 | 109 | 230 | 174 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, bootstrapped standard errors in parentheses (with 1,000 replications and resampling by firm) and clustered by firm. The sample includes door producers in carpentry. We use data on machines used in steps 3-9 of the production process for the main type of door. Firm weights are used. An observation is a production step in a firm. The dependent variable is the log monthly machine hours used in a production step. Our data includes information on: (i) which production steps each machine is used for and (ii) how many hours the machine is used. For those machines used in more than one step, we assign machine time to steps in proportion to the distribution of machines across steps in the data. The share of rented machines is the average of dummies for whether the machines used in a step are rented, weighted by the share of total machine hours in a given step accounted for by each machine type in the data. The labor cost control is the log monthly wage bill used in the production step, calculated as the monthly labor hours in the step, multiplied by the within-firm average predicted hourly wages, where hourly wages are predicted from the regression in column 3 of Appendix Table A10. Machine controls include: log average value; average age; average expected remaining life; share made abroad. These averages are weighted similarly to the share of rented machines. Firm controls are: log quantity of doors produced; an index of door quality (see Appendix B for details); dummies for the most common type of door produced and a dummy for whether the firm produces two-panel doors. If a firm uses more than one machine of each type (e.g. more than one thickness planer), then our data contains one observation for each type of machine per firm, and in this case: monthly machine hours refer to the average machine; current value refers to the total of all the machines; age refers to the average machine; expected remaining life refers to the machine in the best condition; the manufactured abroad dummy takes value one if any of the machines are manufactured abroad. Firms use more than one machine of each type in less than 7% of cases.

Table A7: Step-level capital intensity

| | Share of firms performing step with modern machines | Share of firms performing step with modern machines that are owned | Median Capital Labor Ratio for Owners | Median Capital Labor Ratio for Renters | Median labor expenditure for Owners, as share of total labor expenditure across steps | Median labor expenditure for Renters, as share of total labor expenditure across steps | Ratio of across-firm Average Capital to across-firm Average Labor for owners | $\alpha$ |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Step 3 - Cutting | 77% | 23% | 1.42 | 1.22 | 15% | 15% | 1.72 | 0.59 |
| Step 4 - Planing | 77% | 14% | 1.56 | 0.69 | 17% | 14% | 1.35 | 0.61 |
| Step 5 - Thicknessing | 75% | 12% | 0.85 | 0.74 | 15% | 10% | 1.20 | 0.46 |
| Step 6 - Edging | 76% | 19% | 0.72 | 0.74 | 14% | 13% | 1.26 | 0.42 |
| Step 7 - Sanding | 32% | 14% | 0.88 | 0.40 | 17% | 20% | 0.89 | 0.47 |
| Step 8 - Mortising | 69% | 22% | 1.09 | 0.78 | 16% | 18% | 1.03 | 0.52 |
| Step 9 - Finishing | 52% | 28% | 0.75 | 0.78 | 16% | 15% | 0.88 | 0.43 |
| Average across steps | 65% | 19% | 1.05 | 0.75 | | | 1.18 | 0.50 |

Notes: The sample includes only firms that produced doors in the last three months. The statistics reported are weighted by firm and sub-county weights. For the statistics in column 2, we consider a firm as owning the modern machines used in a given step if they own all the machines used in that step. For the statistics in column 3 we first compute the capital labor ratio within each firm for a given step, and then take the median of this ratio across firms. For details on the computation of the capital labor ratio see Appendix B. In column 3 we do this only for firms that own all the machines used in the production of a given step. In column 4 we do this only for those firms that are renting at least part of the machines used in the production of a given step. The way we price labor and capital in column 3 and 4 is the same. In column 5 we report the median monthly labor expenditure in a given step as a share of total monthly labor expenditure across all steps, and do so for owners. Note that owners are defined at the step level (i.e. firms that own all the machines used in a given step are classified as owners for that step) and so there is no guarantee that all the shares reported in column 5 across steps sum to one, since the composition of owners changes across steps. In column 6 we repeat the same exercise as in column 5 but for renters (a firm is classified as renter for a given step if the manager reports renting at least one machine for that step). Column 7 is similar to column 3 but instead we first compute the average of the numerator across firms, and the average of the denominator across firms, and then compute their ratio. Column 8 reports the implied median values of $\alpha$, as calculated from column 3. In columns 3, 4 and 7 the capital labor ratios are trimmed at the 1st and 99th percentile. In columns 5 and 6 the expenditure shares are also trimmed at the 1st and 99th percentile. The last row reports the average across steps of the statistics shown in each column, where each step is weighted by the median labor expenditure of owners on that step, as a share of labor expenditures across all steps (column 5).

Table A8: Calibrated parameters and moments

| | Aggregation weighted by machine hours (1) | Aggregation unweighted (2) |
|---|---|---|
| *Panel A: Calibrated parameters* | | |
| Median Purchase Price of Machines in USD ($p_b$) | 776.2 | 579.3 |
| Median Hourly Machine Rental Price in USD ($p_r$) | 0.514 | 0.490 |
| Average depreciation rate ($\delta$) | 0.069 | 0.082 |
| Share of Machine Capacity Rented from Specialized Lenders ($\phi/(1+\phi)$) | 0.494 | 0.684 |
| *Panel B: Moments* | | |
| Mechanization Rate | 0.381 | 0.233 |
| Investment Rate | 0.139 | 0.084 |
| Average Firm-Level Capacity Utilization | 0.356 | 0.354 |
| Average Market-Level Capacity Utilization | 0.585 | 0.587 |
| Median Hourly Machine Rental Price in USD | 0.514 | 0.490 |

Notes: The sample is restricted to firms that produced doors in the last three months. All statistics are computed using firm and sub-county weights. In column 1 machines are aggregated weighting each machine type by the share of total machine time the machine type is used in the data, so that machine types that are used more intensively get a higher weight. In column 2 the aggregation of machines is unweighted. Machine purchase and rental prices are trimmed at the 1st and 99th percentile. An exchange rate of 3,800 UGX/USD was used to convert monetary amounts to US dollars. For the definition of the calibrated parameters and moments see Appendix B.

Table A9: Managers' productivity, mechanization and investment choice

| | Log Rev | | Mech Rate | | Inv Rate | | Log Price | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Manager Ability (Std.) | 0.288*** | 0.261*** | 0.025** | 0.017 | 0.048*** | 0.044*** | 0.042* | 0.054** |
| | (0.049) | (0.053) | (0.011) | (0.011) | (0.011) | (0.012) | (0.022) | (0.023) |
| Mechanization Rate (0-1) | | | | | | | 0.559*** | 0.554*** |
| | | | | | | | (0.134) | (0.137) |
| Weighting | Firm | Firm, SC | Firm | Firm, SC | Firm | Firm, SC | Firm | Firm, SC |
| Subcounty FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Product Controls | No | No | No | No | No | No | Yes | Yes |
| Adjusted $R^2$ | 0.494 | 0.449 | 0.465 | 0.488 | 0.200 | 0.185 | 0.640 | 0.591 |
| Observations | 378 | 378 | 381 | 381 | 381 | 381 | 348 | 348 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, robust standard errors in parentheses. The sample includes only firms that produced doors in the last three months. The dependent variable in columns 1-2 is the log of average monthly revenues from the sale of all products in the last three months; in columns 3-4 it is the mechanization rate; in columns 5-6 it is the investment rate; in columns 7-8 it is the log of the average selling price of the main types of door sold to local final customers in the last three months. If the firm produced two-panel doors, the outcomes in columns 7-8 refer to two-panel doors; otherwise these refer to the main type of door produced in the last three months. For the definition of the Mechanization Rate and Investment Rate see Appendix B.2. Managerial Ability Index is a standardized index based on multiple survey questions (for the construction of the managerial ability index see Supplemental Appendix D). The regressions in columns 7-8 further control for dummies for the most common type of door produced in the last three months and a dummy for whether the firm produced the core product of the two-panel door in the last three months. All odd columns weight observations using firm weights. Even columns weight observations using both firm and subcounty weights.

Table A10: Interest rate

| Sample: | Firms that are borrowing | Firms that would need to borrow to cover unforeseen expense |
|---|---|---|
| | (1) | (2) |
| Average interest rate | 0.329 | 0.593 |
| Standard deviation of interest rate | 0.281 | 0.432 |
| Number of firms | 29 | 191 |

Notes: Data is reported for the carpentry sector. Column 1 shows the mean and standard deviation of the interest rate faced by firms that reported borrowing at the time of the survey. In the second follow-up phone survey, we asked firm owners if they would be able to cover an unforeseen business expense, either through own savings or through borrowing. We first asked if they would be able to cover a UGX 1 Million (USD 263) expense. If they said No, then we asked if they could cover a UGX 500,000 expense (USD 132). If they said No, we asked about UGX 300,000 (USD 79). For those that said Yes to any of these questions, we then asked if would be able to cover the expense by borrowing or through savings. To those that reported that they would need to borrow, we then asked the interest rate they would expect to face. Column 2 reports the mean and standard deviation of the interest rate that firms would expect to face, as reported in these questions. For more detail on the second follow-up phone survey, see Appendix C. Value of the interest rate in column 2 are trimmed at the 95th percentile. Means and standard deviations are weighted using firm and sub-county weights.

Table A11: Predictors of access to liquidity

| | Able to cover unforeseen expense of UGX 1M | | | | Would need to borrow to cover unforeseen expense | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Manager Ability (Std.) | 0.059*** | 0.046* | | | -0.021 | -0.017 | | |
| | (0.023) | (0.025) | | | (0.025) | (0.028) | | |
| Investment Rate (0-1) | | | 0.508*** | 0.461*** | | | -0.553*** | -0.555*** |
| | | | (0.132) | (0.140) | | | (0.152) | (0.173) |
| Sample | All firms | All firms | Door producers | Door producers | All firms | All firms | Door producers | Door producers |
| Weighting | Firm | Firm, SC | Firm | Firm, SC | Firm | Firm, SC | Firm | Firm, SC |
| Subcounty FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted $R^2$ | 0.054 | 0.004 | 0.062 | 0.017 | 0.099 | 0.054 | 0.181 | 0.140 |
| Observations | 477 | 477 | 326 | 326 | 475 | 475 | 324 | 324 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, robust standard errors in parentheses. Data is reported for the carpentry sector. In columns 1-4 the dependent variable is a dummy equal to one if the owner would be able to find financial resources to cover an unforeseen business expense of UGX 1 Million (USD 263) either through own savings or borrowing, and zero if they would not be able to cover it. In columns 5-8 the dependent variable is a dummy equal to one if the owner would need to borrow to cover an unforeseen expense, and zero if they would be able to cover it from retained earnings/savings. For more details on the construction of the dependent variable in columns 5-8, see Table A8. For the construction of the managerial ability index see Supplemental Appendix D. For the definition of the Investment Rate see Appendix B.2.

Table A12: Relationship between wage and firm size

| Dependent Variable: Log Monthly Earnings | | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Manager Ability (Std) | 0.088** | 0.073** | 0.060 | | | |
| | (0.037) | (0.036) | (0.037) | | | |
| Log Num Workers | | | | 0.166** | 0.142** | 0.146** |
| | | | | (0.067) | (0.066) | (0.065) |
| Years of Schooling | | 0.029*** | 0.029*** | | 0.027*** | 0.027*** |
| | | (0.008) | (0.008) | | (0.008) | (0.008) |
| Age | | 0.048*** | 0.046*** | | 0.048*** | 0.046*** |
| | | (0.007) | (0.008) | | (0.007) | (0.008) |
| Age Squared | | -0.000*** | -0.000*** | | -0.000*** | -0.000*** |
| | | (0.000) | (0.000) | | (0.000) | (0.000) |
| Tenure at the Firm (Yrs) | | 0.013** | 0.013** | | 0.013** | 0.012** |
| | | (0.006) | (0.006) | | (0.006) | (0.006) |
| Vocational Training (0/1) | | 0.039 | 0.049 | | 0.052 | 0.060 |
| | | (0.063) | (0.062) | | (0.064) | (0.062) |
| Cognitive Score (0-4) | | | 0.033 | | | 0.035 |
| | | | (0.022) | | | (0.023) |
| Agreeableness (1-5) | | | -0.087** | | | -0.095*** |
| | | | (0.036) | | | (0.034) |
| Conscientiousness (1-5) | | | 0.034 | | | 0.042 |
| | | | (0.033) | | | (0.033) |
| Extraversion (1-5) | | | 0.065** | | | 0.073*** |
| | | | (0.026) | | | (0.026) |
| Openness (1-5) | | | 0.007 | | | -0.002 |
| | | | (0.052) | | | (0.052) |
| Neuroticism (1-5) (recoded) | | | 0.037 | | | 0.046* |
| | | | (0.028) | | | (0.028) |
| Log hours worked | 0.320*** | 0.330*** | 0.321*** | 0.333*** | 0.340*** | 0.324*** |
| | (0.075) | (0.073) | (0.072) | (0.080) | (0.077) | (0.075) |
| Observations | 1,062 | 1,062 | 1,062 | 1,062 | 1,062 | 1,062 |
| Adjusted $R^2$ | 0.201 | 0.267 | 0.274 | 0.198 | 0.264 | 0.274 |
| Subcounty FE | Yes | Yes | Yes | Yes | Yes | Yes |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, standard errors clustered at the firm level in parentheses. Regressions are at the employee level and use the carpentry sample. The dependent variable is log monthly earnings. Manager Ability is a standardized measure of managerial quality (for its construction see Supplemental Appendix D). All independent variables refer to the employee, apart from the Manager Ability variable that refers to the manager that the employee works for. All regressions are weighted using firm weights. The cognitive score was measured with a 4-item Raven matrices test. The big five traits were measured through a 10-item big five test. The Neuroticism variable is recoded so that a higher value implies more self-control (less neuroticism).

Table A13: Capital stock and labor choice

| | Log Capital Stock Used | | | | Log Number of Workers | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Manager Ability (Std.) | 0.470*** | 0.474*** | 0.402*** | 0.398*** | 0.116*** | 0.113*** | 0.144*** | 0.135*** |
| | (0.100) | (0.094) | (0.110) | (0.111) | (0.029) | (0.028) | (0.037) | (0.036) |
| Sample | All firms | All firms | Door producers | Door producers | All firms | All firms | Door producers | Door producers |
| Subcounty FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Product Controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Adjusted $R^2$ | 0.165 | 0.212 | 0.228 | 0.237 | 0.217 | 0.239 | 0.217 | 0.230 |
| Observations | 421 | 421 | 311 | 311 | 522 | 522 | 381 | 381 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients, robust standard errors in parentheses. All regressions control for sub-county fixed effects. All regressions are weighted using firm weights. The dependent variable in columns 1-4 is the log of the total value of the capital stock used by the firm (owned and rented); in columns 5-8 it is the log of firm size, as measured by the number of employees plus the owner. The variable Managerial Ability is a standardized index based on multiple survey questions. For the construction of the managerial ability index see Supplemental Appendix D. Regressions in columns 2, 4, 6 and 8 further control for dummies for the most common type of door produced in the last three months and a dummy for whether the firm produced the core product of the two-panel door in the last three months. Regressions in columns 1, 2, 5, 6 include the full sample. Regressions in columns 3, 4, 7, 8 limit the sample to firms that produced doors in the last three months.

Table A14: Outside option and entry choice

| | Predicted Man. Ability (Std) | | | Manager | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Worker (1/0) | -0.285*** | -0.290*** | -0.240*** | | | |
| | (0.051) | (0.052) | (0.053) | | | |
| Rank of predicted man. ability (0-1) | | | | 0.275*** | 0.282*** | 0.204*** |
| | | | | (0.050) | (0.053) | (0.044) |
| | | | | [0.216] | [0.210] | [0.187] |
| Subcounty FE | Yes | Yes | No | Yes | Yes | No |
| Weighting | Firm | Firm, SC | Firm | Firm | Firm, SC | Firm |
| Adjusted $R^2$ | 0.176 | 0.147 | 0.012 | 0.014 | 0.012 | 0.014 |
| Observations | 1,433 | 1,433 | 1,433 | 1,433 | 1,433 | 1,433 |

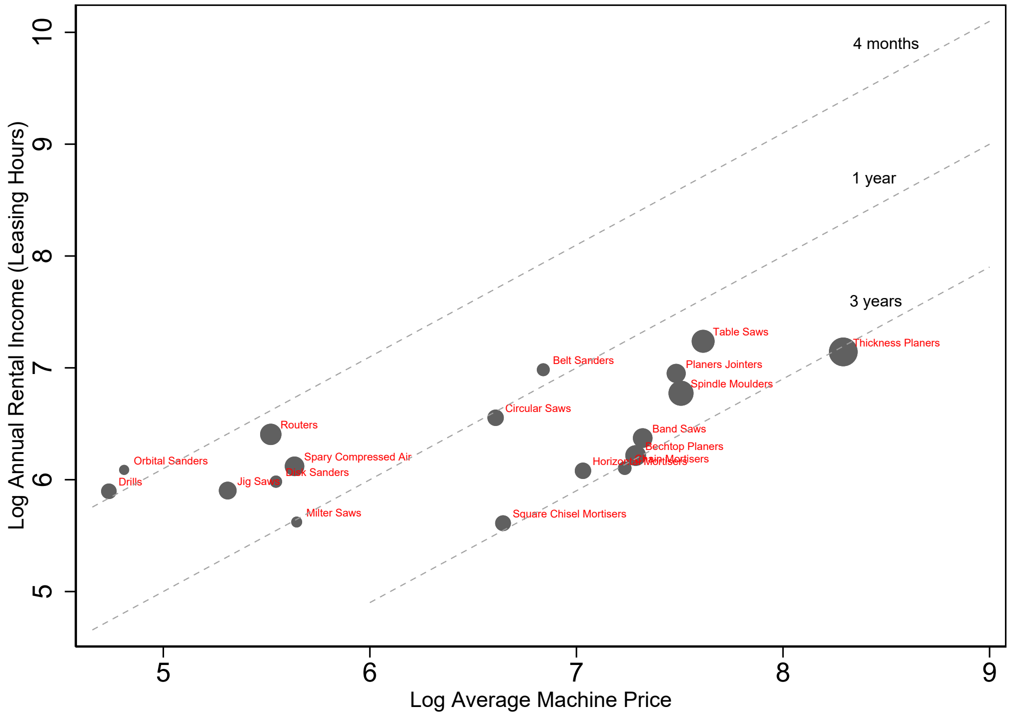
Notes: *** p<0.01, ** p<0.05, * p<0.1. OLS regression coefficients. Standard errors clustered at the firm level in parentheses; and bootstrapped with 1,000 replications and resampling clustered by firm in square brackets. In columns 1-3 the dependent variable is the (standardized) predicted managerial ability of the individual from an OLS regression of our standardized index of managerial ability on: years of schooling, age, age squared, a dummy for whether they attended vocational training, the score on a 4-item Raven matrices test, and the big five traits, measured through a 10-item big five test. For the construction of the managerial ability index see Supplemental Appendix D. To create the predicted measure in column 1 this regression includes sub-county fixed effects, and is weighted using firm weights. To create the predicted outcome for column 2, the regression also controls for sub-county fixed effects, and is weighted using firm and sub-county weights. To create the predicted outcome in column 3, the regression does not control for sub-county fixed effects, and is weighted using firm weights. In columns 4-6 the dependent variable is a dummy for whether the individual is a manager, and zero if they are a worker. The independent variable in these regressions is the rank of the individual, based on the predicted outcomes used in columns 1-3, respectively. To construct the rank, we weight observations so that the weighted sample includes an equal share of managers and workers.

Table A15: Workers-managers gap in variance of income and ability

| | Firm weights, Sub-county FE | Firm and Sub-county weights, No Sub-county FE |
|---|---|---|
| | (1) | (2) |
| Ratio of Workers-Managers Std of Income | 0.898 | 0.700 |
| Ratio of Workers-Managers Std of Managerial Ability | 0.970 | 0.925 |

Notes: Means are reported throughout. The sample includes all managers and workers in the carpentry sector that answered the survey. The first row reports the ratio of the standard deviation of workers' and manager's income. For workers, this corresponds to their monthly labor earnings; for managers, this corresponds to their average monthly profits in the last three months. The second row reports the ratio of the standard deviation of worker's and manager's predicted managerial ability, where managerial ability is predicted from an OLS regression of our standardized index of managerial ability on: years of schooling, age, age squared, a dummy for whether the individual attended vocational training, the score on a 4-item Raven matrices test, and the big five traits, measured through a 10-item big five test. For the construction of the managerial ability index see Supplemental Appendix D. The statistics in column 1 are weighted by firm weights and include sub-county fixed effects. The statistics in column 2 are weighted by firm and sub-county weights and do not include sub-county fixed effects.

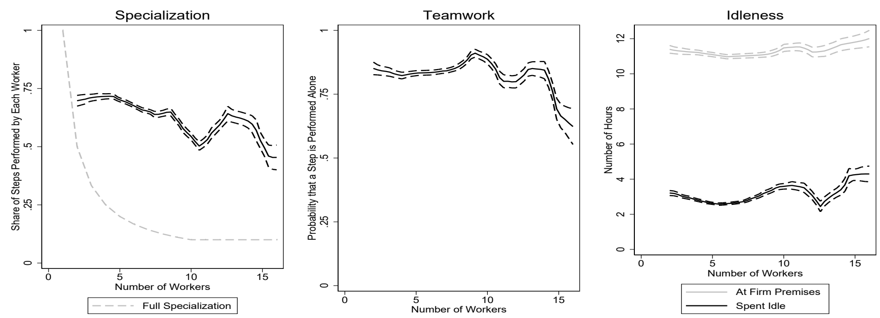
Figure A1: Rental income as a function of machine price in carpentry



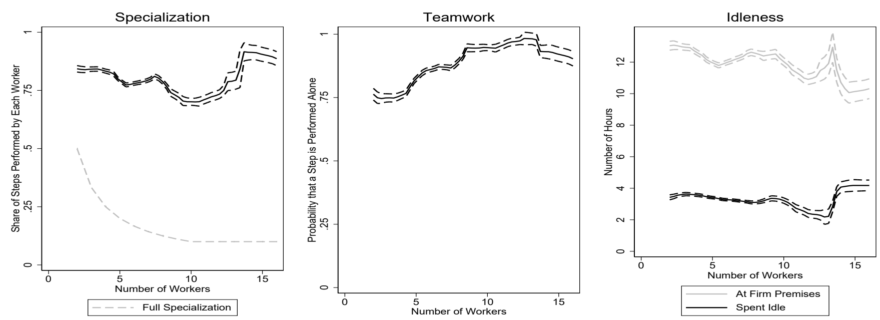

Notes: The figure reports the log of annual rental income (y-axis) from the leasing of modern machines in the carpentry sector against the log of their respective purchase prices (x-axis). The series reported on both axes are constructed using reports from machine owners in the carpentry sector, conditional on leasing out machines. Machines are weighted by the share of firms who report renting in the machine, so that larger dots correspond to machines leased more intensively in the data. The three diagonal lines, corresponding to 4 months, 1 year and 3 years respectively, depict the time taken to recuperate the purchase price of a machine by leasing it out on the rental market (e.g. roughly 4 months for less expensive drills and 3 years for more expensive thickness planers).

Figure A2: Organization of labor across the size distribution

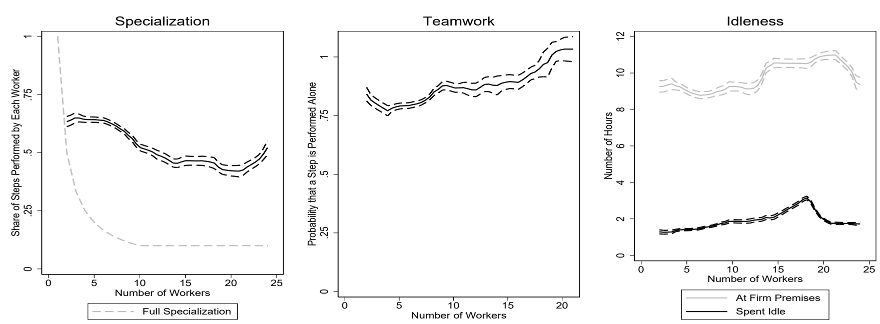
(a) Carpentry




(b) Metal fabrication



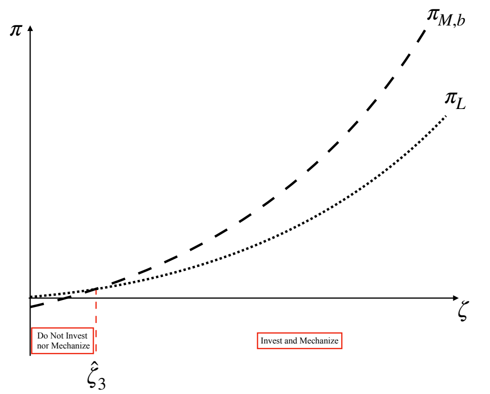

(c) Grain milling



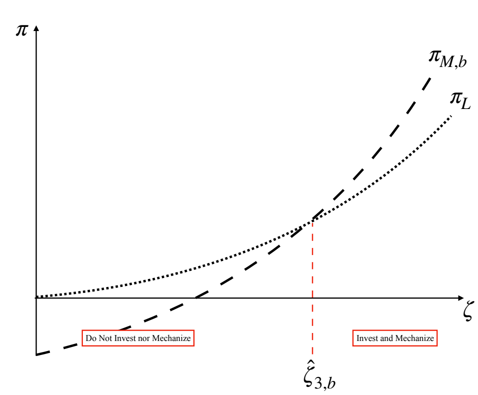

Notes: These figures show how the organization of labor varies with firm size in the three sectors covered by our survey. The black curve in the first panel (on the left-hand side) shows the mean share of production steps performed by each worker conditional on firm size. The conditional mean function was obtained through a non-parametric regression, and the 95% confidence interval is depicted using the black dotted line (here firm size is measured by the number of workers employed). The grey dotted curve shows the minimum share of steps that each worker has to complete given the total number of steps and the firm size on the x-axis. It serves to highlight a large gap between observed patterns of labor organization and full specialization - even among the largest firms. The second panel (in the middle) explores the possible contribution of teamwork in driving economies of scale. The graph plots the probability that a production step is performed alone (on the y-axis) against the number of workers (x-axis). It shows that even in firms with 10-15 employees, at least 60% of the steps are performed alone. The third panel (right-hand side) further investigates whether larger firm size is associated with a more intensive use of labor inputs, as measured by lower idle time among workers. The solid grey curve represents the average number of hours spent by workers at a firm's premises, and the solid black curve represents the average number of hours spent idle by workers employed (both mean functions are conditional on firm size). The graph shows that workers spend close to 3 hours/day idle, and this does not vary much across the size distribution, except at the very top. The dotted lines represent 95% confidence intervals in both cases.

Figure A3: Equilibrium profits when $\theta \to \infty$

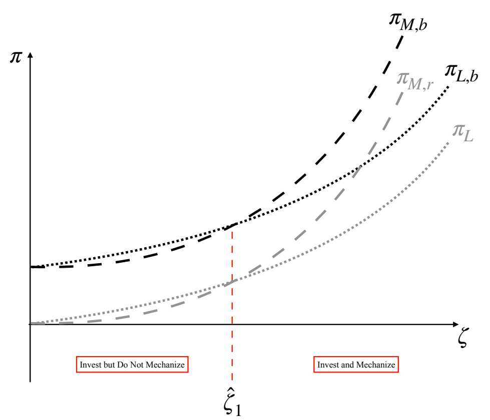
(a) Low $\rho$, $\tau = 0$



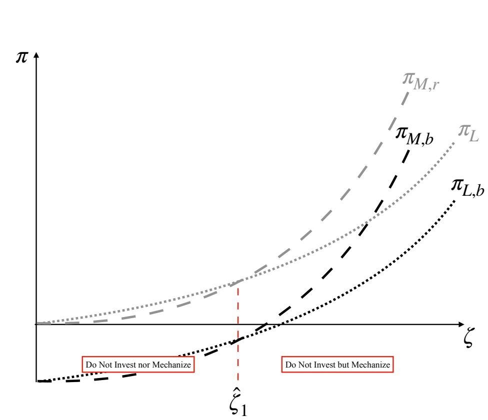

(b) High $\rho$, $\tau = 0$



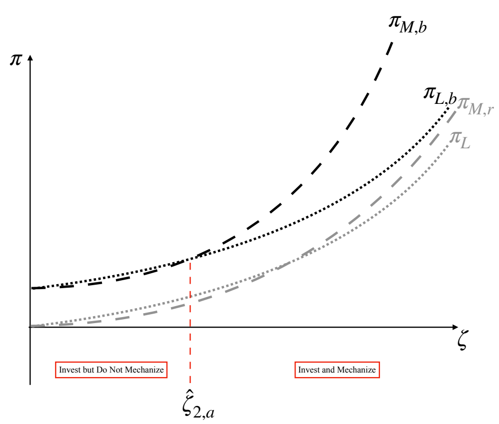

(c) Low $\rho$, $\tau \in (0, \infty)$



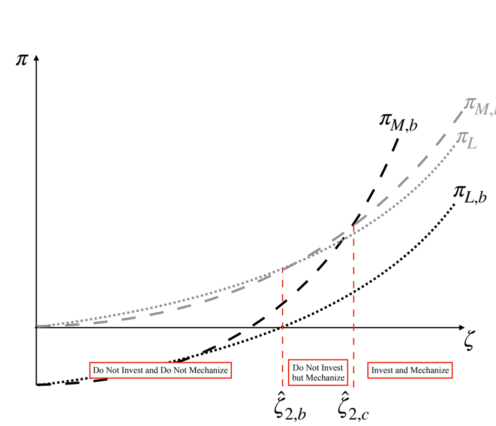

(d) High $\rho$, $\tau \in (0, \infty)$




(e) Low $\rho$, $\tau \to \infty$

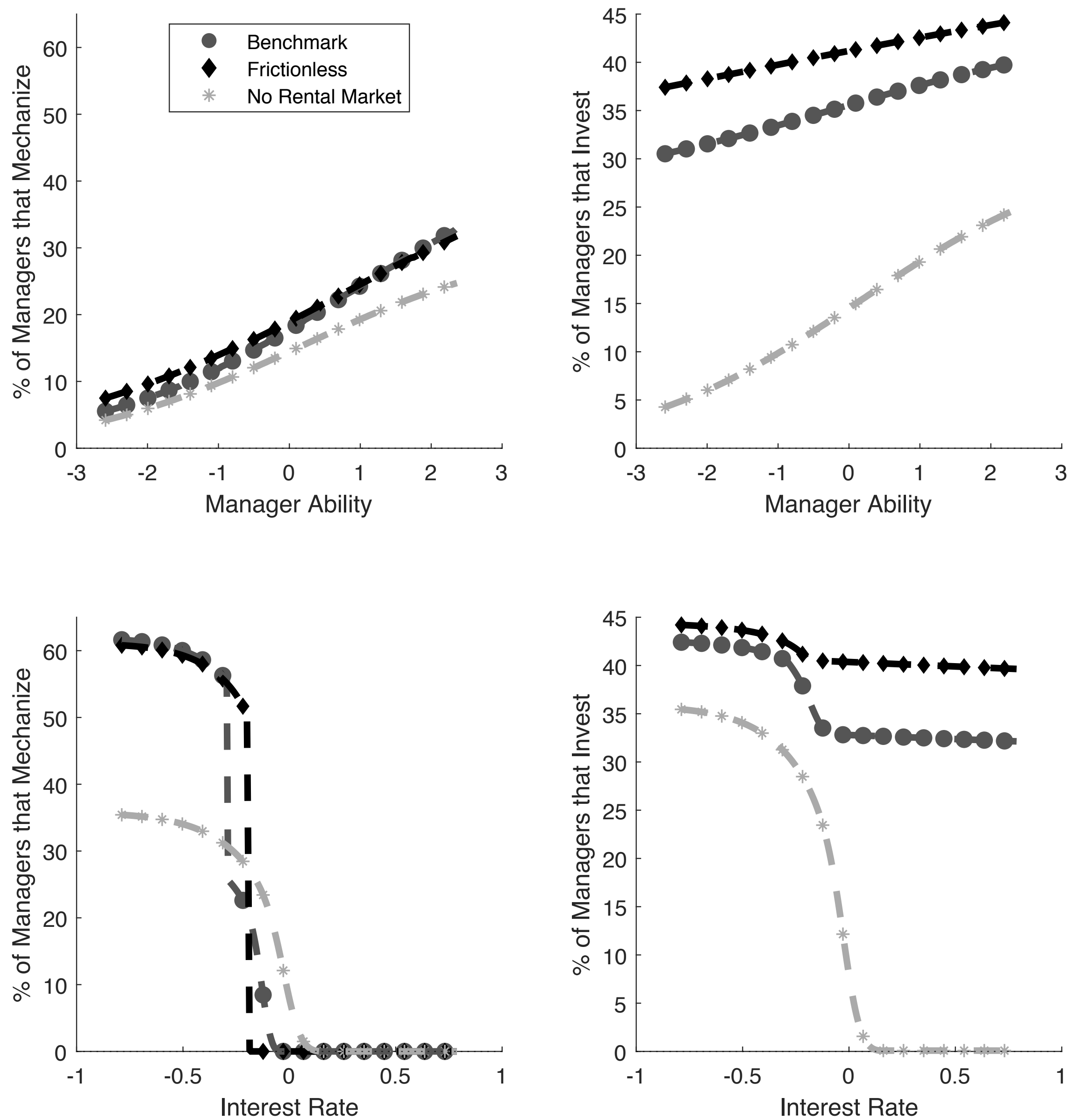



(f) High $\rho$, $\tau \to \infty$




Notes: The Figure shows the profits functions as a function of manager skill $\zeta$ for the four different production choices. The solution of the manager problem implies that the maximized profits are given by the upper envelope of the different profit functions, thus partitioning the $\zeta$ space into four regions.

Figure A4: Investment and mechanization choices in three economies: $\tau = 0$; $\tau = 0.415$; $\tau = \infty$




Notes: The Figure shows the investment and mechanization decisions for three economies: the black circles are for the benchmark economy, with $\tau = 0.415$; the gray diamond are for the frictionless economy, with $\tau = 0$; the light gray stars are for the economy without the rental market, $\tau = \infty$. The top two panels report the share of managers that mechanize and invest as a function of manager ability, or $\zeta$ in the model. The bottom two panels report the same shares as a function of the interest rate faced by managers, or $\rho$ in the model.