

Sources of technological capabilities in low-tech sectors in developing
countries:
A cross-country firm-level study

Micheline Goedhuys¹ Norbert Janz^{1,2} and Pierre Mohnen^{1,3}

- ¹ UNU-MERIT, Maastricht, the Netherlands
² Aachen University of Applied Sciences, Aachen, Germany,
³ University of Maastricht, Maastricht, the Netherlands

Corresponding author:
Micheline Goedhuys:
UNU-MERIT,
Keizer Karelplein 19
6211 TC Maastricht, The Netherlands
Tel: +31 43 3506 380; Fax: +31 43 3506 399
Email: goedhuys@merit.unu.edu

1. Introduction

Innovation - the ability to create, combine, recombine and commercialize knowledge – is not limited to the rich part of the world or to high-tech industries. In traditional sectors, such as agro-processing (especially the production of food and beverages), textiles and garment production, in which developing countries typically have a revealed comparative advantage, knowledge and intangible assets in the production and distribution process are becoming increasingly important. To compete on world markets, even firms in developing countries have to increase their knowledge base, to streamline their production processes, to introduce new products and to engage in various innovation activities. In this context, innovation has to be understood as the introduction of products, processes and managerial techniques new to the firm resulting from a process of technological learning. According to this firm-specific view, adoption of novelties, subsequent improvements and incremental follow-up innovations are at the heart of this innovation process.

Firms can take a variety of approaches to absorb and create knowledge so as to increase the efficiency of production and the quality of output. The traditional view of technology transfer suggests investing in imported capital goods and purchasing licenses of production and distribution rights as a way to access new technologies incorporating R&D from developed countries. Improving human capital by formal education and continuous R&D activities increases the firms' absorptive capacity facilitating technology adoption, and offers possibilities to generate improvements and follow-up innovations. The sources of technological capabilities may differ across countries, industries and firms. Empirically, it remains an open question how different sources of technological capabilities contribute to TFP in firms of developing countries, given that these firms are constrained by institutional malfunctioning as well as political and financial risks.

New firm level data sets, recently made available, allow a quantitative analysis of the impact of different sources of technological capabilities on firm performance, such as total factor productivity. Several developing countries have conducted large-scale surveys at the firm or plant level that provide insights into firm behaviour and performance given the conditions they are operating in. We use the Investment Climate Surveys (ICS) of the World Bank, which use a relatively harmonised core questionnaire. The surveys contain a wide range of information on sampled individual establishments: inputs, outputs, ownership structure, industry structure, financial conditions, and questions regarding R&D efforts, training, and innovation. We use the ICS data from five different countries to study a set of sources of technological capability and their impact on productivity. The firms are selected from three so-called 'low tech' sectors, that are of great importance to developing countries, be it in terms of value added or exports: agro-processing (especially food and beverages), textiles, as well as garments and leather products. By analysing each sector separately, we take into account that innovation and learning are industry specific (Pavitt, 1984, Malerba, 2004). This allows us to gain insights into the specific characteristics and driving forces of productivity in different sectors.

In choosing the countries, we decided to include some least developed countries as well as countries that are well embarked on a process of catching up. In a related study on Tanzania (Goedhuys, Janz and Mohnen, 2006), we found that the typical technology variables, R&D and product or process innovation, did not explain any significant variation in productivity between firms, while institutional aspects of the business environment did have an impact on firm performance. Building further on these findings, we now are interested in investigating

whether it requires a certain level of economic development for certain sources of technological capability to start paying off in terms of productivity. Apart from the varying level of economic development, several additional criteria were taken into account to select the countries for the analysis, such as the importance of at least one of the sectors for the country's export structure or manufacturing employment, a geographical spread over different continents, and last but not least, the availability of a relatively harmonised core data set covering the period 2000-2002. This resulted in the selection of two Latin American countries, Brazil and Ecuador, two African countries, South Africa and Tanzania, and one Asian country, Bangladesh.

Table 1 presents the importance of the selected industries in these five countries, in terms of value added and employment. It underscores the importance of the food processing industry in all countries, but especially in Ecuador and Tanzania. In addition, it highlights the specialisation of Bangladesh in textiles and in the production of labour intensive garments. Among the five countries Brazil has a comparative advantage in the production of leather products and South Africa in other products than the four studies in this paper. In terms of GDP per capita Tanzania and Bangladesh are definitely poorer than the other three countries and are therefore classified in the group of the least developed countries.

The structure of the paper is as follows. Section two highlights some of the characteristics of the innovation process in the industries under study. Section three presents the econometric model. In section four, the data sources and the definition of the variables are discussed. The results of the analysis are discussed in section five. Section six concludes.

2. Characteristics of technology and technological change in the selected industries

Although an extensive literature review is beyond the scope of this paper, some important characteristics and driving forces of innovation and technological change in the three industries that are the object of this paper are worth highlighting.

The *agro-processing industry* covers a wide variety of activities, of which food processing is the most important one. In recent years, the complexity in the production and distribution of agro-processed products has increased, mainly because of the rising standards that govern international trade in food products. These include food safety standards - as expressed in sanitary and phyto-sanitary (SPS) measures implemented by the WTO - but also a variety of standards regarding environmental and social aspects. Countries can use these quality standards strategically to position themselves in global markets (Jaffee and Henson, 2004). The role of the wider institutional context to deal with the consequences of standardisation becomes increasingly important. Individual firms need supporting infrastructure for product testing and certification. They need the support of business associations that develop standards in strategic sectors and spread knowledge and information on for instance packaging and transportation. Large firms develop backward linkages to control primary production and quality of inputs. The importance of the inter-linkages among different actors for the creation and transmission of knowledge is stressed in the innovation systems approach (Hall, Mytelka and Oyelaran-Oyeyinka, 2006), which puts into perspective the role played and the limited success experienced by traditional agricultural research institutes. For the individual firm, the quality of the management is a key factor to source and assimilate

information on market requirements and to manage a variety of relationships and linkages (Jaffee and Henson, 2004). Gehl Sampath (2007) illustrates these issues for the agro-processing industry in Bangladesh. Large firms secure the supply of agricultural inputs through contractual arrangements with growers. Small firms are not involved in production and suffer from unreliable supply due to a lack of efficient channels of collaboration between farmers and agro-processors. In addition, their major concern is quality. They call for an expanded mandate of their Bangladesh Agro-processors Association, in order to have better provision of testing, grading and packaging services, improved access to information on international markets and improved technologies. Their exports are constrained by SPS measures, as they cannot control the amount of fertilizers and other farm-level inputs that need to be declared in certification procedures.

While textiles and clothing industries are often studied together, they cover firms with different activities and production technologies that face their particular challenges. Audet (2004 and 2007) gives an excellent overview of the driving factors underlying competitiveness in the textiles and garments value chain in the light of adjustments following the end of the Agreement on Textiles and Clothing (ATC). He describes *textile firms* as relatively capital-intensive, producing textiles for both clothing and non-clothing applications like car seats. Innovations in textiles machinery have significantly increased the speed of operations and have resulted in significant productivity gains. The use of modern machinery – mainly imported from Germany, Italy, Japan or Switzerland (Audet, 2004) – stands out as crucial (Navaretti et al., 2004, Gruber, 1998, Gehl Sampath, 2007, for Bangladesh). In Asian LDCs this imported machinery is often relocated after use in other Asian countries (Rasiah, 2007). Innovation in the chemical industry is equally important for the development of new textiles in non-natural fibre and for the improvement of its quality. The ability of firms to adopt these new products and processes is crucial for their productivity.

On the contrary, the *garments or clothing industry* is low-skilled labour intensive, especially in the garments assembly stage. This involves the delicate handling and sewing of the garment components. The pre-assembly stage, however, involves design and marking of patterns as well as cutting of textile components requiring advanced design skills and the ability to use CAD/CAM methods (Audet, 2004). International specialisation and division of labour in the ATC period resulted in low wage countries such as Bangladesh or Kenya being involved in the assembly stage, with pre-assembly stages and retailing activities located in developed countries (McCormick, 2001). Large retailers and brand marketers from developed countries got actively involved in garments manufacturing by sourcing from several low wage countries through licensing arrangements and subcontracting. In doing so, they exerted substantial influence on the technical skills of local garment producers, by imposing quality standards and working conditions (Gehl Sampath, 2007) and instructing them on fashion-related preferences and market trends. The acquisition of design skills and market-related knowledge and the ability to establish forward linkages into distribution channels have become even more important in the post ATC period, in which China emerged as an increasingly fierce competitor (Rasiah, 2007). In Bangladesh, firms continue to lack design capabilities and buy designs from Indian designers or follow buyer specifications (Gehl Sampath, 2007). Several studies focus on industrial garments clusters and illustrate the success and failure of cluster firms to develop these design and marketing capacities (eg. for Colombia, Pietrobelli and Barrera, 2002; for Mexico, Bair and Gereffi, 2001; for Kenya, McCormick, 2001; for Peru, Visser, 1999; for Brazil, Schmitz, 1999).

Several authors stress other non-price and institutional factors such as the time factor (Tewari, 2006). Turnaround times in fashion sensitive consumer markets are very short and the ability to deliver a variety of goods in time is equally crucial. This however does not depend only on the individual firm, but especially on transit time for shipments, the efficiency of port infrastructure and customs services (Audet, 2004, Rasiah, 2007, Gehl Sampath, 2007). Countries with quality textile producers able to supply domestic garments producers – more integrated suppliers such as China – are therefore likely to have a time advantage over countries that have to source textiles from abroad.

Leather products is an interesting industry for many developing countries that are endowed with abundant livestock and the share of developing countries in leather products production and trade has increased, at the expense of the activities in developed economies (Muchie, 2000). The technological requirements facing the leather products industry in developing countries are very similar to those in the garments industry, given that they produce goods for an equally fashion-oriented end consumer market. Sourcing companies and agents similarly exert strong influence in the entire supply chain, including design, product specifications, the production process and the implementation of quality systems (UNIDO, 2004). In addition, apart from the product specifications and sensitivity to brand names, consumers raise their concerns regarding environmental and social aspects of the production process, especially in tannery. Tannery businesses, to qualify for ISO 14000 certification, need to take into consideration a wide perspective of environmental issues. Establishing linkages, forming market alliances, developing design skills and marketing (branding) capacities are mechanisms businesses use to upgrade themselves in the value chain.

It is against this competitive setting and institutional background that individual firms take decisions regarding design, skills development, technology licensing, establishment of linkages etc, in order to improve their competitive position. In what follows, we will investigate the effect and relative importance of these activities on productivity.

3. Econometric model

To analyze the effects of technological activities on firm level productivity we estimate a production function in which firms' value added Y_i is a function of the traditional factors of production, physical capital K_i and labour L_i , and of total factor productivity $A(\cdot)$, that is itself determined by a set of variables Z_i , capturing possible sources of technological capabilities, and a set of variables I_i , representing the influence of institutional variables. We assume a non-constant returns to scale Cobb-Douglas functional form for the production function the following specification

$$Y_i = A(Z_i, I_i) K_i^\alpha L_i^\beta e^{\varepsilon_i} \quad (1)$$

in which α and β denote the elasticities of output with respect to physical capital and labour, respectively. Constant returns to scale occur if $\alpha + \beta = 1$, which will be tested empirically. The stochastic term ε_i summarizes unobserved factors affecting firms output.

Rewriting this equation in terms of labour productivity and taking the logarithmic form, equation (1) becomes:

$$\ln(Y_i / L_i) = \ln A(Z_i, I_i) + \alpha \ln(K_i / L_i) + (\alpha + \beta - 1) \ln L_i + \varepsilon_i \quad (2)$$

where the coefficient of $\ln L_i$ measures the deviation from constant returns to scale.

We want to control for a certain number of additional effects. First, we want to control for differences across firms in capacity utilization. Indeed, when firms operate at higher capacity, they are able to produce more with the same amount of inputs. Part of total factor productivity (TFP) can therefore be ascribed to capacity utilization. We therefore introduce a variable u_i measuring capacity utilization, the coefficient of which γ is expected to be positive. Second, country dummy variables D_{ij} are introduced to pick up country-specific effects such as government policies and unobserved institutional factors. The estimating equation now becomes:

$$\ln(Y_i / L_i) = \sum_{j=1}^{n-1} \delta_j D_{ij} + \ln A(Z_i, I_i) + \alpha \ln(K_i / L_i) + (\alpha + \beta - 1) \ln L_i + \gamma u_i + \varepsilon_i \quad (3)$$

where D_{ij} are country dummy variables and I is a vector of institutional control variables.

We also want to test whether the technology variables have the same impact at different levels of development. We therefore interact the technological variables with a binary variable for firms active in LDC countries (in this case Bangladesh and Tanzania) in the following way:

$$\ln(Y_i / L_i) = \sum_{j=1}^{n-1} \delta_j D_{ij} + \ln A(Z_i, Z_i * LDC_i, I_i, I_i * LDC_i) + \alpha \ln(K_i / L_i) + (\alpha + \beta - 1) \ln L_i + \gamma u_i + \varepsilon_i \quad (4)$$

This equation is estimated using OLS, estimating the mean effects of explanatory variables on log value added per employee. To control for the effect of outliers the estimation is also done using least absolute deviations (LAD). Additionally, a weighted OLS is also performed, to control for the unequal size of the samples in the different countries.

Several remarks need to be made to interpret the coefficients. To the extent that technological variables are correlated with productivity, a simultaneity bias may exist in the estimated coefficients. Ideally the use of panel data would help avoiding this problem of simultaneity bias. The data available are cross section data (see next section), hence we have no straightforward solutions to this problem. Multicollinearity problems may arise as more technology variables are added to the equation. It is likely for instance that firms that invest in imported machinery systematically engage in the training of workers to use these new machines.

4. Data sources and definition of the variables

4.1 Data

The data used in the analysis are retrieved from the World Bank Investment Climate Surveys (ICS). The ICS is an important effort coordinated by the World Bank to collect harmonised micro data in developing and least developed countries. By intensive face-to-face interviews, firms are surveyed on conduct and performance as well as their perception on several aspects related to the business environment. The resulting ICS is a rich data set gathering plant-level information helping to understand how technological conditions and institutional constraints affect the operations and performance of firms. The survey questionnaire contains a series of questions on firms' behaviour, their position on finance, factor and output markets accompanied by information on infrastructure, regulation, international trade, innovation and learning as perceived by the firm. To benchmark firms' performance, variables such as sales are included which allow calculating value added and productivity, respectively.

The uniqueness of the ICS lies in the fact that all countries use questionnaires with a set of harmonised core variables that facilitate cross country comparisons. This provides an advantage over typical innovation surveys that have been started to being conducted in several developing countries, following the example of the Community Innovation Surveys (CIS) coordinated by EUROSTAT. While these innovation surveys are focused on technological aspects and innovative activities, including sources of information, collaboration, obstacles to innovation etc., in developing countries they have been tailored to the country-specific needs to such an extent that cross-country comparisons have become difficult and sometimes hardly possible.

For the analysis we used the individual country ICS data sets for Brazil, Ecuador, South Africa, Tanzania and Bangladesh. In the different countries, firms were selected on the basis of a stratified random sample. The strata were defined by industry classification, firm size classes and regional location. Due to the different levels of economic development and size of the economies, the number of firms in the samples varies considerably across countries. Table 2 gives an overview of the number of firms in the sample¹, by country and industry, and includes the number of exporting and foreign owned firms. The largest number of firms is found in the Brazilian sample, the smallest number in the Tanzanian sample. In line with their economic activity, Brazil and Bangladesh have a relatively larger number of firms in the garments and leather industry. In Ecuador, South Africa and Tanzania, it is the food and beverages industry that contains the largest number of firms. The percentage of foreign owned firms rarely exceeds 10%, but the percentage of exporters among the sampled firms is close to 40% on average.

4.2 Variable definitions

In line with the model developed in section three, the dependent variable is LABOUR PRODUCTIVITY, measured by the value added per employee, in logarithmic terms. Value

¹ Due to item non-response on variables crucial for the analysis, a number of observations had to be excluded from the data set, reducing the number of firms to the numbers shown in table 2.

added was calculated as the value of total sales minus material purchases and costs of fuel and electricity. All values are for the final year covered by the survey, mostly 2002².

The traditional explanatory variables for labour productivity are the capital intensity, the CAPITAL/LABOUR ratio (in logs), and the degree of returns to scale measured by the coefficient of LABOUR (in logs). Capital is measured as the firm's end-of-period capital stock. Labour input is measured by the total number of employees in 2002, which is the sum of permanent workers and the average number of temporary workers employed in 2002.

Firms can choose different ways to increase technological capabilities in the production of goods. One way is to adopt technology from foreign sources. Firms can source technology from abroad through established ownership linkages that facilitate transfer of knowledge or organizational capabilities. A dummy variable FOREIGN indicating whether the firm has a positive share of foreign ownership captures this effect. Alternatively firms can directly make use of external technology through licensing agreements with other firms. The dummy variable LICENSE marks whether technology has been licensed from a foreign company. Firms can also introduce innovations by importing new vintage machinery for more efficient production. The dummy variable IMPMAC is therefore included indicating if the firm has imported new machinery in the period 2000-2002.³

Firms conduct R&D for two reasons: as an alternative to imported technology and as a way to build up absorptive capacity to benefit from outside R&D (Cohen and Levinthal, 1989). RD is a binary variable indicating whether a firm was engaged in in-house R&D and design activities. Notice that R&D here includes design as opposed to the narrower definition of R&D from the Frascati manual. To efficiently convert research results into marketable products and to absorb external market information the quality of management is crucial. EDUCGM is a dummy variable for managers with higher education.

R&D, education of the management, licensing, foreign ownership and investment in embodied knowledge are the key sources of technological capacity that we selected. Much more information was available, though, such as dummies for product and process R&D, a dummy for training and the percentage of skilled labor in total personnel. Inclusion of too many of the innovation variables results in collinearity problems inflating standard errors and thereby reducing the statistical significance of the explanatory variables. Many of the innovation activities are indeed simultaneously undertaken. The output measures of innovation as well as training and the percentage of skilled labor were insignificant in various experiments and were therefore dropped from our specification.

² Values are for fiscal year 2002 in Brazil and Tanzania, for calendar year 2002 in Ecuador and South Africa, and for fiscal year 2002 or calendar year 2001 in Bangladesh.

³ It should be noted that the only information we had for Ecuador was the firms total investment, not specifically the imported part of it. Because of this difference in measurement for Ecuador, the dummy IMPMAC was split into two dummies: ECUIMPMAC, equalling one if the Ecuadorian firm invested, and NECUIMPMAC equal to one if firms in Brazil, Tanzania, Bangladesh or South Africa invested in imported machinery and equipment.

Two variables were introduced to control for the institutional environment that firms operate in. In many least developed countries, financial markets are characterized by important failures to obtain credit to finance business operations. The dummy variable CREDIT captures the benefit of having an overdraft facility with a bank or financial institution that allows flexible access to short-term credit. Firms were also asked to indicate the proportion of senior management's time that is spent in dealing with requirements imposed by government regulations such as completing forms, dealing with officials etc. REGULTIME thus takes a value between zero and one. Being member of a business association, which we found to be significant for all Tanzanian firms in Goedhuys et al (2006), turned out to be insignificant in the cross-country industry specific regressions.

Table 3 presents some summary statistics, by industry and country, for the variables used in the regression. Monetary values are transformed into US-dollars taking exchange rates for end of December 2002.⁴ On average, both economic variables and variables capturing technological capabilities vary considerably between industries and countries, reflecting differences in technology and in the state of development.

Value added per employee as well as capital stock per employee is the lowest in the labour intensive garments and leather industries. In the least developed countries, Tanzania and Bangladesh, value added per employee is lower than in the other countries. This does not hold for capital intensity, which is relatively high in Tanzania where capacity utilization is relatively low. Average firm size in terms of employment is the highest in South Africa and in the garments and leather industry in Tanzania.

Heterogeneity across firms is even more reflected in the variables reflecting firm and country strategies of technology sourcing and competence building. The least developed countries show a considerably lower level of R&D activities with the exception of garments and leather industries in Bangladesh. As mentioned above, R&D as measured in the ICS includes design, which is especially crucial for the Bangladesh and Ecuadorian export markets in clothing. In South Africa, R&D activities are more pervasive than in the other countries. Education of the general management is on average the highest in South Africa and Ecuador and in the garments and leather industries in Bangladesh. The high level of education of management in the Bangladesh garments and leather industries underscores again the importance of this export-oriented industry for Bangladesh. The strategies of acquiring new technology from sources external to the country, i.e. either licensing or buying imported machinery incorporating new technology, are often complementary.⁵ With respect to licensing Brazil and Bangladesh are lagging behind the other countries.

⁴ Exchange rates for Brazil and South Africa are taken from the World Bank Online Exchange Rate Statistics (see <http://www.imf.org/external/data.htm>), for Tanzania from the Bank of Tanzania website (see <http://www.bot-tz.org/Archive/Default.asp#CurrencyExchangeRates>) and for Bangladesh from the appendix to the Bangladesh Bank annual report 2005-2006 (see <http://www.bangladesh-bank.org/pub/annual/anreport/ar0506/app21.pdf>). Because of the dollarization of the economy Ecuadorian figures are already expressed in US-dollars.

⁵ For imported machinery, the values of Ecuador are not directly comparable to the other countries due to differences in measurement. The differences are accounted for in the estimation procedure.

Perceptions regarding the institutional environment are also heterogeneous across countries. As expected, financial markets are less developed in the least developed countries, especially in Tanzania, where the majority of firms do not have access to credit loans.⁶ Institutional failures in regulation are the highest in Tanzania and the lowest in Bangladesh and South Africa.

5. Relative importance of different sources of technological capabilities

Because of differences across industries, we have decided to estimate the Cobb-Douglas specification separately for each industry but to pool the data from the five countries. Table 4 presents the results obtained with specification (4), where differences in TFP are explained by sources of technology, controlling for access to credit and regulatory burden. In the second column for each country we also allow some of these effects to be different for the two LDC countries. The reference group is formed by Brazilian firms.

We find an elasticity of output with respect to capital stock of 0.29 in food processing and leather and garments and of 0.26 in textiles. The hypothesis of constant returns to scale cannot be rejected in all three sectors. Returns to scale is therefore not an explanation for differences in TFP levels. Productivity increases with capacity utilization, but a statistically significant effect is obtained only for food processing, where if capacity utilisation increases by one percentage point, productivity increases by 0.87 percent.

The country dummies indicate significant country differences in TFP in all three sectors. The LDC countries Tanzania and Bangladesh have the lowest level of country-specific TFP effects in all three industries. South Africa scores best in food processing. It remains an open question whether these country specificities are due to lower levels of technological activity, or to other country-specific influences that we cannot observe directly from the data. Especially country specific measurement errors in the variables, like differences in the evaluation of the capital stock or imperfect exchange rates, can show up in the country dummies.

Conducting in-house R&D activities appears to be important for TFP in the textiles and garments industries. In textiles, the coefficient is highest and statistically significant at the 1% level, indicating that R&D performing firms have, all other things equal, a 40 percent higher TFP level. In garments and leather products the R&D variable most probably reflects design activities, and doing so raises TFP by 12 percent. In food production, even though a sizeable proportion of firms declare to conduct R&D, doing so does not lead to any statistically significant differences. Although these findings are somewhat counter-intuitive, given that the knowledge intensity of food production is equally high as in textiles and garments, it may

⁶ The relatively low share of firms having access to credit in the South African textile industry should be taken carefully considering the small number firms in this strata. The same holds for the regulation aspect in the Tanzanian garments and leather industry.

support the idea that information on market requirements outweighs the value of laboratory research, and that the role of other agents and support institutions and the ability to interact with them is of greater importance for productivity in the food industry.

This ability is approximated by the quality of management measured by their higher level of formal education. In the food processing industry, it is indeed significant at the 1% level and raises TFP there by 50%. In garments and leather products it raises productivity by 25%. The importance of managerial quality thus seems especially high in industries in which firms need to establish solid forward linkages and capture a variety of market signals with increasing competitive pressures on their product market.

Licensing arrangements with foreign firms is important for garments and leather product producers. Licensing arrangements allow licensee firms to acquire fashion-oriented product designs externally and facilitated market access when licensors source their products directly from them. For textiles and food processing, licensing arrangements do not seem to produce any significant effect on productivity.

In textiles, it is the import of new machinery and equipment that shows up as a major productivity determinant. This observation is fully in line with other studies that mention that productivity gains in textiles have resulted from process innovations improving the speed of operations in textile firms through the introduction of superior spinning and weaving machinery. Unfortunately, for the Ecuadorian firms, this identical information was missing. The proxy variable total investment does not show up significantly in Ecuador.

Foreign owned firms appear to have significantly higher levels of TFP in food processing. Foreign controlled firms have on average TFP levels that are 62 percent higher. No such difference due to foreign ownership shows up in the other industries.

The institutional variable REGULTIME has the expected sign and is statistically significant in textiles and garments: more senior management's time wasted on regulatory matters depresses TFP. The coefficients indicate that a one percentage point increase in the proportion of time spent dealing with regulatory requirements depresses productivity by 1 percent. This means that a 10 percent increase, such as the difference between South Africa and Bangladesh where the average time spent is 14 and 4 percent respectively, depresses TFP by 10 percent, an effect that is comparable with that of doing or not doing R&D and design activities in that industry. Access to flexible forms of credit (CREDIT) also allows firms to be more productive. The effect is high and statistically significant in food processing and garments and leather products, raising TFP by 23 and 20 percent respectively.

In addition, we investigated whether there were differences between LDCs and more advanced developing countries. This was done by interacting the explanatory variables with a dummy variable LDC. For some technology variables, no differential impact on productivity was observed for LDCs versus the other developing countries, i.e. for licensing (LICENSE), foreign ownership (FOREIGN) and imported machinery (IMPMAC). These interaction terms were therefore dropped for the final estimation. The results indicate that the impact of R&D on TFP is weaker in LDC countries, especially in garments and leather products where the coefficient is negative and significant at the 5 % level. Its negative value outweighs the positive coefficient of RD, implying that the net effect of R&D and design activities in LDC countries is at best nihil. The interaction of CREDIT with LDC indicates that in the capital-

intensive textiles industry access to finance is especially crucial in the two LDC countries, where financial markets are less developed.

A few checks were conducted to test the robustness of the empirical results. We investigated whether our results were affected by the fact that our country samples were unbalanced. The number of firms from Bangladesh and Brazil for instance were much larger than from South Africa and Tanzania. We therefore did a weighted regression, in which each country is given equal weight in the regression, i.e. firms from countries with many observations were down-weighted while firms from countries with small samples were given higher weight. This estimation did not produce any results significantly different from OLS. To check for the effect of heterogeneity and especially of potential outliers we estimated the median impact using the Least Absolute Deviation (LAD) estimator. LAD estimators give results for the median in contrast to the mean firm. Once again, the estimation results were very much in line with the OLS results and allowed concluding that the OLS estimation results were robust. Both results can be found in table A1 and A2 in the appendix.

6. Conclusion

This paper has used firm data from the Investment Climate Surveys of the World Bank to assess the relative importance of various sources of technological ability in three low-tech industries (food and beverages, textiles, and garments and leather products) and five countries (Brazil, Ecuador, South Africa, Tanzania and Bangladesh), the first three being considered as developing and the last two as LDC countries. In the food processing industry the two significant sources of technological capabilities are the higher education of the managers and foreign ownership. In the textiles industry it is own R&D and imported capital, and in the manufacturing of garments and leather products it is the higher education of managers, own R&D and licensing from abroad. Institutional variables can also affect productivity. In the leather and garments industry, easy access to bank credit boosts productivity whereas time spent on meeting regulatory matters retards TFP. When comparing the effects of technology sources on LDC and developing countries, we find a significant difference only in leather and garments, where R&D and design display practically no rate of return in the LDC countries compared to a solid 12 % in developing countries. The results obtained are robust to alternative estimation methods.

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Table 1.: Country statistics and the importance of selected industries

	<i>Developing countries</i>			<i>LDC countries</i>	
	Brazil	Ecuador	South Africa	Tanzania	Bangladesh
GDP/Capita (in constant 1995 US\$) ^{a.}	4642	1796	4020	207	396
Population (in millions) ^{a.}	174	13	45	35	135
Manufacturing Value Added (% of GDP) ^{a.}	13	11	19	8	16
<i>Food and Beverages</i>					
% of MVA in GDP ^{b.}	16.9	31.9	16.7	32.5	9.8
% of employment in man ^{b.}	20.9	45.0	15.2	34.4	6.8
RCA in fresh food ^{c.}	3.88	8.96	2.25	19.56	1.44
RCA in processed food ^{c.}	3.11	2.65	0.97	0.74	n.a.
<i>Textiles</i>					
% of MVA in GDP ^{b.}	2.3	2.0	1.7	n.a.	13.1
% of employment in man ^{b.}	5.0	6.0	4.9	25.8 *	29.9
RCA ^{c.}	0.55	0.29	0.28	0.30	2.56
<i>Garments</i>					
% of MVA in GDP ^{b.}	1.4	0.9	2.1	n.a.	19.3
% of employment in man ^{b.}	7.8	4.8	7.1	1.5 *	47.0
RCA ^{c.}	n.a.	0.12	0.66	0.21	22.95
<i>Leather products</i>					
% of MVA in GDP ^{b.}	2.1	0.4	0.7	n.a.	8.0
% of employment in man ^{b.}	7.3	2.0	1.6	2.9	2.3
RCA ^{c.}	3.09	n.a.	0.41	0.39	2.95

Sources: a. World Development Indicators, 2004 (values are for 2002); b. UNIDO Industrial Statistics, data are for 2004 for Brazil, Ecuador, South Africa, 1999 for Tanzania (1995 when indicated by *), 1998 for Bangladesh; c. International Trade Centre, based on COMTRADE data, 2002.

Note: n.a. means not available from the mentioned source; MVA = manufacturing value added; man = manufacturing; RCA (revealed comparative advantage) values are only calculated for important export product categories.

Table 2: Composition of the sample: total number of firms, number of exporting firms and number of foreign owned firms, by industry and country

	Food and beverages			Textiles			Garments and leather products		
	Total	Exporting	Foreign owned	Total	Exporting	Foreign owned	Total	Exporting	Foreign owned
Brazil	111	48	3	93	36	8	529	113	0
Ecuador	49	12	4	20	10	2	23	5	1
South Africa	36	15	4	12	9	3	25	17	3
Tanzania	61	24	12	7	4	4	10	4	2
Bangladesh	142	18	8	238	56	11	378	306	10
Total	399	117	31	370	115	28	965	445	16

Table 3 : Summary statistics

	<i>Ln(Value added/employee)</i> (2)	<i>Ln(Capital/Labour)</i> (3)	<i>Ln(Labor)</i> (4)	<i>Capacity utilization (CAPUT)</i> (5)	<i>RD activities</i> (6)	<i>EDUCG M</i> (7)	<i>LICENCE from abroad</i> (8)	<i>Imported machinery (IMPMAC)</i> (9)	<i>CREDIT</i> (10)	<i>REGUL-TIME</i> (11)
FOOD & BEVERAGES										
Brazil	9.3 (1.2)	8.6 (1.8)	4.8 (1.4)	0.74 (0.21)	39.6	59.5	2.7	6.3	75.7	8.6 (11.7)
Ecuador	8.5 (1.4)	8.7 (1.5)	3.8 (1.4)	0.67 (0.23)	51.0	83.7	22.5	71.4	69.4	15.9 (13.4)
South Africa	9.9 (1.1)	8.6 (1.0)	5.0 (1.4)	0.77 (0.15)	61.1	83.3	16.7	38.9	83.3	8.3 (6.4)
Tanzania	8.2 (1.0)	9.0 (1.9)	4.0 (1.5)	0.57 (0.22)	14.8	70.5	21.3	29.5	36.1	17.1 (17.9)
Bangladesh	7.8 (1.3)	7.5 (1.7)	4.0 (1.4)	0.79 (0.17)	28.2	73.2	0.7	16.2	51.4	3.0 (3.1)
TEXTILES										
Brazil	9.6 (1.3)	8.8 (1.3)	4.3 (1.3)	0.77 (0.19)	43.0	60.1	5.4	30.1	78.5	10.1 (10.2)
Ecuador	9.0 (0.9)	8.7 (1.2)	4.0 (1.2)	0.63 (0.27)	40.0	80.0	10.0	85.0	75.0	11.6 (8.0)
South Africa	9.4 (0.6)	8.2 (1.4)	6.0 (1.5)	0.84 (0.14)	58.3	100.0	16.7	50.0	58.3	8.1 (4.7)
Tanzania	7.8 (0.8)	9.9 (1.2)	4.9 (1.3)	0.63 (0.24)	14.3	57.1	28.6	14.3	57.1	26.5 (27.1)
Bangladesh	7.7 (0.9)	7.9 (1.2)	5.3 (1.1)	0.78 (0.16)	35.3	63.8	2.9	39.1	75.6	4.5 (5.4)
GARMENTS & LEATHER										
Brazil	8.3 (1.1)	7.0 (1.4)	3.9 (1.0)	0.75 (0.16)	46.5	40.6	5.3	15.5	73.2	6.7 (6.8)
Ecuador	8.7 (1.7)	7.7 (1.4)	3.7 (0.8)	0.64 (0.25)	56.5	78.3	8.7	73.9	78.3	15.8 (21.6)
South Africa	8.9 (1.0)	7.8 (1.6)	5.5 (1.4)	0.83 (0.15)	44.0	84.0	16.0	36.0	84.0	14.2 (16.6)
Tanzania	6.8 (1.5)	7.8 (2.2)	3.3 (1.6)	0.56 (0.24)	20.0	40.0	20.0	30.0	30.0	10.7 (15.5)
Bangladesh	7.6 (0.8)	6.6 (1.5)	5.5 (1.0)	0.77 (0.18)	45.8	89.2	2.7	52.4	64.0	4.2 (3.9)

Note: columns 6 to 9 present proportions of firms for which the variable takes the value one; column 2 to 5 and 11 present mean values with standard deviations in parentheses. See section 4 for more details on the variables.

Table 4: OLS estimation results with technological and institutional variables

	food	food	textiles	textiles	garm&leath	garm&leath
lkl02	0.293***	0.294***	0.245***	0.238***	0.295***	0.290***
	(0.037)	(0.037)	(0.045)	(0.043)	(0.026)	(0.026)
ltl02	0.005	0.000	-0.008	-0.017	0.016	0.013
	(0.047)	(0.046)	(0.042)	(0.040)	(0.033)	(0.033)
caput	0.877***	0.911***	0.401	0.483	0.442**	0.455**
	(0.267)	(0.272)	(0.371)	(0.338)	(0.185)	(0.186)
ecua	-1.392***	-1.387***	-0.234	-0.051	1.372	1.390
	(0.375)	(0.385)	(0.237)	(0.214)	(1.160)	(1.179)
safr	0.224	0.230	-0.229	-0.381*	0.094	0.066
	(0.198)	(0.206)	(0.186)	(0.213)	(0.216)	(0.219)
tanz	-1.118***	-1.335***	-1.673***	-1.985***	-1.687***	-1.319***
	(0.181)	(0.328)	(0.439)	(0.700)	(0.247)	(0.287)
bang	-1.279***	-1.434***	-1.681***	-2.112***	-0.790***	-0.299
	(0.158)	(0.313)	(0.145)	(0.483)	(0.100)	(0.187)
rd	0.109	0.208	0.393***	0.451**	0.115*	0.221**
	(0.124)	(0.173)	(0.089)	(0.176)	(0.061)	(0.087)
ldcrd		-0.242		-0.079		-0.288**
		(0.236)		(0.202)		(0.113)
Educgm	0.497***	0.494***	-0.022	0.121	0.246***	0.289***
	(0.124)	(0.181)	(0.098)	(0.233)	(0.080)	(0.097)
ldceducgm		-0.027		-0.152		-0.245
		(0.243)		(0.253)		(0.166)
licence	0.302	0.277	0.101	0.076	0.333***	0.321**
	(0.246)	(0.248)	(0.274)	(0.269)	(0.126)	(0.127)
necuimpmac	0.202	0.174	0.327***	0.304***	0.012	0.015
	(0.155)	(0.155)	(0.110)	(0.114)	(0.067)	(0.067)
ecuimpmac	0.684	0.682	-0.162	-0.416	-1.632	-1.705
	(0.429)	(0.432)	(0.263)	(0.291)	(1.167)	(1.185)
foreign	0.624***	0.602**	0.104	0.129	0.349	0.387
	(0.231)	(0.232)	(0.215)	(0.218)	(0.240)	(0.251)
regultime	-0.007	-0.010*	-0.010*	-0.010	-0.010**	-0.009*
	(0.005)	(0.006)	(0.006)	(0.009)	(0.004)	(0.005)
ldcregultime		0.009		-0.003		-0.011
		(0.008)		(0.011)		(0.010)
credit	0.229*	0.052	0.017	-0.487	0.198***	0.247**
	(0.133)	(0.215)	(0.142)	(0.328)	(0.067)	(0.101)
ldccredit		0.316		0.744**		-0.163
		(0.248)		(0.346)		(0.131)
Constant	5.601***	5.716***	6.947***	7.267***	5.627***	5.558***
	(0.407)	(0.434)	(0.492)	(0.635)	(0.274)	(0.277)
Observations	389	389	365	365	956	956
R-squared	0.49	0.50	0.54	0.55	0.34	0.35

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

APPENDIX

Table A1: Results of the LAD estimation

	food	textiles	garm&leath
lkl02	0.290***	0.238***	0.286***
	(0.050)	(0.045)	(0.024)
ltl02	0.007	-0.008	-0.009
	(0.052)	(0.051)	(0.040)
bang	-1.400***	-1.891***	-0.231
	(0.475)	(0.381)	(0.193)
ecua	-0.833	-0.208	0.714
	(0.549)	(0.367)	(0.983)
safr	0.425**	-0.142	0.202
	(0.201)	(0.255)	(0.227)
tanz	-1.578***	-1.525*	-1.593***
	(0.509)	(0.845)	(0.522)
caput	0.892**	0.417	0.292
	(0.350)	(0.305)	(0.242)
rd	0.157	0.506***	0.387***
	(0.208)	(0.175)	(0.102)
ldcrd	-0.331	-0.083	-0.448***
	(0.323)	(0.220)	(0.140)
Educgm	0.348	-0.046	0.206**
	(0.221)	(0.218)	(0.100)
ldceducgm	-0.145	0.079	-0.248
	(0.348)	(0.245)	(0.176)
licence	0.301	0.065	0.216
	(0.284)	(0.454)	(0.177)
necuimpmac	0.349**	0.286**	0.026
	(0.174)	(0.115)	(0.073)
ecuimpmac	0.610	-0.050	-0.910
	(0.612)	(0.452)	(1.042)
foreign	0.451	0.172	0.490
	(0.304)	(0.342)	(0.494)
regultime	-0.010	-0.006	-0.012**
	(0.008)	(0.010)	(0.006)
ldcregultime	0.020	-0.008	0.004
	(0.013)	(0.014)	(0.014)
credit	-0.209	-0.225	0.301***
	(0.345)	(0.242)	(0.101)
ldccredit	0.341	0.458	-0.255*
	(0.379)	(0.278)	(0.137)
Constant	6.006***	6.994***	5.723***
	(0.599)	(0.538)	(0.327)
Observations	389	365	956

Standard errors in parentheses ; * significant at 10%; ** significant at 5%; *** significant at 1%

Table A2: Results of the weighted regression

	food	textiles	garm&leath
lkl02	0.290***	0.243***	0.301***
	(0.040)	(0.041)	(0.029)
ltl02	-0.005	-0.002	0.032
	(0.053)	(0.039)	(0.035)
bang	-1.320***	-2.199***	-0.234
	(0.365)	(0.601)	(0.201)
ecua	-1.449***	0.007	1.343
	(0.398)	(0.228)	(1.184)
safr	0.289	-0.420*	0.018
	(0.211)	(0.252)	(0.227)
tanz	-1.224***	-2.016***	-1.217***
	(0.371)	(0.753)	(0.317)
caput	0.757**	0.652**	0.445**
	(0.318)	(0.303)	(0.192)
rd	0.330*	0.497**	0.217**
	(0.198)	(0.215)	(0.091)
ldcrd	-0.363	-0.127	-0.301**
	(0.246)	(0.238)	(0.117)
Educgm	0.524**	0.039	0.296***
	(0.218)	(0.245)	(0.092)
ldceducgm	-0.174	-0.062	-0.303*
	(0.271)	(0.259)	(0.167)
licence	0.226	0.026	0.302**
	(0.255)	(0.370)	(0.147)
necuimpmac	-0.046	0.349***	0.031
	(0.168)	(0.120)	(0.071)
ecuimpmac	0.696	-0.422	-1.697
	(0.438)	(0.320)	(1.198)
foreign	0.589**	0.200	0.081
	(0.268)	(0.276)	(0.303)
regultime	-0.010	-0.010	-0.003
	(0.008)	(0.010)	(0.005)
ldcregultime	0.009	-0.006	-0.013
	(0.009)	(0.012)	(0.011)
credit	-0.028	-0.545	0.261***
	(0.253)	(0.453)	(0.100)
ldccredit	0.404	0.806*	-0.181
	(0.261)	(0.465)	(0.132)
Constant	5.893***	7.081***	5.369***
	(0.497)	(0.736)	(0.291)
Observations	389	365	956
R-squared	0.49	0.50	0.33

Robust standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%