Achieving Scale Collectively*

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Abstract

Technology is often embodied in expensive and indivisible capital goods. 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 can alleviate this concern. We design and implement a survey of manufacturing firms in Uganda, which uncovers an active rental market for large machines among small firms. We then build an equilibrium model of firm behavior and estimate it with our data. The model shows that the rental market is quantitatively important for mechanization and productivity since it mitigates imperfections in other markets. The estimated transaction costs in the rental market are relatively small, which motivates us to redefine firm boundaries as a group of workers sharing the same machines. Doing so, the average firm size in our data increases by 77%. We conclude that through the rental market small firms achieve scale collectively.

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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 and indivisible capital goods, such as production machines.[1] The large fixed costs of capital inputs may hinder technology adoption for firms in developing countries, which typically operate at small scale due to many 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 rental market interactions between small Ugandan firms allow them to increase their effective scale, and to overcome barriers to the adoption of large capital equipment: while machines are indivisible, their capacity is divisible and can be shared among many firms.

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 recent studies on 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 an active inter-firm rental market. Back to the example, we document that while less than 10% of firms own a thickness planer, 60% use one. The rental market effectively redefines the firm boundary, allowing workers of different firms to use the same production machines. To highlight this point, we recalculate the firm size distribution in our data consolidating all firms that share the same machines: the average firm size increases from 5 to 8.8 workers, and the share of firms with more than 10 employees goes from 5% to 33%. This exercise suggests that the rental market helps firms effectively increase their scale. However, firms face transaction costs in the rental market: 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.

We show that economies of scales are larger in carpentry and that, consistently, the rental market is more developed there than in the other two sectors.[5] For this reason, we build and estimate the model for carpentry, and explore the reasons behind the cross-sectoral heterogeneity in the last part of the paper. 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,

[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.

the renter pays $1 + \tau$ dollars, where τ 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 to mechanize and invest since they make the marginal cost of capital lower for firms that own machines.[7] 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. 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 the model 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*. For this reason, we argue that redefining the firm boundary in terms of the workers who share the same machines is meaningful for understanding technology adoption and productivity. We then structurally decompose the 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 is almost *three times* larger than the aggregate effect of the same intervention. This is so because a well-functioning rental market attracts low productivity entrepreneurs, diluting average productivity, increasing rental prices, and decreasing output prices. Finally, we show that the rental market redistributes market share from high to low ability entrepreneurs, and

[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.

that it reduces the dispersion of labor productivity and of the marginal product of capital.[8]

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 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).[9] We provide two new insights: (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.[10]

Second, the literature has long argued that the firm size distribution in developing countries is dominated by very small firms (Hsieh and Olken, 2014). We argue that in contexts where firm clusters are important, focusing on firm size as defined by the number of workers under the supervision of one manager (e.g. Lucas, 1978) can be partly misleading, since the effective scale of firms depends on interactions within the cluster. In particular, we show how redefining firm size to include all workers who use the same machines challenges the view that firms in

[8]Ignoring rented capital, as often done due to lack of data, would *increase* the estimated dispersion of marginal products due to mis-measurement. While interesting, we do not explore this possibility in the paper since our cross-sectional data is not well equipped to estimating marginal products of capital.

[9]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.

[10]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.

developing countries are very small. The delineation of firm boundaries through asset ownership also relates to a classic literature on property rights theory and the boundaries of the firm (Grossman and Hart, 1986; Hart and Moore, 1990).

Third, we are not the first to highlight that firm clusters might be an effective way to exploit the benefits of coordination. In fact, this idea goes back at least to Marshall (1920). A literature in economics and sociology has examined the role of firm clusters on dimensions such as the specialization of the production process, or the outsourcing of production steps to suppliers, but the focus has been on case studies with small samples (Rabellotti, 1995; Schmitz, 1995). Our contribution is to provide the first quantitative assessment – to the best of our knowledge – of this type of firm-to-firm interactions in determining access to modern technology and the cost of production. A related literature studies knowledge spillovers in firm networks (Cai and Szeidl, 2018; Perla and Tonetti, 2014). We contribute by showing that physical interactions in the market for capital are another important source of firm-to-firm productivity spillovers.[11]

More broadly, we contribute to an established literature on the causes of industrial agglomeration (Duranton and Puga, 2004; Ellison et al., 2010), by highlighting the sharing of large capital equipment as a potential source of agglomeration for small firms. Finally, we argue that more attention should be given to firm-to-firm interactions and to the functioning of firm clusters when designing interventions to help small firms grow.[12]

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.[13]

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

[12]For recent reviews of micro-entrepreneurship interventions in developing countries, see Quinn and Woodruff (2019) and Jayachandran (2020).

[13]Supplemental appendix materials (not intended for publication) can be found on the authors' websites.

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,[14] 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.[15] We conducted a listing of all the firms in 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.[16] Finally, as described in detail in Supplemental Appendix C, all our results are weighted to reflect our sampling strategy.

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

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

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

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

powered machines or manual tools are used; (ii) which employees work on the step and for how many hours; and, (iii) the time taken by the employee (or team of employees) to complete it.[17]

For each machine, we collected numerous details, 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 measured through direct observation by our enumerators.[18] 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.[19]

3 Descriptives on the Organization of Production

We now present a number of key facts on the organization of production, with a particular focus on the role of capital and labor in production and on 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 Distribution of Economic Activity across Firms and Space

Basic firm characteristics. Appendix Table A1 reports descriptive statistics for the 1,115 firms in our sample. 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.

[17] 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.

[18] 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.

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

Descriptives on production in informal clusters. 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. Among door producers, around 65% produce the two-panel door, our core product.[20] Figure 2b 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 steps for door production.[21] Taken together, this evidence shows that the market is populated by many small firms producing similar products using similar steps. In other words, we do not find evidence of specialization of economic activity across firms.

We use the initial firm listing to study the spatial distribution of firms. Firms concentrate in clusters. One way to see this is to calculate the median number of firms in the same sector 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 there is substantial spatial concentration, especially in carpentry. The clustered nature of economic activity can be appreciated in Appendix Figure S3, which maps the distribution of firms in one of our sampled sub-counties. Indeed, we see that firms tend to cluster around major roads.

3.2 Economies of Scale Due to Indivisibility of 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.[22] 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

[20] The pattern for metal fabrication and grain milling reported in Appendix Figure S6 shows similar results.

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

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

most steps, especially in carpentry and metal fabrication.[23]

We find 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 used by their firm. We can then compute the average minimum time taken to perform a step, by whether it is mechanized or not, after controlling for a large set of firm and worker characteristics.[24] Figure 2c reports the results for carpentry, and shows substantial efficiency gains from mechanization for most steps. For example, thicknessing for a door 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. Atack et al. (2020) estimate even larger productivity effects of mechanization in Nineteenth century America.

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 2c 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 a firm-level measure of the machine utilization rate is strongly correlated with: (i) total revenues per worker (column 1), (ii) revenues per worker from the sale of doors (column 2); (iii) selling price of doors (column 3); and (iv) a standardized index of the quality of doors produced (columns 4).[25] In addition, note that the coefficient in the regression of log revenues per worker from the sale of doors on mechanization (column 2) is roughly twice as large as the coefficient from a regression of log door price on mechanization (column 3). 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.[26]

Machine capacity and economies of scale. Figure 3 shows the percentage of firms using different types of machines in production of the core product in carpentry, together with the

[23]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.

[24]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.

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

[26]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.

average machine price. We note that most machines are expensive.[27] 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 (a) of Appendix Figure S11, and they are used closer to full capacity in grain milling.[28]

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.

3.3 Rental Market for Machines

Prevalence and nature of the rental market. A natural market solution to the presence of capital indivisibilities 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, while less than 10% of firms own a thickness planer, 60% use one. The rental market is instead more limited in metal fabrication and almost entirely absent in grain milling (Appendix Figure S11), 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.[29]

Our data for carpentry further reveals that the rental market is primarily across firms in the

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

[28] 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.

[29] 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).

same cluster: in at least 60% of cases, firms report renting the machine from another carpenter nearby.[30] 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 16 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 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 (Appendix Table S6). 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.[31]

The rental market is more common for large and expensive machines (Appendix Figure S12). While the rental market allows small firms to access machines, it also benefits machine owners, who can use it to 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.[32] Second, the concentration of machines is limited: Appendix Figure S13 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

[30] 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.

[31] 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.

[32] Indeed, 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.

fail to find a negative coefficient in any of the specifications.[33] While this evidence is purely descriptive, it supports the conclusion that rental markets operate competitively.

Achieving scale collectively? Firm size is typically measured by the number of workers under the supervision of the firm manager. However, our data shows that firms are deeply intertwined through a rental market for machines. This suggests that viewing the boundary of the firm as defined by the span of control of the manager might be misleading. An alternative could be to define the firm boundary by the utilization of the same production machines, in line with a classic literature in organizational economics which views the firm as being defined by the ownership of production assets (Grossman and Hart, 1986; Hart and Moore, 1990).

Our unique survey design allows us to compare how the firm size distribution changes as we redefine the boundary of the firm. Figure 4 makes this comparison for carpentry. It reports: (i) the size distribution when a firm is defined by the number of employees working under one manager, and (ii) the size distribution when firms are defined by all employees operating the same machines, which we create by reassigning the employees of machine renters to machine owners.[34] The results are striking: once we account for rental market interactions, the average firm size increases by 77%, from 5 to 8.8 employees, and the share of firms with more than 10 employees increases from 5% to 33%. This is especially notable, given that in developing countries firm size distributions based on the typical definition are known to be characterized by a large mass of small firms, with "missing" medium and large firms (Hsieh and Olken, 2014).

This change in the size distribution illustrates how the rental market helps firms achieve scale collectively. However, the extent to which it is meaningful to define the boundary of firms in terms of machine usage depends on how large are the transaction costs that firms face to access rented capital: the lower these are, the more it justifies looking at firms that share machines as one production entity. Our model, developed in the next section, allows us to measure these transaction costs, and thus to quantify which fraction of the potential gains from scale are reaped collectively through the rental market.

Finally, we note that the puzzle remains of why more profitable firms do not formally take over smaller and less productive firms, and instead engage in rental relationships 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 through the rental market, firms *de facto* already exploit at least some of the productivity benefits of consolidation, which

[33]These results are robust to excluding the smaller machines (e.g. drills) or to including only the largest machines (e.g. thickness planers).

[34]To do so, we first assign the workers of each renter to the machine types they rent, proportionally to the time they use each machine type; then, we sum across renters to create, for each machine type, a "pool" of workers to be redistributed to machine owners. Finally, we reassign this pool of workers by dividing them equally among all owners of that machine type.

substantially limits the impact of any such constraints on productive efficiency.

3.4 Additional Descriptive Results

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 carpentry, and 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.[35] 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 S8 shows that: (i) most workers are hired through referrals, which is a recruitment 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.[36] 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

[35]Figures S14a and S14b in the Appendix show similar results for metal fabrication and grain milling.

[36]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. (2020); Bassi and Nansamba (2020); Abebe et al. (2018); Abel et al. (2019) and Carranza et al. (2019).

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 S15 shows that there is substantial variation in both prices and quality for 2-panel doors even *within* sub-counties.[37] This confirms that there is substantial differentiation even within narrowly defined products. On output market frictions, Appendix Table A4 shows that: (i) the majority of customers originate 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.[38] In line with limited competition due to product differentiation and output market frictions, we estimate markups that range between 21%-24% (Appendix Table A1).[39]

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 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.

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 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 Ψ. 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,

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

[38] 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.

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

$\zeta(\omega)$, which affects both the quality of the manager's products and his[40] productivity, with relative strength modulated by a parameter γ. To keep the notation light, we omit the index ω, unless necessary, throughout 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,[41] $q(\omega)$ is a manager-specific quality that depends on his ability $\zeta(\omega)$ and whether he mechanizes, and $y(\omega)$ is quantity produced.

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

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

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 ω is

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

which is increasing in quality and decreasing in quantity. 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 a manager ω is $p(\omega) = q(\omega) y(\omega)^{-\eta} P$.

Production function. Each manager ω 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.

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

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

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 α is the capital share in production.

The two production processes provide goods of different quality, which in turn affects their prices, as noted. The quality of a good produced by manager ω 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 parameter γ modulates the relative role of managerial ability $\zeta(\omega)$ as a quality and quantity shifter. 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 δ 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,[42] and machines are indivisible.

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

Rental market for machines. A manager ω that purchases a machine, operates it at capacity $C(\omega)$, and uses $K(\omega)$ units of capital in production, has *excess capacity* equal to $C(\omega) - K(\omega) \geq 0$.[43] Excess machine capacity is rented out to other firms in a competitive rental market at equilibrium price p_r. The market is subject to a transaction iceberg cost τ, 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 τ captures the cost of moving inputs to the workshop where the machine is located, or the cost of waiting to use the machine.[44] All costs are expressed in units of output.

[42] 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).

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

[44] 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.

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 ω 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 ν 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 ω makes several choices. First, before observing his cost of capital ρ, he decides whether to enter the market and start producing or take an outside value. The manager ex-ante profits are given by

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

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 (ρ, ζ). $E_\rho[\cdot]$ is the expectation taken with respect to the distribution of the random variable ρ conditional on the managerial ability ζ. We use this notation throughout the model. The expected profits do not depend on the identity of the manager, or its name ω, but only on its characteristics (ρ, ζ). Therefore, we omit ω.

If the manager enters the market, he observes his cost of capital ρ 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

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

Next, we describe each component in the right hand side. A manager that does not invest nor mechanize solves

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

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 τp_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 both his production inputs and the total machine capacity to use. For the managers that 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 inputs and capacity choices are intertwined since the owner can use only as much capital as is supplied by his machine:[45]

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

The 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 ω chooses to not mechanize and $C(\omega) = 0$ if manager ω 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 $C(\omega)$

[45] We are implicitly assuming that managers cannot both use their own machine and rent in additional capital. This assumption is made 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.

are strictly positive, to keep track of whether a given manager ω decides to mechanize and/or invest. If a manager ω 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 ω 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 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

$$\int_{\omega \in \Omega} C(\omega)\, d\omega = \int_{\omega \in \Omega} K(\omega)\, d\omega.$$

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 show 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 work under an empirically motivated assumption. This assumption is not imposed when solving and estimating the quantitative model in the next section.

Parametric assumption. *The constraint $C(\omega) \geq K(\omega)$ is slack for all managers.*

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. It is also motivated by the empirical observation that the great majority of firms own only one machine of each type and that they have excess capacity to rent out to the market.

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 (ζ, ρ) has 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 A.

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 ζ for managers that decide to mechanize.[46] As a result, the (ζ, ρ) state-space is partitioned into compact regions with different production choices. The shape of the partitioning depends on the rental market wedge τ, as 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 $\zeta(\omega) \geq \hat{\zeta}_1$;*

[46] 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 $\beta < 1$.

- *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* τ*, but* $p_r(1+\tau)$ *is increasing in* τ*. 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* τ*;* $\hat{\zeta}_{2,b}$ *is increasing in* τ*;* $\hat{\rho}_2 \leq \hat{\rho}_1$*; and* $\hat{\rho}_2$ *is decreasing in* τ*.*

Figure 5 helps to visualize Proposition 1: it illustrates the partitions of the (ρ, ζ) space in the three cases.[47] 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 ρ, while the second one on the manager's productivity ζ. When $\tau > 0$, the choice to invest and mechanize are, instead, tied together. Managers that purchase the machine face a lower marginal cost of capital, and are thus more likely to mechanize as well. When $\tau \to \infty$, mechanization is possible only through investment in machines.[48]

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

[47] The comparative statics as a function of τ hold for a given set of managers active in the sector. In general, a change in τ 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 S19 in the Appendix shows that Proposition 1 holds in the estimated model.

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

anize, 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 ω draws two vectors of preference shocks: (i) $\{\varepsilon_X; \varepsilon_N\}$ where ε_X is for exit, and ε_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. The shocks are distributed according to independent Type I Extreme Value Distribution with shape parameters $\frac{1}{\tilde{\theta}}$ and $\frac{1}{\theta}$.

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:

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

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 ϕ 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 ρ 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 χ and ξ 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 θ modulates the relative roles of shocks and individual characteristics in determining production choices. The higher is θ, the closer the equilibrium resembles the partitions shown in Figure 5. If $\theta \to 0$, all managers are equally likely to adopt any production method, irrespective of their skills and cost of capital.

The taste shocks do 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 ν 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. high ζ) may charge a higher or lower price depending on the value of γ.[49] Finally, but most importantly, the framework offers a relationship between observable variables that can pin down the rental wedge τ in the data.

Lemma 2. *Consider a manager ω that mechanizes. His 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 ω, and all other terms are as previously defined.

Lemma 2 follows from comparing the capital labor ratios of owners and renters. The relative capital intensity of production 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 τ on top of the direct rental fee. The wedge τ distorts the capital labor ratio of renters compared to owners: renters use relatively more labor.

Next, we describe our estimation strategy. We parametrize the outside option as

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

where $\tilde{\pi}_X$ captures the overall value of the outside option, while ψ 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 (ρ, ζ) 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 τ in the data using the empirical specification provided by Lemma 2. We then calibrate the six parameters that have direct empirical counterparts. Finally, we jointly estimate the remaining 17 parameters to match the 23 moments included in Table 4. We next describe the calibration/estimation of each parameter in detail.

[49] Recall that γ modulates the effect of ζ on output quality and productivity.

5.2 Estimating the Rental Market Wedge τ

Lemma 2 provides an estimating equation to pin down τ in the data. The core of Lemma 2 is that firms who rent machines use relatively more labor than capital to perform the same task. To bring this to the data, we focus on production steps – that are clearly defined tasks in our case – and estimate 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;[50] $Rent_{sj}$ 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;[51] L_{sj} is the monthly labor hours used by firm j in step s; ϑ_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 β_1 is directly related to the rental market wedge τ 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 β_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 S9, 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 S6). 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 spec-

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

[51] We prefer to control for predicted wages (rather than actual wages) to alleviate endogeneity concerns. See the footnotes to Appendix Table A10 for more details on how predicted wages are computed.

ification 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 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 2b. Column 1 reports our preferred estimate of β_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 estimates of β_1 become 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 S10 shows that estimating equation 2 separately for each step yields mostly negative $\hat{\beta}_1$. This justifies our pooled specification in Table 2. Second, in Appendix Table S11, 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 are remarkably similar.[52]

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.

[52] We do not have information on the assignment of labor hours to specific machines, and so in column 1 of Appendix Table S11 the labor cost 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 2 which controls for firm fixed effects.

5.3 Estimating the Other Parameters

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

Calibrated parameters. 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 α 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.[53] 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.[54]

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

[53]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.

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

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.

Jointly identified parameters. 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.

μ is the relative quality of goods produced with the mechanized process. It targets the relationship between mechanization and price (row 9). If μ 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 γ, 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 θ 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 ζ, properly normalized, pins down θ (row 7): it is steep if θ is high. As a proxy of managerial ability ζ 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 δ 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 χ, the lower the capacity. Also, the larger is ξ, the higher the profitability of machine lending, hence the more managers choose to invest. We can thus pin down ξ using the market clearing conditions.

The investment decision depends also on the distribution of the cost of capital ρ. 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 ρ and the manager ability ζ 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).[55]

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 η – the larger the markup, which we target (row 21). The stronger are labor market frictions – i.e. the larger is ν – 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).[56] 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 ψ 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 ψ implies that skills are less relevant if individuals choose not to become managers. Our data suggests that, for

[55] In the data, we only observe the interest rate for managers with an outstanding loan. In the model, we compute the statistics on ρ 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.

[56] 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 ν. 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.

most managers, the outside option is to be a worker in the same industry.[57] We thus discipline ψ by targeting the relative income inequality of managers and workers (row 15). Of course, ψ, together with the variance of the taste shock for entry $\frac{1}{\theta}$, determines also how selected on ability 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 φ 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 φ, and $\hat{m}_x$ is the properly normalized vector of moments computed in the data.[58] 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 φ^*, 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.[59] Row (20) shows that the estimated size of the labor market friction ν is almost identical to what would be pinned down from a regression of wage on size, although several other moments help us to identify ν in the estimation. The labor frictions are sizable, consistent with the direct evidence in Appendix Table S8. One way to interpret the size of ν 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. $\frac{1}{\theta} > \frac{1}{\bar{\theta}}$. As a result, individual characteristics are a stronger determinant of the decision to become a manager than of the decision to mechanize. This

[57] 86% of managers report having worked as employees at some point in the past.

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

[59] In this setting, the parameter η may also capture frictions in the output market.

results likely captures the fact that switching across production methods has smaller associated fixed costs than starting a firm.

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.

Aggregate 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 τ. This exercise essentially computes the long-run impact of a country-wide policy that affects τ. In the long run, the change in τ 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 these equilibrium effects into account.

Figure 6 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 τ. We also consider 1 and 4 as alternative values of $\frac{1}{\iota}$ (2.2. is the benchmark value). We highlight in red the estimated value of τ.

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 τ increases productivity, thus allowing the sector to grow and hire more labor. On the other, a lower τ decreases the marginal cost of capital, thus leading firms to substitute labor for capital. If ι is large, the scope for the carpentry sector to expand is limited and thus the latter force dominates.

Firm size and boundary of the firm. Figure 7 shows how changing the rental market wedge τ impacts the firm size distribution. Decreasing the wedge (i.e. lowering τ) *decreases* the average firm size as defined by the number of employees under the supervision of one manager (left panel). A well-functioning rental market attracts low ability entrepreneurs, diluting the average firm size. Furthermore, when capital is cheaper, firms substitute from labor to capital.

However, and most importantly, in the presence of an inter-firm rental market, the usual notion of firm size might be misleading, especially if we wish to understand technology adoption. In a frictionless rental market, only a small percentage of the overall capital is used by firms that own their machines (middle panel).[60] As a result, it may be useful to redefine the boundary of the firm, shifting the focus from the managerial span of control to the utilization of the same machines, along the lines of the discussion in Section 3.4. In the right panel, we calculate the average firm size when firms are defined by consolidating the labor used by all the manager types that use the same machine,[61] and we then compute the ratio of this measure of firm size to the standard one. In the absence of rental markets (i.e. $\tau = \infty$) the two measures are identical. For the benchmark value of τ, the model is close to the empirical evidence: the average firm size increases by 75% if we change the boundary of the firm (this was 80% in the data). When $\tau = 0$, the gap between the two measures is more than 200%.

In general, the appropriate definition of the firm boundary depends on the context. The managerial span of control definition might be relevant when thinking about demand, as we discussed that managers engage in personal relationships with customers so that the manager's identity is important. The machine perspective might instead be more useful if we are interested in technology adoption and productive efficiency. Moreover, the level of τ plays an important role in guiding this choice. When τ is zero, ownership of machines does not determine production choices since owners and renters face the same marginal cost of capital, and we are thus justified in consolidating firms that use the same machine. When τ is positive, internal capital is cheaper. So as τ increases, the production choices of owners and renters diverge, and it becomes less sensible to treat as one those firms that use the same machines – in other words, transaction costs keep firms distinct. As discussed, our benchmark rental market with $\tau = 0.404$ is already relatively efficient, since it achieves more than half of the possible productivity and output gains. Therefore, accounting for rental market relationships in the definition of firm size is meaningful in our context, and can help understand technology adoption. More broadly, our results show that rental markets have stark implications for how we think about the firm size distribution, and challenge the view that firms in developing countries are very small.

Equilibrium effects. Next, we highlight the importance of equilibrium effects by comparing the impacts of reducing the rental market friction to zero in general equilibrium, to the effects of the same reduction in the rental market friction, but for a small number of firms, hence in partial equilibrium without affecting prices. Table 5 shows the results. The first row shows

[60] The model predicts that in the baseline economy (with $\tau = 0.404$) the share of rented capital is 42.2%. In the data this is 59%. This provides an untargeted check on the ability of the model to match the data.

[61] We replicate as closely as possible the procedure used for Figure 4. Details in Supplemental Appendix F.

our benchmark general equilibrium case, which can be interpreted as the aggregate effect of a country-wide and permanent intervention that reduces τ to zero. As previously discussed, reducing the rental wedge increases aggregate output, employment, labor productivity, and mechanization. It also increases the mass of active managers, as more individuals find it optimal to enter the sector. Prices are affected: the rental market price increases as the lower τ leads to increased demand for capital, and the output price decreases as the sector expands.

In the second row, we keep constant the entry choice, as well as output and rental prices.[62] This exercise corresponds to evaluating the average treatment effect of an intervention that targets a small number of already active individual firms. In order to make the results comparable with the first row, we create the aggregate effects by assigning to all firms in the economy the average treatment effects from this hypothetical RCT. The effects are in the same direction as the ones in the first row, but much larger. The increase in both output and labor productivity is around three times as large. In the model, three types of equilibrium effects dampen the aggregate results, as 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. None of these three channels is operating in the partial equilibrium exercise.

This analysis, which we expand in Supplemental Appendix G, shows the importance of taking into account equilibrium effects when estimating the gains from 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).

Distribution of economic activity and misallocation. The aggregate effects of the rental market hide substantial heterogeneity: while everyone benefits, the rental market favors relatively unproductive entrepreneurs, as Figure 8 shows. A decrease in τ increases revenues per worker through two margins: (i) capital intensity of renters increases, and (ii) more individuals mechanize. Both effects are, in our estimated economy, larger for lower productivity managers since they are more likely to be renters due to their smaller scale of operation and higher cost of investing (left panel).[63]

For the same reasons, reducing τ decreases relatively more the marginal product of capital for the low ability managers (middle panel).[64] The result is a reduction in the overall dispersion of marginal product of capital, a classic measure of misallocation. In fact, when $\tau = 0$, the marginal cost, and thus the marginal product, of capital is identical for renters and leasers.

[62] For this reason columns (5), (6), and (7) are left blank.

[63] 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 τ.

[64] We calculate the marginal product of capital only for mechanized managers. Even when τ is very large (the $\tau \to \infty$ case) a very small share of managers access capital through the rental market.

Also high ability managers benefit from a well-functioning rental market since they earn higher revenues from the rental market. However, 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 (right panel).

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 ρ and ability ζ, which determine their cost of capital and the return from using it. In a first 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 ρ and ζ, and the size of the preference shocks. In Appendix Figure A3 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 ρ and ζ.

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

Our results show that taking into account the rental market is important to understand production in the carpentry sector in urban Uganda. In this section, we ask whether, beyond Uganda, academics and policy makers should pay more attention to rental markets. The answer depends on the setting. We show that rental markets are likely to be more important 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, even 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 showed 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 settings with many 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 9a, 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.[65] 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.[66] When η 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.[67]

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 9b 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 η is large. In this case, firms face strong decreasing returns to scale and thus aggregate output is produced

[65] While reducing the dispersion of ρ, 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).

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

[67] 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.

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.

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 of indivisible capital 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 frictionless rental market has large aggregate effects on the usage of machines, labor productivity and output. We estimate that the rental market in urban Uganda achieves more than half of these possible benefits, as transaction costs are found to be limited. 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 three broad lessons. First, the usual definition of firm size as the workers employed by one manager can be misleading. Redefining firm size as the workers who share the same machines is meaningful and can help understand technology adoption in settings where firm clusters are important. Second, accounting for the fact that many employees share the same fixed capital inputs challenges the view that medium and large firms are missing in developing countries. Third, 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 follow from our work, and seem a promising avenue for future research: 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 path to development of industries in the long run?

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Tables

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

	Log Rev p.w. (1)	Log Rev p.w. Doors (2)	Log Price Doors (3)	Quality Index Doors (4)
Machine Utilization Rate (0-1)	1.125***	0.959***	0.447***	1.462**
	(0.226)	(0.249)	(0.111)	(0.599)
Subcounty FE	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes
Adjusted R^2	0.456	0.422	0.639	0.299
Observations	378	333	348	109

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. OLS regression coefficients, robust standard errors in parentheses. The sample includes only door producers in carpentry and outcome variables are monthly averages over three months preceding the survey. The dependent variables include the log of revenues per worker from the sale of all products (column 1); the log of revenues per worker from door sales (column 2); the log of the price of the main door type sold to local final customers (column 3); and a standardized index of door quality (column 4). If the firm produced two-panel doors, the outcomes in columns 3-4 refer to two-panel doors; otherwise these refer to the main door type produced. Firm controls include a standardized index of managerial ability, dummies for the most common type of door produced and for whether the firm produced two-panel doors in the last three months. For details on variable construction see Supplemental Appendix D.

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

Dependent variable: Log Monthly Machine Hours

	Baseline	Firm FE	No Controls	Only Labor Controls
	(1)	(2)	(3)	(4)
Share of Rented Machines (0-1)	-0.339***	-0.385***	-0.655***	-0.530***
	(0.092)	(0.089)	(0.110)	(0.094)
Labor Cost Control	Yes	Yes	No	Yes
Machine Controls	Yes	Yes	No	No
Firm Controls	Yes	No	No	No
Step FE	Yes	Yes	Yes	Yes
Firm FE	No	Yes	No	No
Subcounty FE	Yes	No	Yes	Yes
Adjusted R^2	0.374	0.608	0.277	0.308
Observations	1,536	1,536	1,536	1,536

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. OLS regression coefficients, standard errors in parentheses, bootstrapped in columns 1, 2, and 4 (with 1,000 replications and resampling by firm) and clustered by firm in the other columns. The sample is restricted to door producers. The dependent variable is a production step-level measure of log monthly machine hours used to produce the main type of door. For machines used in more than one step, we assign machine time to steps in proportion to the distribution of machines across steps. The Share of Rented Machines is the average of dummies for whether machines used in a step are rented, weighted by the share of total machine hours in a step accounted for by each machine type. Machine controls include log average value, average age, average expected remaining life and share made abroad, which are all weighted similarly. Firm controls consist of the log quantity of doors produced, an index of door quality, dummies for the most common type of door produced and for whether the firm produces two-panel doors. For details on variable construction see Supplemental Appendix D.

Table 3: Estimated parameters

	Parameter	Value	Source		Parameter	Value	Source
(1)	τ	0.404	T.2, c.1	(13)	$Std(\log\zeta)$	0.052	
(2)	α	0.50	T.A5, c.4	(14)	χ	0.762	
(3)	p_b	776.2	T.A6, c.1	(15)	ξ	0.717	
(4)	p_r	0.514	T.A6, c.1	(16)	$E(\log\rho)$	2.021	
(5)	δ	0.069	T.A6, c.1	(17)	$Std(\log\rho)$	2.118	
(6)	ι	0.450	BW (2006)	(18)	$Cov(\log\rho, \log\zeta)$	-0.330	Jointly Est.
(7)	ϕ	0.976	T.A6, c.1	(19)	η	0.075	
(8)	A_M	1.431	Jointly Est.	(20)	ν	0.162	
(9)	μ	1.589	Jointly Est.	(21)	W	0.311	
(10)	γ	0.939	Jointly Est.	(22)	$\tilde{\pi}_X$	1.464	
(11)	θ	0.524	Jointly Est.	(23)	ψ	0.851	
(12)	$E(\log\zeta)$	-0.934	Jointly Est.	(24)	$\tilde{\theta}$	3.431	

Notes: This table reports the estimated parameters. See the respective source tables for more details. BW (2006) stands for Broda and Weinstein (2006). The parameters in rows (8) to (24) are jointly estimated using simulated method of moments.

Table 4: Targeted moments and model fit

	Moment	Source	Data	Model	Key Parameter
(1)	Mechanization Rate	T.A6, c.1	0.381	0.355	A_M
(2)	Investment Rate	T.A6, c.1	0.139	0.180	$\mathrm{E}[\log \rho]$
(3)	Average Firm-Level Capacity Utilization	T.A6, c.1	0.356	0.318	$\mathrm{E}[\log \zeta]$
(4)	Average Market-Level Capacity Utilization	T.A6, c.1	0.585	0.585	χ
(5)	Median Hourly Machine Rental Price	T.A6, c.1	0.514	0.514	ξ
(6)	Log Revenues on Managerial Ability	T.A7, c.1	0.288	0.272	$Std\,[\log \zeta]$
(7)	Mechanization Choice on Managerial Ability	T.A7, c.2	0.025	0.021	θ
(8)	Investment Choice on Managerial Ability	T.A7, c.3	0.048	0.055	$Cov\,[\log \rho, \log \zeta]$
(9)	Log Price on Mechanization Choice	T.A7, c.4	0.559	0.560	μ
(10)	Log Price on Managerial Ability	T.A7, c.4	0.042	0.026	γ
(11)	Log Capital Used on Managerial Ability	T.A11, c.2	0.398	0.398	ν, η
(12)	Log Labor Used on Managerial Ability	T.A11, c.4	0.135	0.200	ν, η
(13)	Ratio of Managers to Workers	T.A1, c.2	0.222	0.210	π_X, $\tilde{\theta}$
(14)	Workers-Managers Managerial Ability Gap	T.A12, c.1	-0.285	-0.320	ψ, $\tilde{\theta}$
(15)	Ratio of Workers-Managers Std of Income	T.A13, c.1	0.898	0.854	ψ, $\tilde{\theta}$
(16)	Workers-Managers Std of Managerial Ability	T.A13, c.1	0.970	1.009	ψ, $\tilde{\theta}$
(17)	Entry Choice on Managerial Ability (Normalized)	T.A12, c.3	0.275	0.234	$\tilde{\theta}$
(18)	Hourly Worker Wage Rate	T.A1, c.2	0.333	0.327	W
(19)	Log Hourly Wage on Managerial Ability	T.A10, c.3	0.060	0.036	ν
(20)	Log Hourly Wage on Labor Used	T.A10, c.6	0.146	0.162	ν
(21)	Average Markup	T.A1, c.2	0.229	0.227	η
(22)	Average Interest Rate	T.A8, c.1	0.329	0.340	$\mathrm{E}[\log \rho]$
(23)	Std of Interest Rate	T.A8, c.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 second column includes links to the tables where these moments are computed.

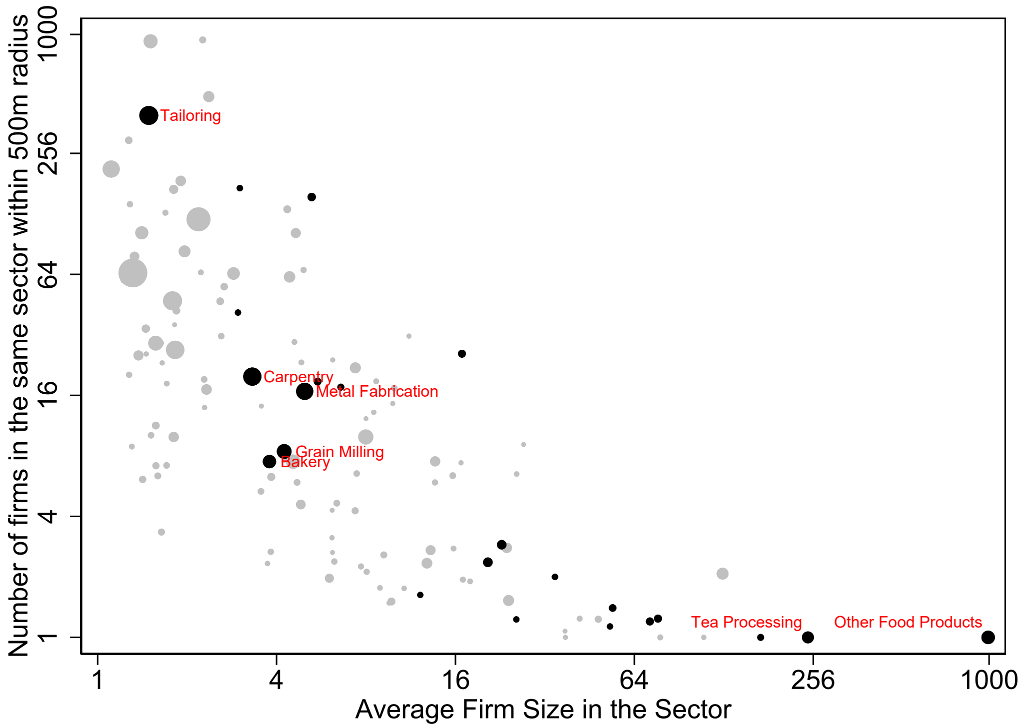
Table 5: Impacts of eliminating the rental market friction: importance of equilibrium effects

		PY_C Output (1)	L Employment (2)	$\frac{PY_C}{L}$ Productivity (3)	$\mathbb{I}_K$ Mechanization (4)	p_r Rental Price (5)	$\mathbb{I}_X$ Entry (6)	P Output Price (7)
Level of intervention:								
(1)	Country-wide (GE)	+8.6	+1.4	+7.1	+15.6	+13.8	+16.4	-3.1
(2)	Small number of firms (PE)	+29.8	+8.1	+20.0	+31.5			

Notes: Each cell shows the average treatment effect of setting $\tau = 0$, relative to the benchmark economy with $\tau = 0.404$. Impacts are expressed as percentage differences for the average firm in the group. The two rows correspond to different potential interventions. In particular, row 1 is a country-wide and permanent intervention, so that General Equilibrium (GE) effects are allowed to operate. Row 2 targets a small number of firms, so that the intervention is in Partial Equilibrium (PE). The columns correspond to different aggregate statistics. Cells that are unaffected by the definition of the exercise are left empty.

Figures

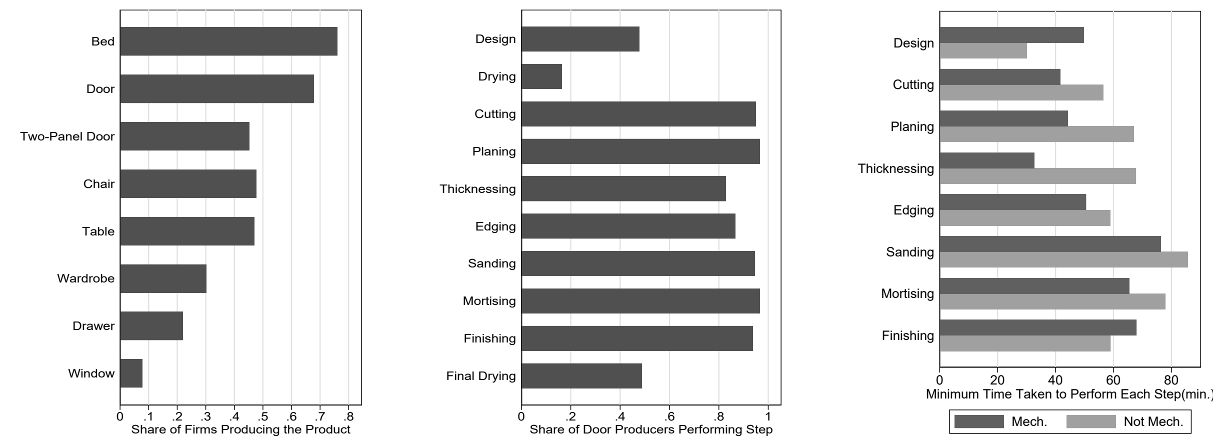
Figure 1: Spatial concentration of firms across sectors in Uganda



Notes: Data from the Census of Business Establishments (2010) for Uganda. For each firm, 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 Uganda, and only label those 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.

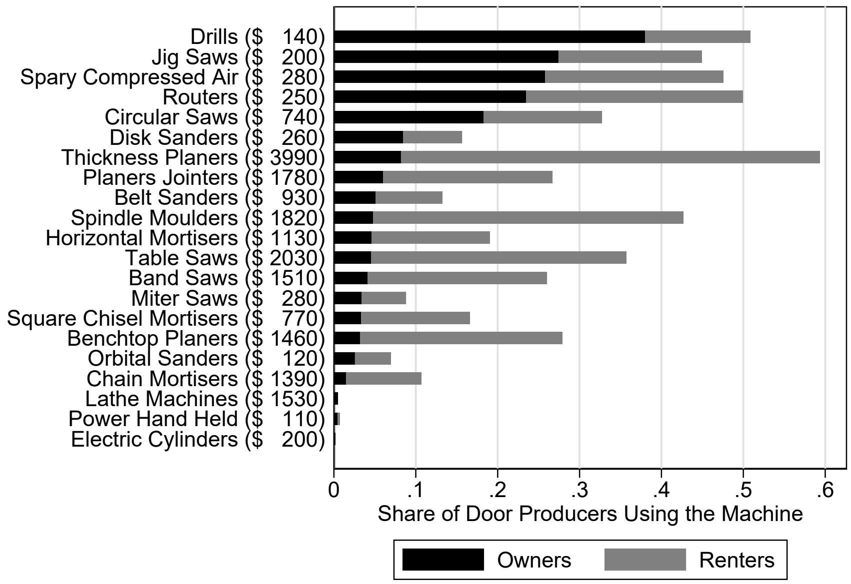
Figure 2: Descriptives on product varieties and production steps in carpentry

(a) Prevalence of product types (b) Prevalence of production steps (c) Productivity gains



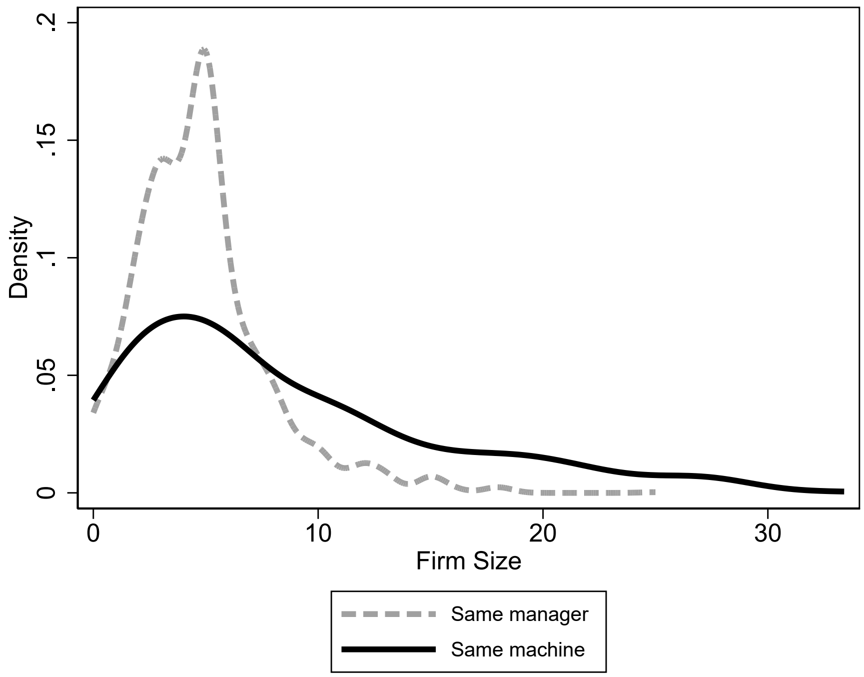
Notes: Figure 2a reports the share of firms which produced different types of products in the 3 months preceding the survey. Figure 2b reports the share of door producers that perform the production steps listed on the y-axis. The bars in Figure 2c represent the average minimum time which employees could 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 a team , the total number of employees, the ability of the manager, and 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 door producers. We omit two steps that are never mechanized, see Appendix Figure S9.

Figure 3: Usage of modern machines in carpentry by ownership vs rental



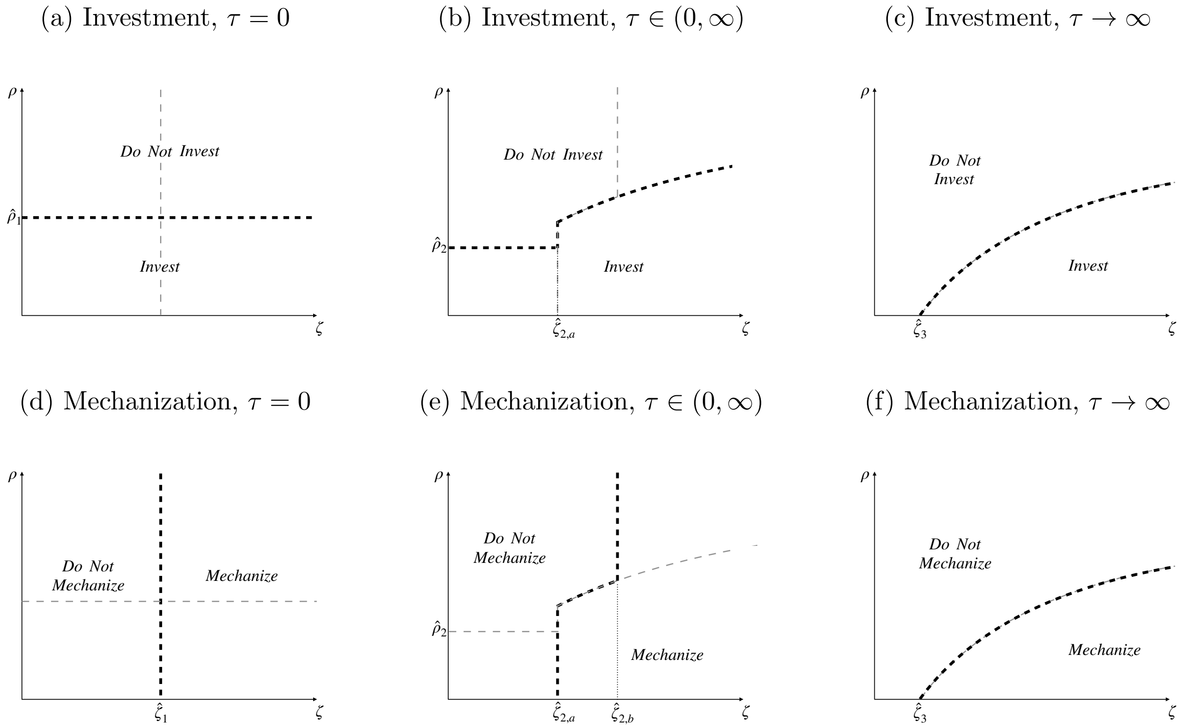
Notes: This figure decomposes the share of door producers in the carpentry sector that use a machine among those firms that own the machine (black) and those that rent it (grey). Machines used in the production of the core product are listed on the y-axis, whereas the share of firms using these machines is displayed on the x-axis. The sample is restricted to firms producing doors.

Figure 4: Firm size distribution in carpentry



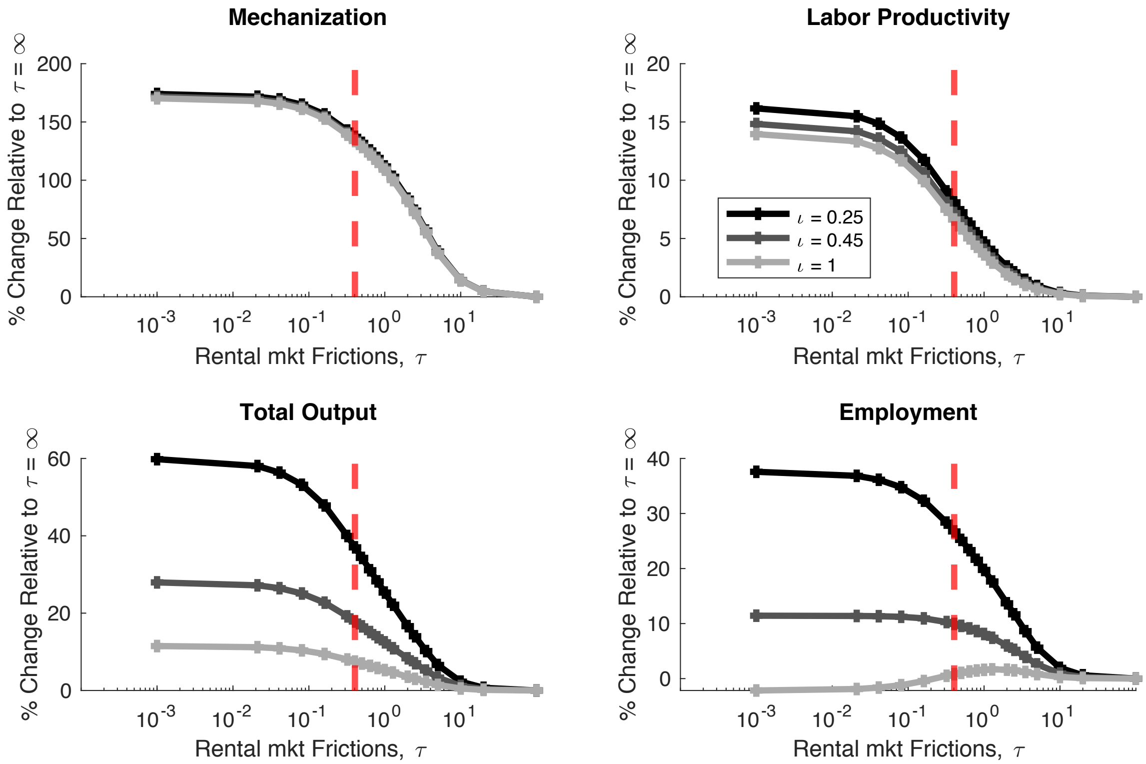
Notes: The figure shows the firm size distribution in our data according to two alternative definitions: (i) for the dashed line, we define firm size as all the workers employed by one manager/owner; (ii) the solid line reports the same distribution, but defining firm size as all the workers who operate the same machines. The sample includes door producers and we only consider machines worth on average at least two months of profits (based on Figure 3), as we are interested in machines with substantial fixed costs and that are not easily movable. To compute the second distribution, we identify firms that only rent machines (and do not own any) in the data. We then assign all the workers of each machine renter to the machine types they rent, proportionally to the time that renters use each machine type. We sum across renters to create, a "pool" of workers to be redistributed to machine owners for each machine type. Since 0.494 of machine capacity is rented from specialized retailers (see Table A6), we drop this share of labor as it should be redistributed to specialized retailers, which are not considered as part of this exercise. We reassign the remaining pool of workers by dividing them equally among all owners for each machine type.

Figure 5: Equilibrium investment and mechanization choices when $\theta \to \infty$



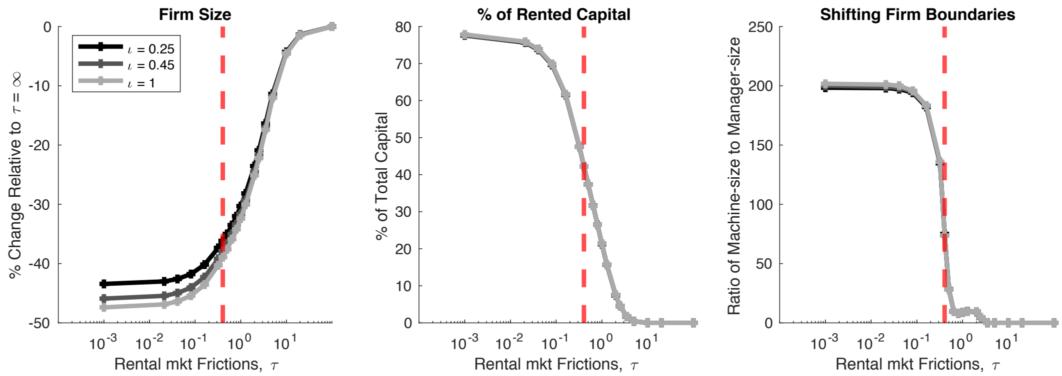
Notes: The figure shows the partitions of the (ρ, ζ) space into regions where managers decide to invest and mechanize, for different values of rental market wedge. Frictionless rental market in the first column, no rental market in the third column, and an intermediate case in the second column. The top panels show the investment choice, while the bottom ones show the mechanization choice. In the investment panels, the black lines represent the investment choices and the light gray lines represent the mechanization choices (and vice-versa).

Figure 6: Aggregate effects of changing the rental market frictions



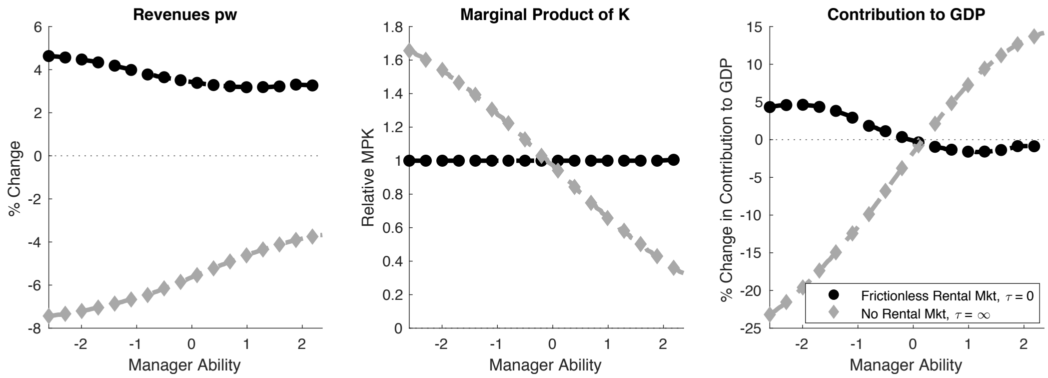
Notes: The figure shows the impact of changing the rental market wedge τ on aggregate outcomes. Each panel, shows, for a different statistic of interest, the percentage change relative to an economy without a rental market. The red dotted line highlights the level of rental market frictions estimated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

Figure 7: Role of the rental market for the firm size distribution



Notes: The figure shows the impact of changing the rental market wedge τ. The left panel shows the percentage change in average firm size relative to the case with $\tau = \infty$. The middle panel shows the percentage of the overall capital in the economy that is provided by rented machines. The right panel shows the percentage increase in firm size if we define the boundary of the firm by machine utilization rather than managerial control.

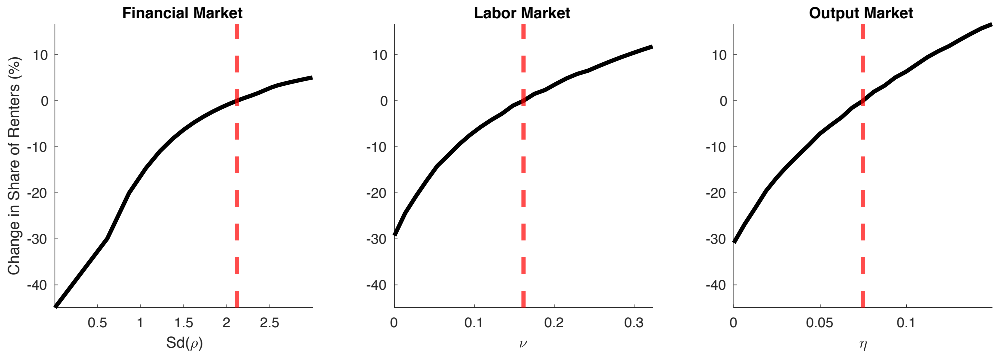
Figure 8: Distributional effects of changing the rental market frictions



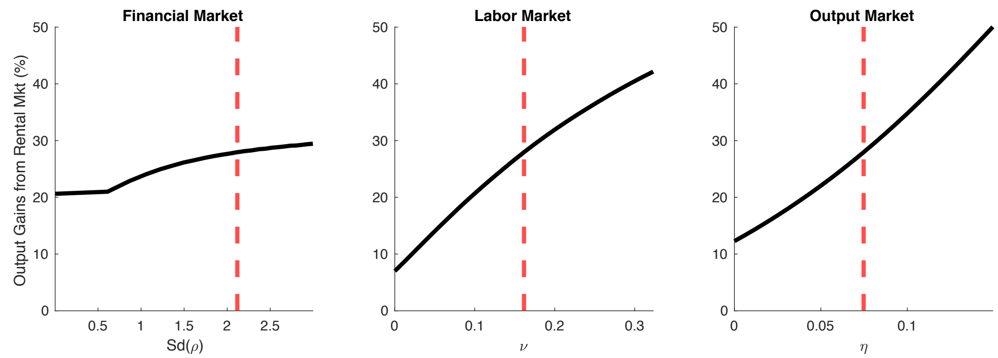
Notes: The black circles are for the economy with $\tau = 0$ and the gray diamonds for one with $\tau = \infty$. All panels have managerial ability on the x-axis. The left panel shows the change in the average revenue per worker relative to the benchmark economy. The middle panel shows the marginal product of capital, normalized relative to the sector average. As a result, the relative MPK averages to 1 for each value of τ. The right panel shows the change in the contribution to total GDP, again relative to the benchmark economy. It is defined as the ratio between the output produced by all the active managers of a given ability type and the total sector output.

Figure 9: 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 change the dispersion of the cost of capital across managers, $Sd(\rho)$. The middle panels vary frictions in the labor market, ν. The right panels alter decreasing returns to scale at the firm level, η, which are driven by the elasticity of substitution across varieties. The red dotted lines highlight the levels of each parameter in the benchmark economy. The top panels (Figure 9a) show the share of mechanized managers in the economy that access capital through the rental market. The bottom panels (Figure 9b) show the output gains of going from an economy without a rental market ($\tau \to \infty$) 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, as well as other important variables used in the paper. More details on the model estimation can be found in Supplemental Appendix E. Supplemental Appendix F describes in detail the computation of Figure 7, and Supplemental Appendix G provides further details on the role of equilibrium effects in the model, expanding the discussion around Table 5. 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

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

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

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

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

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

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

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

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

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

Since capital increases in managerial ability, there is a cutoff value ζ^* 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

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

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 ζ, but do not depend on ρ, while $\pi_{L,b}(\zeta,\rho)$, and $\pi_{M,b}(\zeta,\rho)$ are increasing functions of ζ and decreasing functions of ρ. 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 τ.

Investment. Consider managers that do not mechanize. Since $\pi_{L,b}(\zeta,\rho)$ decreases in ρ, 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 ζ does not mechanize, the investment cutoff does not depend on ζ, 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

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

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

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

where $\tilde{\rho}(\zeta)$ is an increasing function of ζ 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 ζ (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 ρ 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 τ, 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 τ, the difference $\hat{\zeta}_b - \hat{\zeta}_a$ increases in τ.

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

A.1.3 Comparative Statics of Rental Price with Respect to τ

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

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 ω, and $K(\omega) = 0$ if ω does not mechanize.[68]

Keeping p_r constant, the aggregate demand for capital decreases in τ for two reasons: i) conditional on production choices, $K(\omega)$ is weakly decreasing in τ for each ω, and strictly so for renters; ii) the share of managers that decide to mechanize is decreasing in τ since $\pi_{M,r}(\rho,\zeta)$ decreases in τ, 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 ω, and $C(\omega) = 0$ if ω does not invest.

The aggregate supply of machines' capacity increases in τ since, for investors, $C(\omega)$ is not affected by τ, and the mass of investors increases in τ since $\pi_{M,r}(\rho,\zeta)$ decreases in τ, 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 τ.

Finally, notice that $p_r(1+\tau)$ must be increasing in τ – i.e. the change in p_r must be smaller than the change in τ. 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.

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

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 ρ. 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 ζ. 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* ζ *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 (ρ, ζ) 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 ω, 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 μ; 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 ζ.

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 ω 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 ω 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 (α). Appendix Table A5 reports details of how we compute α. As shown in equation 3, α is pinned down by the capital labor ratio. To compute the numerator, we calculate the total hours of machine time used by a firm in a given step per month.[69] 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 A10. We then take the ratio of monthly capital to labor expenditure for each step, and use this ratio for machine owners to compute the implied value of α for each step. Column 4 reports the median value of α for each step, and shows that this does not vary substantially across steps (α is always between 0.42 and 0.61). This justifies taking the average across steps. We do this 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 3).[70]

We note two further results that reassure us about the validity of our approach. First, we find that the production process of renters is less capital intensive, which is consistent with the rental market wedge estimated in Table 2. Specifically, we find that the capital labor ratio for owners (averaged across steps) is 1.05, while this is 0.75 for renters. Second, we find 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 (δ). These are reported in Panel A of Appendix Table A6. 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

[69] 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 S19, 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.

[70] As a robustness check, we also perform 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 then we take their ratio. Reassuringly, the results are similar to computing the capital labor ratio within firm first and then taking the median across firms (our preferred approach described in the main text): the across-step average value of the capital labor ratio from our preferred approach is 1.05, and this is 1.18 in this alternative approach.

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: 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.[71]

The depreciation rate δ 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.[72] 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.[73]

Share of machine capacity rented from specialized lenders ($\frac{\phi}{1+\phi}$). This is reported in Panel A of Appendix Table A6, 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 A6 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.

[71] 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.

[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.

[73] 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.

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).[74] 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 A6. In each paragraph, we refer to the rows of Table A6 that include the computed moments. Two rows are missing: row 5 includes p_r, already described 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 A6. 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 average firm-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.[75] 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 A7 shows the computation of moments related to a manager's productivity, mech-

[74] 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 (50%) is higher than the share of renters using specialized lenders (39%).

[75] 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.

anization and investment choices. We limit the sample to door producers, as the machines that firms were asked about are specific to doors. Columns 1-3 report the results of OLS regressions of log monthly firm revenues (column 1), mechanization rate (column 2) and investment rate (column 3) 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 paragraph. Column 4 regresses log average price from the sale of doors on both the managerial ability index and the mechanization rate.[76]

The results 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 0.025; (iii) an increase in the investment rate of 0.048; and (iv) an increase of 4.2% in output price. In addition, column 4 shows that going from no mechanization to full mechanization is associated with an increase in price of 56%.[77]

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 A8 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 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.[78] This information is available only for firms that would need to borrow to cover it (as opposed to using own savings).[79] 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 lower cost of capital. Second, 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 A9 we verify that higher ability managers and firms that invest in

[76]The regression in column 4 further controls 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.

[77]The results in this table correspond to our preferred specifications where we weigh observations using firm weights, as discussed in Supplemental Appendix C. For robustness, Appendix Table S20 also shows the results weighting by both firm and sub-county weights. Reassuringly, the results are similar.

[78]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.

[79]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.

machines face a lower cost of capital. Column 1 shows that there is a positive correlation between managerial ability and whether the manager reports being able to cover an unforeseen expense of UGX 1M (with either own savings or a loan). Column 3 shows 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 2 and 4 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.[80]

Labor market frictions (Rows 11-12, 19-20). Appendix Table A10 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.[81] This highlights the robustness

[80] The results in this table correspond to our preferred specifications where we weigh observations using firm weights, as discussed in Supplemental Appendix C. For robustness, Appendix Table S21 shows the results weighting by both firm and sub-county weights. Reassuringly, the results are similar.

[81] 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 (δ), 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 set of controls in column 6 of Appendix Table A10. We recover a lower bound on the correlation between firm size and worker wages under these assumptions.

of the estimated correlation between wages and firm size.

To be conservative, for the identification of the labor market friction parameter ν we prefer to target the bundle of moments described in Section 5, rather than relying exclusively on the direct estimates of ν from Table A10. In particular, we also target: (a) the relationship between wages and managerial ability shown in column 3 of Table A10, and (b) the correlation between managerial ability and (i) capital stock and (ii) firm size, reported in Appendix Table A11. The results from part (a) indicate that an increase in managerial ability of one standard deviation is associated with a 6% increase in earnings (which is just at the margin of significance). For part (b), in Appendix Table A11 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. Our preferred specifications are those that limit the sample to door producers (i.e. columns 2 and 4). 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.[82]

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.[83] In columns 1-2 of Appendix Table A12 we regress predicted managerial ability

[82] All regressions in Table A11 include product controls. We note however that the results do not change significantly if these are excluded.

[83] 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.

(standardized) on a dummy for being a worker. The sample includes all workers and managers in the carpentry sector. Column 1 shows that workers score about 0.29 of a standard deviation lower on the predicted measure of managerial ability, a result significant at the 1% level. This result is robust to excluding sub-county fixed effects (column 2).

In columns 3-4 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 weigh 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 2-2.8%. This result is imprecisely estimated once we account for the generated regressor in the estimation through bootstrap standard errors.[84]

Finally, Appendix Table A13 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. The results are similar.

[84]The results in this table correspond to our preferred specifications where we weigh observations using firm weights, as discussed in Supplemental Appendix C. For robustness, Appendix Table S22 shows the results weighting by both firm and sub-county weights. Reassuringly, the results are similar.

Appendix Tables and Figures

Table A1: Basic descriptives

	All sectors (1)	Carpentry (2)	Metal fabrication (3)	Grain milling (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 calculated as averages of total revenues and profits reported for each of the three months preceding the survey reported by managers. 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 firm size distributions across the three sectors along with the construction of the markup variable are shown in the Supplemental Appendix.

Table A2: Descriptives on costs of renting in carpentry

Panel A: 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: 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 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 show the average monthly costs for renters calculated from Panel A. The first value of time is calculated as the sum of the total travel time and the time spent idle at the premises of the rental place, valued at the average wage . 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 (see Appendix Table A1). If renters travel by motorcycle taxis, we compute their direct transportation cost using typical motorcycle fares 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 reports the total direct expenditure on machine rentals at the firm level, valued at median machine prices (taken from Appendix Table A6). All statistics apart from the last row of Panel B come from a short follow-up survey 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 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	Baseline	Baseline
	(1)	(2)	(3)	(4)
Number of Machine Owners	0.000933	0.00324***		
	(0.00101)	(0.00111)		
Number of Machines Owned			0.00115	
			(0.000846)	
Number of Machine Owners (no weight)				0.00185
				(0.0100)
Machine FE	Yes	Yes	Yes	Yes
Subcounty FE	Yes	No	Yes	Yes
Number of Subcounties	29	43	29	29
Adjusted R^2	0.343	0.064	0.346	0.341
Observations	192	192	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 1-4 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. These results are robust to a restriction of the sample to only large machines such as thickness planers, spindle moulders, table saws, horizontal mortisers, chain mortisers, lathe machines and band saws. In column 2 we omit controls for subcounty fixed effects, whereas in Column 3 the dependent variable is replaced with the number of machines owned in each subcounty (also extrapolated from the sample using firm weights). Finally, Column 4 repeats the baseline specification but only for the number of machine owners in each subcounty that are represented in our sample.

Table A4: 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 S12. 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 S13. The share of other routes through which orders are placed is reported in Supplemental Table S14. 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 S16. The share of firms citing other reasons as main reason for price variation is reported in Supplemental Table S15. The share of firms that communicate the quality of their products through other means is reported in Supplemental Table S16. The share of firms that cite other reasons as main reason for locating the business premises is reported in Supplemental Table S17. Finally, the share of firms that indicate other reasons as a main constraint to growth is reported in Supplemental Table S18. All statistics are weighted using firm and sub-county weights.

Table A5: Step-level capital intensity

	Share of firms performing step with modern machines	Share of firms performing step with modern machines that are owned	Median labor expenditure for owners, as share of total labor expenditure across steps	α
	(1)	(2)	(3)	(4)
Step 3 - Cutting	77%	23%	15%	0.59
Step 4 - Planing	77%	14%	17%	0.61
Step 5 - Thicknessing	75%	12%	15%	0.46
Step 6 - Edging	76%	19%	14%	0.42
Step 7 - Sanding	32%	14%	17%	0.47
Step 8 - Mortising	69%	22%	16%	0.52
Step 9 - Finishing	52%	28%	16%	0.43
Average across steps	65%	19%		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. In column 3 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 3 across steps sum to one, since the composition of owners changes across steps. Column 4 reports the implied median values of α. In column 3, the expenditure shares are 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 3).

Table A6: 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 (δ)	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

Notes: The sample is restricted to carpentry 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 A7: Managers' productivity, mechanization and investment choice

	Log Rev (1)	Mech Rate (2)	Inv Rate (3)	Log Price (4)
Manager Ability (Std.)	0.288***	0.025**	0.048***	0.042*
	(0.049)	(0.011)	(0.011)	(0.022)
Mechanization Rate (0-1)				0.559***
				(0.134)
Weighting	Firm	Firm	Firm	Firm
Subcounty FE	Yes	Yes	Yes	Yes
Product Controls	No	No	No	Yes
Adjusted R^2	0.494	0.465	0.200	0.640
Observations	378	381	381	348

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. OLS regression coefficients, robust standard errors in parentheses. The sample is restricted to door producers. The dependent variables include the log of average monthly revenues from the sale of all products (column 1); the mechanization rate (column 2); the investment rate (column 3); and the log of the sale price of the main type of door sold to local final customers (column 4). Outcome variables in columns 1 and 4 are monthly averages corresponding to three months preceding the survey. If the firm produced two-panel doors, the outcome in column 4 refers to two-panel doors; otherwise this refers to the main type of door produced. Column 4 further includes controls for the most common type of door produced and for whether the firm produced a two-panel door in the last three months. For details on variable constriction see Appendix B (Mechanization and Investment Rate) and Supplemental Appendix D (Managerial Ability). All columns weight observations using firm weights. Robustness to the inclusion of firm and subcounty weights is shown in the Appendix Table S20.

Table A8: 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 A9: 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)
Manager Ability (Std.)	0.059***		-0.021	
	(0.023)		(0.025)	
Investment Rate (0-1)		0.508***		-0.553***
		(0.132)		(0.152)
Sample	All Firms	Door producers	All Firms	Door producers
Weighting	Firm	Firm	Firm	Firm
Subcounty FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.054	0.062	0.099	0.181
Observations	477	326	475	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 1-2 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 3-4 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 details on the construction of the dependent variable in columns 3-4, see Table A10. For the measurement of the Investment Rate and the Managerial Ability index, see Appendix B.2 and S. Appendix D respectively. All columns weight observations using firm weights. Robustness to the inclusion of firm and subcounty weights is shown in Appendix Table S21.

Table A10: 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)
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)
Skills Controls	No	No	Yes	No	No	Yes
(Joint p-value)			0.013			0.001
Subcounty FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.201	0.267	0.274	0.198	0.264	0.274
Observations	1,062	1,062	1,062	1,062	1,062	1,062

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. Columns 3 and 6 additionally control for the following worker skills controls: cognitive ability (measured through a 4-item Raven matrices test), as well as agreeableness, conscientiousness, extraversion, neuroticism and openness (measured through a 10-item Big Five test). The Joint p-values at the bottom of columns 3 and 6 are from a joint F-test that the additional skills controls are jointly insignificant in predicting wages. All regressions are weighted using firm weights.

Table A11: Capital stock and labor choice

	Log Capital Stock Used		Log Number of Workers	
	(1)	(2)	(3)	(4)
Manager Ability (Std.)	0.474***	0.398***	0.113***	0.135***
	(0.094)	(0.111)	(0.028)	(0.036)
Sample	All Firms	Door producers	All Firms	Door producers
Subcounty FE	Yes	Yes	Yes	Yes
Product Controls	Yes	Yes	Yes	Yes
Adjusted R^2	0.212	0.237	0.239	0.230
Observations	421	311	522	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 and use firm-level weights. The dependent variable in columns 1-2 is the log of the total value of the capital stock used by the firm (owned and rented); in columns 3-4 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 - see Supplemental Appendix D for details. All columns include product controls, i.e. dummies for the most common type of door produced and for whether the firm produced two-panel doors in the last three months. However, the omission of product controls does not significantly alter the results. Regressions in columns 1 and 3 include the full sample, whereas columns 2 and 4 limit the sample to door producing firms (in the three months preceding the survey).

Table A12: Outside option and entry choice

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

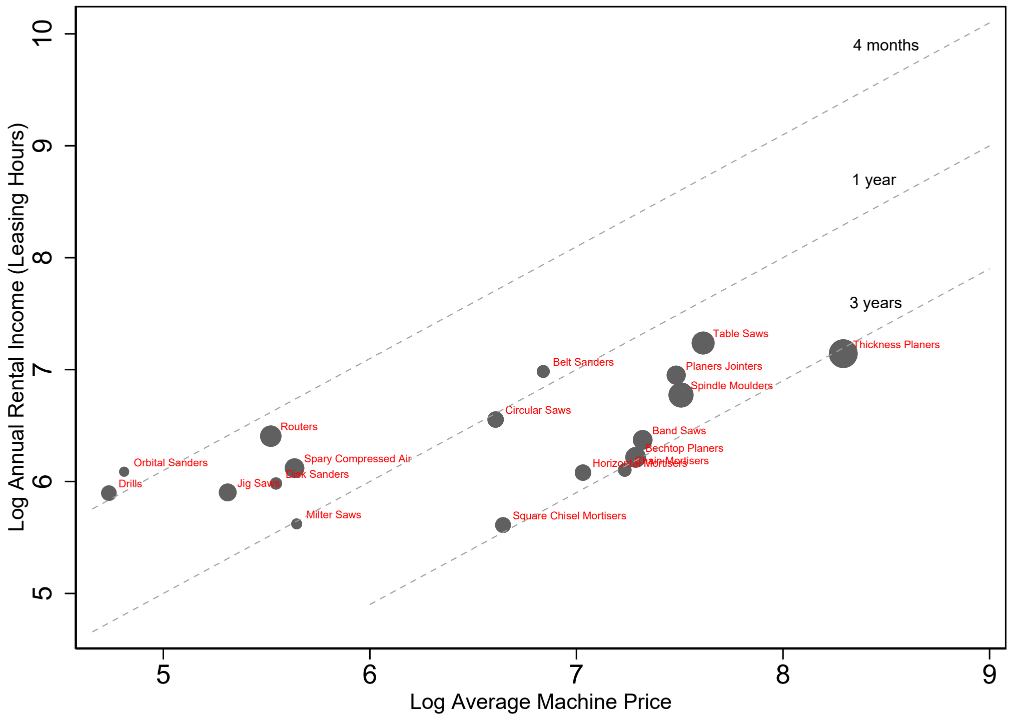
Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. OLS regression coefficients. Standard errors clustered at the firm level in parentheses; and bootstrapped with 1,000 replications and resampling clustered by firm in square brackets. In columns 1-2 the dependent variable is the (standardized) predicted 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 details on variable construction see Supplemental Appendix D. To create the predicted measure in column 1 (column 2) this regression does (not) control for sub-county fixed effects, and is weighted using firm weights. In columns 3-4 the dependent variable is a dummy for whether the individual is a manager, and zero if they are a worker. The independent variable is the rank of the individual, based on the predicted outcomes used in columns 1-2, respectively. To construct the rank, we weight observations so that the weighted sample includes an equal share of managers and workers. Robustness of these results to the inclusion of firm and subcounty weights is shown in Appendix Table S22.

Table A13: 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

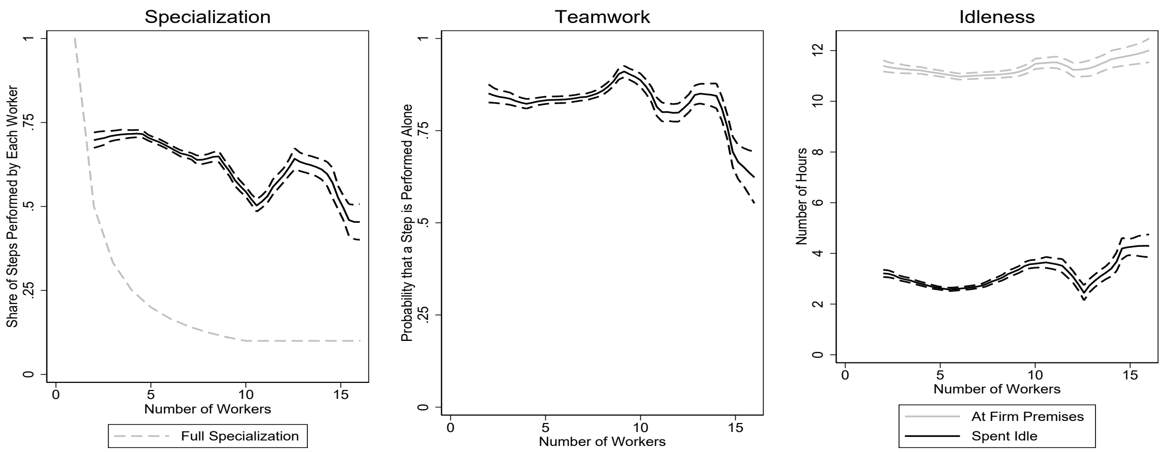
Notes: Means are reported throughout. The sample includes all managers and workers in the carpentry sector that answered the survey. The first row reports the ratio of the standard deviation of workers' and manager's income. For workers, this corresponds to their monthly labor earnings; for managers, 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



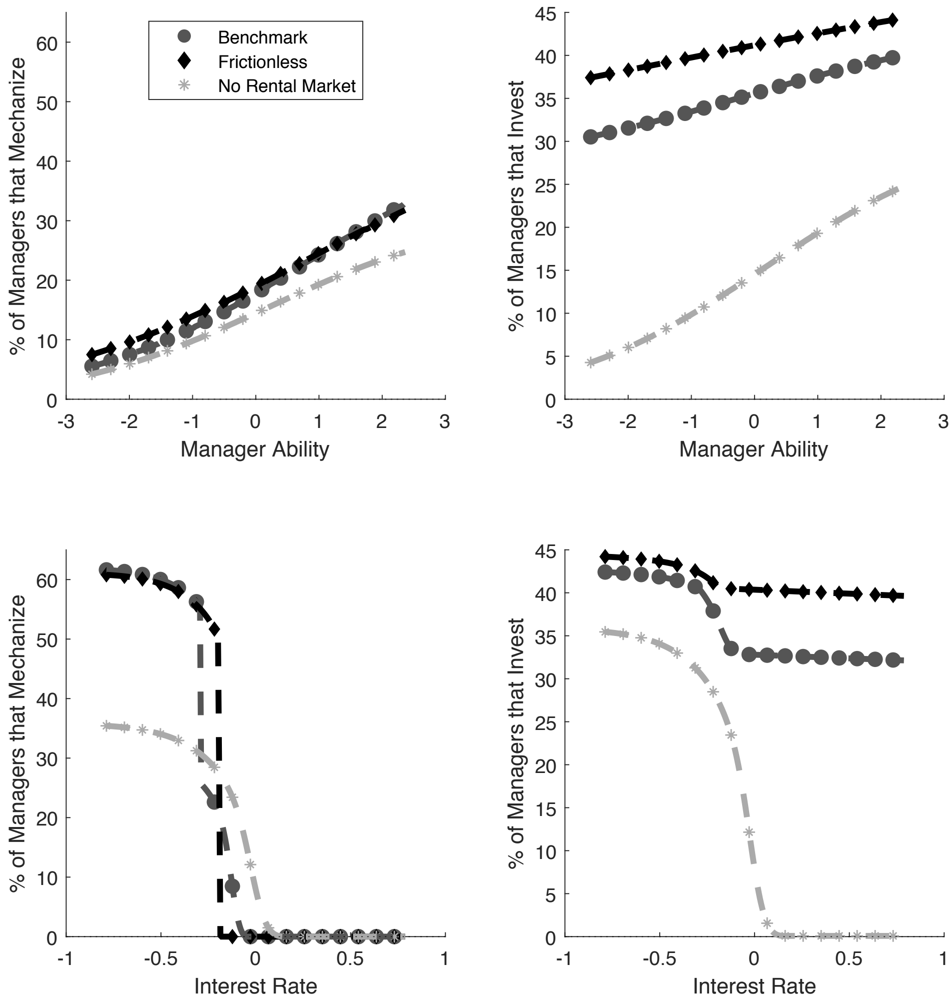
Notes: The figure reports the log of annual rental income (y-axis) from the leasing of modern machines in the carpentry sector against the log of their respective purchase prices (x-axis). The series reported on both axes are constructed using reports from machine owners in the carpentry sector, conditional 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



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: Investment and mechanization choices in three economies: $\tau = 0$; $\tau = 0.404$; $\tau = \infty$



Notes: The figure shows the investment and mechanization decisions for three economies: the black circles are for the benchmark economy, with $\tau = 0.404$; 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 ζ in the model. The bottom two panels report the same shares as a function of the interest rate faced by managers, or ρ in the model.