Wages and Labor Management in African Manufacturing*

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Abstract

Using matched employer-employee data from 10 African countries, this paper examines the relationship between wages, worker supervision, and labor productivity in manufacturing. Wages increase with firm size for both production workers and supervisors. We develop a two-tier model of supervision that can account for this stylized fact and we fit the structural model to the data. Employee data is used to derive a firm-specific wage premium that is purged of the effect of worker observables. We find a strong effect of both supervision and wages on effort and hence on labor productivity. Labor management in sub-Saharan Africa appears problematic, with much higher supervisor-to-worker ratios than elsewhere and a higher elasticity of effort with respect to supervision than in Morocco.

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1. Introduction

It is widely acknowledged that firms pay different wages, so much so that unemployment is often modeled as a sequential search process for the best wage offer. In particular, large firms are uniformly found to pay higher wages than small firms (e.g. Oi and Idson 1999, Mazumdar and Mazaheri 2002).

Different explanations have been proposed for this state of affairs (e.g. Troske 1999, Bayard and Troske 1999). One category of explanations is based on the idea that workers differ in dimensions that are hard to measure. Firms employing better workers pay higher wages because their workers are more productive. This, by itself, does not explain why large firms pay more. To account for this, it is possible to assume, as does Stiglitz (1987), that large firms need better workers and consequently screen job applicants and new workers more thoroughly. While the notion that the size-wage differential is driven by unobserved heterogeneity may be intuitively appealing, it does not appear to be fully supported by the empirical evidence. In recent years a number of data sets have become available that enable researchers to estimate the size-wage effect while controlling for unmeasured heterogeneity in the form of individual fixed effects. Spanning a wide range of countries, Brown and Medoff (1989), Criscuolo (2000), Arai (2003), and Söderbom, Teal and Wambugu (2005) all reject the hypothesis that the size-wage effect can be attributed solely to the omission of individual fixed effects.[1] These studies also indicate that the magnitude of the bias from omitting controls for worker heterogeneity is relatively moderate.

Another category of explanation for wage differences across firms focuses on labor management. In order to be productive, workers need to be motivated to exert effort and initiative. Firms can motivate workers in two ways: by supervising the workforce more closely to minimize shirking and idle time; or by paying workers more to increase firm loyalty and the opportunity cost of losing one's job. To motivate workers, there is thus a trade-off between supervision and wages. Because of moral hazard, and because information processing requirements are more difficult in large and multi-tiered hierarchies, the management and supervision of workers becomes increasingly complex as firm size increases (e.g. Williamson 1975, Itoh 1991, Meagher 2001). As a result, large firms may choose to motivate their workers through higher wages instead. The intellectual appeal of this explanation comes from its parsimony: it

[1] Brown and Medoff: the U.S.; Criscuolo: Germany; Arai: Sweden; Söderbom et al.: Ghana and Kenya.

explains wage differentials across firms in a way that also accounts for the empirical relationship between firm size and wages.[2]

This paper revisits these issues using matched employer-employee data in manufacturing. We contrast two mechanisms by which firms seek to motivate their workers: supervision and wages. To capture them, we formulate a two-tier model of supervision in which middle-level managers must be monitored by shareholders. The model predicts that worker supervision falls with firm size while wages rise, a feature consistent with the descriptive analysis of our data. This structural model is then econometrically estimated using data from ten African countries – nine in Sub-Saharan Africa (SSA) and one in North-Africa. Africa is a very suitable test case for a study of the trade-off between supervision and wages. Firstly, supervision rates in Africa appear to be high relative to other parts of the world. Acemoglu and Newman (2002) report averages of the ratio of managerial to production workers in six OECD countries. In no case does this ratio exceed 0.25. In contrast, the average supervision ratio is 0.39 in SSA.[3] Secondly, the wage premium given by large firms relative to small firms is larger in SSA than elsewhere (e.g. Velenchik 1997, Bigsten, Collier, Dercon, Fafchamps, Gauthier, Gunning, Isaksson, Oduro, Oostendorp, Patillo, Söderbom, Teal and Zeufack 2004). Taken together, these two stylized facts suggest that in Africa labor management problems may indeed be driving part of the wage differences across firms. The model is estimated separately for Morocco and SSA to account for structural differences between the two groups of countries brought to light by the descriptive analysis.[4]

Econometric estimation yields parameter estimates of the structural two-tier supervision model. Estimation is accomplished by solving the theoretical model numerically and iterating on parameter estimates. Results suggest that, at the sample average, the elasticity of worker effort with respect to wage is around 0.52 in SSA and 0.78 in Morocco. In contrast, the elasticity of worker effort with respect to supervision is around 0.23 in SSA and 0.13 in Morocco. We find a non-negligible trade-off between supervision and wages as alternative ways of motivating workers. At the sample average, a decrease in supervision by

[2] In a related vein, Garicano and Hubbard (2003) and Garicano and Hubbard (2004) show that hierarchies play an important role in capturing increasing returns.

[3] As noted by Acemoglu and Newman, cross-country comparisons should be interpreted with caution, since the definition of a manager or production worker may vary across countries.

[4] Due to the small size of the valid samples in SSA, we have no choice but to pool the observations across countries. In the analysis, country dummies are use throughout to control for differences in legal institutions and labor market structure.

20 percent reduces worker effort by 5 percent in SSA and 3 percent in Morocco, holding everything else constant. To keep effort constant, workers' wages must increase by about 10 percent in SSA and by 4 percent in Morocco.

This paper contributes to the literature in several ways. The model and analysis presented here elaborate on a possible explanation for the often observed positive relationship between wages and firm size (Oi and Idson 1999). The fact that wages in SSA increase particularly rapidly with firm size is consistent with our findings that labor management is a more acute problem there. On the empirical side, we use matched employer-employee data covering ten African countries, a part of the world for which labor management issues have received little formal attention to date (Abowd and Kramarz 1999). Our contribution is also methodological as we combine non-parametric and structural estimation methods to throw light on labor efficiency issues.

The paper is organized as follows. A conceptual framework is introduced in Section 2. A two-tier efficiency wage model is constructed in which production workers are supervised by middle-rank managers and administrative staff, who in turn are monitored by firm owners. The data are presented in Section 3 together with a non-parametric analysis of labor management. Using matched employer-employee data, we find that wages increase with firm size even after we correct for observable human capital. We also find that supervision ratios fall with firm size, a finding contrary to that of Ringuede (1998) for French enterprises. Section 4 estimates a structural efficiency wage model that combines firm level and employee level data. Conclusions appear in Section 5.

2. Conceptual framework

As a basis for our empirical analysis, we construct a two-tiered model of wages and worker supervision. This model is inspired by the literature on efficiency wages and hierarchies (e.g. Calvo and Wellisz 1978, Calvo and Wellisz 1979, Rosen 1982, Garicano and Hubbard 2004) except that it ignores multi-layered hierarchies. We have two reasons for doing so. The first is practical: since our data does not permit a precise identification of hierarchical layers, we cannot estimate a multi-tiered structural model. We therefore limit ourselves to a two-tiered model.

The second reason is empirical. In multi-tiered models such as those developed by Calvo and Wellisz (1979) and Garicano and Rossi-Hansberg (2003), a relationship between hierarchical complexity and firm size arises from the assumption that an additional hierarchical layer is added only if the firm would benefit from one person working full-time in the new layer. This implies that, as firm size grows, the hierarchy gains additional layers. This in turn makes it more costly to have high-level supervisors shirking because of what it implies for the whole line of workers below them. As a result, CEO in large firms are paid more (Garicano and Rossi-Hansberg 2003).

In our firm population, supervisors in small firms often divide their time between various supervision tasks – e.g., firm oversight and day-to-day team management. This means that, effectively, they work simultaneously in different hierarchical capacities. If supervisors divide their time between different hierarchical layers, even small firms can have a virtual (part-time) multi-layered hierarchy. As a result, it is difficult to study the relationship between firm size and hierarchical complexity in small firms. Since most firms in our study are rather small, we choose to ignore the issue of number of supervision layers and we regard the hierarchical supervisory structure as exogenous and independent of firm size.

We begin by presenting the most general model. This model nests a number of simpler models as special cases. These special cases are discussed sequentially to illustrate how they differ in their predictions regarding wages and supervision. We then describe our testing strategy.

2.1. The general model

We construct a model of firms' labor management decisions. Workers are divided into two categories: production workers (hereafter workers), denoted L, and supervisors, denoted S. Firms choose the number of workers and supervisors they hire. They also set wages w for workers and m for supervisors. The effort provided by workers depend on their wage w and on the extent of supervision p. We write the effort function as:

$$e = (w - x)^c \left(d + \frac{1}{p} \right)^{-b} \tag{2.1}$$

where x, c, d, and b are parameters, with $c \geq 0$, $b \geq 0$, $d \geq 0$, and $x \geq 0$. A similar effort function is assumed for supervisors:

$$e' = (m - x')^{c'} \left(d' + \frac{1}{p'} \right)^{-b'} \tag{2.2}$$

where p' measures the extent to which supervisors are themselves supervised by firm owners, and x', c', d', and b' are model parameters. Equation (2.2) should be thought of as a reduced form summarizing the effectiveness of the supervisory hierarchy, i.e., relating the effective supervision of production workers e' to the number of supervisors (through p' – see below) and their average wage m.

Equations (2.1) and (2.2) imply that effort is increasing with wage (w and m) and with supervision (p and p'). The choice of this functional form is dictated by several considerations. First, it is sparse in parameters and yet able to deliver results of interest (Stiglitz 1987). Second, it nests a number of interesting special cases. For instance, if $c = 0$ ($b = 0$), effort is unresponsive to wages (supervision). Finally, the effort function derived by Sparks (1986) using an explicit worker dismissal model is a special case of equation (2.1) with $c = b = 0.5$, $x = rV^U$, and $d = 1/2r$ where r is the workers' rate of time preference and V^U is the expected life-time utility from becoming unemployed (see also Ringuede (1998)).[5] In the Sparks model there are no supervisors. We sometimes refer below to a generalized, two-tier, Sparks model in which $c = b = c' = b' = 0.5$. Because in the Sparks' framework x is interpretable as the income employees receive if they are sacked from their current job, we sometimes refer to x and x' as measuring the 'outside option' of workers and supervisors.

Equations (2.1) and (2.2) are sufficiently general to capture a variety of effects that have been discussed in the literature (e.g. Stiglitz 1987, Oi and Idson 1999, Abowd and Kramarz 1999). The effect of wages on effort may be due to the fear of losing one's job or to the morale-boosting of higher-than-average wages. Supervision effects may be due to the probability of dismissal of workers found shirking, as in Shapiro and Stiglitz (1984) and Sparks (1986). It may also be driven by other labor management effects, such as information processing within the firm, the organization of team work, etc. (e.g. Itoh 1991, Fudenberg and Tirole 1991, Williamson 1985).

[5] Sparks uses a slightly different formulation with $(1+\frac{2r}{p})^{\frac{1}{2}}$ as second term. Given that we use a Cobb-Douglas production function, dividing Sparks' second term by $2r$ yields an effort function equivalent to ours, except for a $(2r)^{\frac{1}{2}}$ term in front. The factored out term only affects the constant in the production function and can be ignored in the analysis.

Next we assume that extent of supervision p is proportional to the supervisor per worker ratio, corrected for the effort of supervisors:

$$p = \frac{e'S}{L} \tag{2.3}$$

This implies that the more effort supervisors provide, the more closely monitored workers are, and the more effort is supplied by workers themselves. We apply the same reasoning to the supervision of supervisors, treating the owner or board of directors as one. Consequently, we have:

$$p' = \frac{1}{S} \tag{2.4}$$

Firms are assumed to choose employment levels L and S and remuneration levels w and m so as to maximize profits:

$$\max_{L,S,w,m,p,p'} \quad a(eL)^{\beta} - wL - mS$$
$$\text{subject to equations (2.1), (2.3), (2.2), and (2.4)}$$

where a stands for everything other than labor in the production function. After replacing throughout p and p' by equations (2.3) and (2.4), the first order conditions are:

$$\begin{aligned}
w &= ae^{\beta}\beta L^{\beta-1} - a\beta e^{\beta-1}e_p S e' L^{\beta-2} && (2.5)\\
m &= a\beta e^{\beta-1}e_p \left[\frac{e'}{L} + \frac{S}{L}e'_S\right] L^{\beta} && (2.6)\\
L &= a\beta e^{\beta-1}e_w L^{\beta} && (2.7)\\
S &= a\beta e^{\beta-1}e_p S e'_m L^{\beta-1} && (2.8)
\end{aligned}$$

where the derivatives of the effort functions are given by:

$$
\begin{aligned}
e_w &= c(w-x)^{c-1}(d+\frac{1}{p})^{-b} \\
e_p &= (w-x)^c(d+\frac{1}{p})^{-b-1}\frac{b}{p^2} \\
e'_m &= c'(m-x')^{c'-1}(d'+S)^{-b'} \\
e'_S &= -b'(m-x')^{c'}(d'+S)^{-b'-1}
\end{aligned}
$$

2.2. No effort function

To understand the properties of the model, it is useful to proceed step by step and to start from a simplified version with no supervision. Formally, let $c = b = c' = b' = 0$. Consequently, e and e' are constant. In this case, the firm's profit maximization problem boils down to:[6]

$$\max_{L,S\geq 0} \; a(\bar{e}L)^{\beta} - wL - mS$$

which immediately yields $S = 0$ and the usual first order condition:

$$w = a\beta L^{\beta-1}.$$

In this simple case all firms pay the same wage and so there is no relationship between w and firm size. Moreover, there are no supervisors.

[6] Since wages have no effect on effort, the firm would naturally wish to set $w = 0$. This unrealistic prediction can be eliminated either by assuming that firms do not set wages, or that, by an arbitrage argument, they must set wages at least equal to wages paid by other employers. In this case, firms choose a wage exactly equal to the going market wage.

2.3. Efficiency wage model

The standard efficiency wage model without supervision is obtained by assuming that $b = c' = b' = 0$. Profit maximization with respect to L and w yields the usual first order conditions:

$$
\begin{aligned}
w &= ae^{\beta}\beta L^{\beta-1} \\
L &= a\beta e^{\beta-1}e_w L^{\beta}
\end{aligned}
$$

which, after straightforward manipulation, yields the standard Solow condition:

$$w = \frac{e}{e_w}.$$

Since here e (and thus e_w) only depends on w, the Solow condition implies that all firms pay the same wage, irrespective of size. Sparks (1986) provides behavioral underpinnings for a special case of this model in which $c = 0.5$.

2.4. Supervision by owner

Let us now assume that the effort of workers varies with wage and supervision matters but that all workers are supervised by the firm owner. Formally, this means assuming that $c' = d' = 0$ and $b' = 1$, implying that $e' = 1/S$, and thus that $p = 1/L$. In this case, the optimization model is:

$$
\begin{aligned}
&\max_{L,S\geq 0,w,m} \; a(eL)^{\beta} - wL - mS \;\text{ subject to} \\
e &= (w-x)^c(d+\frac{1}{p})^{-b} \\
p &= \frac{1}{L}
\end{aligned}
$$

As in the previous sub-sections, it is optimal to set $S = m = 0$. For the other choice variables, the first order conditions are:

$$
\begin{aligned}
w &= ae^{\beta}\beta L^{\beta-1} - a\beta e^{\beta-1}e_p L^{\beta-2} \\
L &= a\beta e^{\beta-1}e_w L^{\beta}
\end{aligned}
$$

Combining the two first order conditions, we obtain:

$$e - e_p p = we_w \tag{2.9}$$

which can be manipulated to yield an expression for w as a function of p:

$$w = \frac{x(1-b+pd)}{1-b-c+pd-cpd}$$

Totally differentiating with respect to w and p we get:

$$\frac{dw}{dp} = -\frac{bcxd}{[b+(c-1)(1+pd)]^2} \leq 0$$

Since $p = 1/L$, this shows that larger firms in terms of L pay higher wages: workers need to be motivated to exercise more care or effort given that they are monitored less closely. Wages are used to compensate for lower levels of supervision.

2.5. Constant supervisor effort

Next we introduce supervisors but keep e' constant. Formally, this boils down to assuming $c' = b' = 0$, which implies that $e' = 1$. Given this assumption, it makes sense to assume that the wage rate of supervisors is given exogenously.[7] We have:

$$
\begin{aligned}
& \max_{L,S,w} \; a(eL)^{\beta} - wL - mS \text{ subject to} \\
e &= (w-x)^{c}(d+\frac{1}{p})^{-b} \\
p &= \frac{S}{L}
\end{aligned}
$$

which can be rewritten more simply as:

$$
\begin{aligned}
& \max_{L,p,w} \; a(eL)^{\beta} - wL - mpL \text{ subject to} \\
e &= (w-x)^{c}(d+\frac{1}{p})^{-b}
\end{aligned}
$$

since $S = pL$. The first order conditions boil down to:

$$
\begin{aligned}
w + pm &= ae^{\beta}\beta L^{\beta-1} \\
L &= a\beta e^{\beta-1} e_w L^{\beta} \\
mL &= a\beta e^{\beta-1} e_p L^{\beta}
\end{aligned}
$$

In this model, the supervision ratio S/L is constant across firms of different size. Indeed the first order conditions can be manipulated to obtain:

$$
m = \frac{e_p}{e_w} \tag{2.10}
$$

which establishes a relationship between w and p that does not depend on firm size L. Combining the first two first order conditions, we get:

$$
w + pm = \frac{e}{e_w}
$$

which sets another relationship between p and w that does not depend on L. Consequently, in this model, p and w are constant across firms. The intuition is that the firm can buy the supervision from the market at a constant marginal price.

[7] Or that, by an arbitrage argument, firms have to pay the going market wage for supervisors.

2.6. Constant supervisor wage

Next we consider what happens if supervisor effort varies with the supervision of supervisors by the owner. We continue to assume that m is exogenously given. This means that m is not regarded as a choice variable for the firm. We have:

$$\begin{aligned} & \max_{L,S,w} \; a(eL)^{\beta} - wL - mS \text{ subject to} \\ e &= (w-x)^{c}(d+\frac{1}{p})^{-b} \\ p &= \frac{e'S}{L} \\ e' &= (m-x')^{c'}(d'+S)^{-b'} \end{aligned}$$

where we have used $p' = 1/S$: supervisors are supervised by the owner. The first order conditions are:

$$\begin{aligned} w &= ae^{\beta}\beta L^{\beta-1} - a\beta e^{\beta-1}e_p S e' L^{\beta-2} \\ m &= a\beta e^{\beta-1}e_p\left[\frac{e'}{L}+\frac{S}{L}e'_S\right]L^{\beta} \\ L &= a\beta e^{\beta-1}e_w L^{\beta} \end{aligned}$$

In this model, the effort of supervisors is not constant. Raising the effort of production workers by hiring supervisors has a cost that increases with firm size. This can be seen by manipulating the first order conditions to obtain:

$$\frac{e_p}{e_w}\left[e' + Se'_S\right] = m$$

which is different from our earlier expression (2.10) because of the presence of S. The implication is that the wage w increases with firm size. This is because the owner finds it difficult to monitor all supervisors, whose effort level therefore drops with firm size. As a result the firm will trade higher wages for less effective supervision p, a result similar to that obtained in the model where the owner monitors everyone directly. Of course, the wage m paid to supervisors does not increase with firm size since, in this special case, it is assumed constant.

2.7. The testing strategy

The general model is the same as the model discussed in the previous sub-section, except that we regard m as a choice variable. In this scenario m increases with firm size. The reason is that larger firms need more supervisors to monitor their growing workforce but cannot monitor the supervisors as closely. This reduces supervisors' incentives. To compensate, large firms pay higher supervisor wages m to induce more effort. This effect is similar in spirit to the force that affects workers' wage w. This in turn implies that supervision costs increase with firm size. To economize on supervision, large firms may lower the supervision ratio S/L. To minimize the negative effect on workers' motivation, they raise the wage w of production workers.

These effects are illustrated on Figures 1 and 2 which show, for some reasonable choice of parameter values, how wages and supervision ratio change with firm size.[8] We see that w and m are increasing in L while S/L is decreasing in L.[9] Larger firms pay higher wages to both supervisors and production workers. At the same time, they monitor production workers less closely. The magnitude of the effect is large but commensurate with what is observed in our data. Of course, different parameters may yield different patterns. We discuss this issue further in Section 4.

To summarize, we have shown that our general model nests a variety of simpler models, including the standard producer model and the efficiency wage model. It can therefore be used as a way of testing the restrictions imposed by simpler models. To this effect, we estimate a five equation model composed of the four first order conditions (2.5) to (2.8) and the production function

$$Q = a(eL)^{\beta} \exp(\varepsilon_q) \tag{2.11}$$

where ε_q is an error term interpretable as measurement error in value-added. Observed values of $\widetilde{w}, \widetilde{m}, \widetilde{L}$,

[8] The figures are obtained using coefficient values derived from the generalized Sparks model, namely, $c = b = c' = b' = 0.5$, $x = rV^U$, and $d = d' = 1/2r$ where r is the workers' rate of time preference and V^U is the expected life-time utility from becoming unemployed.

[9] In fact, if $c = b = c' = b' = 0.5$ - a case which we refer to as the generalized Sparks model - supervisor effort and worker effort are constant in equilibrium: $e = \sqrt{x/d}$ and $e' = \sqrt{x'/d'}$. Thus, given the definition of the worker effort function, increasing worker wages will be accompanied by lower supervision ratios in this case.

and $\widetilde{s}$ are also assumed to include measurement error so that:

$$\begin{aligned} \ln \widetilde{w} &= \ln w + \varepsilon_w && (2.12) \\ \ln \widetilde{m} &= \ln m + \varepsilon_m && (2.13) \\ \ln \widetilde{L} &= \ln L + \varepsilon_l && (2.14) \\ \ln \tilde{S} &= \ln S + \varepsilon_s && (2.15) \end{aligned}$$

where w, m, L, and S are the values that solve the system of first order conditions (2.5) to (2.8). The advantage of formulating the error structure using (2.12) to (2.15) is that, from an econometric point of view, the system to be estimated is a reduced form system of non-linear equations, thereby eliminating simultaneity concerns. The system formed by the five equations (2.11) to (2.15) is estimated using non-linear generalized least squares (GLS). The details of the estimation procedure are discussed in the econometric section.

In testing the theory we begin by examining the data for evidence of the kind of patterns predicted by the theory. In particular, we examine whether w and m increase with firm size and how S/L varies with firm size using basic multivariate regressions and non-parametric methods. We do this in order to pre-validate the model, and to avoid 'forcing' on the data a relationship that is not there. We then proceed by estimating the complete model and test the coefficients of the effort functions individually – in particular, we test whether $c = 0$, $b = 0$, $c' = 0$, and $b' = 0$. Indeed we have seen that, when these coefficients are 0, the general model simplifies to one of the special models discussed earlier. We also test whether $c = b = c' = b' = 0.5$ - i.e. the generalized Sparks model - is supported by the data.

As mentioned in the introduction, there are other possible reasons why large firms pay high wages (e.g. Troske 1999, Bayard and Troske 1999). One reason that has received some attention in the literature is the possibility that large firms employ better workers. Stiglitz (1987), for instance, argues that worker productivity – observed and unobserved – will be correlated with firm size if the returns to better workers are larger in large firms. This is because large firms would either screen workers more effectively at hiring, or dismiss those who prove less productive. As a result of this self-selection process, their workforce may be more skilled than that of smaller firms where worker quality has less impact on firm productivity.

Given that we do not have panel data on individual workers, we cannot fully control for unobserved heterogeneity in workers across firms. But we can purge wages from observed differences in worker characteristics, and, to some extent, from differences in unobserved worker quality that are correlated with observable worker characteristics.[10] Worker ability and discipline, for instance, are often thought to be correlated with education. To net out these effects, we proceed as follows. Let w_{ijt} be the wage of worker j in firm i at time t, and let h_{ijt} denote the observed characteristics of worker j, such as education, tenure, gender, and age. We first regress the log of w_{ijt} on h_{ijt} and firm-time fixed effects ω_{it}. We do this separately for supervisors and production workers. This procedure yields firm-time specific estimates of the wage premia paid to workers $\widehat{\omega}_{it}^{w}$ and supervisors $\widehat{\omega}_{it}^{m}$. Then when estimating (2.11) to (2.15), we replace throughout w and m by $\widehat{\omega}^{w}$ and $\widehat{\omega}^{m}$. This ensures that our firm-specific wage measure is purged of differences in worker productivity – whether observed or unobserved – that are correlated with observable traits h_{ijt}. The average human capital of the workforce is also included in a to control for its effect on firm productivity.[11]

3. The data

To investigate these labor management issues, we test the model presented in Section 2 on matched employer-employee data collected on the manufacturing sector of nine SSA countries and one North-African country, Morocco. The data used here have been collected by various teams of researchers. The bulk of the data from SSA was collected as part of the Regional Program for Enterprise Development (RPED), organized by the World Bank, in which typically samples of approximately 200 randomly selected

[10] More precisely, observed variables will mop up variation in unobserved variables only to the extent that the unobservables are correlated with the observables within firm-year. Of course, if the unobserved variable contains a firm-year specific effect, this will be absorbed by the fixed effect. Consequently, the estimated fixed effects may contain the average unobserved ability in the firm at a given point in time, and it is therefore possible in principle that unobserved ability will generate a relationship in the data between purged wages and firm size. As already discussed however, several recent studies (including one based on African data) based on individual panel data have documented a positive size-wage relationship even when controlling for individual unobserved heterogeneity. In view of this, it would seem unlikely that the size-wage relationship is driven entirely by differentials in average ability across firms or over time.

[11] Underlying this approach is an implicit arbitrage argument by which the individual return to human capital is equal to the associated productivity gain. Put differently, firms are at the margin indifferent between hiring workers with different human capital endowment because the premium paid for additional human capital is equal to the additional output generated. If this arbitrage argument is combined with the assumption that returns to human capital are linear, then the effect of human capital on output can be captured by including in a the average human capital of the workforce – which we do.

firms were interviewed in eight countries (Burundi, Cameroon, Cote d'Ivoire, Ghana, Kenya, Tanzania, Zambia, and Zimbabwe). The surveys started with Ghana in 1992, and most other country surveys were initiated in 1993. Firms were re-interviewed three years in a row in most countries; as some firms dropped out of the sample, they were replaced with other firms with similar characteristics.[12] Four sectors of activity were covered: textile and garments; wood products; metal products; and food processing. Firms of all sizes are included, but we exclude from the sample firms with less than six employees. This is mainly because we suspect problems posed by imperfect information and hidden action are unlikely to be important in extremely small firms. It also implies that the SSA and the Moroccan samples are comparable with regard to the size range covered.

Information is available on a wide range of variables, including sales and output, capital stock, entrepreneur characteristics, employment by occupational category, labor turnover, wages, and conflicts with workers. The RPED data have been extensively analyzed and have greatly improved our understanding of manufacturing in the continent (e.g. Bigsten, Collier, Dercon, Fafchamps, Gauthier, Gunning, Oduro, Oostendorp, Patillo, Söderbom, Teal and Zeufack 2000, Bigsten, Collier, Dercon, Fafchamps, Gauthier, Gunning, Isaksson, Oduro, Oostendorp, Patillo, Söderbom, Teal, Zeufack and Appleton 2000).

In order to form as large a sample as possible on SSA firms, we augment the RPED sample with data from two other sources. First, we add data on Ethiopian manufacturing firms that were collected independently of RPED but using the same questionnaire.[13] Ethiopia was surveyed three times but we only have data for the first year, 1992. Second, we use data from the Kenyan Manufacturing Enterprise Survey (KMES), fielded in 2000 and designed as a follow-up to the last Kenyan RPED survey.[14] This survey generates data for 1998 and 1999.

In addition to our sample from SSA, we have data on one North-African country, namely Morocco. The Moroccan data were collected as part of the Firm Analysis and Competitiveness Surveys (FACS), carried out jointly by the Ministry of Commerce and Industry and the World Bank in 2000. A random sample 860 firms were interviewed in six towns and seven sectors. Here we only use the sample firms in

[12] Burundi was surveyed only once due to the rapid deterioration of the political situation following the Rwandan genocide. Cote d'Ivoire was surveyed only twice due to insufficient funding.

[13] The Ethiopian survey was coordinated by Taye Mengistae.

[14] The KMES was organized by the Centre for the Study of African Economies, University of Oxford. See Söderbom and Teal (2001) for a report based on these data.

food processing, textile, and garment to ensure comparability. The Moroccan survey generates data for 1998 and 1999.

After eliminating observations with missing data, we end up with 694 firm-level observations for Morocco and 1,041 firm-level observations for SSA. Given the small size of valid samples for each individual SSA country, we have no choice but to pool the SSA observations. In the subsequent analysis, country dummies are used to control for differences in labor market and legal institutions.

One unusual feature of the data sets is that they all contain matched employer-employee information. At the same time as the firms were surveyed, a random sample of workers was selected in each firm. Whenever firm size allowed, up to 10 workers were interviewed in each firm. To increase the informational content of the data, the worker sample was stratified according to occupational status. Where there is panel data, samples of workers have been interviewed again in subsequent years, but the identity of the workers differs across survey rounds.[15]

For the purpose of our analysis, workers are divided into three categories: production workers, supervisors, and other staff. Production workers are skilled and unskilled workers on the factory floor, plus technicians and maintenance personnel. These are the workers most directly involved in the production process itself. Supervisors include managers, foremen, and administrative staff. In small and medium-size firms such as the ones in our sample, foremen represent middle-rank management and can thus be counted as part of the management/supervision process. Among our sample firms, the main role of administrative staff is to assist management in gathering and processing information essential to the monitoring of the production process, such as reports, accounts, inventories, time sheets, and the like. For this reason, we count them as part of the supervision personnel of the firm: if the small manufacturers in our sample had fewer employees, they essentially would keep accountants and office staff to the strict minimum – which, in our case, is 0. The 'other staff' category is a residual category that includes commercial staff, trainees, craftsmen, and other support staff. These workers are excluded from either L of S but are included in the production function as part of a (see below).

The characteristics of the firms in our pooled sample are summarized in Table 1. Manufacturing firms

[15] In all surveys, information on worker identifiers was not collected to protect the confidentiality of workers' responses.

in SSA are small by international standards. The average level of employment is 161 and the median is 60, a discrepancy consistent with the usual skewed distribution of firm size. Firm size is marginally larger in Morocco, with average employment of 167 and a median of 100. Measured in constant US$ (base year 2000) to facilitate comparison, value-added per employee is also broadly similar across the two sub-samples. The capital-to-labor ratio is higher in sub-Saharan Africa, reflecting the fact that our Moroccan firm population is dominated by labor-intensive garment and textile manufacturers. Between 20 and 27 percent of the firms in the two samples have some foreign ownership.[16]

While the SSA and Moroccan firm populations appear similar in many respects, they differ markedly in terms of supervision ratio, defined as the number of supervisors divided by the number of production workers. This ratio is 0.14 in Morocco and 0.39 in SSA, a difference that, according to a t-test, is significant at the 1 percent level. Medians are 0.07 and 0.22, respectively. Acemoglu and Newman (2002) report the average ratio of managerial to production countries in six OECD countries. Of the countries considered, the ratio is lowest in Spain (approximately 0.025) and highest in Norway (approximately 0.25), suggesting that the supervision intensity is indeed higher in SSA than in more developed countries. As noted by Acemoglu and Newman, differences in cross-country averages should interpreted with some caution, since the definition of a manager may vary across countries and/or over time. Given that a serious effort was made to use comparable job definitions in the SSA and Moroccan surveys, the difference between SSA and Morocco is striking.

Could this difference be due to variation in worker quality? If SSA production workers have much lower levels of human capital, more intensive supervision may be required. Furthermore, if SSA supervisors are on average much less educated, more supervisors may be needed to achieve the same level of supervision.

In Table 2 we show summary statistics based on the sample of workers and supervisors. We have data on 17,908 production workers and 6,963 supervisors. We find that, if anything, production workers in SSA are better educated, more experienced, and older than in Morocco. These differences are small but for both tenure and education they are statistically significant. The proportion of female production workers

[16] The main industrial cities are as follows: Kenya - Nairobi; Burudi - Bujumbura; Ivory Coast - Abidjan; Ethiopia - Addis Ababa; Cameroon - Douala; Zambia - Lusaka; Tanzania - Dar es Salaam; Zimbabwe - Harare; Ghana - Accra; Morocco - Casablanca.

is much higher in Morocco than in SSA. Interestingly, the average level of education among production workers does not vary much across countries. Morocco, the country with the highest per capita income in our sample ranks third from the bottom in terms of the average level of education of production workers; only Burundi and Ivory Coast record lower sample averages.

The picture is different for supervisors, mainly in the sense that Moroccan supervisors have significantly more education than their counterparts in SSA. Moroccan supervisors also have less tenure, on average. Average age and the proportion of female workers are by and large the same in the two samples. While the difference in education levels may make Moroccan supervisors more productive, the productivity gain would have to be extremely large to explain, on its own, a 2.7 times difference in the supervision ratio between the two samples.

Average earnings also differ markedly between the two samples. Measured in constant 2000 US$, average annual earnings for production workers are 2.6 times higher in Morocco than in SSA. For supervisors, the difference in average annual earnings is even larger: 3.3 times higher in Morocco. These differences largely reflect the higher standards of living prevailing in Morocco.[17] But they are at prima facie difficult to reconcile with the high capital-labor ratios observed in the SSA sample (see Table 1): if labor is so much cheaper in SSA than in Morocco, we would have expected manufacturing firms to be more labor intensive. When asked why they choose a capital intensive technology even though labor is cheap, manufacturers operating in SSA often respond that it is a way to reduce labor management difficulties (Steel and Evans 1981). High capital-labor ratio coupled with high supervision ratio and low wages can thus be seen as consistent with labor management being more problematic in SSA. To this we now turn more in detail.

4. Econometric estimation

We begin our empirical analysis by estimating earnings regressions using the worker data. As explained in Section 2, the purpose of running these regressions is to obtain a measure of firm-specific wage premium

[17] A breakdown by country (not shown to save space) further reveals substantial differences across countries in the SSA sample, with Tanzania having the lowest average earnings and Cameroon the highest. Differentials in earnings between countries tend to follow quite closely the differentials in per capita income as reported in the World Development Indicators (WDI) database. The correlation between per capita income in year 2000 and the country averages of earnings in our dataset is 0.85 for the full sample of ten countries and 0.78 if Morocco is excluded.

that is net of observable differences in workforce quality. These firm-specific wage premia are then used as estimates of w_i and m_i.

4.1. Earnings regressions

The estimated earnings equation takes the form:

$$\log w_{ijt} = \omega_{it} + \theta h_{ijt} + \upsilon_{ijt} \tag{4.1}$$

where w_{ijt} is the wage of worker j in firm i at time t, h_{ijt} is a vector of human capital characteristics of worker j, ω_{it} is a firm fixed effect allowed to vary over time, and υ_{ijt} is an error term (Abowd and Kramarz 1999). The regression is estimated separately for production workers and supervisors, yielding estimates of $\hat{\omega}_{it}^{w}$ and $\hat{\omega}_{it}^{m}$.

Results are presented in Table 3. For the four specifications reported, the observed characteristics and the firm-year fixed effects explain between 61 and 84 percent of the variation in the dependent variable.[18] When decomposing the variance of the explained part of the dependent variable into three parts - $var\left(\hat{\omega}\right)$, $var\left(\hat{\theta}h\right)$, and $2cov\left(\hat{\omega},\hat{\theta}h\right)$, all normalized by $var\left(\hat{\omega}+\hat{\theta}h\right)$ - it is clear that most of it is generated by the fixed effects. As expected, the within R-squared is rather much lower than the levels R-squared. Nevertheless, the demeaned observable characteristics explain between 13 and 30 percent of the demeaned dependent variable, so purging the wage variable from heterogeneity in observables is potentially important.

Consistent with Fafchamps, Söderbom and Benhassine (2005) and Söderbom, Teal, Wambugu and Kahyarara (2005), education is found to have a non-linear, convex, effect on earnings, manifesting itself here through the significance of the squared term on education. Since marginal returns to education vary with the level of education, for ease of interpretation we show the marginal returns computed at six and twelve years of education. For production workers, the returns are very low at low levels of education; they are equal to 1.3-1.4 percent at six years of education. At twelve years, the marginal

[18] R-squared levels is simply the R-squared obtained from the model where the fixed effects are captured by means of dummy variables.

return is about 5 percent in SSA and about 3 percent in Morocco. Marginal returns to education are higher for supervisors, especially at higher levels of schooling in SSA. This suggests a high demand for highly educated supervisors south of the Sahara.

The age-earnings profile has an inverse U-shape in all cases. The tenure coefficient is positive and significant, indicating that new workers earn less. This feature is consistent with the idea that firms adjust wages to productivity after hiring – either because workers learn on the job and become better, or because firms learn more about workers' intrinsic ability. It is noted, however, that the reward to tenure is small – typically about one percent per year for production workers, less for supervisors.[19] The gender dummy is negative in both sub-samples, indicating that women have significantly lower earnings than men with the same observable characteristics (Fafchamps et al. 2005).

4.2. Validating the model

Before we estimate the structural parameters of the model presented in Section 2, we need to ensure that the model is broadly consistent with the data. If the model was incapable of accounting for the data, estimating its structural parameters would be a meaningless exercise. The model predicts that (1) the wages of production workers and supervisors rise with firm size; (2) the supervision ratio falls with firm size; and (3) the wage gap between supervisors and production workers increase with firm size, for many reasonable parameter values (including the generalized Sparks model which is nested in the general framework). We investigate whether these predictions are borne by our data.

We begin by checking whether predicted firm-level wage premia $\hat{\omega}_{it}^{w}$ and $\hat{\omega}_{it}^{m}$ correlate with firm size. We first regress them non-parametrically on the log of firm employment. Results, not shown here to save space, show a strong positive relationship between the two variables in both samples and for production workers as well as supervisors. We also find that the relationship is basically linear. This relationship survives the inclusion of controls. In Table 4 we summarize the results from a least squares regression of $\hat{\omega}_{it}^{w}$ and $\hat{\omega}_{it}^{m}$ on the log of firm employment the capital-labor ratio and a wide range of additional controls (some of which are not shown to save space). These results demonstrate that earnings (purged from

[19] In fact, our estimates of the tenure effect are broadly in line with the returns reported by Altonji and Williams (2005) for the U.S., which are also quite low.

observed human capital heterogeneity) increase significantly with firm size, a finding consistent with the model presented in Section 2.[20]

Finally, we examine the relationship between firm size and the supervision ratio. We estimate a non-parametric regression of the log of S/L on the log of L.[21] Results, shown in Figure 3, indicate that the supervision ratio falls significantly with firm size in SSA as well as Morocco. In Table 1 we noted that SSA has a higher supervision ratio than Morocco. Figure 3 shows that S/L in SSA is systematically above that in Morocco. This suggests that the higher supervision ratio observed in Africa is not due to a difference in firm size: the supervision ratio in SSA is significantly above that in Morocco at all firm sizes.

Finally we examine the earnings differential between supervisors and production workers. Figure 4 shows that in our two samples the earnings differential increases significantly with firm size, a result that can also be accounted for by our model. As was shown in Figure 2, for instance, the earnings differential between workers and supervisors is predicted to increase rapidly with size when Sparks coefficients of 0.5 are used for c, c', b, and b'.[22]

4.3. Structural Estimation

The verification exercise has shown that our two samples display empirical regularities that are broadly consistent with the supervision model presented in Section 2. This does not imply that this model is the only possible explanation for these empirical regularities, a point we discuss in detail at the end of this paper. But it means that imposing the structure of the model does not do violence to the data.

With this reassurance, we now estimate the production function and the first order conditions described in equations (2.11) to (2.15). Our task is to estimate the parameters of the production function plus c, b, x, d, c', b', x', and d'.[23] For estimation purposes, the total factor productivity (TFP) parameter

[20] To check for robustness, we estimated earnings regressions without firm fixed-effects and we took the firm-specific averages of the residuals as an alternative measure of $\widehat{\omega}_{it}$. We then regressed the alternative measures of $\widehat{\omega}_{it}$ on various measures of firm size and various controls. Similar results to those shown in Table 4 were obtained.

[21] Results were obtained using locally weighted regressions based on an Epanechnikov kernel. A 95% asymptotic confidence interval is displayed. It is computed on the basis of the standard error of the constant in locally weighted regressions. The bandwidth is 0.4.

[22] This is also true in the vicinity of these parameter values, but need not be the case with very different values.

[23] In the estimation, the values of c, c', b, d, d', and b' are constrained to be positive. None of the estimated coefficients is at the boundary.

a is expanded into:

$$a = \alpha_0 K^\gamma O^\delta \exp(\sum_i \lambda_i F_i + \sum_j \theta_j D_j) \tag{4.2}$$

where α_0 is a constant, K is capital stock, O is staff other than production workers and supervisors, and F_i is a series of firm characteristics including the average education level and length of tenure of the workforce, the age of the firm, and a dummy for any foreign ownership. The D_j's are sector and country-time dummies. Country dummies are further included in the effort functions to capture possible differences in the outside option value, possibly stemming from differences in legal institutions and unemployment rates, and their disciplining effect on workers. All these variables are regarded as exogenous in the estimation that follows. In equation (4.2) Greek letters are parameters to be estimated.

From an econometric point of view, the system formed by equations (2.11) to (2.15) is a non-linear system of reduced form equations. Given the non-linear nature of the system, it is not possible to solve for w, m, L, S analytically. But it is possible to solve the system numerically, conditional on parameter values and the exogenous variables entering the calculation of a. This yields model predictions about the optimal values of w, m, L, and S which can be compared with actual values.[24] Iterating on the parameter vector yields the values that provide the best match between model predictions and the actual values of w, m, L, and S.[25]

The estimator used is generalized least squares (GLS). Estimation is accomplished in two steps: in a first step we estimate the system assuming a diagonal covariance matrix for the errors. An estimate of the cross-equation covariance matrix of the errors is then obtained from the first step and the system is reestimated with the error covariance matrix.[26] Standard errors for parameters are obtained using the outer product of the gradient.

[24] Note that the actual values of w, m, L, and S do not enter in the calculation of the optimal values w, m, L, and S, thereby eliminating the possibility of endogeneity bias. In a previous version of this paper we estimated equations (2.5) to (2.8) using a non-linear instrumental variable GMM estimator. This approach is faster because it bypasses the need to solve the first order conditions at each iteration. This is accomplished by replacing w, m, S and L by their actual values in the *right* hand side of each first order condition. In the end, we found this approach unsatisfactory because results vary with arbitrary algebraic transformation of the first order conditions.

[25] In practice, this is achieved by nesting the solution of the system of first order conditions within the search for parameter estimates. That is, we start from a 'guess' of the parameter vector, and, conditional on these values, solve the first order conditions (2.5) to (2.8) for each observation. We then calculate the residuals by subtracting predicted from actual values, and compute the relevant criterion value. We then update the parameter vector and start the process all over again, as long as there is scope for further improvements in the criterion value. If there is not, the search stops.

[26] Formally this is equivalent to one-step non-linear seemingly unrelated regressions. In our case, the purpose of estimating the model as a system is not to increase efficiency but to impose cross-equations restrictions that are consistent with the model.

As is often the case in non-linear estimation, finding the global maximum is not a trivial task since there may exist local optima. In our case we found that conventional algorithms, such as Newton-Raphson or Davidon-Fletcher-Powell, sometimes converged at a local minimum. To deal with this problem we adopted a simulated annealing algorithm, which has been found much more robust for difficult optimization problems than the conventional methods (Goffe, Ferrier and Rogers 1994). This algorithm worked very well for our application. In particular, experimenting with different starting values we found that all searches converged to the same parameter vector. We therefore think it extremely unlikely convergence has occurred at a local minimum in our case. The main drawback of simulated annealing is that computation is slow.

4.4. Results

Estimation results are summarized in Table 5 for Morocco and SSA. We first discuss the parameters of the production function. There are important similarities and differences between SSA and Morocco. The estimated share of capital is small in both samples: 0.145 in Morocco, 0.290 in SSA. The share of labor is high in Morocco – 0.681 – but low in SSA – 0.355. Firm age is significant in SSA but not in Morocco. Firms with some foreign ownership are more productive in both samples, but the effect is only mildly significant in Morocco. Of the two human capital variables, education has a positive and highly significant effect in both regressions, while job experience – proxied by length of tenure – is only significant in SSA. Returns to schooling appear to be higher in SSA than in Morocco: one additional year of education for the entire labor force raises output by 6.9 percent in SSA vs. 1.0 percent in Morocco. In both samples, we see that support staff makes an important and significant contribution to output. Sector and country-year dummies are included in the set of TFP shifters but omitted from the table to save space.

We now turn to the parameters of the effort functions (2.1) and (2.2). We begin with parameters x and x' which measure the level of wage above which effort increases. To facilitate comparison, all estimates are expressed in constant US$ per year (base year 2000). Since outside options may vary across countries, parameters x and x' are country specific. With the exception of supervisors in Ivory Coast, the results indicate that both x and x' are larger in Morocco than in SSA. This reflects our earlier observation that workers are better paid in Morocco (see Table 2). We also find large differences between SSA countries, with outside options being much larger in Cameroon and Ivory Coast. This may reflect the overvaluation of the CFA Franc during the survey period.

As anticipated, we find $x' > x$ in all cases: this is consistent with the idea that the value of the outside option of supervisors is higher than that of production workers. The difference between the two is larger in SSA, however, where x' is around 3 times x. In contrast, in Morocco x' is only twice x. The theory implies that as the difference between x' and x shrinks, the ratio of supervisors to workers will rise, everything else constant. This is because as x' falls relative to x, it becomes cheaper to motivate production workers via better supervision. Of course, in the data the supervisor-worker ratio is *lower* in Morocco than in SSA. This pattern must therefore be explained by differences in other parameters in the model. Had the relative difference between x' and x been constant across the two samples, there would have been even greater differences in the implied supervisor-worker ratio.

Turning to the other coefficients of the effort functions, we find that, with the exception of d in both samples, our coefficients c, b, d, c', b' and d' are all significantly different from zero at the 10 percent level or better. This tends to reject *all* the simpler models discussed in Section 2 in favor of our more general two-tier supervision model.[27] We also find that the estimates of c and b are lower in SSA than in Morocco, implying that workers' effort is less responsive to changes in wages and supervision in SSA than in Morocco. For supervisors, we find that b' is similar in the two samples, but c' is also smaller for SSA, suggesting that supervisors are less sensitive to wage incentives in SSA.

How effort responds to changes in total factor productivity (TFP) a is central to our understanding of how the incentive structure faced by supervisors and workers in the firms impacts on various aspects of firm behavior. In the special case of $c = b = c' = b' = 0.5$, our model boils down to a generalized (two-tier) version of the Sparks (1986) model. A special feature of that model is that, in equilibrium, worker and supervisor effort does not vary with a (see footnote 9). In the more general case where c, b, c', b' are not restricted to be equal to 0.5, effort varies with a. Coefficient estimates of c, b, c', b' are jointly significantly

[27] The low standard errors on these parameters result in part from the non-linear nature of the model and should not be taken too literally. It is indeed likely that similar – though not identical – predicted behavior would obtain from slightly different combination of values for c, b, c', and b'. But changing only one of these parameters independently from the others dramatically decrease the quality of the fit. This explains the high gradient and hence low standard error.

different from 0.5, hence rejecting the generalized Sparks model. Worker effort therefore varies with TFP.

To illustrate the net effect of TFP differences on effort, we show in Figure 5 how (the logarithm of) worker effort responds to a change in TFP (i.e. a). There is a striking difference between the two samples. An increase in TFP has a positive effect on worker effort in Morocco, but a negative effect in SSA. In other words, while the incentive structure in Morocco is such that an increase in TFP leads to more worker effort, the converse is the case in SSA. This suggests that high TFP firms in SSA hire fewer workers and supervisors (and produce less output) relative to what they would have done if the incentive structure had been similar to that in Morocco. Quantitatively, the net effect on output is large: a 1 percent increase in TFP raises output by 2.6 percent in Morocco but only by 1.3 percent in SSA. This is because high TFP firms in SSA find it more difficult than in Morocco to manage their labor force so as to maintain worker effort.

To facilitate the interpretation of estimated parameters in terms of firm behavior, we calculate the relationships between firm size and worker and supervisor wages implied by estimated parameter values. Results are presented in Figures 6-7. Figure 6 shows the association between wages and employment, as predicted by the model on the basis of estimated parameters. The model reproduces the positive association between these two variables that is present in the data. In equilibrium, a doubling of employment is associated with an increase in worker wages between 8 and 9 percent. Figure 7 shows a similar positive association between predicted supervisor wages and firm employment. We also find that supervisor wages increase more rapidly with firm size in Morocco than in SSA. A further implication of the results is that the supervision ratio decreases with firm size in all countries. Doubling the number of production workers is associated with a fall in the supervision ratio of 12 percent in Morocco, 7 percent in Ethiopia and between 3 and 5 percent in the remaining countries.

It follows that, in order to grow, firms must address serious incentive problems among production workers and supervisors. Our parameter estimates imply that doubling the number of production workers is associated with an increase in total labor cost per unit of effort, defined as $(wL + mS) / (eL)$, by 6 percent for Morocco, 15 percent for Ethiopia and between 22 and 25 percent for the remaining SSA countries. This is the penalty large firms have to incur in order to motivate workers and manage a large workforce. The difference between Morocco and SSA in this respect is thus dramatic.

Our results hence suggest that there are significant differences in the incentive structures across Morocco and SSA, and that these differences are economically important. Taken together, our findings suggest that managing and monitoring workers is more costly and more problematic in SSA than in Morocco. Estimation results also suggest an explanation for the higher absolute levels of S/L in SSA. This is because supervisors, in spite of costing relatively more to the firm, have a relatively stronger effect on worker effort.

4.5. Alternative explanations

We have estimated a structural model in which monitoring requirements generate a positive relationship between firm size and the wages of workers and managers, and a negative relationship between firm size and supervision ratio S/L. While the model is consistent with empirical regularities present in the data and generates plausible insights, other forces could generate similar empirical relationships. By the very nature of structural estimation, we have imposed a general model on the data. As shown in Section 2, this model nests a number of interesting special cases. But it does not nest *all* possible models. Inference based on structural parameter estimates should therefore be seen as *conditional* on the estimated model being by and large correct.[28]

We have adopted a hidden action framework in which workers and supervisors work harder because they are paid more: higher wage causes more effort and thus higher productivity. The converse is also conceivable. Suppose that labor productivity does not depend on incentives but varies with worker ability. In a competitive labor market, high productivity workers are paid more. If large firms hire more able workers and supervisors, we would observe a positive relationship between wages and firm size (Garicano and Rossi-Hansberg 2003). Furthermore, if more able supervisors can monitor more workers, we would also observe a lower supervision ratio S/L in large firms. One possible reason why large firms may require better workers is that, in large firms, the organization of work is complex and worker discipline is important to achieve coordination. This idea is close in spirit to our approach, except that we regard

[28] Of course, specification error is not specific to structural models but also applies to the linearized reduced form regressions that are usually estimated by economists. In that case, the validity of inference is conditional on the model including (i.e., nesting) all relevant explanations.

worker effectiveness as an action subject to moral hazard instead of as an immutable individual trait.

Because we do not have a panel of workers across firms, we cannot completely rule out that sorting by ability accounts for our results. Using similar data, Fafchamps et al. (2005) indeed show that sorting across firms explains a third of the education wage differential between workers. However, since our analysis controls for observed worker characteristics, sorting by unobserved ability would need to follow productivity differences that are orthogonal to observable worker characteristics. Given the magnitude of the wage-firm size relationship present in our data, these unobserved productivity differences would have to be very large. In other countries, the empirical literature has failed to find strong evidence that sorting by ability explains the wage-firm size relationship (see for instance Brown and Medoff (1989), Criscuolo (2000), Arai (2003), and Söderbom, Teal and Wambugu (2005)).

Technological differences between small and large firms could explain why large firms pay higher wages: large firms may be more capital intensive, or they may use complicated equipment that is hard to operate and vulnerable to mishandling. In our analysis, we partially control for this possibility in two ways. First we limit our empirical investigation to a subset of industries that share fairly similar technology and capital intensity. Secondly, we explicitly control in our estimation for differences in capital intensity – and other labor productivity shifters – through the a parameter.

Large firms may also use a more sophisticated technology – e.g., computerization – to reduce the need for supervision. For instance, using a sample of 60 firms, Reilly (1995) shows that after controlling for computer access the wage-firm size relationship is no longer significant. While computerization may be relevant for developed economies, it is unlikely to apply to our firm population. Most surveyed firms use second-hand machines obtained from Europe and elsewhere. In the 1990's when the data were collected, these machines were seldom computerized.

The wage-firm size relationship could also arise because small firms tap into cheap labor resources such as unpaid family members and apprentices, a phenomenon that is known to benefit microenterprises (Fafchamps 1994). We control for this possibility in two ways. First, as explained in the data section, we have restricted our attention to firms above a minimum size. This eliminates microenterprises from our analysis, and it is only in microenterprises that family labor represents a sizeable proportion of total labor. Secondly, we have estimated the wage premia $\hat{\omega}_{it}^{w}$ and $\hat{\omega}_{it}^{m}$ from data on paid employees. It follows that our wage premia estimates ignore unpaid family workers and apprentices. In medium size firms, family labor need not be cheaper. In a detailed analysis of Ghanaian labor markets, for instance, Barr and Oduro (2002) find that, if anything, employees related to the entrepreneur earn higher wages.

Another possible explanation is the presence of a job ladder effect. Suppose that firms design internal tournaments to generate incentives. Winners earn higher pay and change their job title to that of 'supervisors' but do not change the activities they perform. If providing incentives is more important in larger firms, this could explain why wages for workers and 'supervisors' rise with firm size even in the absence of labor monitoring. To investigate this possibility, we examined job history data collected in the Moroccan survey to see what proportion of individuals classified as supervisors ever worked as production workers. We find this proportion to be extremely small: the separation between blue and while collar workers is nearly complete. There is, however, ample evidence that unskilled workers get promoted to skilled worker positions, with a wage increase. Similarly, we find evidence of promotion from clerical to managerial positions. This suggests the existence of a job ladder effect within production workers and within supervision workers. In our empirical analysis, we have combined skilled and unskilled workers into a single category. Similarly we have combined various levels of management into a single supervisor category. So doing minimizes the risk that our analysis is biased by a strong job ladder effect.

As we have already pointed out in the conceptual section, our approach is closely related to the literature on hierarchies. By postulating two-tier supervision structure in our model, we have not allowed firm size to affect the complexity of the supervision hierarchy. Hence our effort functions (2.1) and (2.2) do not depend directly on firm size. Calvo and Wellisz (1979) in contrast propose a model of efficiency wages in which, as firm size grows, the hierarchy gains additional layers (see also Calvo and Wellisz (1978) and Garicano and Hubbard (2004)). Since higher layers supervise lower layers, shirking by high level supervisors reduces effort among all low level supervisors and workers below them. Employers thus have an incentive to minimize shirking among high level supervisors by paying them better.

This reasoning predicts that the average wage of supervisors increases with hierarchical complexity. It can thus account for the relationship between firm size and supervisor wages. However, it also predicts that the size of the hierarchical pyramid rises with firm size. As a result, the supervision ratio S/L may rise as well. This latter prediction is contradicted by our data, suggesting that a simple hierarchy story cannot, by itself, account for what happens in our samples.

There nevertheless remains the possibility of a more complex story combining the rich incentive structure of our model with hierarchical complexification. Given reliable data on hierarchical layers, it is possible to analyze hierarchical complexification directly, as done, for instance, by Garicano and Hubbard (2004) and Garicano and Hubbard (2003). Unfortunately, in our case job ladder effects imply that, within the blue and white collar categories, reported job titles convey unreliable information about hierarchical layers, thereby making analysis problematic. These issues deserve more research.

Finally, differences in unionization between small and large firms could in principle account for the wage-firm size relationship observed in our data. We have some data on firm-level unionization, showing that about 15 percent of the firms in Morocco, and 67 percent of the firms in SSA, employ unionized workers. A simple correlation analysis reveals a significant positive correlation between wages and unionization. But this relationship is no longer significant once we control for firm size: adding a unionization dummy to the regressions presented in Table 4 yields very small t-values – all below 0.5. This finding is very robust and obtains whether we add various controls or not, and whether capital is included or omitted from the regression. These findings therefore suggest that, in our samples, the correlation between unionization and wages is entirely due to firm size.

To summarize, alternative possible explanations exist for the empirical regularities found in our data. We have made numerous efforts to control for these alternative explanations in our analysis. But we recognize that, from the data at hand, we cannot provide definitive evidence that these forces are absent in our population of firms. Our results should thus be interpreted in this light.

5. Conclusion

In this paper we have examined whether data on manufacturing firms are consistent with a two-tier supervision model of worker effort. We began by constructing an efficiency labor model whereby firms optimally choose their level of supervision and the wage premium they pay their workers and supervisors.

This model predicts that the worker wage increases and that the supervisor-to-worker ratio decreases with firm size, for certain parameter values. The reason is that supervisors have to be motivated to manage the workforce well.

We then take the model to a data set covering ten African countries. The main difficulty about testing supervision models is that any observed relationship between wages and firm size can potentially be attributed to systematic differences in workers' traits across firms. To minimize this bias, we take advantage of matched worker-employer data to construct a firm-specific wage measure that is purged of all observable differences across workers. As was explained in the paper, this approach does not entirely eliminate the possibility of a selection bias – there might remain systematic differences in unobservable worker traits across firms – but it singularly reduces the likely magnitude of the bias. This is particularly important given that the studied sectors belong to light manufacturing such as garment, textile and food processing. Most surveyed firms use dated equipment for which production work is relatively straightforward. In such an environment it is doubtful that unobservable worker traits would account for much of the productivity differences across firms, a notion supported by recent research by Söderbom, Teal and Wambugu (2005) based on worker-level panel data from Ghana and Kenya.

We begin by testing whether the data is broadly consistent with model predictions. We find that wages increase with firm size for both production workers and supervisors. We also find that the supervision ratio drops dramatically with firm size. Given these encouraging preliminary results, we proceed by estimating the structural model itself. To do so, we estimate a system of five non-linear equations by generalized least squares. Results show that workers in SSA are less responsive to monitoring by supervisors than workers in Morocco. This suggests that labor management is more difficult in Africa than elsewhere. This point has already been made by some authors, although mainly based on anecdotal evidence. Using data from manufacturing firms in Cote d'Ivoire, Azam and Lesueur (1997) for instance show that worker supervision is a serious concern among large firms. Many African entrepreneurs complain about the difficulty of managing a large labor force.[29]

[29] It has been claimed that managers and workers in African firms often show little loyalty to their employer (Ezeala-Harrison 1991). Pilferage may be a concern too: Fafchamps and Minten (2001) show that 37% of agricultural traders in Madagascar refrain from hiring more employees for fear of employee theft.

According to our estimates, a doubling in the number of production workers is associated with an equilibrium increase in wages between 8 and 9 percent in both Morocco and SSA. At the same time, supervisors' wages increase by 27 percent in Morocco and between 10 and 14 percent in SSA. A doubling of the number of production workers is also associated with an equilibrium fall in supervision ratio of 12 percent in Morocco, 7 percent in Ethiopia and between 3 and 5 percent in the remaining countries in SSA, and an increase in effort by 3 percent in Morocco and a decrease in SSA by between 7 and 13 percent. As a result of these combined effects, total labor cost per unit of effort (including supervisors' wages) increases by 6 percent for Morocco, 15 percent for Ethiopia and between 22 and 25 percent for the remaining SSA countries. This is the penalty large firms have to incur in order to motivate workers. Clearly the firms in SSA face a much more severe penalty than the firms in Morocco.

The analysis presented here suggests that labor management is a seriously underestimated problem. This leaves open the question of what type of labor management problems is responsible for our findings. Labor management difficulties can be divided basically into two broad categories: those due to a poor organization of work that leaves workers idle or unproductive part of the time (task assignment, coordination between workers and production units, information transfer within the firm); and those coming from poor enforcement of labor contracts (shirking, absenteeism, pilferage).[30]

Although the methodology used here cannot distinguish between the two, we can volunteer some thoughts as to where the most promising avenue for future research might be. Presumably, it is easier to organize work within a large firm if workers are well educated and hence can read written instructions and report on their progress. Education may also raise worker discipline through the routine of daily school attendance throughout adolescence. For these reasons, one may expect countries with low school enrollment rates to experience difficulties running large organizations. Because of the low education level of many SSA countries, it may be tempting to blame labor management problems there on the poor education of the workforce – and hence to call for more investment in education (e.g. Mazumdar and Mazaheri 2002, Strobl and Thornton 2001).

The empirical evidence presented in this paper challenges this interpretation. First, although the

[30] In practice, it is often very difficult to distinguish between the two because workers found shirking can blame their idleness on ambiguous or incorrect task assignment.

African workforce *in general* is poorly educated, the evidence presented here shows that production workers *in manufacturing* have a fairly high average level of schooling; they certainly are not, as a rule, illiterate. Second, although production workers in our Moroccan sample are less well educated than those in our SSA sample, labor management problems have been shown to be less acute in Morocco. It is therefore at prima facie unlikely that, as is sometimes assumed, labor management problems in African manufacturing arise primarily from the difficulty of organizing a poorly educated manpower.

The explanation must probably be sought elsewhere. One possibility is that the internal organization of labor is difficult in SSA for reasons other than insufficient education, for instance because of frequent machine breakdown, power cuts, and input shortages (Fafchamps, Gunning and Oostendorp 2000). It is also conceivable that the enforcement of employment contracts is more problematic in SSA than elsewhere, perhaps because of weak legal institutions.[31] These issues deserve more investigation.

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[31] Another possibility is that, as discussed in Platteau (1996), the strength of sharing norms in SSA weakens loyalty to employers. Some – admitedly impressionistic – evidence of employer distrust towards employees can for instance be found in the work of Barr and Oduro (2002) who find that Ghanaian workers related to their employers earn a premium and that there is statistical discrimination in favour of inexperienced co-ethnic workers. Fafchamps (2004) reports ample evidence of imperfect enforcement of commercial contracts in SSA.

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TABLE 1
SUMMARY STATISTICS, FIRM LEVEL VARIABLES

	[1] Sub-Saharan Africa*			[2] Morocco			
	Mean	Median	SD	Mean	Median	SD	t-statistic
Employment	161	60	333	167	100	210	0.39
Value-Added / Employee	6,639	3,142	10,287	6,343	4,219	7,286	0.58
Capital / Employee	17,936	7,932	29,974	11,354	4,196	17,265	4.53
Firm Age (years)	21	19	14	16	12	13	5.99
Any Foreign Ownership (0/1)	27%			20%			2.36
Supervisors / Prod. Worker	0.39	0.22	0.77	0.14	0.07	0.43	7.97
Observations	1,041			694			

Note: All financial variables are expressed in constant USD (base year 2000).
The t-statistics refer to tests for constant means SSA - Morocco.
(*) Within the SSA sample, the number of observations are as follows. Kenya: 1992 - 91, 1993 - 81, 1994 - 43, 1998 - 31, 1999 - 88. Burundi: 1992 - 15. Cote d'Ivoire: 1994 - 12, 1995 - 17. Ethiopia: 1992 - 17. Cameroon: 1992 - 51, 1993 - 23. Zambia: 1992 - 92, 1993 - 70, 1994 - 53. Tanzania: 1992 - 72, 1993 - 26, 1994 - 10. Zimbabwe: 1992 - 67, 1993 - 64. Ghana: 1991 - 26, 1992 - 41, 1993 - 51.

TABLE 2
PRODUCTION WORKER AND SUPERVISOR CHARACTERISTICS

	[1] Sub-Saharan Africa			[2] Morocco			
	Mean	Median	SD	Mean	Median	SD	t-statistic
A. Production Workers							
Education (years)	8.5	9.0	4.1	7.3	8.0	5.0	10.64
Age (years)	33.4	32.0	9.6	33.1	32.0	8.5	1.58
Tenure (years)	7.4	5.0	6.9	6.8	5.0	6.0	3.32
Female	0.12			0.47			30.22
Annual earnings	1,183	819	1,324	3,021	2,583	1,671	48.51
Observations	9,841			8,067			
B. Supervisors							
Education (years)	11.6	12.0	3.1	13.9	14.0	3.5	18.24
Age (years)	36.6	35.0	9.2	36.8	35.0	8.4	0.84
Tenure (years)	8.6	6.0	7.6	7.2	5.0	6.0	5.84
Female	0.24			0.26			1.62
Annual earnings	2,881	1,655	3,582	9,548	7,077	8,110	25.18
Observations	5,369			1,594			

Note: Earnings are expressed in constant USD (base year 2000).
The t-statistics refer to tests for constant means SSA - Morocco.

TABLE 3
EARNINGS REGRESSIONS WITH FIRM-YEAR FIXED EFFECTS

	(a) Production Workers						**(b) Supervisors**					
	[1] Sub-Saharan Africa			[2] Morocco			[3] Sub-Saharan Africa			[4] Morocco		
	Coef.	Std. Err	t-value	Coef.	Std. Err	t-value	Coef.	Std. Err	t-value	Coef.	Std. Err	t-value
Education (years)	-0.022	0.005	-4.57	-0.002	0.003	-0.86	-0.076	0.013	-5.60	0.020	0.018	1.09
$Education^2$ / 100	0.301	0.031	9.70	0.126	0.020	6.41	0.888	0.068	13.01	0.039	0.082	0.48
Age	0.040	0.003	12.69	0.023	0.003	9.08	0.073	0.007	9.75	0.020	0.017	1.21
Age^2 / 100	-0.038	0.004	-9.48	-0.020	0.004	-5.72	-0.063	0.009	-6.80	0.013	0.020	0.64
Tenure (years)	0.006	0.001	6.20	0.010	0.001	11.74	0.001	0.002	0.34	0.013	0.005	2.88
Female	-0.168	0.017	-9.89	-0.126	0.008	-16.20	-0.141	0.023	-6.03	-0.212	0.040	-5.27
Firm x year fixed effects	Included but not shown			Included but not shown			Included but not shown			Included but not shown		
Marginal return at education = 6	1.4%			1.3%			3.1%			2.4%		
Marginal return at education = 12	5.1%			2.8%			13.8%			2.9%		
R-squared within	0.13			0.18			0.30			0.25		
R-squared levels	0.84			0.61			0.82			0.77		
Variance decomposition												
$var(\theta_h)/var(\omega+\theta_h)$	0.068			0.331			0.190			0.321		
$var(\omega)/var(\omega+\theta_h)$	0.837			0.742			0.758			0.815		
$2cov(\omega,\theta)/var(\omega+\theta_h)$	0.094			-0.074			0.052			-0.135		
Observations	9,841			8,067			5,369			1,594		

Note: The dependent variable is the logarithm of annual earnings, expressed in USD (base year 2000).

TABLE 4
THE FIRM-SIZE EARNINGS RELATION

	(a) Production Worker Wage				**(b) Supervisor Wage**			
	[1] Sub-Saharan Africa		[2] Morocco		[3] Sub-Saharan Africa		[4] Morocco	
ln Employment	0.067	0.065	0.076	0.083	0.074	0.069	0.149	0.163
	[4.82]	[4.74]	[6.13]	[6.60]	[4.11]	[3.8]	[5.52]	[6.16]
ln Capital-Labor Ratio		0.01		0.024		0.033		0.053
		[0.86]		[2.22]		[2.15]		[2.69]
Firm age (years) / 100	0.252	0.250	0.156	0.107	0.312	0.306	-0.190	-0.296
	[1.79]	[1.78]	[0.89]	[0.62]	[1.71]	[1.70]	[0.70]	[1.09]
Any foreign ownership	0.143	0.141	0.034	0.029	0.179	0.171	0.133	0.123
	[3.90]	[3.83]	[1.08]	[0.94]	[3.82]	[3.68]	[1.72]	[1.59]
Average education (years)	0.013	0.013	0.003	0.001	0.008	0.005	0.023	0.019
	[1.31]	[1.21]	[0.66]	[0.18]	[0.59]	[0.37]	[2.85]	[2.36]
Average tenure (years)	-0.011	-0.011	-0.002	-0.004	-0.004	-0.005	0.007	0.004
	[2.55]	[2.59]	[0.59]	[0.96]	[0.82]	[1.00]	[0.84]	[0.45]
Sector dummies	Included but not shown				Included but not shown			
Country-year dummies	Included but not shown				Included but not shown			
R-squared	0.44	0.44	0.14	0.15	0.40	0.40	0.15	0.17
Observations	1,041	1,041	694	694	1,041	1,041	694	694

Note: The wage variables have been purged from differences in observed worker characteristics based on the regressions shown in Table 3 (see main text for details). The numbers in [ ] are t-statistics, which are based on standard errors that are robust to heteroscedasticity and serial correlation.

TABLE 5
ESTIMATES OF STRUCTURAL PARAMETERS

		[1] Sub-Saharan Africa			[2] Morocco		
		Coef.	Std. Err	t-value	Coef.	Std. Err	t-value
Production Function							
β	Labor share	0.355	0.036	9.75	0.681	0.031	22.23
γ	Capital share	0.290	0.013	22.50	0.145	0.011	12.90
TFP Shifters:							
	Average education (years)	0.069	0.013	5.28	0.010	0.003	3.04
	Average tenure (years)	0.016	0.006	2.55	-0.002	0.003	0.89
	Firm age (years) / 100	0.437	0.182	2.41	-0.045	0.102	0.44
	Any foreign ownership	0.156	0.048	3.25	0.047	0.026	1.85
	Log (Support staff + 1)	0.256	0.019	13.35	0.176	0.016	11.27
	Sector dummies			included but not shown			
	Country-year dummies			included but not shown			
Effort Function							
x	Production Workers						
	Kenya	268.4	103.5	2.59			
	Burundi	297.6	119.6	2.49			
	Ivory Coast	696.7	261.1	2.67			
	Ethiopia	323.3	128.3	2.52			
	Cameroon	600.9	219.9	2.73			
	Zambia	206.0	80.3	2.57			
	Tanzania	166.0	64.8	2.56			
	Zimbabwe	320.8	124.6	2.58			
	Ghana	222.5	86.1	2.59			
	Morocco				782.7	298.6	2.62
x'	Supervisors						
	Kenya	862.1	164.9	5.23			
	Burundi	1010.3	235.0	4.30			
	Ivory Coast	2216.6	477.3	4.64			
	Ethiopia	1545.9	323.2	4.78			
	Cameroon	1359.5	268.6	5.06			
	Zambia	586.4	111.7	5.25			
	Tanzania	396.0	73.5	5.39			
	Zimbabwe	1532.2	300.3	5.10			
	Ghana	531.8	102.8	5.17			
	Morocco				1547.2	310.3	4.99
c		0.367	0.087	4.23	0.571	0.100	5.69
b		0.547	0.064	8.60	0.698	0.152	4.58
d		0.516	0.481	1.07	0.612	0.695	0.88
c'		0.218	0.082	2.66	0.597	0.115	5.20
b'		0.603	0.084	7.21	0.580	0.107	5.43
d'		1.092	0.625	1.75	2.330	0.784	2.97
	Test: $c=b=c'=b'=0.5$ (p-value)	0.000			0.000		

Note: Effort function x and x' parameters are expressed on an annual basis in constant US$ (base year 2000).

Figure 1. Supervision and Firm Size

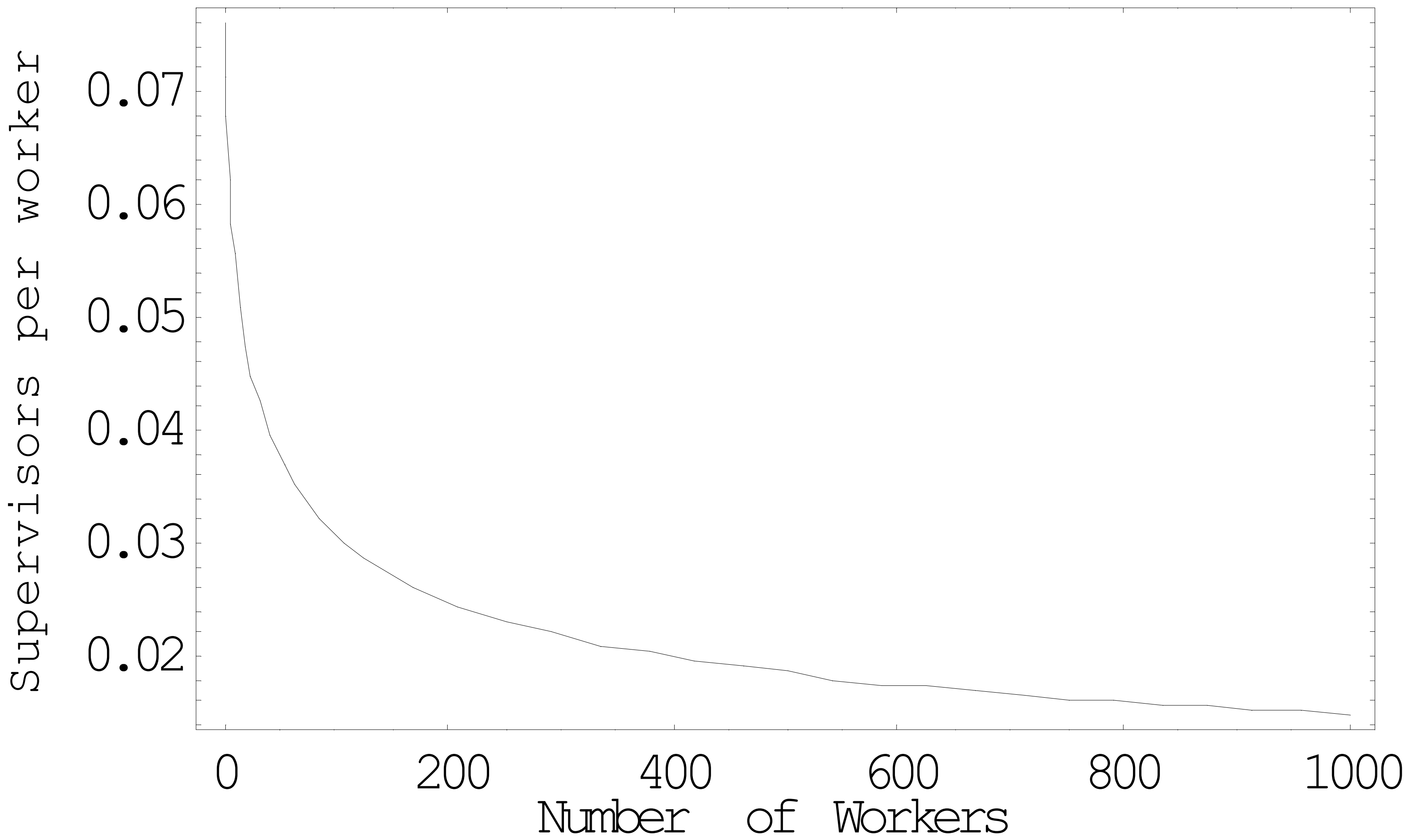


Figure 2. Wages and Firm Size – supervisor wages in bold

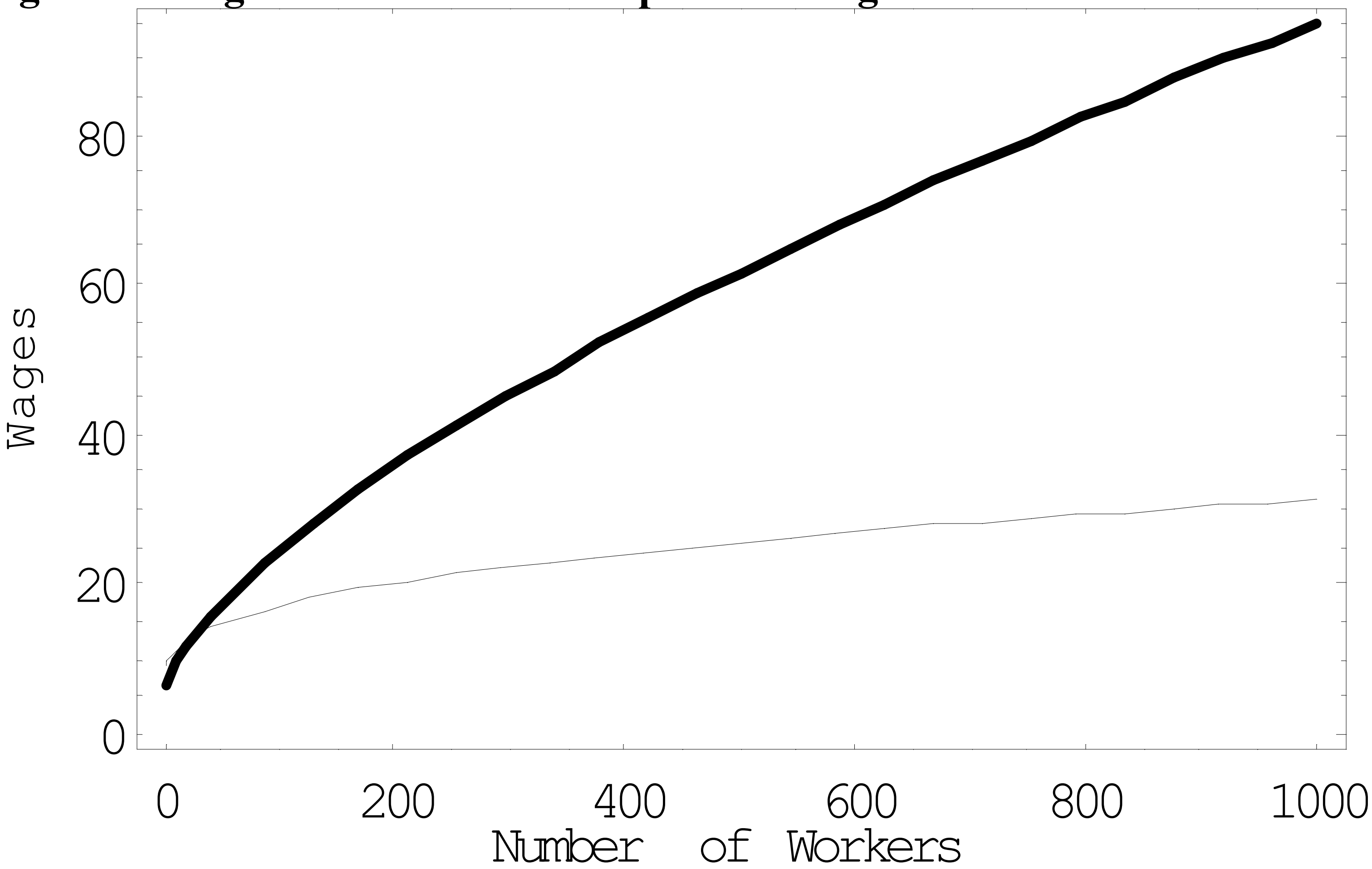
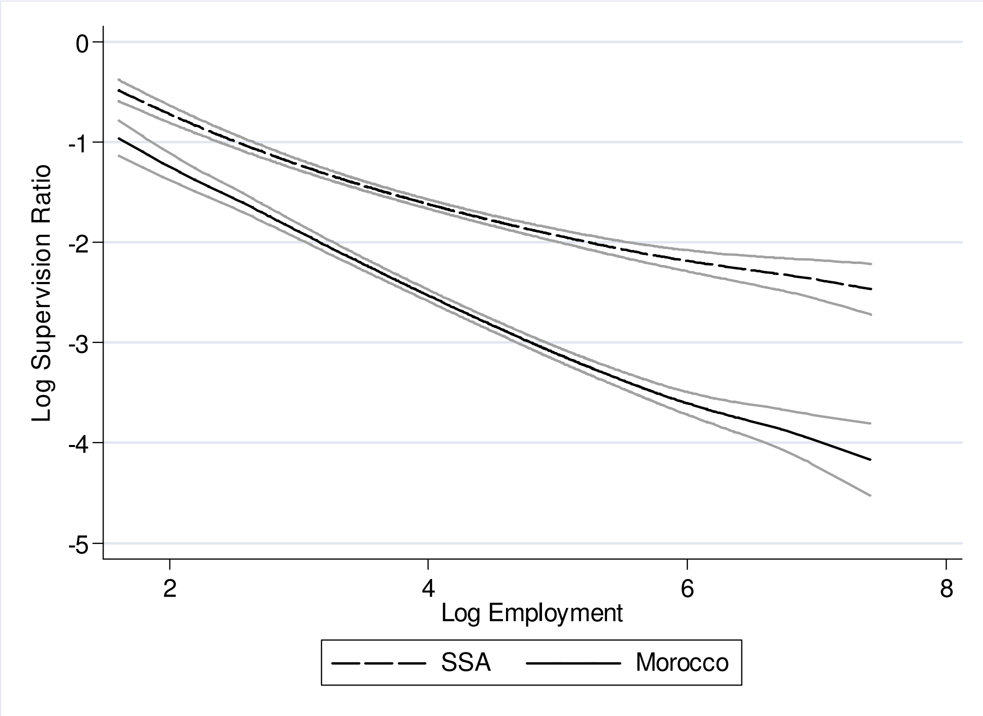
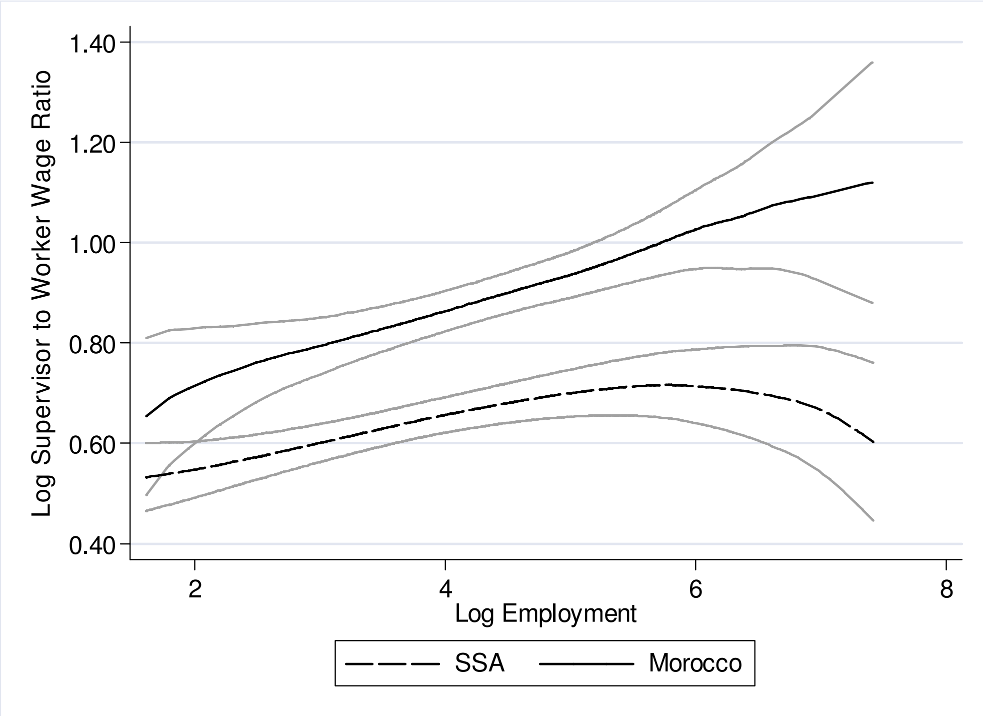


Figure 3: Firm Size and Supervisor-to-Worker Ratio



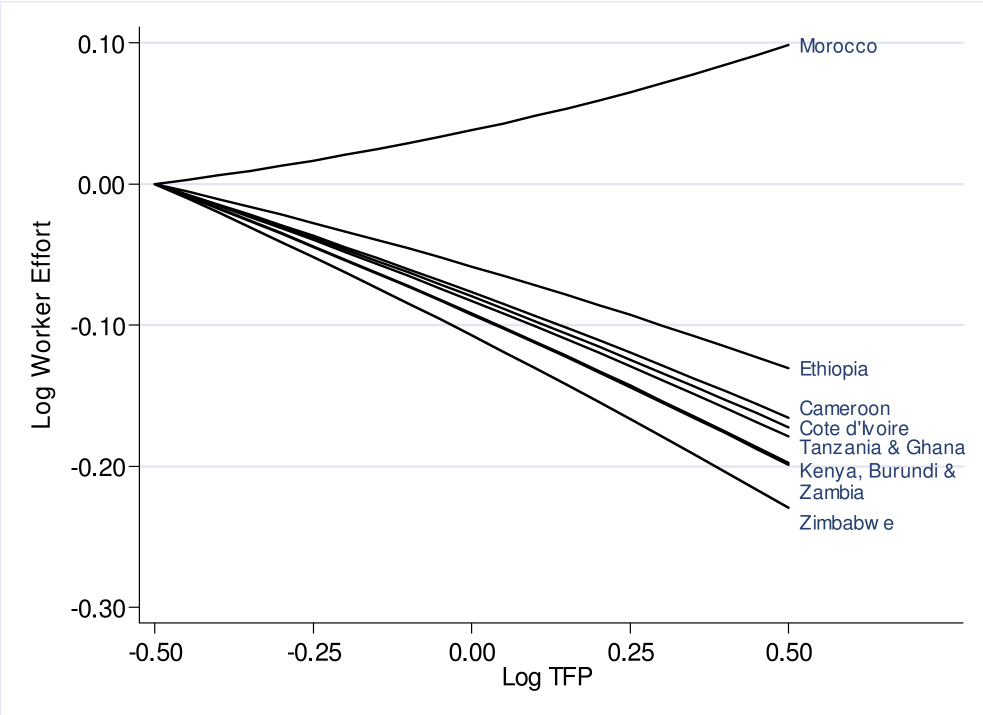
Note: Results were obtained using locally weighted regressions based on an Epanechnikov kernel. A 95% asymptotic confidence interval is displayed. It is computed on the basis of the standard error of the constant in locally weighted regressions. The bandwidth is 0.4.

Figure 4: Firm Size and Supervisor-to-Worker Wage Ratio



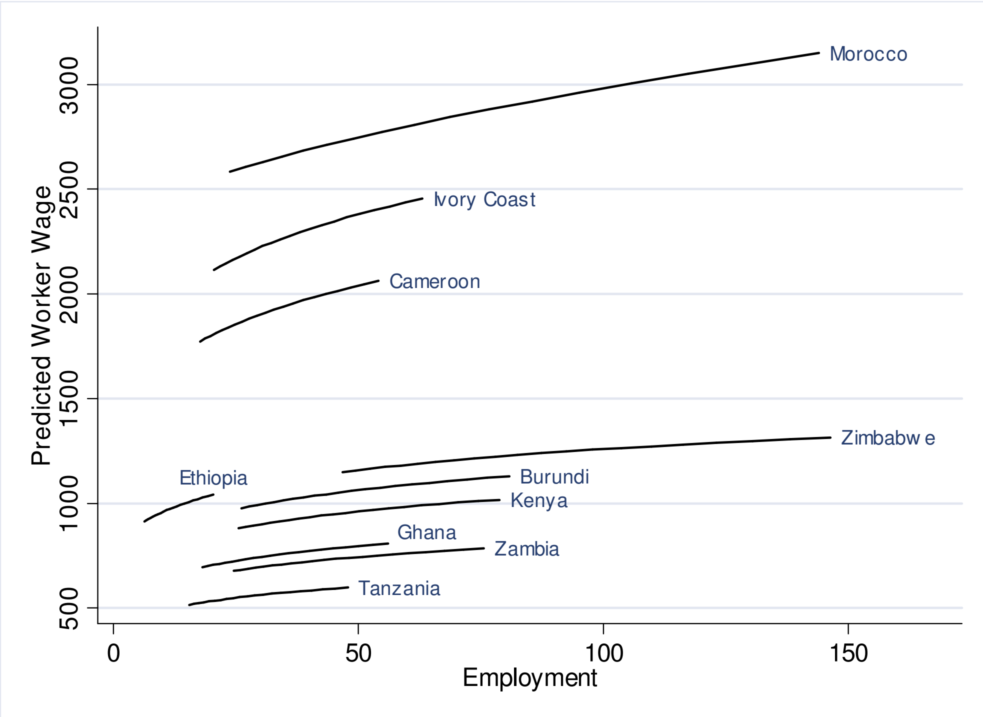
Note: Results were obtained using locally weighted regressions based on an Epanechnikov kernel. A 95% asymptotic confidence interval is displayed. It is computed on the basis of the standard error of the constant in locally weighted regressions. The bandwidth is 0.4.

Figure 5: The Effect of a Change in TFP on Worker Effort



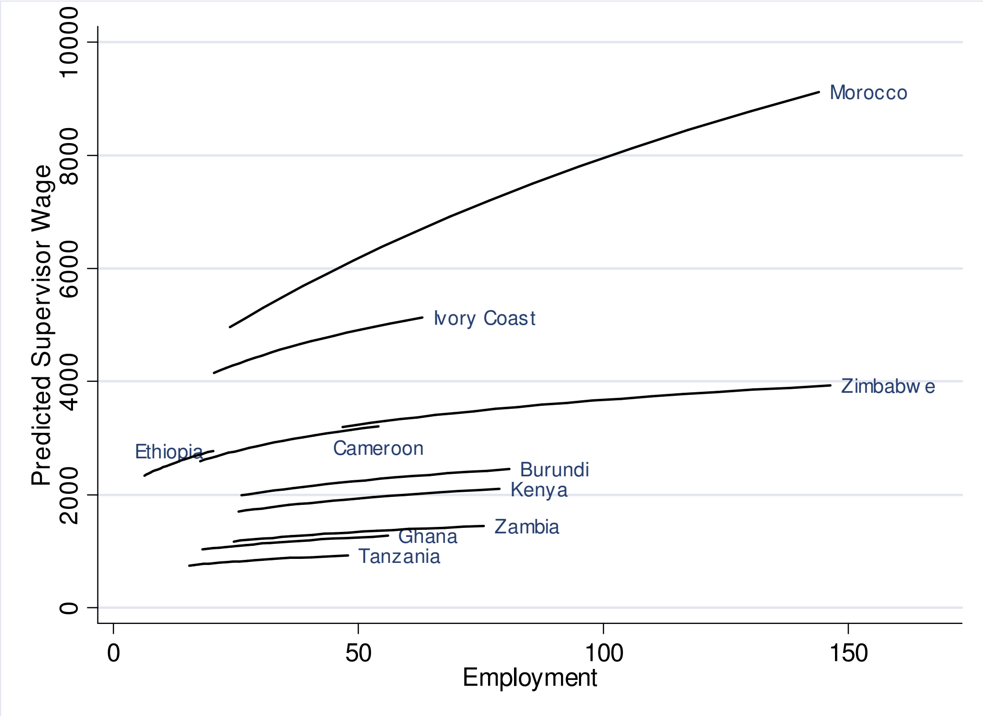
Note: The figure shows the predicted relationship between log worker effort and log TFP implied by the estimates of the structural model. For each country, log TFP is normalized by the country average, and log effort is normalized to 0 at log TFP = -0.5.

Figure 6: Production Worker Wages and Firm Size



Note: Predictions based on the estimates of the structural parameters reported in Table 5. The predicted wage is expressed in constant US$ with base year 2000.

Figure 7: Supervisor Wages and Firm Size



Note: Predictions based on the estimates of the structural parameters reported in Table 5. The predicted wage is expressed in constant US$ with base year 2000.