Gender and Technology Use in Developing Countries: Evidence from Firms in Kenya

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Abstract

Kenyan firms rely on technology to overcome obstacles associated with excessive regulations, poor infrastructure and widespread corruption. This study shows that reliance on technologies such as email, website and the internet for communication purposes has significant positive impacts on productivity for firms with one or more female owners. Using a representative sample of industries, the exogenous component of technology use is isolated by using information on the presence of schools from colonial Kenya as well as a geographical indicator measuring rainfall shocks. These instruments pass a series of checks on strength and relevance, and satisfy the exclusion restriction. Results indicate that for firms with female owners, a 10 percent increase in technology use results in a 1.69 percentage point increase in value-added per worker. For male-owned firms, a positive effect is evident but significantly more muted.

Keywords: Communications Technology, Obstacles, Colonial Education, Kenya, Firms, Female Owners

JEL Classification Codes: O14, O33, L22, N37

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Section 1. Introduction

It is difficult to start a firm in Kenya. Recent estimates indicate that in terms of the number of procedures required to start an enterprise, the number of procedures required to register property, and the overall expenses of enforcing contracts, Kenya ranks 136th or lower in a global rank of 188 countries (Doing Business in Kenya 2010). Moreover, once in existence, firms in Kenya continue to face large operation costs due to regulatory and infrastructural hurdles. These include long delays in gaining access to telephone land-lines, electricity, and water connections, and informal payments that are required to expedite licenses and contracts. When such obstacles to business exist, firms may rely on technology to overcome many of the hurdles faced. For example, if there are significant delays in obtaining mainline telephone connections, firms may opt to use email and the internet for communication and advertisement purposes. Aker and Mbiti (2010) note the inverse relationship between the quality of landline service and adoption of mobile phones in Kenya. Further, access to landline service in Kenya is slow and expensive with firms reporting an average delay of 100 days and the payment of substantial bribes (Aker and Mbiti 2010). About 43 percent of firms in the data we use in this research report using email to interact with clients and suppliers. This suggests that use of communication technologies is endogenous to obstacles posed by excessive regulations and poor infrastructure in Kenya.

In dealing with the constraints presented by business obstacles it may be argued that firms with female owners are at an even greater disadvantage. This is because women-owned businesses in Kenya tend to be more credit-constrained that those run by men (Central Bureau of Statistics 1999). A contributing factor is that women hold only 1-6 percent of registered land titles in Kenya, the main form of collateral required by commercial banks (World Bank 2004). Moreover, unlike firms operated by men, women-owned businesses are often isolated from formal and informal networks that provide information and support. Women-run businesses also tend to be small scale. For these reasons, giving gifts or making informal payments may pose a greater hardship for them.

Since women-owned firms face higher costs of operation, intuitively, one would expect different patterns in their reliance on technologies as compared to male-owned businesses. Menon (2013) analyzes the effect of business obstacles and finds that while all firms rely on technologies such as computers and cell-phones, firms with female principal owners experience net effects that are statistically different from those experienced by firms with male principal owners. In particular, the probability of technology ownership is 0.15 higher for firms with female owners as compared to all other firms.

The aim of this study is to analyze whether conditional on business obstacles, region, firm and industry covariates, the use of email, a website or the internet for communication with clients and suppliers (referred to as "communications technologies" from now on), has significant impacts on firm productivity.[1] We consider the use of email, a website, or the internet for communication purposes as a proxy measure of the role of computers in firm operations (computer usage for business purposes is not directly gauged in our data), the beneficial effects of which have been documented in studies in the developed world including Brynjolfsson and Yang (1996) and Bresnahan and Greenstein (1997). Using the World Bank's Enterprise Survey data from 2007 on Kenyan manufacturing, retail and micro-enterprises, this study shows that reliance on communications technologies has beneficial impacts on firm productivity, particularly in establishments that are female-headed. Using rainfall shocks and historical measures of education from Kenya's colonial past as identifying instruments, this research demonstrates that conditional on obstacles, firm, industry and top manager covariates, use of communications technologies has significant beneficial effects on value-added per worker in Kenyan firms. For female-headed firms, a 10 percent increase in technology use results in a 1.69 percentage point increase in value-added per worker. The effect of technology use is positive but significantly smaller in magnitude for firms with male owners (a 10 percent increase in technology use results in only a 0.26 percentage point increase in value-added per worker). The use of an alternate method confirms these results.

Section 2. Review of previous research

The literature on the effect of regulatory obstacles has mainly been theoretical in nature for advanced countries (Acemoglu *et al*. 2007, Alesina and Zeira 2009, Acemoglu and Autor 2010), and in terms of the developing world, has concentrated on the adverse economic impacts of restrictive labor legislations (Besley and Burgess 2004, Lall and Mengistae 2005, Sanyal and Menon 2005, Almeida and

Carneiro 2009, Amin 2009). The impact of computers on firm productivity in advanced countries is well documented. Stoneman and Kwon (1996) uses data on firms from the UK to study the diffusion of technology and shows that non-adopters experience lower profits as other firms adopt new technologies such as computer-controlled machine tools. Brynjolfsson and Hitt (2000) notes the wider applicability of the computer as being a tool that is effective in many things other than just rapid computation. In particular, the study notes the productivity enhancing effects of computer-controlled machinery that is documented in Keller (1994), and the improvement in productivity of government services such as toll collections that resulted from increased computerization (Mukhopadhyay *et al*. 1997). Black and Lynch (2001) shows that plant productivity is higher when a larger proportion of non-managerial staff use computers, and Bresnahan *et al*. (2002) finds that use of technologies such as computers and telecommunications equipment works in a complementary manner with workplace reorganization to increase productivity and the demand for skilled labor. There is little previous work in developed countries that has considered the adoption of technology as a means of mediating the effects of constraints due to excessive regulations. The few studies that have looked at technology, productivity, and regulations in the same context either consider the negative impacts of regulations on productivity (Scarpetta and Tressel 2002), or why technology adoption has been low in industrial countries other than the US. Gust and Marquez (2004) attributes low technological adoption to stringent regulations.

In the developing world, the impact of technological innovation has mainly been studied in the context of research and development (R&D) and foreign direct investment. For example, Basant and Fikkert (1996) finds that an Indian firm's returns to internal R&D expenditures are often low and insignificant whereas its returns to technology purchases have large significant impacts on output. Vishwasrao and Bosshardt (2001) finds that an Indian firm's probability of adopting new technology is largely dictated by foreign ownership and firm size. Using data on firms from China, Hu *et al*. (2005) documents that the effect of foreign technology transfer on firm's productivity depends on the manner in which transfers interact with internal R&D. Estimates from information and communication technology (ICT)-augmented production functions applied to unique firm level surveys in India and Brazil reveals that adoption of ICTs is constrained by labor market policy and poor infrastructure, especially power disruptions (Commander *et al*. 2011). In Africa, few studies have analyzed the association between technology and productivity (Harding and Rattso 2005, Goedhuys *et al*. 2006), but none have considered the role of technology in mitigating the constraining influences of regulations and weak infrastructure.

This research contributes to the literature by highlighting the role that technology plays in alleviating the costs of excessive regulations and poor infrastructure in poor countries. Specifically, it considers regulations, technology adoption and firm productivity in a unified framework, focusing on the relative advantages that technology use may bestow by gender of the firm's principal owners.

Section 3. Theoretical framework

This section formulates a theoretical model to understand the manner in which use of technologies affects a firm's value-added in environments with obstacles to business.[2] The insight is the following: in the case of a restricted value-added function (Varian, 1992) without adjustments in output price, quantity, and choice of inputs (as in the short-run), value-added is higher when total cost is lower. We consider the short run case since in the long-run it is possible that choice of technologies directly affects the production process.[3] Total costs are lower with use of technology since this reduces the cost of inputs. Consider communication which is different from traditional inputs such as labor and capital, but clearly important in a firm's production process. The costs of communication can be high in environments with excessive regulations and long delays in obtaining basic services such as mainline telephone connections. Using email, own website or the internet to communicate with clients and suppliers decreases this cost.[4] Assume a firm has the following production function:

$$y = x_1^a x_2^b \qquad (1)$$

Where y is output, x_1 is a conventional input such as labor, and x_2 is another input important for production such the ability to communicate easily with clients and suppliers. For ease of exposition we assume that the presence of obstacles in the environment affects only the price of good x_2, the communications input. This means that where w_1 and w_2 are the factor prices associated with x_1 and x_2

respectively, w_2 is higher than its optimal value. In this set-up, the firm's cost minimization problem before it owns any technology is:

$$\min w_1\, x_1 + w_2\, x_2$$

$$\text{such that } x_1^a x_2^b = y \qquad (2)$$

It is straightforward to see that the conditional demand for the conventional factor is:

$$x_1 = \left[\frac{aw_2}{bw_1}\right]^{\frac{b}{a+b}} y^{\frac{1}{a+b}}$$

and conditional demand for the communications factor is:

$$x_2 = \left[\frac{aw_2}{bw_1}\right]^{\frac{-a}{a+b}} y^{\frac{1}{a+b}}$$

Substituting these values into the cost function, we obtain[5]:

$$C_1^* = \left[\left(\frac{a}{b}\right)^{\frac{b}{a+b}} + \left(\frac{a}{b}\right)^{\frac{-a}{a+b}}\right] w_1^{\frac{a}{a+b}} w_2^{\frac{b}{a+b}} \; y^{\frac{1}{a+b}} \qquad (3)$$

In the case of a constant returns to scale Cobb-Douglas production function, (3) reduces to

$$C_1^* = a^{-a}(1-a)^{a-1} w_1^a w_2^{1-a} y \qquad (4)$$

since $a + b = 1$.[6] If adopting technology reduces the cost of communication for a firm, then equation (2) may be re-written as:

$$\min w_1\, x_1 + (w_2 - \tau)\, x_2$$

$$\text{such that } x_1^a x_2^b = y \qquad (5)$$

Where τ is the "price-offset" that technology brings and $\tau > 0$, $\tau < w_2$. The $\tau < w_2$ assumption states that firms still have some costs associated with the communications input; these are not driven to zero by virtue of technology ownership. Solving (5) leads to the following optimal cost function:

$$C_2^* = a^{-a}(1-a)^{a-1} w_1^a (w_2 - \tau)^{1-a} y \qquad (6)$$

In order to demonstrate formally that the costs in (6) are lower than those in (4), consider the following restricted value-added functions faced by a firm without $(\pi_1(p, w))$ and with $(\pi_2(p, w))$ the use of communications technologies:

$$\pi_1(p,w) = py - C_1^* \qquad (7)$$

$$\pi_2(p,w(\tau)) = py - C_2^* \qquad (8)$$

where p is the sale price of output and w is a vector of input prices. Adoption of technology has a positive effect on value-added if $\pi_2(p,w(\tau)) \geq \pi_1(p,w)$, which occurs if $\left(\frac{C_1^*}{C_2^*}\right) \geq 1$. Obtaining the ratio of costs from (4) and (6):

$$\left(\frac{C_1^*}{C_2^*}\right) = \left(\frac{w_2}{(w_2-\tau)}\right)^{1-a} \qquad (9)$$

It is clear that $\left(\frac{w_2}{(w_2-\tau)}\right)^{1-a} \geq 1$ since $\tau < w_2$ and $a < 1$. That is, productivity increases with technology adoption. We test the relative productivity enhancing effects of technology adoption conditional on gender of principal owners, constraints, and firm and industry covariates below.

Section 4. Empirical methodology

Since technology use may be endogenous to the business environment, estimating the effect of technology on value-added per worker by OLS will result in biased estimates. If firms are likely to use technology when the business climate is poor, and poor climates reduce productivity, then OLS will underestimate the impact of technology on firm productivity. To ascertain whether use of communications technologies has positive effects on firm productivity, we use instrumental variables (IV) in a two stage least squares framework where the first stage is:

$$T_{ij} = \gamma_0 + \gamma_1 Z_{ij} + \vartheta_{ij} \qquad (10)$$

where *i* denotes a firm and *j* denotes a region, T_{ij} is the average of an indicator for whether firm *i* in region *j* uses email, own website, or the internet for communication with clients and suppliers and Z_{ij} are the identifying instruments. We discuss these identifying instruments, emanating from the theoretical framework developed above and representing measures of current and "historical price" of operating technology, in detail below. Results of the first stage in equation (10) and tests for the strength of instruments are reported in Table 6.

In the second stage, we estimate the reduced form version of the value-added function in (8) which includes the orthogonal component of T_{ij}:

$$V_{ij} = \beta_0 + \beta_1 \hat{T}_{ij} + \beta_2 O_{ij} + \beta_3 F_{ij} + \beta_4 (F_{ij} * O_{ij}) + \beta_5 R_j$$

$$+\beta_6 X_{1ij} + \beta_7 X_{2ij} + \varepsilon_{ij} \qquad (11)$$

Where V_{ij} is value-added per worker, $\hat{T}_{ij}$ is the orthogonal component of the dependent variable in (10), O_{ij} is a vector of obstacles faced by the firm, F_{ij} is an indicator for whether the firm has one or more female principal owners, R_j are regional indicators, X_{1ij} represents firm and industry characteristics, X_{2ij} represents the firm's top manager's characteristics, and ε_{ij} is the standard error term. Relating back to the theory, the labor-related variables in (11) pertain to the conventional input x_1 and $\hat{T}_{ij}$ and O_{ij} pertain to the communications input x_2. For the full sample of firms, β_1 is the impact of technology on value-added per worker. β_3 indicates how value-added per worker differs between firms with female owners and those that have only male owners, and the net amplified effect of obstacles for firms with female owners is measured by $(\beta_2 + \beta_4)$. The results of these models are reported in Table 7.

Section 5. Data and descriptive statistics

Data used in this research are from the Enterprise Survey which was implemented by the World Bank in Kenya in 2007. Surveyed firms were located in the capital city of Nairobi, the coastal city of Mombasa, Nakuru in the Rift Valley and Kisumu which is located on Lake Victoria in the Western region of the country (Map 1). Nairobi, Mombasa, Nakuru, and Kisumu were selected since they collectively compose the largest share of economic activity in Kenya. Firms in all manufacturing sectors, construction, retail and wholesale services, hotels and restaurants, transport, storage and communications were administered the survey. Those that had five or more full-time permanent paid employees were stratified into five groups: manufacturing (food and beverages), manufacturing (garment), manufacturing (other), retail trade, and "rest of the universe" (RoU) which included construction, wholesale trade, hotels and transportation. Firms having fewer than five full-time permanent paid employees ("micro establishments") were not stratified by industry.

The Enterprise Survey asks detailed questions on the environment faced by firms. These include those related to firm characteristics, gender participation, sales, costs of inputs, and obstacles related to telecommunications, licensing, infrastructure and restrictions on hours of operation and pricing and mark-ups. Given the level of detail in the survey, these data are particularly apt for purposes of this study.[7] The sampling methodology is stratified random sampling where the strata are firm size (number of employees), business sector (manufacturing, retail, and other services) and geographic region; estimates reported are adjusted with weights to account for differing probabilities of selection across these strata.

It is possible that given the specificity of required skills, firms with female owners in chemicals or machinery and equipment manufacturing industries are less representative of the average women-owned firm in the economy. A way to improve representativeness is to restrict the analysis to firms in industries where barriers to entry for women are comparatively low. These industries include manufacturing industries such as garments, food, textiles, and non-metallic minerals (these include gemstones and gold, which is mainly processed by small-scale artisanal workers in the Western regions of the country near Lake Victoria), retail industries, and service industries such as hotels and restaurants. We also exclude all firms that are legally classified as "public" since the majority of firms in Kenya are small and medium enterprises (SMEs), and public firms may not face similar barriers. The estimation sample thus has 499 firm-level observations of which 213 firms (42.7 percent) have one or more female owners and 286 firms (57.3 percent) have only male owners.

Figure 1 depicts the percentage of firms with female principal owners and those without by industries. The figure is arranged such that classifications that have the largest difference between female-owned and male-owned firms appear first. The largest difference by gender of firm owner is found in manufacturing garment industries (22.5 percent female, 15 percent male-only) followed by retail industries (32.4 percent female, 31.8 percent male-only). Textiles have relatively the same proportion of female and male headed firms, and the proportion of firms with only-male owners exceeds that of female-owned firms in non-metallic minerals, construction and transport, and hotels and restaurants. Figure 1 shows that the fewest relative number of firms with female owners is found in food industries.

Figure 2 portrays the breakdown of firms by gender-of-owner and use of email, own website, or the internet for communication purposes. It is striking that firms with female owners rely on communications technologies to such a large extent. Figure 2 shows that the proportion of female firms that use technologies is about 87 percent of the proportion of male firms that also use these technologies. Figure 3 is a plot of the median value-added (in 2006 US $) for firms with female principal owners and those without.[8] It is apparent that value-added per worker in male and female firms is about the same in garments, food, and textile industries, and comparable to some degree in retail firms and firms in the hotels and restaurants industry. Value-added per worker is significantly different between male and female owned firms in only non-metallic minerals (higher for female-owned firms) and construction and transport (higher for men-only owned firms). We focus next on firms' perceptions of obstacles.

The Enterprise Survey data report constraints related to different types of obstacles. For expositional purposes, the separate types are combined into six categories – regulations, infrastructure, security, workforce, corruption, and finance. The regulations group includes labor regulations, licensing and permits, customs and trade regulations, regulations on hours of operation, regulations on pricing and mark-ups, zoning restrictions, tax rates, and tax administration. The infrastructure group includes obstacles related to telecommunications, electricity, transportation, and access to land. The security category includes constraints related to crime, theft, and disorder, political instability, macroeconomic instability and functioning of the courts. The workforce group includes obstacles related to an inadequately educated workforce, and the corruption group includes obstacles related to corruption and practices of competitors in the informal sector. The last group includes obstacles related to finance.

In the data, firms are asked to rank obstacles on a scale of five – no obstacle, minor obstacle, moderate obstacle, major obstacle, and very severe obstacle. Tables 1 - 3 report weighted proportions of firms characterizing obstacles as moderate, major, or very severe by industry and technology use.[9] Table 1 shows that over 90 percent of firms report regulations, infrastructure and finance to be binding constraints; this pattern is also true upon disaggregation by gender of firm owner. Table 2 reports weighted proportions by industrial groupings; regulations continue to be the most widely cited obstacle for female-owned firms. Such firms in manufacturing and construction and transport are also particularly concerned with security and corruption whereas firms that are male-owned in manufacturing are less likely to cite security as a major concern. Table 3 also shows that firms who report using technology are also more likely to report regulations, security and infrastructure to be binding constraints.

Obstacles discussed in Tables 1 – 3 reflect a firm's perceptions of its operating environment. In order to eliminate measurement errors and other factors that may lead to these being endogenous, we take averages of these variables at the region, industry, legal status and firm size level (Angrist and Krueger 2001, Dethier *et al*. 2008, Amin 2009).[10] The estimations that follow are conducted on constructed means of the obstacles rather than an individual firm's perceptions of them.

Table 4 provides weighted means and standard deviations of the characteristics of firms with female owners and those without, and a measure of whether there are statistical differences in these characteristics (the specifications that follow include the full set of characteristics listed in Table 4). The characteristics reported include value-added per worker, use of communications technologies, obstacles, the variables used as identifying instruments (discussed below), regional indicators, firm and industry characteristics including firm size, value of property and machinery, industrial classification, number of employees, and characteristics of the firm's principal owner(s) and top manager including education and number of years of experience. On average, firms with female owners have lower value-added and lower percentage values in terms of technology use as compared to male-only owned firms, although only the former difference is statistically significant. The reported differences in obstacles for female-headed and male-headed firms show that the weighted average value is somewhat higher for female-owned firms in five of the six categories; however these differences are not statistically significant. There are relatively fewer female-owned firms in Nairobi and relatively more in Mombasa. In terms of firm and industry characteristics, female-owned firms have lower property values. There are no other instances of measurable statistical differences in characteristics between female and male-owned firms in the remaining variables of Table 4. This underscores that male and female-owned firms are comparable in observed covariates in the representative sample of industries we consider.

Section 6. Impact of technology use on firm productivity

We rely on instrumental variables estimation to assess the impact of technology use on firm productivity. The instruments are derived from the theoretical framework and affect τ, the extent of the price-offset that technology adoption brings. We argue that τ is influenced by the "historical price" of technology adoption which is determined retrospectively by the distribution of mission, private and government schools from Kenya's colonial past. We also use the *deviation* in annual rainfall from the 1910-2000 rainfall average as an additional source of exogenous variation. These instruments and tests for validity are discussed below.

Instruments for technology use

Regional distribution of schools in Kenya from 1844 - 1935

The use of email and the internet requires a basic amount of skills associated with recognizing letters from the English language, understanding Arabic numerals and competence associated with elementary vocational training. The earliest foundation for such knowledge was laid by mission organizations in Kenya, primarily the Church Mission Society (CMS) which established the first school in Rabai Mpia near Mombasa in 1844. Starting from 1844 through 1935, CMS and other missionary groups (primarily the Holy Ghost Mission, Church of Scotland Mission and the Protestant Alliance of Missionary Societies) enjoyed a virtual monopoly in educating Kenyans of African origin (Furley and Watson 1978). These schools taught facts about the Christian religion and "secular" subjects that led to apprenticeships in trade or teacher training. Mission schools also enjoyed a monopoly over girl's education as other schools were reluctant to educate girls' for fear of clashing with local cultural traditions. By the time of the Fraser Report (1919) that urged greater government role in the education of Africans, mission schools were dominant in the provinces of Kenya.

Using primary sources (archives of the CMS housed at the University of Birmingham in the UK) and information in Furley and Watson (1978), we compiled a list of all main mission schools that existed in Kenya from 1844 to 1935. 1935 is the end-point of our data since after that year mission schools came under the control of the British government (Kenya became a British protectorate in 1895), and although still present in the delivery of education throughout the colony, were no longer active in their original autonomous form. From 1844 until 1919, all schools that we have information on are missionary schools that educated both girls and boys and primarily “targeted” Africans. From 1919 until 1935, government schools (segregated by race – European and Asian) and private schools (also segregated by race) began to be established. Government and private schools engaged relatively little in educating Africans and girls; private schools were particularly elitist in their educational policies (these private schools are different from those that operate today in that they are not profit-seeking). The data that we collected over the 1844-1935 time-span has information on 80 schools including their year of establishment and original location. Among these, 56 are mission schools, 17 are government schools and 7 are private schools.

Mission schools in Kenya were the first to provide elementary education and vocational training, were unique in providing access to girls, and African education was primarily in their hands until 1919. This is important from our point of view since over 70 percent of firms in our sample have African principal owners. Gender-based equality in education that mission schools afforded is also important from our perspective since we are interested in how firms with female owners respond differently as compared to their all-male counterparts. We argue that mission schools in this time period (and government and private schools to a lesser extent) laid the foundations for historical differences in skills.

In order to be a valid instrument, we require that the location of schools in the 1844 to 1935 time-period satisfy the exclusion restriction; that is, conditional on technology adoption, location of schools from history should have no effect on firm value-added today. We provide supportive evidence for this since establishment of mission schools solely reflected Christian evangelical zeal in the nineteenth century (Furley and Watson 1978), and the religious motives that fueled the creation of such schools had few economic underpinnings that may influence firm productivity today. In fact the main objective of establishing mission schools in the 1844 to 1935 period was to counter the growing influence of Islam in colonial East Africa (Strayer 1973).[11]

Following Lewis (2010) which uses exogenous variation in the area-specific supply of skills as an instrument for technology, we argue that the location of schools as of 1935 provides exogenous variation from history which may be used to instrument technology use today. In the terminology of our theory, the location of schools as of 1935 affects the price-offset that technology adoption affords. Only those firms with sufficiently large τ use technology (since they experience a larger net input price reduction), and the regional average value of τ is likely to be historically determined by the regional location of schools in colonial Kenya. Using data on the location of schools as of 1935, we allocate each school by distance to the closest location of firms in the sample, and then use this information to construct the number of mission, private, and government schools in each of the regions. Each firm in the data is then given a value for the number of schools *based on its region and co-incidence of start dates of the firm and the school*. We call these instruments "number of mission schools", "number of private schools", and "number of government schools", and present tests of their validity below.

Deviation in region-year rainfall level from the 1910-2000 rainfall average

We construct another instrument that is geographical in nature and relates to *rainfall shocks* as measured by *deviations* in annual region-year rainfall from the 1910-2000 rainfall average. Our use of this instrument comes from the observation that the operation of the technologies we consider depend on power. In Kenya, 60 percent of power is generated from hydro-electricity (Kirai 2009). Kenya Electricity Generating Company (KENGEN), a state-owned generation company at the time these data were collected, is the main power generator and controls all publicly-owned plants in Kenya to produce about 80 percent of the power consumed in the country (Kirai 2009). As of 2007, fourteen of its twenty power plants are hydro-electric in nature (Map 2).

A facet of hydro-electricity is that the quantity of power generated is heavily dependent on rainfall. During times of drought (negative rainfall shocks) plants are unable to operate at their peak capacity and the supply of electricity is insufficient. Alternatively, excess rainfall (positive rainfall shocks) is also a problem because it causes landslides and flooding which destroys power lines.[12] Using information on year of commissioning, district of location and deviations in annual rainfall from the 1910-2000 average level of rain in the four regions of our data, we construct a measure of rainfall shocks for each firm in the dataset. This construction allows for a firm's exposure to the rain shocks to be dependent on year of origin of the firm and commissioning year of the power plant(s) in the firm's region. This is because the rainfall that a firm may "avail" of depends on the year of commissioning of the power plant and the year in which the firm began operations. For example, the earliest plant that was commissioned near Mombasa is Lamu in 1989. Thus firms in Mombasa that had a start year before 1989 get a value of zero for the rainfall deviations variable since no plant existed before that date. Firms with start year of 1989 were affected by shocks received only at Lamu – they thus receive a value of rainfall deviations equal to that in the region in 1989.

Information on historical rainfall from 1901 to 1990 for four stations in Kenya (Machakos (close to Nairobi), Malindi (close to Mombasa), Nakuru, and Kisumu – see map 1) are available from the Global Historical Climatology Network (GHCN) precipitation data which is part of the National Oceanic and Atmospheric Administration's (NOAA) national climatic data center. Since the Enterprise Survey has information on firms as of 2006, the remaining years of rain data were obtained from UNDP Climate Change Country Profile for Kenya which is available from Oxford University's School of Geography and the Environment. A combination of these two data sources allowed the creation of a historical time series from 1901 to 2006 of annual precipitation data for each of the regions in the study. These data were used to construct a firm-level measure of rainfall deviations (in mm) called "rainfall shocks".

To be clear, we use *rainfall deviations* from the historical 1910-2000 averages as the instruments, not rainfall levels in of itself. Greater rainfall uncertainty will influence decisions that firms make in the short-run regarding investing in computers, for example, but conditional on that decision, should have little to no impact on value-added per worker since firms that operate in rain uncertain environments would have internalized that fact in their choice of inputs and industries (this being a more long-run decision). We present detailed tests of instrument validity below.

Ordinary least squares results

We begin by discussing results from OLS models that treat technology as an exogenous variable. These are reported in Table 5 (tables report standard errors that are clustered at the regional level). The OLS estimates are small in magnitude and measured with error. This is as expected and consistent with the observation that if firms are more likely to use technology when the business climate is poor, then given the negative correlation, OLS will underestimate the impact of technology on firm productivity.

First stage regression results

The columns of Table 6 show first stage results for all firms, those with female owners and those without, where the indicator of email, website, or internet usage for communication purposes is averaged at the region, industry, legal status, and firm size levels.[13] The third column in each grouping of firms reports results from the full set of instruments. For the full sample, all instruments are significant and explain about 8 percent of the variation in technology use. Mission schools and government schools have strong positive effects on technology use consistent with our hypothesis that the historical presence of schools in the region significantly increased the regional historical stock of basic skills of the African population. Results in the second column of Table 6 which focuses on these instruments alone is consistent with this. An indicator for the absence of rain shocks has a positive effect on the technology measure indicating that usage is least disrupted when rainfall is neither too heavy nor too light.[14]

The remaining columns of Table 6 show separate first stages for firms with female principal owners and for firms with only male owners for different sub-sets of instruments. Focusing on the third set of columns for each of these firm categories, mission schools have a particularly pronounced effect on technology use in firms with female headship. For the male-only sample, mission schools still matter although to a smaller extent. The F-statistics in the third, sixth and ninth columns of Table 6 are all above 10, the rule-of-thumb threshold value for sufficiently strong identifying instruments. Second stage regression results below reflect use of the full set of instruments noted in these columns.

Second stage regression results

Table 7 reports the two stage least squares (TSLS) results for technology use for all firms, for firms with female owners and for firms with male owners. We begin by noting that a test of over-identifying restrictions which tests the joint null hypothesis that the instruments are valid (that is, not correlated with the error term and correctly excluded from the estimated second stage) cannot be rejected in all models of Table 7 (Hansen’s *J* statistic). Further, a comparison of the Kleibergen-Paap Wald F statistic and the Stock-Yogo weak ID test critical values reveals that the IV bias is relatively very small (substantially less than 5 percent of the OLS bias) across all models. Column (1) of Table 7 shows that the establishment's use of communications technology has strong, positive and significant effects on value-added per worker; estimates indicate that a unit increase in the average measure of technology use increases value-added per worker by about 34 percentage points. This means that for a 10 percent increase in technology use, value-added per worker increases by 1.45 percentage points. As expected, many obstacles have a modest negative impact on firm productivity. The indicator variable for whether the firm has one or more female principal owners in column (1) is positive but insignificant indicating that conditional on technology use and obstacles, firms with female owners are not consistently different from their counter-parts in terms of effects on value-added per worker. The *p*-value of the joint test of the interaction of the female-headship variable with different obstacles indicates that the null hypothesis cannot be rejected. That is, conditional on the use of communications technologies, no differential relative patterns exist for female-owned firms. Finally, the *p*-value of the joint test of significance on obstacles indicates that the null hypothesis can be rejected at the 10 percent significance level.

The second column of Table 7 reports results for female-owned firms only. It is evident that technology use has significant positive impacts on productivity. The coefficient indicates that a unit increase in the average measure of technology use increases value-added per worker by approximately 43 percentage points. This translates into a 10 percent increase in technology adoption resulting in a 1.69 percentage point increase in value-added per worker. Technology use has a positive effect on value-added per worker in male-headed firms although the magnitude of the coefficient is about one-seventh that of female-owned firms. The estimate for male-owned firms indicates that for a 10 percent increase in technology use, value-added per worker increases by only 0.26 percentage points.

Robustness checks on instruments

Validity of the instruments rests on their satisfying the exclusion restriction. This evidence is presented in Table 8 and follows the methodology of the overidentification tests developed in Acemoglu *et al*. (2001). As noted there, the test will reject the validity of the procedure if the instrument that is assumed to be exogenous has a direct effect on productivity *or* if the instrument whose exogeneity is being tested affects productivity through omitted variables.

The results of the overidentification tests presented in Table 8 are divided into four panels. Column (1) of panel A reports the IV estimates of the impact of technology use on the log of value-added per worker using the absence of rain shocks as an instrument while Panel B presents the corresponding first stage estimates. The first column of panel D reports the corresponding IV estimate with the inclusion of the schooling instruments. If the schooling instruments have a direct effect on firm productivity then these variables should be significant. Column (1) of Table 8 shows that the schooling variables are all measured imprecisely, thus the effect of these variables operates through their impact on technology use. Panel C reports the *p*-value for the corresponding χ^2 overidentification test that the IV coefficients on technology use estimated in Panel A and Panel D are equal. The *p*-value in column (1) indicates that at we cannot reject the hypothesis that these coefficients are the same. The estimates reported in panels A – D of column (2) of Table 8 correspondingly test the exogeneity of the rainfall shock instrument with results that are in keeping with those in column (1). Taken together, the estimates in Table 8 indicate that our instruments satisfy the exclusion restriction, that is, there is no evidence that they directly (or indirectly through omitted variables) affect firm productivity.[15] As a further check on instrument validity, we use information from the Kenya Integrated Household Budget Survey (KIHBS) from 2005-2006 on average consumption, poverty rate, unemployment rate, and net secondary school enrolment at the provincial level to conduct correlation tests between the number of schools of different types and the current provincial economic situation. These tests reveal no association, that is, the historical presence of schools in unrelated to the current economic climate across provinces of Kenya.[16]

As another test for the absence of direct instrument effects on our measure of productivity, we check to ensure that the regional historical distribution of the number of mission, private, and government schools is not correlated to a firm's top manager's education.[17] Since the manager's educational level may conceivably affect a firms' value-added, any correlation between the number of schools and a manager's educational level would invalidate these instruments. We conduct this test in two steps. First, we rank order the regional means of the schooling variables and compare these to a rank order of the regional means of an indicator for top manager's educational level.[18] This comparison reveals that there is no correspondence between the regional share of colonial schools and the regional educational level of managers. Second, note that the top manager's education is already controlled for in the second stage of the IV models in Table 7, which shows that technology use has a beneficial impact on productivity.

Another manner in which the schooling instruments might directly affect firm productivity is by influencing the education of the workforce, that is, workers might be better educated in regions that had a large historical presence of mission, private and government schools. We contend that this is not the case since in order to maintain racial separation from non-whites, the education imparted to the native population by mission schools was of low quality. Mission schools "transferred to Africa a curriculum and a method designed to meet the needs of the British working class" (Strayer 1978). Thus, lasting influences on the education of the workforce are unlikely. In order to address this more rigorously, we note first that the industries in our sample are those in which skills and education of the worker are likely to matter less in determining overall productivity (these are not highly skill-intensive industries). These industries are primarily retail firms or firms in garments where average education and skills are likely to be lower as compared to firms in information and technology (IT) industries or manufacturing industries in machinery and equipment or chemicals. A basic comparison of skills and education for workers across industries confirms this intuition. In our sample of industries, the mean weighted share of unskilled production workers is about 32 percent whereas mean weighted share of such workers in more skill-intensive industries is lower at 28 percent (using the full sample of firms).

The second route by which we control for possible influences of the school instruments on the education of the workforce is to include indicators for the education of a typical production worker directly in the second stage. Since the average education level of production workers is asked only of manufacturing firms, we first estimate the model in column (1) of Table 7 for manufacturing firms only. Next we include measures of education for a typical production worker directly in the second stage of this model. Restricting the sample to only manufacturing firms allows a comparison of coefficients across the models. These results are reported in Table 9. It is clear that although indicators for the average education of production workers are significant, the positive impact of technology use on productivity is still evident. In fact, the coefficient on technology hardly changes across the two specifications of Table 9.   That is, even with controls for workers' educational levels, our main result remains intact.

Next, our rain shocks instruments are open to the claim that they might affect firm productivity directly by influencing firm location. That is, firms might locate in areas with different geographic characteristics and this could independently affect value-added. We note first that it is not easy for firms to migrate to other regions in search of greener pastures and our data confirm this. If there were no costs associated with moving, we should expect to see most if not all firms located in Nairobi and Mombasa (the financial and commercial hubs). This does not seem to be the case – although Nairobi does have a large share of firms (57 percent), the remaining are equitably distributed across Mombasa, Nakuru, and Kisumu (about 14-15 percent each). Next, evidence for certain industries originating only in certain areas would be present if we saw "bunching" of firms by industry in certain regions. Again this does not appear to be the case. We have seven industries in our sample and tabulation exercises reveal that all seven are present in each of the four regions in roughly the same proportions. Moreover, industrial classifications are included in the second stage. This would adjust for possible correlation with the rainfall instruments if there were any. The contention that rainfall might affect production directly through its effect on the availability of power or through the fact that water is an important intermediate input in some industries is addressed by noting the rain instrument measures deviations from historical averages, not actual rainfall levels. Further, this rain shocks variable satisfies the exclusion restriction as demonstrated in column (2) of Table 8. Finally, in Kenya, industries that rank highest in terms of unit water consumption are basic metals, chemical and petroleum products and paper products and printing (Republic of Kenya 1992). None of these industries are present in our sample.

Our final set of robustness tests ensures that the instruments have no indirect effects on firm productivity through their correlation with omitted variables. For example, historical schooling measures might influence whether the firm acquired technological innovations recently, which could affect value-added. Or firms in regions that are better endowed in terms of retrospective schooling and geographic attributes might have easier access to credit which might directly influence productivity. Overidentification tests presented in Table 8 already provide evidence that the instruments do not affect firm productivity through their correlation with omitted variables. The set of tests presented in Table 10 further corroborate the estimates reported in Table 7 by demonstrating that the instruments are randomly assigned. Table 10 ascertains the lack of correlation between the instruments and a wide range of observed variables including the number of skilled production workers, whether the firm acquired technological innovations in the last three years, the proportion of working capital borrowed from commercial banks, from state-owned banks and/or government agencies and from non-bank financial institutions, whether the firm distributed HIV prevention messages to employees, and the proportion of the workforce that is unionized. It is clear that the instruments are not correlated with any of these variables; these tests confirm that the instruments are relevant and satisfy the exclusion restriction.

Robustness checks on main results using an alternate method

As a robustness check for the main results in Table 7, we evaluate the effect of communications technology on value added per worker using an alternative technique: the nearest neighbor matching estimator (NNME). Based on the value of covariates, firms self-select to use technology. Another method to control for the endogeneity of technology adoption that may result from such selection is to match observable characteristics of firms that use technology and those that do not. This allows the creation of a counterfactual to answer the following question - what would value-added per worker have been if the firm had not opted to use technology? If the decision to use technology is assumed to be random for firms with similar measures of the pretreatment covariates, then an approach to create such a counterfactual would be to use the average outcome of firms who chose not to use technology (Abadie and Imbens 2002, Imbens 2003). This is the concept that underlies the formulation of matching estimators. We report the result of the NNME method in Appendix Table 1.

Appendix Table 1 reports the average treatment effect and the average treatment effect for the treated (those firms that use such technologies) for the full sample of firms, for firms with female owners, and for firms with male owners. The NNME conditions on matching regional variables as well as firm, industry and manager characteristics. The results show that for all firms, the average effect of using communications technologies is an increase in value added of about 34 Kenyan shillings; approximately 11percent of the average of value added per worker in the full sample of firms. The effect of technology for firms that use it is higher at 111 Kenyan shillings. Estimates specific to the sample of firms with female owners are broadly similar and show that both the average treatment and the average treatment for the treated is positive and strongly significant. In particular, the effect of technology for female-headed firms that use it is an increase in value added of about 570 Kenyan shillings. The NNME returns negative average effects in firms with male owners. This finding is broadly in keeping with that reported in Table 7 where male-owned firms do not benefit as much from technology use. These results show that use of an alternative method leads to conclusions that are generally consistent with those of the main results above.

Section 7. Conclusion and implications for policy

This study demonstrates that the use of communication technologies has important measurable effects on firm productivity in environments with excessive regulations, poor infrastructure and rampant insecurity, particularly in establishments with female principal owners. A 10 percent increase in technology use results in a 1.69 percentage point increase in value-added per worker in firms with female-headship; the corresponding estimate is positive but significantly smaller in male-owned firms.

Our findings indicate that in addition to removing regulatory hurdles, improving physical infrastructure and curbing crime, Kenyan firms may benefit from policies that enable greater use of technologies. A way to foster this would be to extend low-cost loans for purposes of purchasing technology for business use, especially for female-owned firms. For example, "Mwamba" loans that are currently provided to women business owners for acquiring machinery by the Kenya Women's Finance Trust Ltd. could now also be used for the purchase of communication technologies. Furthermore, the provision of subsidized vocational training and computer literacy courses would also be of value. Finally, policies that build networks among female-owned establishments would help diffuse expertise on how to use technology to mitigate regulatory burdens in the difficult business environment of Kenya.

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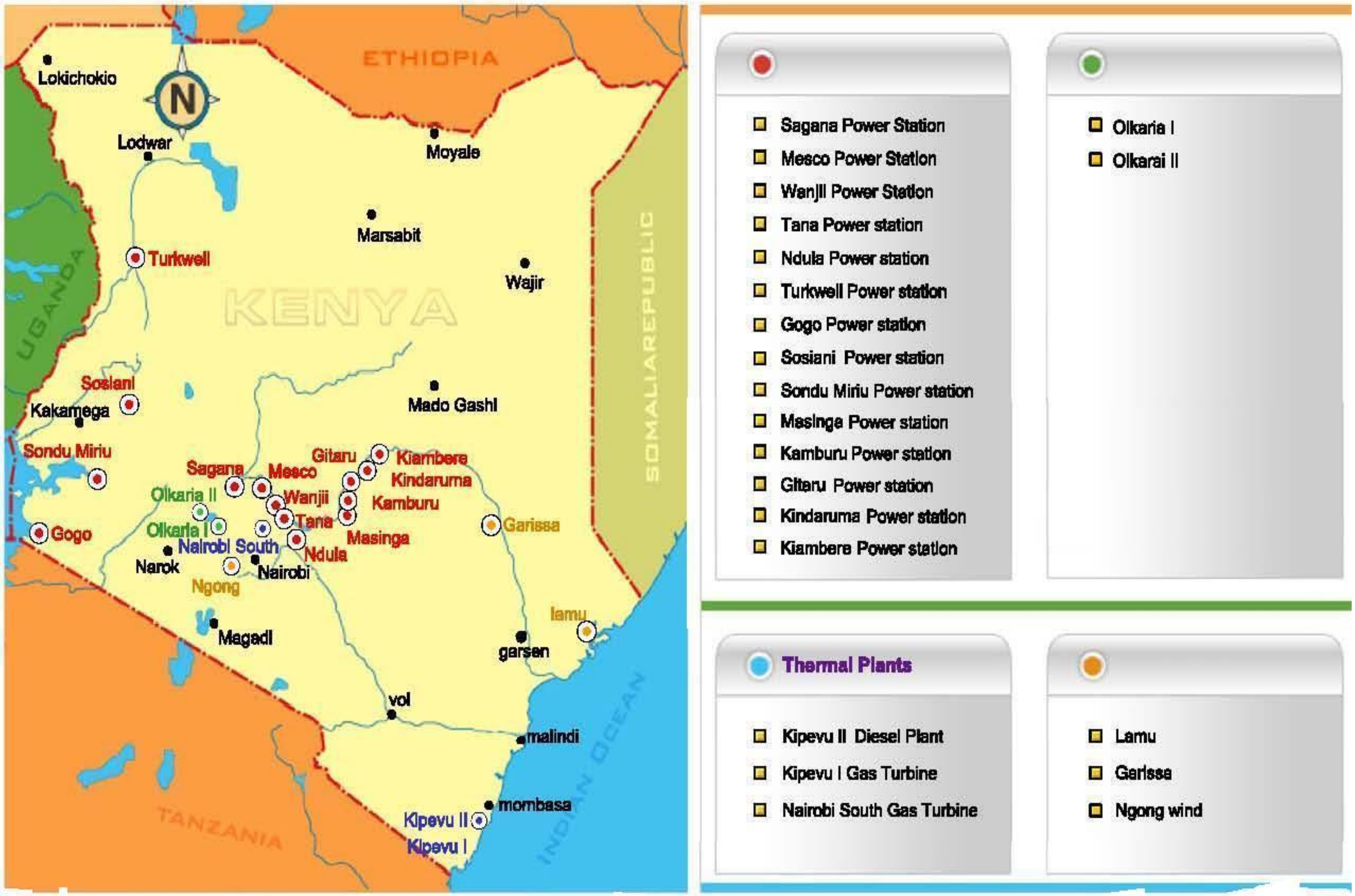
Map 1: Political map of Kenya

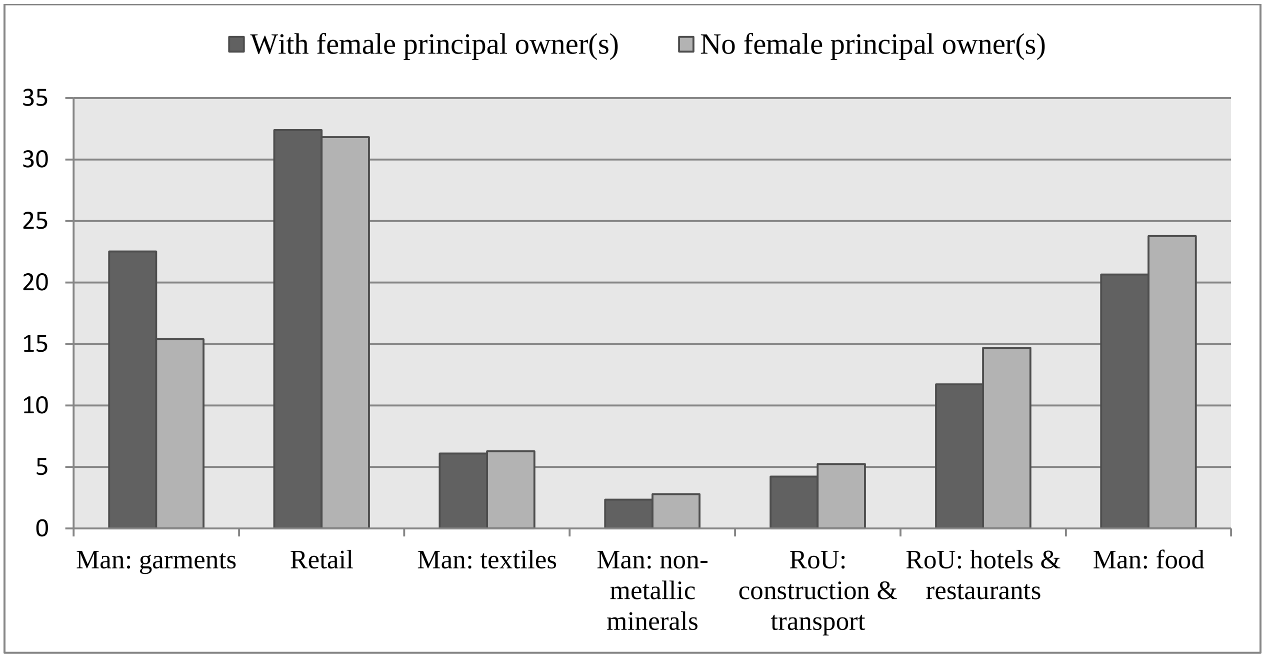
Source: http://www.nationsonline.org/oneworld/map/kenya_map.htm.

Map 2: Map of power plants in Kenya



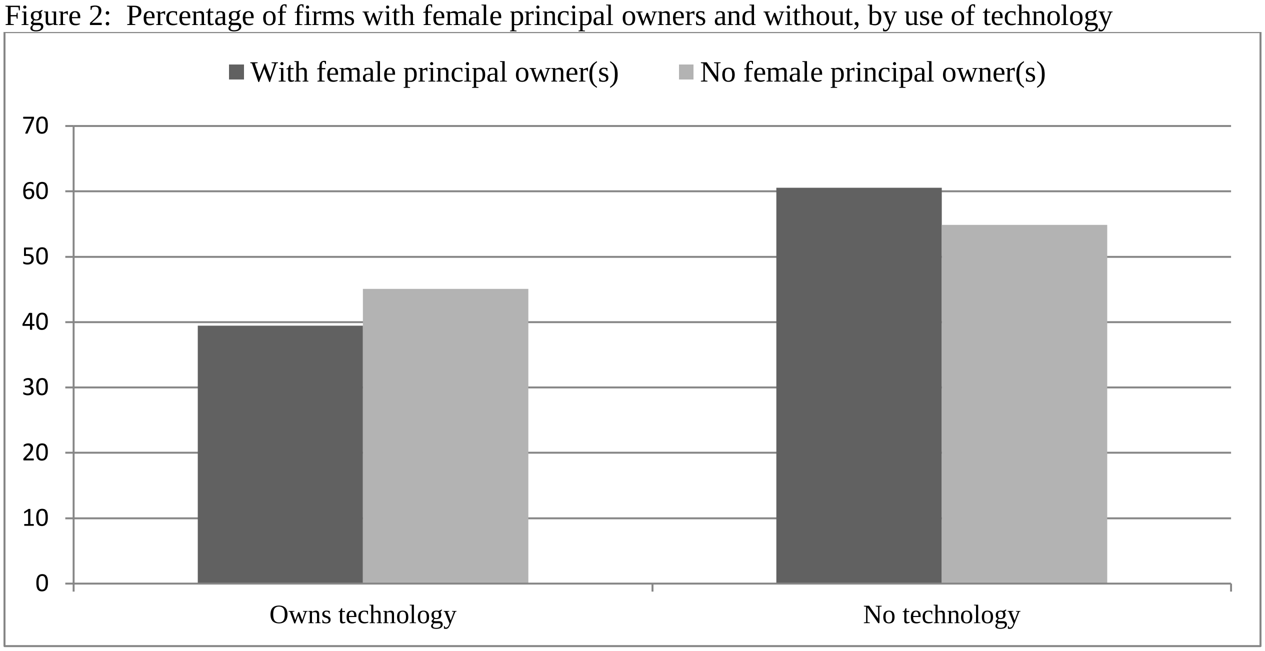
Source: http://www.kengen.co.ke/index.php?page=business&subpage=powerplant.

Figure 1: Percentage of firms with female principal owners and without, by industry



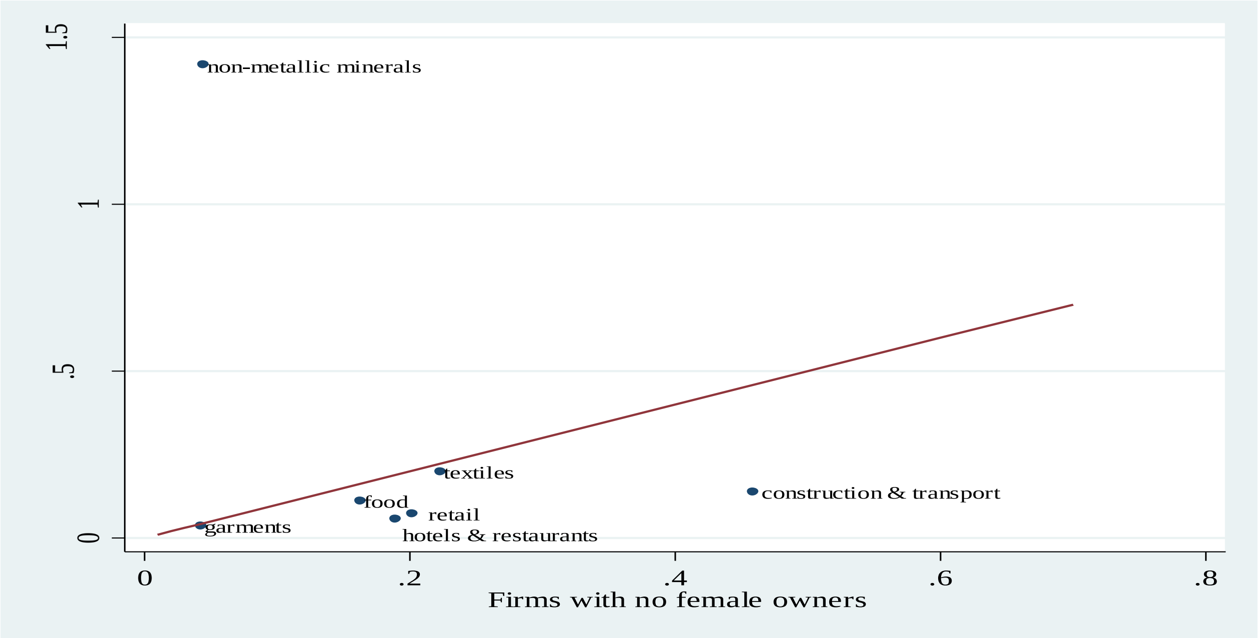
Notes: Industries are arranged by order of the difference between firms with female principal owners and firms with no female principal owners (from largest to smallest), within each industry grouping.

Figure 2: Percentage of firms with female principal owners and without, by use of technology



Notes: "Technology" implies that the firm uses email, its website, or the internet to communicate with clients and suppliers.

Figure 3: Median value-added per worker, by gender of firm owner (2006 US $)



Notes: Author's calculations. Value-added per worker is in 10,000 Kenyan Shillings before being converted to 2006 US $.

Table 1: Weighted proportions of firms characterizing obstacles as moderate, major or very severe

	Total	*With female principal owners*	*No female principal owners*
Obstacles related to			
regulations	0.997	0.998	0.999
	(0.001)	(0.002)	(0.00002)
infrastructure	0.930	0.954	0.907
	(0.004)	(0.034)	(0.037)
security	0.728	0.725	0.730
	(0.095)	(0.143)	(0.050)
workforce	0.180	0.236	0.126
	(0.082)	(0.127)	(0.021)
corruption	0.842	0.835	0.850
	(0.059)	(0.053)	(0.068)
finance	0.965	0.947	0.983
	(0.020)	(0.036)	(0.006)

Notes: There are 499 total firms in the sample of which 213 firms have female principal owners and 286 have only male principal owners. Weighted to national level with weights provided by the Enterprise Survey of Kenya. Table reports percentage values. Robust standard errors in parenthesis.

Table 2: Weighted proportions of firms characterizing obstacles as moderate, major, or very severe by industry

	With female principal owners				**No female principal owners**			
	Manufacturing	*Retail*	*Construction & Transport*	*Hotels & Restaurants*	*Manufacturing*	*Retail*	*Construction & Transport*	*Hotels & Restaurants*
Obstacles related to								
regulations	1.000	0.996	1.000	1.000	1.000	0.999	1.000	1.000
	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	(0.0001)	(0.000)	(0.000)
infrastructure	0.982	0.926	0.976	0.995	0.691	0.991	0.674	0.972
	(0.020)	(0.052)	(0.025)	(0.005)	(0.336)	(0.005)	(0.009)	(0.012)
security	0.997	0.639	0.995	0.714	0.771	0.645	0.995	0.967
	(0.002)	(0.120)	(0.008)	(0.259)	(0.111)	(0.095)	(0.008)	(0.010)
workforce	0.006	0.334	-	0.193	0.228	0.078	0.328	0.039
	(0.003)	(0.187)		(0.130)	(0.114)	(0.074)	(0.006)	(0.038)
corruption	0.983	0.927	0.992	0.536	0.979	0.774	1.000	0.993
	(0.021)	(0.052)	(0.013)	(0.126)	(0.027)	(0.134)	(0.000)	(0.003)
finance	0.955	0.924	0.967	0.987	0.983	0.988	0.989	0.937
	(0.045)	(0.051)	(0.033)	(0.010)	(0.010)	(0.007)	(0.006)	(0.027)

Notes: There are 499 total firms in the sample of which 248 are in manufacturing firms, 160 are retail firms, 24 are Construction and Transport firms, and 67 are Hotels and Restaurant firms. Weighted to national level with weights provided by the Enterprise Survey of Kenya. Table reports percentage values. Robust standard errors in parenthesis.

Table 3: Weighted proportion of firms characterizing obstacles as moderate, major, or very severe by use of communications technology

	With female principal owners	**No female principal owners**
	Firm uses email, website, or an internet connection for communication with clients and suppliers	*Firm uses email, website, or an internet connection for communication with clients and suppliers*
Obstacles related to		
regulations	0.912	0.996
	(0.061)	(0.001)
infrastructure	0.643	0.919
	(0.051)	(0.055)
security	0.878	0.935
	(0.044)	(0.052)
workforce	0.041	0.786
	(0.017)	(0.113)
corruption	0.641	0.946
	(0.092)	(0.057)
finance	0.336	0.835
	(0.056)	(0.103)

Notes: There are 499 total firms in the sample of which 212 firms use email for communications with clients and suppliers, 57 firms use their own website for communications with clients and suppliers, and 18 firms use high-speed, broadband internet connection to communicate with clients and suppliers. Weighted to national level with weights provided by the Enterprise Survey of Kenya. Table reports percentage values. Robust standard errors in parenthesis.

Table 4: Weighted means and standard deviations disaggregated by gender of principal owners

	Firm has at least one female principal owner	*Firm has no female principal owner*	*Difference (column 1 - column 2)*
Endogenous variable			
Natural log of value added per worker	1.412	2.757	-1.346***
	(0.330)	(0.287)	(0.438)
Firm uses email, its website, or the internet to	0.019	0.072	-0.052
communicate with clients and suppliers	(0.006)	(0.051)	(0.051)
Obstacles related to			
Regulations	0.999	0.998	0.0003
	(0.0004)	(0.0004)	(0.001)
Infrastructure	0.950	0.911	0.039
	(0.024)	(0.028)	(0.036)
Security	0.749	0.706	0.043
	(0.041)	(0.047)	(0.063)
Workforce	0.190	0.170	0.020
	(0.039)	(0.036)	(0.053)
Corruption	0.819	0.865	-0.046
	(0.033)	(0.029)	(0.044)
Finance	0.968	0.962	0.006
	(0.007)	(0.007)	(0.009)
Instruments			
Number of mission schools as of 1935 in region	13.932	16.810	-2.878
in the year the firm was established	(1.416)	(1.301)	(1.923)
Number of private schools as of 1935 in region	2.466	2.672	-0.206
in the year the firm was established	(0.101)	(0.093)	(0.137)
Number of government schools as of 1935 in region	5.923	7.542	-1.619
in the year the firm was established	(0.808)	(0.742)	(1.097)
Indicator for no deviation in region-year rainfall	0.050	0.048	0.001
from 1910-2000 rainfall average	(0.047)	(0.046)	(0.066)
Regional indicators			
Nairobi	0.488	0.692	-0.203
	(0.101)	(0.093)	(0.137)
Mombasa	0.490	0.289	0.201
	(0.102)	(0.093)	(0.138)
Nakuru	0.013	0.010	0.003
	(0.004)	(0.003)	(0.005)
Kisumu	0.009	0.009	-0.001
	(0.003)	(0.003)	(0.004)

Table 4: Weighted means and standard deviations disaggregated by gender of principal owner (continued)

	Firm has at least one female principal owner	*Firm has no female principal owner*	*Difference (column 1 - column 2)*
Firm and industry characteristics			
Natural log of value of machinery (machinery, vehicle equipment new and/or used)	6.329 (0.977)	6.866 (0.889)	-0.537 (1.321)
Natural log of value of property (land and buildings)	0.012 (0.006)	1.075 (0.554)	-1.064* (0.554)
Percent of firm owned by largest shareholders	97.162 (1.814)	95.723 (2.464)	1.440 (3.060)
Dummy for manufacturing firm	0.133 (0.067)	0.159 (0.071)	-0.026 (0.097)
Dummy for retail firm	0.552 (0.101)	0.647 (0.090)	-0.095 (0.135)
Firm has 20 – 99 employees (“medium” firm)	0.006 (0.002)	0.010 (0.003)	-0.004 (0.003)
Firm has 5 – 19 employees (“small” firm)	0.020 (0.005)	0.029 (0.006)	-0.009 (0.008)
Firm has African-origin principal owner	0.956 (0.036)	0.991 (0.003)	-0.034 (0.036)
Firm has Indian-origin principal owner	0.006 (0.002)	0.007 (0.002)	-0.001 (0.003)
Number of skilled production workers	69.727 (30.509)	65.175 (13.841)	4.551 (33.502)
Acquired technological innovation in past 3 years	0.530 (0.055)	0.562 (0.047)	-0.032 (0.072)
Proportion of working capital borrowed from private commercial banks	12.593 (2.394)	13.353 (1.952)	-0.759 (3.089)
Proportion of working capital borrowed from state-owned banks and/or government agencies	0.725 (0.349)	1.328 (0.779)	-0.603 (0.853)
Proportion of working capital borrowed from non-bank financial institutions	0.680 (0.484)	0.692 (0.448)	-0.012 (0.660)
Establishment distributed HIV prevention messages to employees	0.615 (0.054)	0.566 (0.048)	0.050 0.072)
Proportion of workforce that is unionized	28.648 (3.923)	33.834 (3.695)	-5.185 (5.388)

Table 4: Weighted means and standard deviations disaggregated by gender of principal owner (continued)

	Firm has at least one female principal owner	*Firm has no female principal owner*	*Difference (column 1 - column 2)*
Top manager's characteristics			
Illiterate	-	0.00004	-0.00004
		(0.00004)	(0.00004)
Some primary or primary school graduate	0.341	0.224	0.117
	(0.097)	(0.081)	(0.126)
Some secondary or secondary school graduate	0.591	0.618	-0.027
	(0.099)	(0.092)	(0.135)
Vocational training	0.013	0.098	-0.085
	(0.004)	(0.056)	(0.056)
Some university training or graduate degree	0.051	0.057	-0.006
	(0.036)	(0.035)	(0.050)
MBA or PhD from Kenya or another country	0.004	0.003	0.001
	(0.002)	(0.001)	(0.002)
Years of managerial experience in this sector	7.598	7.326	0.272
	(1.027)	(1.289)	(1.648)

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Table reports percentage values. Standard errors in parentheses. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Significance denoted on the basis of respective *p*-values.

Table 5: OLS results for the effect of communications technology on natural log of value added per worker

	All firms	*Has female owners*	*No female owners*
Firm uses email, its website, or the internet to communicate with clients and suppliers	1.573*	1.293	-0.217
	(0.612)	(0.819)	(0.355)
Obstacles related to regulations	3.776	-8.337	10.784**
	(5.684)	(4.251)	(2.430)
Obstacles related to infrastructure	-1.703*	-1.247	-0.738
	(0.607)	(0.688)	(0.422)
Obstacles related to security	-4.815	-3.808	-0.342
	(3.114)	(2.932)	(0.334)
Obstacles related to workforce	2.691	1.866	2.801***
	(1.289)	(0.988)	(0.365)
Obstacles related to corruption	4.661	4.484*	0.300
	(4.042)	(1.425)	(0.809)
Obstacles related to finance	1.876*	0.192	0.647
	(0.688)	(0.528)	(0.618)
Firm has one or more female principal owners	9.221**		
	(2.861)		
Female principal owner interactions with:			
Obstacles related to regulations	-11.990**		
	(2.509)		
Obstacles related to infrastructure	3.049*		
	(1.102)		
Obstacles related to security	4.783		
	(3.259)		
Obstacles related to workforce	-3.555		
	(1.681)		
Obstacles related to corruption	-2.140		
	(4.054)		
Obstacles related to finance	-2.718*		
	(1.091)		
χ^2 *value of joint test of significance of Obstacles*	18.290	2.720	15.83
	[0.020]	[0.216]	[0.024]
χ^2 *value of joint test of significance of female principal owner interactions with obstacles*	95.160		
	[0.002]		
Includes region, firm, industry, and manager chars.	YES	YES	YES
Observations	464	200	264

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Standard errors, clustered by region, in parentheses. *p*-values in square brackets. The notation *** is p<0.01, ** is p<0.05, * is p<0.10. Significance denoted on the basis of respective *p*-values. Regressions include a full set of controls and a constant term.

Table 6: First stage regressions

	Firm uses email, its website or the internet to communicate with clients and suppliers								
	All firms			*Firms with female owners*			*Firms with no female owners*		
Instruments									
Number of mission sch. as of 1935	0.003***	0.012*	0.011***	0.003***	0.014*	0.014***	0.002***	0.010**	0.009***
in the year the firm was established	(0.001)	(0.006)	(0.000)	(0.001)	(0.008)	(0.000)	(0.001)	(0.005)	(0.000)
Number of private sch. as of 1935			-0.142***			-0.161***			-0.122***
in the year the firm was established			(0.000)			(0.000)			(0.001)
Number of govt. schools as of 1935		0.018*	0.003***		0.021	0.001***		0.015*	0.003***
in the year the firm was established		(0.011)	(0.000)		(0.014)	(0.000)		(0.008)	(0.000)
Indicator for no dev. in region-year	0.007	0.001	0.008***	0.008	0.002	0.008**	0.003	-0.003	0.004***
rain from 1910-2000 rainfall av.	(0.006)	(0.011)	(0.001)	(0.005)	(0.010)	(0.002)	(0.007)	(0.011)	(0.000)
R-squared	0.022	0.053	0.083	0.032	0.078	0.130	0.013	0.032	0.050
F	6.050	265.420	110e+07	3.310	99.330	420e+04	11.070	655.55	310e+03
	[0.089]	[0.000]	[0.000]	[0.174]	[0.002]	[0.000]	[0.041]	[0.000]	[0.000]
Observations	499	499	499	213	213	213	286	286	286

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Table reports OLS regressions. Standard errors, clustered by region, in parentheses. The notation *** is p<0.01, ** is p<0.05, * is p<0.10. Significance denoted on the basis of respective *p*-values. F-statistics reported in the table are for all identifying instruments. *p*-values in square brackets. Regressions include full set of controls and a constant term.

Table 7: IV results for the effect of communications technology on natural log of value added per worker

	All firms	*Has female owners*	*No female owners*
Firm uses email, its website, or the internet to communicate with clients and suppliers	33.996**	42.824***	5.808***
	(16.964)	(8.450)	(1.663)
Obstacles related to regulations	13.804*	5.388	14.794***
	(7.129)	(6.627)	(1.682)
Obstacles related to infrastructure	-5.360	-4.177	-0.876
	(4.033)	(3.763)	(0.661)
Obstacles related to security	-10.198	-10.382***	-0.327
	(6.694)	(2.306)	(1.057)
Obstacles related to workforce	-5.698*	-6.881***	0.306
	(3.062)	(2.351)	(0.785)
Obstacles related to corruption	10.189	4.688	1.468
	(6.866)	(2.981)	(1.734)
Obstacles related to finance	17.269**	16.214***	2.764***
	(8.149)	(4.728)	(0.747)
Firm has one or more female principal owners	10.730		
	(6.695)		
Female principal owner interactions with:			
Obstacles related to regulations	-16.329**		
	(7.681)		
Obstacles related to infrastructure	3.051		
	(3.030)		
Obstacles related to security	9.096*		
	(5.203)		
Obstacles related to workforce	-1.582		
	(3.478)		
Obstacles related to corruption	-3.086		
	(6.425)		
Obstacles related to finance	-1.568		
	(2.185)		
χ^2 *value of joint test of significance of Obstacles*	6.310	32.560	168.990
	[0.098]	[0.000]	[0.000]
χ^2 *value of joint test of significance of female principal owner interactions with obstacles*	5.540		
	[0.137]		
Kleibergen-Paap rk Wald F statistic	102.438	93.029	46.143
Stock-Yogo critical values: 5% max. IV rel. bias	13.91	13.91	13.91
Hansen's J Statistic	1.689	2.594	0.155
	[0.430]	[0.273]	[0.693]
Observations	464	200	264

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Table reports two stage least squares estimates. Standard errors, clustered by region, in parentheses. *p*-values in square brackets. The notation *** is p<0.01, ** is p<0.05, * is p<0.10. Significance denoted on the basis of respective *p*-values. Regressions include a full set of controls and a constant term.

Table 8: Overidentification tests of the exclusion restriction

	(1)	(2)
Panel A: Two-stage least squares		
Firm uses email, its website, or the internet to communicate with clients and suppliers	128.057*	8.544*
	(66.946)	(4.392)
Panel B: First stage for firm uses email, its website, or the internet for communications		
Indicator for no deviation in region-year rainfall from 1910-2000 rainfall average	0.009***	
	(0.001)	
Number of mission schools as of 1935 in region in the year the firm was established		0.011***
		(0.00001)
Number of private schools as of 1935 in region in the year the firm was established		-0.141***
		(0.0001)
Number of government schools as of 1935 in region in the year the firm was established		0.002***
		(0.00003)
R^2	0.026	0.083
Panel C: Results from overidentification test		
p-value (from χ^2 test)	[0.209]	[0.420]
Panel D: Second stage with excluded instrument(s) as exogenous variables		
Firm uses email, its website, or the internet to communicate with clients and suppliers	132.356**	13.881***
	(66.589)	(2.814)
Number of mission schools as of 1935 in region in the year the firm was established	23.348	
	(15.050)	
Number of private schools as of 1935 in region in the year the firm was established	136.531	
	(114.696)	
Number of government schools as of 1935 in region in the year the firm was established	-17.307	
	(17.539)	
Deviation in region-year rainfall from 1910-2000 rainfall average		-14.772
		(18.796)

Notes: Panel A reports the two-stage least-squares estimates with natural log of value added per worker as the dependent variable. Panel B reports the corresponding first stage. Panel C reports the *p*-value for the null hypothesis that the coefficient on the endogenous communications technology variable in Panel A is the same as in Panel D. Weighted to national level with weights provided by the Enterprise Survey for Kenya. Standard errors, clustered by region, in parentheses. The notation *** is p<0.01, ** is p<0.05, * is p<0.10. Significance denoted on the basis of respective *p*-values. Regressions include a full set of controls and a constant term.

Table 9: IV results for the effect of communications technology on natural log of value added per worker with inclusion of average educational attainment of typical production worker in the second stage

	Manufacturing firms	*Manufacturing firms*
Firm uses email, its website, or the internet to communicate with clients and suppliers	4.480***	4.150***
	(1.322)	(1.287)
Obstacles related to infrastructure	-2.579***	-2.748***
	(0.721)	(0.303)
Obstacles related to security	2.953***	2.747***
	(0.728)	(0.706)
Obstacles related to workforce	-0.575	-0.582
	(1.073)	(1.331)
Obstacles related to corruption	3.402***	3.646***
	(0.292)	(0.504)
Obstacles related to finance	-0.064	-0.159
	(0.489)	(0.446)
Firm has one or more female principal owners	-3.969***	-4.148***
	(1.012)	(0.637)
Typical production worker has between 0-3 years of education		-0.649
		(0.715)
Typical production worker has between 4-6 years of education		-0.869***
		(0.204)
Typical production worker has between 7-12 years of education		-0.742***
		(0.213)
Female principal owner interactions with:		
Obstacles related to infrastructure	4.441***	4.606***
	(0.884)	(0.663)
Obstacles related to security	-0.196	0.150
	(0.847)	(0.618)
Obstacles related to workforce	-0.552	-0.121
	(1.042)	(1.164)
Obstacles related to corruption	-1.216*	-1.602**
	0.632)	(0.746)
Obstacles related to finance	2.206**	2.193**
	(0.919)	(0.952)
χ^2 *value of joint test of significance of obstacles*	33.460	410.870
	[0.000]	[0.000]
χ^2 *value of joint test of significance of female principal owner interactions with obstacles*	10.870	14.670
	[0.012]	[0.002]

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Table reports two stage least squares estimates. Standard errors, clustered by region, in parentheses. *p*-values in square brackets. The notation *** is p<0.01, ** is p<0.05, * is p<0.10. Significance denoted on the basis of respective *p*-values. The excluded education category is the indicator for whether a typical production worker has 13 years and above of education. Obstacles related to regulations (and its interaction) is dropped from the model with the inclusion of indicators for the education level of the typical production worker. Number of observations is 230 since the average education level of production workers is asked only of manufacturing firms. Regressions include a full set of controls and a constant term.

Table 10: Robustness of the instruments with respect to other variables that might be correlated with natural log of value added per worker

Dependent variable	*Number of skilled production workers*	*Acquired technology innovation in past 3 years*	*Proport. of working K borrowed from private commer. banks*	*Proport. of working K borrowed from state-owned banks*	*Proport. of working K borrowed from non-bank inst.*	*Establish. distributed HIV prev. messages to emp.*	*Percent of workforce that is unionized*
Instruments							
Number of mission schools as of 1935 in region	36.882	0.150	3.876	1.164	-0.695	-0.056	9.284
in the year the firm was established	(22.977)	(0.121)	(2.770)	(0.838)	(0.513)	(0.077)	(13.085)
Number of private schools as of 1935 in region	53.201	0.728	-9.333	4.186	-1.885	-0.608	81.300
in the year the firm was established	(71.341)	(1.655)	(12.202)	(6.199)	(2.223)	(0.549)	(86.339)
Number of government schools as of 1935 in region	2.261	-0.101	2.693	-0.716	-0.006	0.122	-14.774
in the year the firm was established	(7.119)	(0.310)	(2.054)	(0.896)	(0.251)	(0.085)	(13.242)
Indicator for no deviation in region-year rainfall	-41.222	0.021	5.909	0.024	-0.616	0.086	9.274
from 1910-2000 rainfall average	(26.561)	(0.065)	(6.913)	(0.484)	(0.824)	(0.153)	(6.267)
Includes region, firm, industry, and manager chars.	YES	YES	YES	YES	YES	YES	YES
Observations	229	229	421	421	430	305	224

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Table reports OLS regressions. Standard errors, clustered by region, in parentheses. The notation *** is p<0.01, ** is p<0.05, * is p<0.10. Significance denoted on the basis of respective *p*-values. Regressions include a full set of controls and a constant term. Number of skilled production workers, technological innovation, and unionized questions are asked only of manufacturing firms.

Appendix Table 1: Matching estimator results for the effect of technology on value added per worker

	All firms	*Firm has at least one female owner*	*Firm has no female owners*
Average treatment effect	34.231*	170.874***	-230.324***
	(19.687)	(38.638)	(21.430)
Average treatment effect for the treated	111.013*	570.027**	-49.627***
	(57.303)	(258.658)	(17.886)
Includes region, firm, industry, and manager chars.	YES	YES	YES
Observations	464	200	264

Notes: Weighted to national level with weights provided by the Enterprise Survey for Kenya. Estimates are as reported by the bias corrected matching estimator which uses the inverse variance weighting matrix. Table reports robust standard errors in parentheses. The notation *** is $p<0.01$, ** is $p<0.05$, * is $p<0.10$. Significance denoted on the basis of respective *p*-values.

Endnotes

[1] We do not include cell-phones in this definition as use of mobile phones is fairly widespread (there is little variation in this indicator).

[2] We assume that the decision to invest in communication technologies is economically rational for firms that choose to do so. Given data constraints, we do not model this choice.

[3] As noted in Bresnahan *et al*. (2002). In so far as the general effect of technology is likely to be beneficial on the whole (increase the efficiency of production and reduce input costs), we consider the magnitude of the short-run effects measured here to be an underestimate of long-run adjustments in the future.

[4] Modeling technology adoption as a reduction in price is similar to the intuition provided in Rosenzweig and Wolpin (1986).

[5] We abstract from thinking of productivity change as increasing at a decreasing rate mainly because given the business circumstances in Kenya, firms are unlikely to reach the "tipping point" in the short run.

[6] We assume that the total factor productivity (TFP) parameter equals one. A way to incorporate long run effects of technology ownership on input choice would be to condition TFP on technology as in Hu *et al*. (2005). This framework would also be amenable to thinking of technology adoption as a productivity shifter.

[7] Carlin et al. (2007) argues that measures of obstacles may be endogenous in that firms experiencing the constraints more often are the ones who are likely to report the constraint as binding. We take averages of the obstacles variable to address this issue (similar to Angrist and Krueger 2001, Dethier *et al*. 2008 and Amin 2009, and a section in Carlin et al. 2007) and note that the main variable of interest is technology and not obstacles in of themselves. Further, we use these data because there are few alternatives with comparable detail on firm characteristics, obstacles and technology in one source.

[8] Value-added per worker is measured in 10,000 Kenyan Shillings.

[9] Sensitivity tests with only the major or very severe categories did not lead to appreciably different results.

[10] Taking averages addresses the possibility that those firms who experience constraints are more likely to report that they are binding.

[11] We check to ensure that there is no systematic correlation between the regional distribution of such schools as of 1935 and the regional distribution of firms in our data. The earliest firm was established in 1920 in Mombasa and as of 1935, only 4 of the 499 firms in our sample had been established. Only 10 percent of firms had been set-up by 1975, forty years after the end-point of the schools data (the majority of firms was established in 2000).

[12] World Bank (2008) notes that droughts/floods are among the most common shocks in Kenya. Given their frequency, it is likely that such shocks have little direct impact on factors that could potentially affect input prices for labor and capital and thus, firm productivity.

[13] Without this averaging, the dependent variable in the first stage is non-linear. Angrist and Krueger (2001) show that estimating a two-stage model with a non-linear functional form for the first-stage is invalid since the model is essentially identified from the non-linearity.

[14] We do not use actual rainfall shocks directly since given that droughts are relatively common, this variable has a large number of negative values. Hence we lose observations upon taking logs (positive shocks can be as large as 35mm above normal, a relatively large number that requires the log transform to fit the data appropriately).

[15] We note that information on value-added per worker is available for 464 of the 499 firms since value-added is exactly zero for 10 firms (these values are dropped with the natural log transformation), and is not defined for 25 firms (these are micro firms that do not employ any permanent full-time paid employees; these firms are thus dropped upon dividing by 0 in order to obtain value-added per worker).

[16] Information on KIHBS indicators was obtained from World Bank (2008). These tests are available on request.

[17] We note that mission schools espoused a notion of "trusteeship" which implied that non-white races were considered to be biologically inferior (Strayer 1978). Thus, although such schools engaged in educating native populations, the education imparted was of low quality and similar to that provided to the "lower social orders in England" (Strayer 1978).

[18] This variable is binary in nature and represents whether the manager has some school (primary or secondary or vocational training) or whether he/she has advanced schooling (some graduate training or holds an M.B.A. or Ph.D.)