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Is African Manufacturing Skill-Constrained?

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Continued efforts to develop high-level industrial skills in Sub-Saharan African countries may be wasteful without a more competitive environment in the industrial sector. But lack of such skills may limit the benefits to the industrial sector from future liberalization. As a result, the supply response to improved incentives may be weak

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Summary findings

Total factor productivity has been low in most of Sub-Saharan Africa. It is often said that the binding constraint on African industrial development is the inadequate supply of technologically capable workers. And many cross-country studies imply that the low level of human capital in Africa is an important source of low growth in per capita income.

The results of Pack and Paxson's study do not necessarily conflict with this view. They indicate that in noncompetitive industrial sectors with little inflow of new technology, the contribution of technological abilities, however it is measured, is limited.

If liberalization of the economy generated greater competition, or if export growth were accelerated — permitting the import of inputs embodying new technology — local skills could contribute significantly more in raising output.

The experience of other countries also suggests that as the economy opens to flows of international knowledge — whether through technology transfers or through informal transfers from purchasers of exports — the technological capacity of local industry becomes important.

The policy implications of this analysis are clear: Without the prospect of a more competitive environment, continued efforts to develop high-level industrial skills may be wasteful. But the absence of such skills may limit the benefits to the industrial sector from future liberalization, as a result of which the supply response to improved incentives may be weak.

This paper — a product of Public Economics, Development Research Group — is part of a larger effort in the group to analyze the effect of public policies on industrial productivity. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Hedy Sladovich, room MC2-609, telephone 202-473-7698, fax 202-522-1154, Internet address hsladovich@worldbank.org. Policy Research Working Papers are also posted on the Web at http://wbln0018.worldbank.org/research/workpapers.nsf/policyresearch?openform. The authors may be contacted at packh@wharton.upenn.edu or cpaxson@wws.princeton.edu. October 1999. (19 pages)

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1. Introduction

In most of the Sub-Saharan African economies neither the levels of total factor productivity (TFP), nor the growth rates of TFP in manufacturing have been high. All studies of cross-country performance find that the Sub-Saharan African economies are the largest bloc of nations that have not converged on the United States. Most of the intercountry explanations have focused on easily measured aggregate variables such as the ratio of investment to GDP, education levels, and in some models, proxies for political stability (Barro and Lee 1993 and Easterly 1993). These models have as their underlying theoretical framework a view that the national economy can be modeled with a set of multiplicative inputs—an increase in the right-hand side variables such as the investment rate or education level will produce an increase in growth rates. However, as is increasingly recognized, including many authors of papers on convergence, the particular specification of the implied production function is open to question and the right-hand side variables may themselves be endogenous. Moreover, in the case of the African nations, close observers question whether a simple increase in investment rates will generate the impact implied by the cross country regressions—many countries have experienced growing marginal capital-output ratios over the last two decades (Husain 1993).

There are two divergent though complementary views of the lack of productivity growth in Sub-Saharan Africa.[1] The first holds that pervasive government intervention imposes large costs on individual firms and reduces incentives to become efficient (Collier and Gunning 1999). It is not only protection from foreign competition that has such effects but also problems stemming from bad macroeconomic policies such as highly variable real exchange rates which make long-term planning difficult for firms. A second interpretation focuses on the paucity of technological competence as measured by the small supply of trained managers and engineers.[2] This paper examines the determinants of manufacturing productivity and the role of education and technology variables at the level of individual firms. A major implication of our results is that, ceteris paribus, it is unlikely that an increase in education levels will have much impact on manufacturing TFP levels. We suggest a more complex view of the role of education, emphasizing that in the absence of technology inflows, higher skills may have very low productivity.

Using the results of surveys of industrial firms in Ghana, Kenya, and Zimbabwe, we consider the connection between technological abilities and productivity in the three nations. Section 2 sets out the determinants of productivity. Section 3 provides some aggregate measures of factors that may affect productivity in the three economies in question. Section 4 presents empirical results for the analysis of the determinants of productivity in a large group of firms in the three countries. Section 5 offers an interpretation of the results. Section 6 concludes.

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[1] Meier and Steel (1989) contains a good selection of representative views.

[2] For a general discussion of the technological requirements for industrial development see Lall (1990). Pack (1993) provides an overview of industrial development in Africa and extensive references to the literature.

2. The Determinants of Productivity Levels

While economy-wide and sectoral shortages of human capital are widely assumed to limit efficient industrial development, there is little empirical evidence on whether this is indeed the case in individual African firms. The presence of trained and experienced managers and workers does not guarantee high firm productivity for several reasons. First, individuals with formal credentials may not possess the cognitive skills necessary to improve TFP. Second, if there is limited rivalry, firms may view investment in cost-reducing efforts as not being necessary to remain competitive. Third, an industry's organization such as vertical integration between manufacturers and retailers may result in low productivity if, for example, each firm produces a large range of products, the profitability of firms being guaranteed by protection from imported goods. Hence, the frequently drawn policy conclusion of the need for higher levels of education and training based on the assumed shortages of skilled manpower may be unwarranted.

In theory technological abilities are important for cost reduction in industrial firms, facilitating learning-by-doing. The simplest interpretation of pure learning-by-doing envisions a manual worker tightening a bolt in forty percent less time the hundredth time she does it as compared to the first time. But a complete specification of "pure" learning by doing would recognize that there is usually an ongoing reorganization of the flow of work, the design or distribution of improved machinery, and additional training. Thus, even in the simplest case of learning-by-doing, one would expect that the presence of more educated or trained supervisors and production workers will facilitate realization of greater TFP growth. However, there is little empirical support even in industrialized countries establishing a close relation between technological abilities and cost reduction for industrial firms.[3]

By itself, the purchase of modern equipment does not guarantee that high TFP will be realized with such machinery—many complementary firm-level actions are required. Production engineering must be mastered, the flow of intermediate inputs to the plant and spare parts must be arranged, workers must be trained, and marketing must be enhanced so that it is not necessary to produce short production runs to order and incur excessive set up costs. Education, vocational training, foreign training, firm-level research and development, expenditures on technology licenses, and the nationality of owners may all affect the ability of firms to master the software of technology and are thus important determinants of firm-level productivity.

The economic environment established by macro- and microeconomic policies will also impinge on the firm and discourage or partly offset positive efforts at the firm level. Difficulty in obtaining raw and intermediate inputs of a given quality due to exchange controls, erratic supply of public services such as electricity, the incentive provided by import restrictions to expand the range of products, and the general absence of incentives to improve productivity all affect firm-level performance. For any given set of firms the impact of the economic environment and firm-level factors jointly determine productivity.

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[3] For studies demonstrating the interaction of education and technological change in agriculture see Welch (1970), Rosenzweig (1995), Foster, Rosenzweig, et al. (1995), and Foster and Rosenzweig (1995).

Assuming that all firms within a given industry face the same economic environment, it is possible to test whether firm technological abilities affect TFP or its mirror image, unit costs.

There are two alternate views of the role of education and technology in the production function. The first views them as multiplicative inputs in a standard production function. Thus, if a production function is estimated, elasticities of output with respect to technology inputs can be calculated. A second view that we believe is more useful (Nelson and Phelps 1966) argues that education will have its greatest impact when there is rapid technological change. If the basic technology (a loom used in weaving) is largely unchanged over time, the production process becomes routine and the ability to deal with change is not germane - high education results in only limited productivity gains. In contrast, where technology is rapidly evolving, learning about the existence of new processes, learning to use them when they are deployed, and staying abreast of new developments requires the adaptability provided by formal education.

The preceding can be formalized following a model of Nelson and Phelps (1966). Firms in developing countries (DCs) operate with a technology level equal to $A(t)$ in period t. Their peers in industrial countries (IC) operate technology $T(t)$. The rate at which the IC technology is introduced into the DC depends on the level of human capital, h, and is

$$(1) \qquad A'(t) / A(t) = \alpha(h) \left[\frac{T(t) - A(t)}{A(t)} \right].$$

The extent to which local DC technology improves is a positive function, $\alpha'(h) > 0$ of the level of human capital and proportional to the magnitude of the differential between current and "best practice" technology. As the technology $T(t)$ does not have to be invented, the potential productivity gain from the transfer of this technology is the benefit of relative backwardness (Gerschenkron 1962). Assume that the IC technology improves each year by φ percent so that

$$(2) \qquad T(t) = T_o e^{\varphi t}.$$

Given (1) and (2), the underlying differential equation implies that the *potential* equilibrium path of technology of a DC firm is

$$(3) \qquad A(t) = [\alpha(h)/(\alpha(h)+\varphi)]T_0 e^{\varphi t}.$$

The potential level of technology realized by an DC firm at a moment in time will thus be higher: (1) the greater its ability to deal with new technologies as a result of the presence of qualified individuals on its staff; (2) the larger the inflow of technology to the firm in the form of new equipment, new material inputs, new knowledge obtained from consultants, licensors, and foreign owners. The potential level of technology characterizing a firm will evolve along (3) and depends solely its own level of h and the rate of technical progress in the ICs that becomes available to the DC firm. If foreign exchange shortages or arbitrary rules prohibiting some forms of technology imports reduce the inflow of new knowledge, the benefit conferred by h is reduced. This might stem, for example, from regulations that limit expenditures on technology licensing payments so that a firm cannot purchase a potentially useful technology, implying that $\varphi_F < \varphi$ where φ_F represents the lower rate of technology inflow. Thus (3) can be rewritten as

$$A(t) = [\alpha(h)/(\alpha(t) + \varphi_F)]T_0 e^{\varphi_F t}. \tag{4}$$

Equation (4) underlines the fact that, at a given point in time, the level of productivity *A(t)* for a given firm may be weakly associated with *h* unless firms' ability to obtain new technology varies systematically with ***h***. Unlike formulations which treat education or purchases of knowledge as conventional inputs in the production function, (4) implies that human capital will have no effect on the level of output obtained with conventional inputs unless $\varphi_F > 0$ which can only occur if new productive inputs are introduced.

Schultz (1975) argued that in addition to the ability to absorb new technology, education would be important if there were a changing sectoral structure or internal product mix of firms, more highly educated workers being better at reallocating factors, exploring new profitable opportunities, and securing markets. Changing sectoral structure and internal product mix in turn reflect growth in per capita income in the internal market combined with different Engel elasticities and changes in the net trade balance in individual commodities. If sectors are not changing, it is likely that product mix within a sector is also stable, putting little premium on the ability to cope with change.

3. Aggregate Evidence on Technology

The payoff to education depends in the above view on two measurable magnitudes: (1) the inflow of imported machinery and industrial intermediate inputs that may embody new technology and (2) the sectoral structure of production. To measure the first Table 1 shows the rate of growth of all imports of goods and services, in constant prices, for the three African countries as well as the Republic of Korea and Malaysia, two Asian countries that are widely viewed as having benefited from the inflow of technology. The second is measured by the change in the split between light and heavy industry and the standard deviation of the percentage change in sectoral shares of value added.[4]

In the period 1980–93, the three African economies exhibited a negative or very slow growth of all imports, reflecting their inability to earn foreign exchange through exporting and the limited inflow of concessional aid. Kenya, for example, experienced a decline in constant price imports of 0.8 percent per year over the period. As the share of machinery and transport equipment and other manufactured inputs in total imports was roughly constant over the 1985–93 period, the absolute level of imports that could embody new technology declined.[5] In Ghana and Zimbabwe there were significant declines in the

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[4] An alternate measure is provided by Szirmai and Timmer (1997) which measures the similarity of the two value added structures. Calculations using their method provide roughly similar qualitative results.

[5] The measures described in the text and shown in Table 1 could be improved. For example, standard international trade data contained in the U.N. *Yearbook of International Trade Statistics* allows a

Table 1. Imports of Goods Embodying New Technology

Country	*Growth rate of imports*	*Share of machinery and transport equipment in total imports*		*Share of other manufactured imports in total imports*	
	1980–93	1985	1993	1985	1993
Kenya	-0.8	23	25	28	29
Ghana	2.7	40	26	28	31
Zimbabwe	0.2	65	36	26	31
Korea	11.4	34	34	23	29
Malaysia	9.7	46	54	28	30

Source: *World Development Report*, various issues.

share of imported equipment with only slight growth of exports, thus a significant decline in the level of imported capital goods occurred. The figures also suggest that, at most, a modest increase occurred in manufactured intermediate inputs. In contrast, in Korea and Malaysia, two newly industrializing countries (NICs) in which the level of education is widely perceived to have been an important contributor to industrial growth, the level of imports was rising very rapidly, reflecting the growth in export earnings, and the share of the two technology embodying inputs was constant or increasing, implying potential for significant returns from the ability to effectively utilize the new technology component of these imports.

There was also a dramatic change in sectoral structure in the Asian NICs compared to the sectoral stagnation of the African nations. Table 2 shows the distribution of manufacturing value added among light and heavy manufacturing for the five countries in question and an index of structural change given by the standard deviation of the percentage change between 1980 and 1990 in value added, calculated over all three digit industrial sectors. As can be seen, both the sectoral distribution between heavy and light and the summary standard deviation measure, show that the three African economies have experienced relatively little change in the structure of sectoral production, a phenomenon also replicated at the firm level.[6] The firms in our sample manufacture relatively simple products and it is unlikely that the internal product mix of firms has changed much. Indeed, many of the items produced by the larger firms are not that different from those fabricated in the informal sector.

disaggregated breakdown of imports that would allow more precision with respect to the both equipment and intermediate imports. However, the latest date for which these are available for the African economies is 1990, two years before the firm-level surveys were carried out. Thus we have cited the aggregate data generated by the World Bank.

[6] The greater summary measure in Zimbabwe compared to Ghana and Kenya is largely due to the expansion in the share of the beverage sector, a branch in which the technology employed has not changed.

Table 2. Sectoral Distribution of Value Added in Manufacturing

	Ghana		*Kenya*		*Zimbabwe*		*Korea*		*Malaysia*	
	1980	1990	1980	1990	1980	1990	1980	1990	1980	1990
Light industry	57.8	59.9	52.7	55.2	49.3	53.3	41.5	29.6	47.8	30.8
Heavy industry	42.2	40.1	47.2	45.1	50.7	46.7	58.5	70.4	52.2	69.2
SD of the % change	1.58		1.25		2.05		2.18		2.98	

Source: UNIDO (1993).

These results suggest that unless some firms were able to deviate from the overall pattern of stagnation of new inputs, it would be surprising if firms with higher technical skills realized greater levels of productivity.

4. Empirical Results at the Firm Level

A. The data

We analyze the relationship between skills and production costs using firm-level data from three African countries, Kenya, Zimbabwe, and Ghana. The survey data were collected in 1993 (for Kenya and Zimbabwe) and 1992 (for Ghana) by the Regional Program on Enterprise Development of the World Bank. Although the data are by now panel data, with up to three years of information for each firm, only the first year of data was available for this study. The surveys for each country used similar questionnaires and sampling procedures. All collect information on the value of output, production costs, the skill level of the owners and managers in each firm, and each firm's involvement in foreign markets, such as raw material imports, exports, and foreign ownership.

The Kenyan data are drawn from a survey of 223 manufacturing firms. The original sample consists of 162 formal sector firms drawn from the Central Bureau of Statistics register of firms, and 61 informal (i.e., nonregistered) firms. Four sectors are represented: food processing, textiles and garments, woodworking, and metalworking. The sample is stratified by sector and (for formal firms) by firm size. Detailed information on the survey design and the procedures used to compute sampling weights are in World Bank (1993b). Although the descriptive statistics presented below make use of data on all 223 firms, we had to exclude 51 firms when estimating cost functions, because of missing or incomplete data on costs, output, capital values, and other variables used in the analysis.

In Zimbabwe, 201 firms were surveyed in the summer of 1993. The firms were selected from two sources. Large firms, with 50 or more employees, were drawn from a Firm Registration List provided by the Central Statistical Office. Smaller firms were drawn from a list compiled by the Gemini Survey of small-scale firms, conducted in 1991. (See World Bank 1994 for further details on the sample design and the sample weighting procedure.) We use data on 200 firms (one firm had no sector information and was excluded), and lose an additional 30 firms for the estimates of cost functions due to missing data.

The sample from Ghana consisted of 186 firms surveyed in the summer of 1992. The sample design is described in World Bank (1993c). The design of the survey appears to have been complicated by the fact that two Censuses, an Industrial Census and a Population Census, yield inconsistent information on the numbers of small-scale enterprises (World Bank 1993c, p. 28.) Because of this ambiguity, we do not use survey weights, the number of firms in each category, in calculating the summary statistics that follow but the means of all firms. It is thus possible that our sample statistics may not accurately reflect the characteristics of the population of firms in Ghana.

The firms in the Ghanaian sample tend to be smaller than the firms in Zimbabwe and Kenya. Furthermore, there is no simple definition of "formal" versus "informal" firms as there is for the other two countries. In what follows, we sometimes split the Ghanaian sample between "large" firms, defined as those with 10 or more employees (as opposed to more than 50 employees for Zimbabwean formal-sector firms), and small firms. The Ghanaian data also have a larger fraction of missing values than the other two surveys. Of the original 186 firms, only 132 can be used to estimate cost functions. Valuation of the capital stock of firms appears to have been a particular problem in Ghana, and so we do not include capital stock in the cost functions: doing so would have resulted in losing 19 more firms. The results for Ghana should be treated with extra caution, because of the small sample and the selection problems that may result from missing dependent variables.

B. Descriptive information on the firms

The majority of firms are engaged in producing fairly simple products. In all three countries the modal product of firms in the food sector is breadmaking. Garments and wooden household furniture are the modal responses for the textile and woodworking sectors. The metal sectors in each of the three countries are somewhat more diverse, although the majority of sampled firms report metal doors, windows, gates and burglar bars as their primary products. The picture does not change much in Kenya and Zimbabwe when sample weights are used to calculate the percentage of firms in the population (and labor shares) in each activity.[7]

Most of the firms in each of the countries are sole proprietorships, partnerships, or limited liability enterprises, and for almost all of these firms a person identified as "the

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[7] It should be noted that the use of sample weights together with small sample sizes can yield a misleading picture of the activities of these firms. For example, the Kenyan numbers indicate that 58.7 percent of wood-sector workers are in the "miscellaneous" category that includes "carvings, camping equipment, and automobile trim." This is due to one 70-person firm that makes camping equipment, and which was given a sample weight 4 times the sector average. Likewise, the result that 41 percent of food and beverage workers make animal feed and hay is due to 1 poultry-feed firm with 420 workers and a sample weight 3 times the sector average.

owner" was administered a survey about his education, experience, and personal background. Owners in each country were asked about the highest educational level obtained, and were also asked if they had additional vocational, technical, or (for Kenya and Ghana) professional training. In each country the majority of surveyed owners had at least some secondary education, and one-third to one-half of these had extra training as well. Without reliable data on the distribution of skills in the populations of each of these countries it is impossible to tell if owners of manufacturing firms have better-than-average skills. Data from the Ghanaian Living Standards Measurement Study, conducted in 1988 and 1989, indicate that average years of schooling among people aged 15 to 55 was six years (Jolliffe 1995), with a lower average for people in older age groups, so it is likely that owners of manufacturing firms have better-than-average skills than the working population.

Owners may hire managers with skills that exceed their own, in which case the appropriate measure of skill for the firm may be that of the manager rather than the owner. Tables 3a, 3b, and 3c tabulate the education levels of "general managers" and "production managers" for firms that indicate that they have a manager of either type. The distribution of education among managers is not too dissimilar from the distribution among owners, although a higher fraction of managers have attended a university. However, this does not imply that owners hire managers who are more educated than themselves, and may reflect the fact that it is larger firms with more educated owners that hire managers. Among firms that have both owners and managers present, there is a high correlation between the skill levels of the two.[8] The survey also asks about the average education levels of "managerial employees." Tabulations of these for Kenya and Ghana are shown in Table 4 (the results for Zimbabwe were miscoded and cannot be used), and these indicate that the majority of managerial employees have attended secondary school, and roughly a quarter of the sampled firms with managerial employees list the average education level of their managers at the university level. In the cost functions presented below we use a variety of skill measures that reflect the education levels of both owners and managers.

Table 3a. Kenya: Distribution of Managers' Education

	General manager (N=110)		*Production manager (N=58)*	
None	2	0.1%	1	15.2%
Primary	8	33.4%	3	1.2%
Secondary	47	40.2%	25	57.7%
University – nontechnical	25	3.4%	5	1.4%
University – technical	21	17.8%	21	23.8%
Post-graduate (Kenya)	3	0.3%	1	0.3%
Post-graduate (abroad)	4	4.9%	2	0.5%

Note: Percentages are calculated using survey weights based on number of firms sampled.

[8] The survey does not ask whether the owner and manager are the same person, and this might account for the similarity between the education of owners and managers.

Table 3b. Zimbabwe: Distribution of Managers' Education

	General manager (N=190)		*Production manager (N=108)*	
None	3	2.4%	1	0.9%
Primary	27	42.4%	16	14.8%
Secondary	86	47.1%	49	45.4%
University – nontechnical	31	3.7%	10	9.3%
University – technical	31	2.7%	27	25.0%
Post-graduate (local)	2	0.1%	3	2.8%
Post-graduate (abroad)	10	1.7%	2	1.9%

Note: Percentages are calculated using survey weights.

Table 3c. Ghana: Distribution of Managers' Education

	General manager (N=46)		*Production manager (N=51)*	
None	4	8.5%	0	0.0%
Primary	4	8.5%	3	5.9%
Secondary	10	21.2%	11	21.6%
University – nontechnical	7	14.9%	2	3.9%
University – technical	18	38.3%	28	54.9%
Post-graduate (local)	1	2.1%	1	2.0%
Post-graduate (abroad)	3	6.4%	6	11.8%

Note: Percentages are calculated as means.

Table 4. Average Education of Managerial Employees (126 firms)

Education level	*Total*		*Vocational*		*Technical*		*Professional*	
Kenya (126 firms)								
None	1	0.2%	0	0.0%	0	0.0%	0	0.0%
Primary	8	14.2%	0	0.0%	2	8.0%	0	0.0%
Secondary	82	74.2%	7	6.4%	8	14.3%	11	1.5%
University	35	11.4%	1	0.0%	0	0.0%	9	1.6%
Ghana (64 firms)								
None	2	3.1%	0	0.0%	0	0.0%	0	0.0%
Primary	1	1.6%	0	0.0%	0	0.0%	0	0.0%
Secondary	45	70.3%	4	6.2%	8	12.5%	14	21.9%
University	16	25.0%	0	0.0%	0	0.0%	2	3.1%

Note: Numbers indicate numbers of sampled firms. For Kenya, the percentages are calculated using weights provided by the survey. The data from Ghana are unweighted.

We have no direct measures of the rate at which different firms acquire new technology (i.e., the term φ_F in equation 4). However, it is likely that the acquisition of new technology from abroad is positively correlated with activities in foreign markets, and Table 5 presents information on these activities. The predominant picture is of firms that have little involvement in international markets. The vast majority of all firms import none of their raw materials, export none of their output, and do not have any foreign ownership. The firms were also asked about the use of foreign technology licenses and foreign technical assistance. In Kenya, only 9 out of 220 firms who answered these questions had foreign licenses, and 17 out of 220 received foreign technical assistance. In Zimbabwe licenses and technical assistance were somewhat more common: 28 out of 200 firms has foreign licenses and 26 out of 200 received technical assistance. The questions asked of Ghanaian firms were phrased differently, but also indicate little use of licenses or assistance. Of the 186 firms in the sample, only 6 firms indicated that they had held at least one foreign license during the past 10 years, 6 said they had received foreign technical assistance in the last year, and 2 said they had used foreign consultants in the past 2 years.

Table 5. Involvement in Foreign Markets

	None	*0-25%*	*25%-50%*	*50%-75%*	*75%-100%*
Kenya					
Percentage of raw materials	121	32	15	25	25
Imported	(76.1%)	(11.4%)	(3.3%)	(3.3%)	(5.9%)
Percentage of output exported	170	29	7	4	8
	(78.0%)	(6.6%)	(0.1%)	(0.2%)	(0.3%)
Percentage of foreign	184	4	6	10	14
Ownership of the firm	(96.5%)	(0.2%)	(1.7%)	(0.3%)	(1.3%)
Zimbabwe					
Percentage of raw materials	92	57	20	13	12
Imported	(93.0%)	(4.4%)	(0.9%)	(0.4%)	(1.3%)
Percentage of output exported	104	58	23	9	6
	(92.2%)	(4.4%)	(1.1%)	(1.1%)	(1.3%)
Percentage of foreign	155	12	7	8	15
Ownership of the firm	(96.7%)	(0.5%)	(0.6%)	(0.9%)	(1.3%)
Ghana					
Percentage of raw materials	127	12	6	11	19
Imported	(72.6%)	(6.9%)	(3.4%)	(6.3%)	(10.9%)
Percentage of output exported	163	11	2	1	4
	(90.1%)	(6.1%)	(1.1%)	(0.6%)	(2.2%)
Percentage of foreign	154	2	12	13	5
Ownership of the firm	(82.8%)	(1.1%)	(6.5%)	(7.0%)	(2.7%)

Note: The numbers in parentheses indicate percentage of firms. The percentages for Kenya and Zimbabwe are calculated using survey weights. The percentages for Ghana are unweighted.

C. Estimates of cost functions

The data described above have been used to estimate cost functions for firms in each of the three countries. Our primary interest is to see whether firms with more skills (as measured by the education levels of owners and/or managers) and more involvement in foreign markets have lower productions costs, given output. We start with the short-run cost function for firm i:

$$c_i = C(p_i, k_i, q_i / A_i), \qquad (5)$$

where c is costs defined as the cost of labor, raw materials, and indirect costs such as utilities and rent, p is a vector of input prices, q is the value of output, k is the replacement value of the firm's capital equipment, and A is a measure of the technology level of the firm. This form of the cost function follows from the assumption that the short-run production function has the form $q_i = A_i Q(M_i, k_i)$, where M_i is a vector of variable inputs and A_i depends on the level of "technological" inputs such as education. The Nelson-Phelps view discussed in Section 2 implies that A_i is a function of both the skill level of the firm (measured by h_i) and also by factors that affect the firm specific rate of flow of new technologies from abroad (measured by φ_F), the two entering the cost function interactively.

We start by estimating basic cost functions that do not include any variables that may affect A_i. Because we have small samples of cross-sectional data, and no data on input prices p, we employ simple specifications for the short-run cost functions. We work with the following:

$$(6) \qquad \ln(c_i) = \beta_s + \alpha_q \ln(q_i) + \alpha_{qq}[\ln(q_i)]^2 + \alpha_k \ln(k_i) \\ \alpha_{kk}[\ln(k_i)]^2 + \alpha_{qk}\ln(q_i)\ln(k_i) + \varepsilon_i \ ,$$

where β_s is a sector-specific intercept meant to capture the effects of differences in input prices across sectors. As discussed above, the data from Ghana contain many missing values for the value of capital, and so for it the terms in (6) that involve the logarithm of capital are excluded. Estimates of these basic cost functions are shown in Table 6. The top panel shows estimates for formal firms (or, in the case of Ghana, firms with 10 or more employees), and the bottom panel shows results for the full set of firms. The estimates for the three countries are quite similar, and are also similar for the formal and full samples. In all specifications the sectoral dummy variables are jointly insignificant.[9] The results for the simplest specification, in which the logarithm of costs is regressed on the logarithm of output and a set of sector dummies, indicate that the underlying production technology displays constant or slightly increasing returns to scale. Variation in output explains a high fraction of variation in costs, with R^2's that exceed 0.92 for all countries. Including the logarithm of output squared, the measures of capital, and the interaction of capital and output does not greatly improve the fit of the cost functions.

The cost function shown in equation (6) was modified to include variables that are likely to affect A. As discussed above, A is meant to capture the effects of skills and determinants of technology inflows on costs. We begin by including measures of the skill level of firm's owners or, if no owner was present, the skill level of the firm's manager. For Kenya and Ghana, the education levels of owners and the average education of managerial employees was coded in the same way, and we construct dummies that indicate whether the owner (or managerial employees) had no schooling, primary schooling, secondary schooling, or university training. We also experimented with using more finely detailed educational categories that made use of the information on whether owners/employees had received occupational or vocational training. These results are not reported, but were essentially no different than the results that are discussed below. For Zimbabwe the variable pertaining to the average education of managerial employees was miscoded, and so for firms without owners we substitute the education level of the general manager or, if there was no general manager, the production manager. There are only 3 firms in

[9] We also experimented with including dummy variables for the city in which firms are located, and these were also insignificant. The results are consistent with there being neither regional nor sectoral variation in input prices.

Zimbabwe with owner/managers with no education, and so we combine the "no schooling" and "primary education" categories. For all countries, we experimented with altering the definition of "skills" in a variety of ways, for example by using the education level of managerial employees and only using the owner's education if no managerial employees were present. Doing so had no effect on the results.

Table 6. Basic Cost Functions For Formal Sector Firms or (For Ghana) Large Firms
(absolute values of t-statistics in parentheses)

	Kenya		*Zimbabwe*		*Ghana*	
Wood	-0.11	-0.09	-0.23	-0.22	-0.32	-0.32
	(0.92)	(0.70)	(1.55)	(1.60)	(1.58)	(1.56)
Textiles	-0.03	-0.02	0.01	-0.04	-0.18	-0.15
	(0.23)	(0.20)	(0.08)	(0.38)	(0.96)	(0.79)
Metal	0.06	0.04	-0.02	-0.01	-0.18	-0.19
	(0.48)	(0.32)	(0.12)	(0.09)	(0.95)	(0.98)
ln(q)	0.915	0.75	0.88	0.42	1.00	1.33
	(44.94)	(5.68)	(43.20)	(3.87)	(27.10)	(6.45)
$\ln(q)^2$		0.02		0.05		-0.022
		(1.57)		(1.90)		(1.64)
ln(k)		0.24		0.37		
		(1.65)		(3.65)		
$\ln(k)^2$		-0.01		-0.01		
		(0.70)		(.73)		
ln(q)ln(k)		-0.01		-0.02		
		(.43)		(0.36)		
Obs	125	125	142	142	80	80
R^2	.95	.95	.93	.94	.93	.93
Full sample of firms						
Formal	0.35	0.28	0.32	0.31	0.12	0.10
	(3.56)	(2.15)	(2.40)	(2.26)	(0.72)	(0.65)
Wood	-0.18	-0.17	-0.11	-0.06	-0.14	-0.11
	(1.59)	(1.50)	(0.83)	(0.51)	(0.73)	(.55)
Textiles	-0.10	-0.09	0.04	0.03	-0.14	-0.11
	(0.85)	(0.79)	(0.42)	(0.27)	(0.77)	(0.63)
Metal	-0.08	-0.09	0.07	0.04	0.02	0.02
	(0.70)	(0.79)	(0.56)	(0.30)	(0.09)	(0.12)
ln(q)	0.90	0.78	0.89	0.69	1.109	1.19
	(47.93)	(9.94)	(46.29)	(9.46)	(25.78)	(8.21)
$\ln(q)^2$		0.022		0.06		-0.01
		(2.03)		(3.06)		(1.17)
ln(k)		0.10		0.13		
		(1.54)		(2.69)		
$\ln(k)^2$		0.003		0.016		
		(0.33)		(1.42)		
ln(q)ln(k)		-0.02		-0.06		
		(1.11)		(2.09)		
Obs	172	172	170	170	132	132
R^2	.96	.96	.96	.96	.92	.92

The first columns of Tables 7a, 7b and 7c show estimates of cost functions when the "skill" measures are included. As the coefficients on the variables shown in Table 6 are largely unchanged, only coefficients for the skill variables are reported. The results are easily summarized. In no country are higher managerial skills associated with lower costs, given output. There is one anomalous result for formal sector firms in Ghana (Table 7c): firms with educated owners appear to have *higher* costs than those with no education. However, the three educational dummy variables are not jointly significant.

In the second column of the three tables we include variables that measure involvement in foreign markets: the percentage of raw materials imported, the percentage of output exported, and the percentage of foreign ownership. If firms with more involvement in foreign markets have more access to lower-cost technology, then these variables should be negatively correlated with costs. However, interpreting the parameter estimates requires caution: it could be that firms whose costs are initially lower export their output. This could also produce a negative correlation between exports and costs, and it would be incorrect to interpret the results as reflecting the effects of the rate of technology transfer on costs (Clarides, Lachs, and Tybout 1999).[10] However, the results indicate that there is no correlation between involvement in foreign markets and costs in any of the countries, and the hypothesis that the variables are individually and jointly insignificant cannot be rejected. The lack of a statistically significant relationship between these variables and costs may not be surprising given that very few of the firms have any involvement in foreign markets.

If only high-skill firms are able to take advantage of new technologies from abroad, the Nelson-Phelps view, there should be a negative correlation between costs and an interaction term between skills and the variables reflecting access to foreign markets. The third column of Tables 7a, 7b and 7c show estimates of cost functions when these interactions are included. Overall, the results provide very little support for the hypothesis that high skills combined with access to foreign markets result in reductions of unit costs. With only one exception, the coefficients on these interactions are insignificant. The exception is for Kenya, for which firms with university-trained owner/managers who export higher fractions of their output have lower costs, all else being equal. One should not, however, make too much of this finding. First, there are only 17 formal sector and 1 informal sector firms with university-trained owner/managers who export any of their output. Second, as discussed above, without better information on exogenous determinants of access to export markets, it is not possible to know whether low-cost firms with educated owners are better equipped to sell their output abroad, or whether involvement in foreign markets makes it easier for more educated owners to produce using lower-cost methods.

[10] One of the benefits of panel data would be the ability to address the question of whether efficient firms select into exports or whether exporting generates learning.

Table 7a. Formal Firms, Kenya
(Obs=125)

Firms				*Sample means*
Owner/manager's education:				
Primary school	–0.038 (0.32)	–0.017 (0.15)	–0.053 (0.45)	0.32
Secondary school	–0.062 (0.47)	–0.065 (0.49)	–0.009 (0.07)	0.18
University	–0.056 (0.47)	–0.041 (0.33)	0.032 (0.23)	0.31
% raw materials imported		0.0006 (0.46)	0.0000 (0.04)	26.8
%output exported		–0.0034 (1.78)	0.0014 (0.59)	8.9
%foreign ownership		–0.0019 (1.16)	0.0001 (0.04)	10.2
owner/manager education is university times:				
%raw material imported			0.0010 (0.43)	16.5
%output exported			–0.0115 (3.20)	4.3
%foreign ownership			–0.0023 (0.72)	6.5
R^2	0.95	0.95	0.96	
Kenya: all firms (obs=172)				
Owner/manager's education:				
Primary school	–0.054 (0.56)	–0.034 (0.35)	–0.042 (0.42)	.31
Secondary school	–0.005 (0.05)	0.004 (0.03)	0.033 (0.26)	.15
University	0.016 (0.15)	0.039 (0.34)	0.076 (0.60)	.24
% raw materials imported		0.0000 (0.02)	–0.0008 (0.47)	22.3
%output exported		–0.0026 (1.26)	0.0027 (1.09)	6.5
%foreign ownership		–0.0020 (1.27)	–0.0021 (0.84)	8.2
owner/manager education is university times:				
%raw material imported			0.0017 (0.74)	12.4
%output exported			–0.0123 (3.33)	3.1
%foreign ownership			0.0011 (0.32)	5.3
R^2	0.96	0.96	0.97	

Note: Absolute values of t–statistics in parentheses. Also included in cost functions were the logarithms of output and capital, each of these terms squared, and an interaction term between output and capital.

Table 7b. Formal Firms, Zimbabwe
(obs=142)

Firms				*Sample means*
owner/manager's education:				
secondary school	0.0216 (0.15)	.0107 (0.08)	−0.041 (0.29)	.48
university	−0.0373 (0.25)	−0.0321 (0.21)	0.102 (0.63)	.42
% raw materials imported		0.0004 (0.24)	0.0024 (1.19)	19.2
%output exported		0.0030 (1.46)	0.0033 (1.33)	13.0
%foreign ownership		0.0011 (0.80)	0.0032 (1.62)	14.0
owner/manager education is university times:				
%raw material imported			−0.0044 (1.50)	8.7
%output exported			−0.0025 (0.61)	5.7
%foreign ownership			−0.0041 (1.58)	8.0
R^2	0.95	0.95	0.95	
Zimbabwe: all firms (obs=170)				
owner/manager's education:				
secondary school	0.0500 (0.44)	0.0376 (0.33)	0.0008 (0.01)	.46
university	−0.0256 (0.20)	−0.0204 (0.16)	0.1104 (0.77)	.37
% raw materials imported		0.0005 (0.33)	0.0025 (1.21)	16.0
%output exported		0.0031 (1.48)	0.0034 (1.37)	11.5
%foreign ownership		0.0012 (0.86)	0.0030 (1.50)	11.8
owner/manager education is university times:				
%raw material imported			−0.0043 (1.45)	7.2
%output exported			−0.0023 (0.56)	4.8
%foreign ownership			−0.0037 (1.36)	6.7
R^2	0.96	0.96	0.97	

Note: Absolute values of t–statistics in parentheses. Also included in cost functions were the logarithms of output and capital, each of these terms squared, and an interaction term between output and capital (as in Table 6.)

Table 7c. Large Firms, Ghana
(10 or more employees) (obs=80)

Firms				*Sample means*
owner/manager's education:				
primary school	0.043 (0.22)	0.038 (0.19)	0.044 (0.22)	.39
secondary school	–0.087 (0.42)	–0.091 (0.44)	–0.135 (0.61)	.33
university	0.427 (1.71)	0.426 (1.70)	0.340 (1.22)	.16
% raw materials imported		–0.0006 (0.29)	–0.0041 (1.29)	20.0
%output exported		–0.0023 (0.78)	–0.0034 (0.77)	6.7
%foreign ownership		0.0044 (1.36)	0.0099 (1.71)	10.6
owner/manager education is university times:				
%raw material imported			0.0059 (1.40)	11.5
%output exported			0.0022 (0.38)	3.7
%foreign ownership			–0.0070 (1.14)	6.6
R^2	0.93	0.93	0.94	
Ghana: all firms (obs=132)				
owner/manager's education:				
primary school	0.389 (2.29)	0.386 (2.24)	0.389 (2.23)	.45
secondary school	0.216 (1.16)	0.215 (1.15)	0.190 (0.96)	.27
university	0.526 (2.12)	0.519 (2.07)	0.465 (1.72)	.11
% raw materials imported		–0.0002 (0.09)	–0.0019 (0.57)	12.8
%output exported		–0.0027 (0.75)	–0.0038 (0.72)	4.0
%foreign ownership		0.0027 (0.80)	0.0045 (0.92)	7.2
owner/manager education is university times:				
%raw material imported			0.0035 (0.75)	7.1
%output exported			0.0024 (0.35)	2.3
%foreign ownership			–0.0037 (0.54)	4.0
R^2	0.92	0.92	0.92	

Note: Absolute values of t–statistics in parentheses. Also included in cost functions were the logarithm of output and the logarithm of output squared (as in Table 6.)

5. Interpretation of the Results

There are a number of potential explanations for the absence of significance of the components of technological ability (*A*) in countries in which it is generally believed that a constraining factor is human capital and technological infrastructure. Consider the specification that assumes the components of *A* are multiplicative elements in the cost function. First, the relatively non-competitive environment may lead to limited efforts to utilize those skills that are present. Second, even where skilled managers are present or R&D takes place, these may simply be devoted to efforts to redress the productivity depressing effects imposed by the protectionist regimes. For example, engineers may spend their time adjusting equipment to cope with low quality intermediate inputs that are locally available. While this may lead to higher productivity than in their absence, they are mainly redressing the productivity depressing effects of policy and the net effect of their effort is likely to be small.

Surveys of firms in Africa repeatedly find that firms frequently encounter difficulties with arbitrary foreign exchange allocations, zoning, building and licensing codes, and uncertain quality of telecommunications and electricity. For example, the surveys discussed in this paper indicate that the availability of foreign exchange is a special problem among formal sector firms. In Kenya, 35.4 percent of firms indicate having "very severe problems" regarding delays in obtaining foreign exchange, and 41.6 percent report very severe problems in foreign exchange availability. Of formal firms in Zimbabwe, 27 percent of firms report very severe problems with delays in obtaining foreign exchange and 52.1 percent report very severe problems with foreign exchange availability. Reports of problems with infrastructure are also common. With such a large set of government imposed handicaps affecting them, it would be surprising if their technological abilities, however, measured, would reveal themselves in a systematic fashion across firms. Some companies may use technologists to address regulations, some to correct infrastructure deficiencies as in Nigeria (Lee et al. 1990) and others to improve productivity. Only after liberalization are the benefits from improved technological capacity likely to be measurable and lead to a significant reduction in costs.

The firms in our sample have not been challenged by newer technologies where the payoffs to domestic skills are likely to be largest. Simultaneously the failure of agricultural productivity to grow has limited the economy-wide growth in per capita income. Thus the change in sectoral structure engendered by different income elasticities among industrial goods has not had an effect. The absence of a need to alter production methods or sectoral mix has reduced the payoff to education.

Even if there were an inflow of technology and high education made its absorption potentially productive, the absence of a competitive environment limits these gains. Much of the empirical testing of the role of education in adjusting to technical change has been in the agricultural sector which is usually much more competitive than the industrial sector, particularly in developing countries (see the references in footnote 3.) In contrast, in Ghana, Kenya, and Zimbabwe the survival environment is lax. Tariffs and quotas protect industrial firms from external competition while internal rivalry is reduced by the relatively small number of firms producing a specified product. The shift in short-run supply curves induced by abnormal profits in competitive markets is not forthcoming as there are a limited number of firms capable of entering most industries. Firms possessing technical abilities may choose not to utilize them to increase productivity or reduce costs. The abilities of skilled personnel may be devoted to insuring the existence and exploitation of profit possibilities made possible by tariffs, quotas, and cheap credit.

Firm-level efforts to improve productivity are the result of an income and a substitution effect. High levels of protection, ceteris paribus, increase the firm's profits per unit of effort. If the foregone "leisure" or easy life is a normal good, protection will tend to reduce cost saving efforts. However, higher levels of effective protection increase the opportunity cost of foregoing additional output from productivity augmenting activities. Thus, the impact of firm-level abilities on productivity in the presence of protection is ambiguous. An absence of an association between firm skills, however measured, and productivity levels among firms is not an indication that such skills do not provide the *potential* to raise productivity. Rather, such a capacity may not be deployed in pursuit of greater cost reduction rather than the search for greater rents or an easier life.

6. Conclusions

The absence of a significant private payoff to technological capability may be surprising given the frequently heard statement that the binding constraint on African industrial development is an insufficient supply of technologically capable manpower. This is also the implication of the many cross-country studies that find that an important source of low growth in per capita income in Africa is the low level of human capital, however measured. Our results are not necessarily in conflict with this view. They should be interpreted as indicating that in non-competitive industrial sectors with very little inflow of new technology, the contribution of technological abilities, however measured, is limited. If there were a liberalization of the economy that generated greater competition or if there were an acceleration of export growth, permitting the import of new technology embodying inputs, the contribution of local skills would become more significant in raising output. The experience of other countries also suggests that as the economy becomes open to flows of international knowledge, whether through informal transfers from purchasers of exports or through technology licenses, the technological capacity of local industry becomes important.[11]

The policy implications of the empirical analysis are clear. Absent greater prospective competition, continued efforts to develop high-level industrial skills may be wasteful. The conundrum is that their absence may limit the benefits to the industrial sector from future liberalization and lead to a weak supply response to improved incentives.

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[11] See the East Asian Economic Miracle, Chapter 6.

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