ISSN 1753-5816

School of Oriental and African Studies University of London

DEPARTMENT OF ECONOMICS
Working Papers

No.160

LINKING TECHNOLOGY DEVELOPMENT TO ENTERPRISE GROWTH:

EVIDENCE FROM THE MOZAMBICAN MANUFACTURING SECTOR

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September 2008

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http://www.soas.ac.uk/economics/research/workingpapers/

Linking technology development to Enterprise Growth: Evidence from the Mozambican manufacturing sector

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Draft Version of 5th August 2008

Abstract

This paper examines the relationship between firm-level technological development and enterprise performance in the Mozambican manufacturing sector. It does this on the basis of primary data collected for two industries – metalworking and light chemicals – and the triangulation of quantitative and qualitative information. Overall, the analysis presented in this paper only identifies a weak and, in some cases counterintuitive, association between levels of technological capability and innovation and enterprise performance. There are, however, some isolated exceptions to this finding, in which technology development has played a more decisive role in driving enterprise growth, such as the cluster of firms subcontracting work with the Mozal aluminium smelting plant. The case study of this cluster of firms allows the identification and illustration of conditions that might be required to facilitate a process of technology-led manufacturing growth.

Keywords: Technology change; Enterprise Performance; Industrial Policy; Sub-Saharan Africa; Mozambique.

1. Introduction

The notion that technology change drives industrial growth and economic development is deeply rooted in economic thinking and can be traced back the work of Smith, Marx and, Schumpeter, the latter often being cited in the literature as the precursor of studies of technological innovation, entrepreneurship and industrial development. Underlying this conceptualisation of capitalist development is the view that technology development, in its various forms, provides innovating firms with a competitive advantage that allows them to capture a greater share of the markets in which they operate, or enter new ones. The sudden loss of competitiveness of competitor firms provides them a stimulus for further technology development, triggering a process of cumulative technology development, market competition and industrial growth. Several channels provide this link between firm-level technology development and manufacturing growth. Product development leads to product differentiation, which typically enables firms to exercise market power and extract innovaion rents. Similarly, the use of inputs of improved quality increases product competitiveness and allows firms to enter higher, less price-elastic segments of the markets in which they operate, with the potential of increasing their revenues. On the other hand, the acquisition of new technologies embodied in new equipment, together with improvements in process-engineering and industrial organisation can lead to substantial technical efficiency gains, increasing

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productivity levels and industrial competitiveness. Finally, in-house efforts to improve skills and technological capabilities, and to adapt these to local or firm-specific circumstances can have a significant impact on firm-level technical efficiency and levels of productivity (Evenson and Westphal, 1995).

It is in this context, that this paper examines the role of firm-level technology development in shaping patterns of enterprise performance in the Mozambican metalworking and light-chemicals manufacturing sector. The underlying objective is to identify conditions under which the relationship the relationship between technology development and enterprise growth holds, including those relating to supply and demand conditions faced by industrial firms, and the policy or quasi-policy setting in which these enterprises operate.

The paper is organised as follows. Section two presents a brief review of the empirical literature examining the links between firm-level technology dynamics and enterprise performance, which special attention given to the technological capability framework. This is followed in section 3 with a linear regression exercise aimed at identifying factors associated to enterprise performance for firms operating in the Mozambican metalworking and light chemical sectors. The results of this analysis suggest that, on the whole, technology considerations play only a small role in directly shaping patterns of growth in these two sectors. Still, some indirect channels can be identified in this direction, highlighting the potential links that exist between technology development and enterprise growth. In particular, linkages with the Mozal aluminium smelting plant, appears as an important factor underlying manufacturing performance in these two sectors. Following these findings, the role of Mozal in triggering cumulative processes of technology development and enterprise growth in these sectors is examined in detail in section 4. This case study analysis finds that, despite important limitations, Mozal has provided the appropriate supply and demand conditions to promote technology development to subcontractor firms. In this respect, it is argued that Mozal's support and mode of operation with these firms presents many of the traits identified in recent industrial policy for development literature (Chang, 1995, Rodrik, 2004) likening this project to a quasi-policy environment for technology development and industrial growth.

2. The empirical analysis of technology development and enterprise growth

The theoretical propositions outlined above linking technology development and enterprise growth have been amply tested in the applied literature, with numerous studies examining the links between firm-level technology dynamics and industrial performance in both industrial and developing countries. These studies usually focus on a specific dimension of technology development to examine its association to firm or industry-level indicators of manufacturing performance, measured in terms of improvements in technical efficiency, enhanced export performance or growth in total factor productivity, labour productivity, sales or employment. Overall, this literature has tended to find a positive association between the different measures used to capture firm-level technology development efforts and manufacturing performance.

Part of this empirical literature has followed the methodology developed by Griliches (1998), Scherer (1982) and, more recently, Crepon *et al* (1998) to examine the links between R&D investments and firm-level productivity growth on the basis of micro-econometric estimations of structural models of R&D and enterprise performance.[1] This literature has largely focused on the case of firms and industrial sectors in OCCD countries, partly as a result of the scarcity of firm-level data and the lack of formal R&D activities by firms operating in developing economies. A significant exception has been the case of studies of the

[1] See Hall and Mairesse (2006) for a recent review of this literature.

Indian manufacturing industry (e.g. Ferrantino, 1992; Raut, 1992; Kumar and Siddharthan, 1994; Narayanan, 1997; Hasan, 2002; Hasan and Raturi, 2003; Kathuria, 2002; Katrak, 2002) and, to a lesser extent, that of Argentina (Chudnovski *et al*, 2006), Chile (Benavente, 2002), China (Hu *et al*, 2006) or Taiwan (Wang and Tsai, 2003).

Other studies, centred mostly on middle-income developing countries, have focused on the firm-level efficiency gains derived from importing foreign technologies –as embodied in manufacturing equipment, purchased through technology licenses or resulting from FDI flows– and the potential tradeoffs and complementarities that exist between foreign technologies and locally produced machinery and R&D efforts. Within this body of research, greater access to foreign technology has often been associated with firm-level productivity gains (e.g. Schor, 2004; Iacovone and Hoyos, 2006), in line with classical trade theory propositions on the dynamics gains associated to international trade. Moreover, in some cases, important complementarities may exist between foreign and locally developed technologies and R&D efforts (Hu *et al* 2006; Narayanan 1997). However, other authors have downplayed this positive impact of foreign technologies, at least when comparing them to the productivity gains derived from domestic R&D efforts (e.g. Katrak, 2002; Hasan, 2002; or Keller; 2001, 2000; for OECD economies); or have highlighted that complementarities between local and foreign technologies, and their effects on manufacturing performance are not uni-variant (Hasan and Raturi, 2003; Kathuria, 2002), in the sense that they tend to vary significantly across different firms and sectors.

Whilst this literature has provided valuable insights into this issues, its strong focus on R&D activities reduces its applicability to least developing economies. Hence, in these countries, a significant part, if not all, technological efforts by manufacturing firms take the form of acquisitions of foreign technologies, informal technology development activities or initiatives to improve technological capabilities in production that can ensure the effective and efficient use of foreign technologies. In this respect, the technology capabilities methodological framework developed by Sanjaya Lall and others (Lall, 1991, 1992) provides a more appropriate framework for the analysis of the links between technology development and manufacturing performance in the Mozambican manufacturing sector. Lall's technology capabilities framework defines spheres of technology development in the various areas of manufacturing production. It focuses in those areas that are considered relevant for these purposes, such as product development, process development or industrial engineering. Activities in these broadly defined spheres of manufacturing technology can then be identified and defined into a set of firm characteristics, relating to the different facets that technological activities take within the firm, and empirically tested using industrial survey data.

Several studies have followed this technology capabilities approach to examine technology and manufacturing development in least developed economies. Most of these studies finds a positive association between degrees of firm-level technology development – measured in terms of firms' skills, capabilities and technological efforts – and manufacturing performance, as captured by labour productivity and technical efficiency differentials, export performance or employment growth. For instance, Wignaraja (2002, 1999) examines technology and performance dynamics in Mauritian garment firms and Kenyan garment and metalworking sectors, using a composite technology index capturing different dimensions of technology capabilities and efforts, as well as other relevant variables (e.g. firm size, foreign ownership, skills). In both these studies, Wignaraja finds a considerably strong association between variables capturing degrees of firm-level technological development and manufacturing performance. Deraniyagala and Semboja (1999) obtain similar results for the Tanzanian metalworking sector using a similar composite technology index, with both firm-level skills and levels of technological activity statistically positively associated with growth in value added per worker and with inter-firm differences in export intensity. Deraniyagala (1999) reaches similar conclusions for the pooled analysis of employment growth and export performance of the Tanzanian, Kenyan and Zimbabwean metalworking and garments sectors. In a similar study of the Sri Lankan clothing and agricultural machinery industries Deraniyagala (2001a, 2001b) also finds a significant positive effect of technology accumulation and in-house strategies and efforts to adapt foreign technologies to local circumstances on firm-level technical efficiency. More recently, Rasiah (2004) has followed a similar approach to examine the incidence of technology capabilities and foreign ownership on inter-firm differences in export intensity and labour productivity performance in sectoral studies for Uganda, Kenya, Indonesia, Malaysia, the Philippines and Thailand, generally finding a positive association between these two groups of variables. Badhuri and Ray (2004) have also applied this technology capability framework to examine the potential impact of technological capabilities on export performance of firms pertaining to the Indian pharmaceutical and electrical/electronics sectors. Rather than using a single composite technology index, their analysis examines specific spheres of technology capabilities, finding that, whilst simple production engineering capabilities augment exports in both sectors, reverse engineering efforts are relevant only for exports in pharmaceuticals.

3. A regression approach to the analysis of technology development and enterprise performance

It is in this context, that this section undertakes an econometric analysis of the links between patterns of firm-level technology development in the Mozambican metalworking and light chemicals manufacturing sectors and enterprise performance in these two industries.

3.1. Specification of performance model[2]

The estimation of factors associated with enterprise performance is loosely based on a production function approach. The underlying idea is that firms' growth, proxied here as real sales' growth, can be accounted by the accumulation of the different production factors used in manufacturing. This conceptualisation is better illustrated by taking the basic expression of a Cobb-Douglas production function, such as the one represented in equation (1) below:

$$Q_t = Ae^{\lambda t}K_{t-1}^{\alpha}L_t^{\beta}e^{\varepsilon} \qquad (1)$$

Where '*Q*' is real output, '*K*' the stock of physical capital, 'e' the base of natural logarithms, '*L*' labour inputs and '*A*' a technology variable capturing contributions to output growth that cannot be solely accounted by the accumulation of any of the other factors of production. This measure of technology can, itself, then be expressed as a function of R&D investments, technology-upgrading efforts or improved skills, among others. The superscripts α and β capture the marginal contribution of each of these factors to firms' production, whilst their sum typically defines the nature of returns to scale in production. Finally, 'ε' encapsulates all unspecified determinants of output. Ideally this is a disturbance term, capturing random forces affecting production that are not accounted by factors of production that firms usually employ in manufacturing, such as temporary, non-systematic breakdowns of equipment, absentee workers or power cuts.

Taking logarithmic values, expression (1) can be rewritten as:

$$Log((Q_t) = log(A)+ \lambda t + \alpha log(K_{t-1})+ \beta log(L_t)+ \varepsilon_t \qquad (2)$$

[2] This section is largely based on CBO (2005).

And, again, by taking first differences, it can be further rearranged and approximated in the following fashion:

$$\Delta Qt / Q_{t-1} = \lambda + \alpha(\Delta K_{t-1}/K_{t-2}) + \beta(\Delta L_t/L_{t-1}) + \Delta\varepsilon t \qquad (3)$$

Which is essentially an expression of the relationship between the growth of factors of production, technology change (captured by λ) and the resulting growth in output over a given period of time. In this expression, the coefficients α and β capture output elasticities with respect to each of the factors of production under consideration. In an ideal scenario, with only these two factors of production used in production, '*K*' and '*L*', and no other systematic internal or external effect on production, this formulation can be seen as an accountancy relationship in which growth in output is explained by the accumulation of factors of production and improvements in efficiency, captured by the λ parameter.

Yet, other factors are likely to affect manufacturing production. The omission of these variables from the production function regression specification would entail that, in addition to random factors, the disturbance term would also be capturing more systematic forces shaping production, leading to problems of serial correlation in the estimation of this equation. To avoid this, the above expression is typically augmented to include other potential factors that are deemed to play a significant role in shaping rates of output growth and which cannot be strictly explained by the accumulation of capital and labour, or by efficiency gains. In this sense, most econometric studies extend the above production specification to incorporate other relevant factors, including intermediary inputs, skills, R&D or technological capabilities. Often, these studies also include other 'non-production' variables which contribute to explain differences in output growth across different firms or periods in time, including firm-identity traits (size, age, ownership) and, in macroeconomic growth models, the influence of geography, institutions, political features and other macroeconomic phenomena which might have a systematic effect on growth performance.

Taking this approach, the literature examining the impact of technology on firm-level performance has typically augmented the above production specification to include, among others, the differential impact of skills and technology development investments, following the seminal work by Lucas (1988), with regard to skills, and Griliches (1979), in relation to R&D efforts. In this perspective, equation (3) can be rewritten as follows:

$$\Delta Qt / Q_{t-1} = \alpha(\Delta K_{t-1}/K_{t-2}) + \beta(\Delta L_t/L_{t-1}) + \delta(\Delta R_{t-1}/R_{t-2}) + \gamma(\Delta H_t/H_{t-1}) + \Sigma\phi_i(\Delta Z_{it}/Z_{it-1}) + \Delta\varepsilon t \qquad (4)$$

Where R_t is a variable capturing investments in R&D, H_t a measurement of human capital and Z_{it} a vector of other variables entering the production function, for instance technological capabilities, levels of capacity utilization and other factors, internal or external, that have a differential impact on output growth across various firms. It is this latter production function model that inspires the econometric analysis of technology and manufacturing performance in the Mozambican light chemicals and metalworking sectors presented in this paper.

3.2. Regression Strategy and methodological considerations

The econometric exercise presented in this section is based on a linear regression analysis of the above production function specification. This exercise uses firm-level data collected during a survey of industrial firms undertaken during the first half of 2004, and which corresponds to events taking place between 1999 and 2003. This survey focused on firms employing ten or more workers operating in the Mozambican light chemical and metalworking industries in the capital province of Maputo, which accounts for around 70 percent of industrial production in Mozambique (RPED, 2003). The survey included a total of 90 firms, 56 in metalworking and 34 in light chemicals industries, representing 98.3 and 75.6 percent of the true population of firms operating in each of these industries within the sampling frame predefined for this study. The design and implementation of this survey was based on Sanjaya Lall's technology capability conceptual and methodological framework (Lall, 1992, 1993), and follows similar empirical work undertaken in Tanzania (Deraniyagala & Semboja, 1999), Kenya (Wignaraja & Ikiara, 1999), Mauritius (Wignaraja 2002) and, more recently, Uganda, Philippines, Malaysia, Indonesia and Thailand (Rasiah, 2004).

The analysis undertaken here focuses on a sub-sample of 74 firms that reported performance figures for the survey. Manufacturing performance is measured as firms' real growth in sales over the 1999-2003 period.[3] This choice follows similar work on firm growth, including that analysing the links between technology and enterprise performance (e.g. Katrak, 2002; Wignaraja and Ikiaira, 1999). Firm-level performance is regressed against a number of explanatory regressors, including various technology-related variables discussed in earlier research on this topic conducted by the author (Warren-Rodriguez, 2008a, b), as well as other variables identified in the economic literature analysing firm growth. In addition to the basic variables included in Equation (3), capturing accumulation of capital and labour factors of production, the explanatory variables under consideration include firm identity variables, such as firm size, age, the historical period when they were established, degree of foreign ownership, or whether they were ever state owned enterprises. Also variables capturing firm-specific production conditions, such as the degree of product integration, capacity utilisation rates or imputed equipment age. Finally, it includes various purposely constructed indices capturing skills, technological capabilities and technology development efforts, all which would appear as proxies of the human capital and R&D variables that appear in Equation (4) – H_t and R_t. Skills are measured in terms of both managerial and of a firm-wide skills levels. Technology capabilities and efforts, on the other hand, capture dynamics of this nature in the spheres of product development, production technology and industrial engineering and organisation development. Finally, the impact of technology development efforts in manufacturing performance is also tested separately three different dummy variables capturing firms' efforts to (1) introduce new products, (2) purchase new items of equipment; (3) incorporate new production technologies embodied in acquisitions of machinery and (4) participate in programmes to introduce ISO production standards.

Table 1: Variables considered in Logit analyses

Variables capturing firms' general traits

1. *SIZE*: Size of firm as captured by the number of full time workers employed by each firm.
2. *AGE*: Age of firm in 2004, since date it was firm established.
3. *FOROWN*: Proportion of foreign ownership in firms' shareholdings.
4. *COLONIAL, CENTRALPLAN, POST1987*: Dummy variables capturing the historical period in which firms were established: during colonial times, during the post independence period of central planning or since the adoption of the liberalisation agenda in 1987, respectively.
5. *SOE*: Dummy variable capturing whether firm was previously a state owned enterprise

Variables capturing "technological" traits and events

1. *MANSKILL*: Managerial skills index
2. *FIRMSKILL*: Firm wide skills index
3. Three measures of technology capabilities in production: product development capabilities (*PRODEVCAP)* production technology capabilities *(PRODTECHCAP)* and process/industrial engineering capabilities *(PROCESSCAP*)

[3] Real sales growth values were obtained by adjusting reported annual sales to their 1999 values, applying the deflators used by the Mozambican Institute of Statistics to calculate the value of manufacturing production.

4. *COOPERATION*: Technology cooperation index
5. Technology upgrading efforts in other areas of technology development: namely product development (PRODDEV), Production technology development (PRODTECHDEV), and Process/industrial engineering development (QUALDEV).
6. Technology development dummy variables *(see description in page 6, above)*

Variables capturing external conditions affecting firms

1. *CONTINUOUS*: Whether firm produces on continuous or on a made-to-order basis
2. *SECTOR*: Dummy variable on whether firm operates in metalworking or light chemicals.
3. Dummy variables for the main markets served by sample firms, namely: Construction, Industry, Transport, Agriculture, Services, State contracts, MOZAL and the Exports sector.
4. NBFIRMSIND: degree of competition, as captured by the number of firms operating in each sub-sector, namely: Metalo-mechanic, aluminium products, zinc sheets, other metalworking, plastics products, mixed chemicals, rubber products, chemical gases

The estimation procedure consists of an OLS backward, general-to-specific estimation of the above equation, aimed at obtaining a regression specification that maximises the goodness of fit of the estimated model. This estimation procedure involves an iterative process that starts by estimating the model specification that includes all potential explanatory variables. This model is then narrowed down by eliminating those variables with highest *p*-values, and then proceeding to re-estimate a reduced version of the model. This process continues to a point in which only variables with coefficients presenting a significance level below a certain threshold – established here at $\alpha = 0.10$ – are included, whilst also ensuring that standard diagnostic tests reject the presence of heteroskedasticity, serial autocorrelation, problems of functional form and non-normality. This estimation process also ensures that the elimination of non-significant regressors is compatible with ensuring the highest explanatory power and fit of the chosen model, as captured by the adjusted R^2 value and the F-test of overall model fit. It is important to stress that the analysis presented here is essentially of an exploratory nature, given potential problems arising from using small samples and the fact that there is no clear structural model underlying this estimation exercise. Therefore it should be seen as a process of identifying variables associated with firm-level performance, including those of a technological nature, rather than a strict analysis of determination and causality of sample firms' manufacturing performance. In this respect, the estimation procedure just described, based on backward, general-to-specific estimation techniques is considered particularly useful in exploratory analysis (Field, 2005).

There are a number of data weaknesses and methodological problems regarding this estimation approach that impede an exact estimation of the model expressed in equation [4]. These limit the interpretation that can be made of the results obtained in this analysis, in terms of their conclusiveness and direction of causation, reinforcing its exploratory nature. Hence, the estimation of equation [4] would ideally involve the use of growth indices for all explanatory variables and, in some cases, lagged values for those variables whose impact on manufacturing performance is not immediate, such as investments in physical capital and R&D. However this was only possible for a reduced number of variables, and only partly. These include labour, which is measured as the variation in the number full-time workers employed between 1999 and 2003; also, variations in capacity utilization rates. Finally, it also includes a measure for physical capital accumulation based on manager's responses on the proportion of manufacturing equipment less than five years old. Given that the survey was implemented during the first half of 2004, this proportion would reflect investments undertaken between 1999 and 2004 and, therefore, can be taken as a proxy of the rate capital accumulation during that period. The remaining regressors considered in the analysis – including those capturing skills, technology capabilities and upgrading efforts, firms' idiosyncratic traits and prevailing market conditions – are of a static nature. That is, they capture events that took place during the period of analysis, yet without capturing their hange in time. Consequently they cannot be taken as potential drivers of manufacturing performance as measured here but, rather, as firm-level technological, production or identity states and external conditions associated with firms' sales performance during this period.

In addition to these problems, it is necessary to comment on the methodological shortcomings associated with this estimation approach. A first concern relates to the problems of simultaneity and endogeneity between the dependent and explanatory variables that are likely to emerge following this estimation procedure. In the presence of simultaneity the usual approach is to use instrumental variables or two and three-stage least square estimation. However, the data available is insufficient to proceed in either of these ways and, consequently, impedes correcting for these problems. This reinforces the importance of viewing the findings of this analysis as only providing a first insight into the association between manufacturing growth and the explanatory variables under consideration. The case study of the cluster of firms subcontracting work with Mozal presented in section four provides some further light into the nature of these interdependencies.

Another problem that may arise is that of imperfect multicollinearity. Hence, the technology literature would suggest that several of the explanatory factors under consideration are likely to be correlated, as is the case of the variables capturing skills, technology capabilities and technology upgrading efforts. Although the presence of some degree of multicollinearity is common and does not affect the BLUE properties of OLS estimators it will reduce their precision and might lead to the acceptance of the null hypothesis that estimated coefficients are statistically insignificant more readily (Gujarati, 1995). Ideally, to address problems of multicollinearity one would substitute correlated variables with a restriction capturing the nature of this association, using extraneous information regarding this relationship. However, as found in earlier research on the Mozambican case (Warren Rodriguez, 2008b), these variables tend to co-evolve in a complex, interdependent way, consequently, advising against imposing restrictions (linear, quadratic) that may not capture the nature of these interdependencies. Instead, we increase the significance level at which variables are included in the final model specification to a 10 percent level, to reduce the risk of leaving out variables that in truth are significant. Yet, this approach does not fully correct problems of multicollinearity, so that it is not possible to conclude that excluded variables are not associated with manufacturing performance. Again, this underscores the exploratory nature of this regression analysis. As with problems of endogeneity and simultaneity, the case study of Mozal partly helps to overcome these shortcomings by illustrating the nature of these interdependencies between the various explanatory variables considered for this analysis.

3.3. Does technology matter for manufacturing growth?

The regression analysis undertaken following the methodology described above suggests only the existence of a weak and sometimes counterintuitive association between levels of technology development n the sample and enterprise performance. Table 1 below presents the best model specification of factors associated with manufacturing performance in sample firms, as measured by their real growth in sales between 1999 and 2003. The factors selected through the estimation process described above have been grouped into three categories: *(i)* those capturing the basic growth model described in equation [3]; *(ii)* those of a technological nature; and *(iii)* a third group of dummy variables capturing the markets in which firms operate. As indicated in the previous section, this model captures all statistically significant variables at a 10 percent significance level.

Overall, this estimation exercise results in a reasonably good model fit, in terms of presenting a high level of overall significance and a relatively strong fit, with the F-Statistic reporting a *p*-value of 0.00, a coefficient of determination of 0.71 and an adjusted R^2 of 0.66. Furthermore, diagnostic tests performed as part of this estimation exercise rejecting the presence of problems of serial autocorrelation, functional form, normality or heteroskedasticity in the estimation.

TABLE 1. OLS Estimation of factors associated with sample Growth in Sales

Dependent variable is GRSLLNDF2
74 observations used for estimation from 1 to 74

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
Basic Growth Model			
INTCP	1.8037	.24576	7.3394[.000]
GREMPLLN	.49164	.16032	3.0666[.003]
GRKLN	-.89401	.30990	-2.8848[.005]
GRCURLN	1.2424	.21148	5.8749[.000]
Technology Augmented Model			
LNFSKILL	.46802	.10388	4.5054[.000]
TDQUAL	-.39294	.13442	-2.9233[.005]
COOP	-.22941	.078663	-2.9163[.005]
Market Augmented Model			
EXPORT	.39796	.20936	1.9009[.062]
MOZAL	.79533	.22421	3.5473[.001]
ESTADO	-.68713	.15822	-4.3428[.000]
TRANSPORT	-.54257	.19534	-2.7775[.007]

R-Squared	.71021	R-Bar-Squared	.66421
S.E. of Regression	.61349	F-stat. F(10, 63)	15.4399[.000]
Mean of Dependent Variable	.27137	S.D. of Dependent Variable	1.0587
Residual Sum of Squares	23.7111	Equation Log-likelihood	-62.8909
Akaike Info. Criterion	-73.8909	Schwarz Bayesian Criterion	-86.5633
DW-statistic	2.0839		

Diagnostic Tests

Test Statistics	LM Version	F Version
A:Serial Correlation	CHSQ(1)= .21110[.646]	F(1, 62)= .17738[.675]
B:Functional Form	CHSQ(1)= .11330[.736]	F(1, 62)= .095072[.759]
C:Normality	CHSQ(2)= 1.9285[.381]	Not applicable
D:Heteroscedasticity	CHSQ(1)= .010934[.917]	F(1, 72)= .010640[.918]

A:Lagrange multiplier test of residual serial correlation
B:Ramsey's RESET test using the square of the fitted values
C:Based on a test of skewness and kurtosis of residuals
D:Based on the regression of squared residuals on squared fitted values

However, this best-fit model presents some striking results, especially in relation to the role played by technology-related variables in the determination of patterns of sales performance. This best-fit specification does include the growth accounting explanatory variables generally found in the literature: labour and physical capital factor accumulation (GREMPLLN, GRKLN) and the adjustment variable capturing variations in capacity utilisation over the period under analysis (GRCURLN), all of which present high levels of significance. However, in some cases these coefficients present unforeseen signs. Those for the labour and capacity utilisation do show the expected positive sign (0.49 and 1.24), indicating that firms that have experienced greater growth in sales have also registered growths in employment and capacity utilisation levels. Yet, this is not the case of the variable capturing capital accumulation (GRKLN), which presents a negative coefficient of -0.89. This indicates that firms which have invested more intensively in capital accumulation during the 1999-2003 period have, on average, performed worse than less investment-intensive firms.

These latter results should be viewed with caution. Hence, indicators capturing capital stock levels and investment efforts do not originate from book records but from managers' responses on the proportion of production equipment less than five years old. Moreover, the direction of causation, if any, is not clear, since it is plausible that firms investment more heavily are doing so due to their weak performance in earlier periods, precisely in an attempt to improve this situation. Yet, despite these problems these findings do indicate that manufacturing growth in these two sectors has not been driven by firms' capital accumulation efforts between 1999 and 2003. Furthermore, in the likely event that, to some degree, these investments in machinery and production equipment embody new or upgraded technologies, these findings would also suggest that, on average, production technology development efforts have not played any significant role in shaping patterns of manufacturing performance in the sample during the 1999-2003 period.

The results of this regression exercise also underscore the role played by market conditions in shaping performance patterns in the sample. As can be seen, on average, sales performance of exporting firms and, especially, firms subcontracting work with Mozal has tended to be significantly higher than that of other companies. On the other hand, firms operating in the transport and state procurement markets have performed below the sample average between 1999 and 2003.

With regard to the role played by technology-related conditions and dynamics in shaping real sales growth patterns only three variables enter directly into the best-fit model specification: firm-wide skills levels (LNFSKILL), industrial engineering efforts (TDQUAL) and firms' technology cooperation with other external agents (COOP). Yet, only firm-wide skills are positively associated with sales' growth, indicating that firms with more skilled workforces have, on average, tended to perform better than less skilled ones. The other two statistically significant variables in the technology sphere – industrial engineering efforts and technology cooperative arrangements – are negatively associated with firms' sales growth between 1999 and 2003. Again, it is difficult to establish with certainty the direction of causation. Still, *a priori*, there is no reason to expect technology cooperation and technology development efforts in process and industrial engineering to weaken manufacturing firms' sales performance. This would appear to suggest that causation, if any, runs in the opposite direction. That is, worst-performers might be driven to engage in this type of efforts as a response to their weak manufacturing performance.

Perhaps more notable, is the lack of statistical significance of the remaining technology-related variables not included in the estimated model specification, meaning that they hold no direct, systematic association with firms' manufacturing performance. This is especially so, given the weight given to these considerations in the literature on technology and industrial development. Excluded variables include all measures of firm-level technological capabilities, which is in sharp contrast with findings of the technology capability literature, which generally finds a positive association between measures of technological capability and manufacturing performance (e.g. Lall, Rasiah, 2004; Wignaraja, 1998, 2002; Deraniyagala, 1999). It also includes variables capturing technology upgrading efforts in product and production technology development, although in this latter case it is likely that efforts to acquire new machinery and other production equipment are largely captured by the capital accumulation variable: GRKLN. Also noteworthy is the lack of significance of the variable capturing managers' skills. This is especially important, given the weight given to these considerations in management studies. Finally it is also necessary to refer to the lack of statistical significance of the various variables capturing the impact of foreign ownership on manufacturing performance. This is particularly striking given the importance attributed to FDI as a mechanism of technology and skill transfer, capability building and industrial development.

Whilst these results provide a valuable insight into the relationship between technology development and enterprise growth, it is important to note that there are number shortcomings associated with this type of regression approach. These limit the extent to which these results can provide a full understanding of the lack of a strong association between sample technological conditions, dynamics and manufacturing performance. Some have already been identified above, and relate to the problems posed by the potential presence of imperfect multicollinearity, simultaneity and endogeneity in the estimation process. Another matter of concern is that, by limiting the analysis to the 1999-2003 period, this regression exercise may be overlooking ongoing dynamics that could eventually lead to a process of technology development-led growth. As already suggested, this is perhaps the case of those technology-related areas where there are signs of a relatively strong association between firm-level technology conditions (e.g. levels of skills and capabilities), technological dynamics and firms' manufacturing performance. Although in most of these cases the estimated coefficients for these variables appear with a negative sign, this may be an indication that, in some instances, firms are responding to their weak manufacturing performance by engaging in greater technological efforts in the areas identified, with the expectation of future improvements in their manufacturing performance. Finally, it is important to note that regression analysis of the type undertaken here is, essentially, an analysis of averages, aiming at identifying systematic trends in the (co)relationship between a particular group of variables; In the present case, between firms' sales' growth, on the one hand, and the various factors initially considered as being associated with manufacturing performance, on the other. As a result, this type of exercise is likely to miss important firm or case-specific technological dynamics, which, if examined at a later date, might play critical role in driving industrial development, appearing as a statistically significant drivers of manufacturing performance.

4. Mozal: Illustrating the cumulative links between technology development and manufacturing growth in Mozambique

The case study of the Mozal aluminium smelter and of those firms in the sample subcontracting work from this industrial project serves to illustrate this. In particular, it provides evidence of the cumulative links between technology development and enterprise performance in Mozambique, as well as into some of the results obtained in the various analyses undertaken in previous sections. It also serves to identify the role played by foreign direct investment and industrial (technology) policy in promoting processes of technological change and industrial development in developing countries through the international transfer of technology and know-how to local firms.

The Mozal aluminium smelter started its operations in Mozambique in late 2000 in a purposely-built industrial free zone located in the outskirts of Maputo. At the time of its construction it was considered one of the largest aluminium smelters in the world, supplying an estimated 2 percent of world consumption of aluminium ingots (Thomas, 2005). This industrial project is participated by three strategic investors: BHP Billiton, which holds 47 percent of MOZAL's shareholding, the Mitsubishi Corporation, with another 25 percent and the Industrial Development Corporation, a South African public industrial development bank holding 24 percent of Mozal's capital. In addition, the Government of Mozambique retains minor shareholding interest of 4 percent.

The construction phase of this industrial project involved an investment of over USD 2 billion and was undertaken in two different phases: an initial investment phase spanning from 1998 to 2000, followed by a second expansion project undertaken between 2001 and, which saw the doubling of Mozal's production capacity. This two-phase investment process involved contracting over 15000 workers, the construction of over 25 kilometres of roads, a new berth in the nearby port of Matola and other related infrastructure facilities, including water and sewage systems and new harbour facilities. A third expansion phase is currently under consideration that would see a doubling of Mozal production capacity to around one million tons of aluminium ingots a year.

4.1. The impact of Mozal on technology transfer and upgrading dynamics in the sample

A first insight into the technological and performance impact of Mozal on the sample can be seen in the figures reported in Tables 2 and 3 below. Table 2 presents a comparison of several key indicators relating to firms' identity traits, skills levels, technical capabilities, technological efforts and manufacturing performance for sample firms which subcontracted work for Mozal during the period under analysis vis-à-vis the remaining firms in the sample. Table 3, on the other hand, presents this same comparison of identity, skills, technology and performance indicators, but restricted to the sub-sample of firms operating in the metal-engineering sub-industry, which is the industrial sector were most of the firms working for Mozal operate.[4] This latter comparison can be considered as a more relevant between-groups comparator, given that these firms share similar technological and production traits and, therefore, at the outset, would have had similar chances of sub-contracting work with Mozal.

Table 2: Test of Means: Firms working for MOZAL Vs. Firms that don't

	MOZAL (n: 15)		**Non-Mozal (n:75)**		**T-Test**	**Total (n: 90)**	
	Mean	*Std.Dev.*	*Mean*	*Std.Dev.*	*p-value*	*Mean*	*Std.Dev.*
Identity Variables							
Size *(Nb. workers in 2003)*	78.60	48.29	49.64	56.47	*0.067*	54.47	56.00
Age of firm	25.47	19.43	24.01	17.59	*0.775*	24.26	17.80
Share of Foreign Ownership	43.87	41.47	51.40	46.98	*0.565*	50.14	45.97
Degree Production Integration	4.30	2.31	3.47	1.78	*0.123*	3.61	1.89
Skills Indicators							
Managerial Skills	1.25	0.20	1.05	0.38	*0.051*	1.08	0.36
Firm-Wide Skills	0.80	0.49	0.57	0.44	*0.073*	0.61	0.45
ALL SKILLS	1.01	0.25	0.80	0.30	*0.013*	0.84	0.30
Technological Capabilities							
Product Development Cap.	0.87	0.66	0.33	0.60	*0.002*	0.42	0.64
Production Technology Cap.	2.98	1.05	2.89	1.59	*0.834*	2.90	1.51
Process/Industrial Eng. Cap.	1.40	0.74	0.77	0.95	*0.018*	0.88	0.95
TECHCAP	3.46	0.83	2.32	1.09	*0.000*	2.51	1.13
Technological Efforts							
Product Development Efforts	4.07	2.52	3.32	2.50	*0.294*	3.44	2.50
Production Technology Efforts	2.98	2.52	3.02	3.14	*0.957*	3.02	3.04
Process & Industrial Eng. Eff.	1.53	0.64	0.99	0.56	*0.001*	1.08	0.60
Share of Equip. < 5 y.o.	31.00	37.09	23.67	32.22	*0.435*	24.89	32.97
Overall Technology Efforts	34.35	40.78	22.67	37.27	*0.278*	24.62	37.89
Overall Technology Efforts	12.80	6.59	5.62	5.27	*0.000*	6.82	6.10
TECHDEV	3.48	0.80	2.49	1.20	*0.003*	2.65	1.20

[4] Thirteen out 15 sample firms working for MOZAL belonged to this sub-industry, which is part of the broader metalworking industry.

Performance Indicators [a]							
Growth in Sales (deflated)	80.5%	0.95	14.7%	1.05	*0.035*	27.1%	1.06
Capacity Utilisation - Growth	14.8%	0.28	-9.2%	0.42	*0.044*	-4.7%	0.40
Capacity Utilisation - 2003	47.04	22.25	51.50	26.74	*0.565*	50.65	25.87

[a] Based on performance data for 14 'Mozal' firms and 60 'non-Mozal' sample points

Table 3: Test of Means in metalworking: firms working for Mozal Vs. firms that don't

	MOZAL (n: 13)		Non-Mozal (n: 25)		T-Test	Total (n: 38)	
	Mean	*Std.Dev.*	*Mean*	*Std.Dev.*	*p-value*	*Mean*	*Std.Dev.*
Identity Variables							
Size *(Nb. workers in 2003)*	85.15	47.94	47.32	37.84	*0.011*	60.26	44.78
Age of firm	25.92	19.54	29.84	15.57	*0.505*	28.50	16.87
Share of Foreign Ownership	42.92	39.78	37.20	44.77	*0.701*	39.16	42.67
Degree Production Integration	4.65	2.25	4.44	1.89	*0.759*	4.51	1.99
Skills Indicators							
Managerial Skills	1.29	0.17	1.02	0.42	*0.034*	1.11	0.38
Firm-Wide Skills	0.77	0.49	0.38	0.30	*0.004*	0.51	0.41
ALL SKILLS	1.02	0.25	0.70	0.31	*0.002*	0.81	0.32
Technological Capabilities							
Product Development Cap.	1.00	0.60	0.74	0.73	*0.276*	0.83	0.69
Production Technology Cap.	3.03	1.12	2.20	1.36	*0.068*	2.49	1.33
Process & Industrial Eng. Cap.	1.46	0.66	0.44	0.77	*0.000*	0.79	0.87
TECHCAP	3.52	0.89	2.01	1.16	*0.000*	2.53	1.29
Technological Efforts							
Product Development Efforts	4.15	2.51	3.32	2.46	*0.332*	3.61	2.48
Production Technology Efforts	3.20	2.57	2.81	3.19	*0.700*	2.94	2.96
Process & Industrial Eng. Eff.	1.54	0.66	0.92	0.64	*0.008*	1.13	0.70
Share of Equip. < 5 y.o.	28.08	33.45	12.60	23.66	*0.106*	17.89	27.95
Overall Technology Efforts	36.87	42.84	20.62	36.85	*0.230*	26.18	39.20
Overall Technology Efforts	13.38	6.88	4.12	4.67	*0.000*	7.29	7.02
TECHDEV	3.54	0.84	2.23	1.34	*0.003*	2.68	1.34
Performance Indicators [a]							
Growth in Sales (deflated)	79.6%	0.95	-37.9%	1.08	*0.004*	3.5%	1.17
Capacity Utilisation - Growth	15.2%	0.30	0.9%	0.37	*0.255*	5.9%	0.35
Capacity Utilisation - 2003	40.71	16.58	51.81	27.69	*0.215*	47.89	24.67

[a] Based on performance data for 12 'MOZAL' firms and 22 'non-MOZAL sample firms in the metal-engineering sub-industry

On the whole, when comparing the mean values for each of the indicators reported in Tables 2 and 3 and the results of the corresponding tests of equality of group means, a similar pattern emerges: firms that during the 1999-2003 period have subcontracted work with Mozal come out, on average, as: *(i)* having higher levels of skills, both in terms of managerial and firm-wide skills; *(ii)* being technologically more capable; *(iii)* technologically more dynamic, in particular in the spheres of process and industrial engineering technology development efforts; and *(iv)* having outperformed other firms in the sample, in terms of the real growth of their sales between 1999 and 2003. The fact that the strength of these results, as measured by the *p-values* in the corresponding test of means, remains very similar for both the analysis taking the full sample and for the analysis focusing on the sub-sub-sample of metal-engineering firms, provides an indication of their robustness.

To understand how these results relate to the discussion of the determinants of technological dynamics and manufacturing performance it is necessary to look into some of the key aspects and events surrounding the establishment of this mega-project and its current operations in Mozambique. Hence, as part of its investment and social corporate responsibility strategy, Mozal established several training and technical capacity building programmes during its investment phase. Hence, during this period around ten thousand people were trained, at a cost of USD 8 million, for which Mozal created several training centres as well as a capacity development programme for local small and medium sized enterprises, the SME Empowerment and Linkages Program (SMEELP), resulting from a partnership between Mozal, the government's investment agency and the World Bank. The creation in 2001 of this SMEELP program was especially important for this strategy, as it was specifically created to promote the participation of Mozambican SMEs in tendering processes during Mozal's investment. It aimed at achieving this by articulating interventions in three main areas: *(i)* generating business opportunities for local SMEs, *(ii)* providing them with training, and (iii) promoting the upgrade and development of their technical capabilities through a purposefully designed mentoring and coaching programme, so as to meet Mozal requirements for subcontracting firms. In July 2003 this programme was replaced by Mozlink, an extended version of the original SMEELP devised to continue supporting local SMEs and promote new linkages with Mozal during its operational phase (Thomas, 2005). Hence, in addition to the original three components of SMEELP, Mozlink includes specific packages to facilitate access to other business support services, in areas such as quality assurance, safety or production standards, as well as working capital finance channelled through credit lines managed by two local credit institutions. It also widened its scope to promote linkages with other foreign projects operating in Mozambique (IFC, 2003). In essence, these linkages and capacity building programmes catered for the different dimensions associated with the process of effective technology transfer and development, namely: the upgrade of skills and technological capabilities, the promotion of technological efforts, and the creation of an incentives framework that encouraged firms to engage in this type of technology-related investments. This incentive framework included both the provision of financial support to cover for recurrent financial needs and the opportunity given to these firms to subcontract a significant volume of work with MOZAL on a regular basis.

The technological and performance impact of these linkages and capacity building initiatives and, more generally, of Mozal on its local subcontractors, needs to be qualified to take into account strong elements of self-selection in the identification of local firms that could participate in these programmes and subcontract work from this mega-project. Hence, the selection of local firms to participate in these programmes and, subsequently, subcontract work from Mozal was based on a pre-assessment screening process aimed at identifying the most able local manufacturing companies with the technical capacity and means to meet the strict technical and production requirements of this industrial project (PoDE, 2004). In other words, these were already the most skilled and technologically capable manufacturing firms operating in Mozambique, or subsidiaries of foreign firms established in Mozambique to take part, as subcontractors, in the investment and operational phase of Mozal.

However, beyond this initial process of self-selection, the available evidence suggests that the firms subcontracting from Mozal, including those in the sample, gained from substantial support to upgrade and improve their skills and technological capability base. Hence, once local firms were selected to participate in these programmes they underwent a six-months development plan, which included a training and a mentoring module. The training module was aimed at capacitating these firms in tendering, contract execution, quality assurance and control, business management and human resources. As part of this programme, all participating firms were also required to take part in a quality assurance course to implement a simplified version of the ISO-9000 quality assurance standard: Rule 1005. This standard was purposefully developed by the Mozambican Institute for Quality and Standards, INNOQ, in collaboration with Mozal during this project first investment phase. The mentoring module, on the other hand, consisted of a mentoring and coaching programme tailored to the needs of each participating firm, and included the provision of financial and commercial assistance and on-site regular technical mentorship in safety, quality assurance and industrial engineering. After this stage, these firms were then able to participate in the tendering processes for any of the 27 dedicated contract packages created under this programme. The projects in which firms in the sample have been involved included contract packages to repair aluminium smelter pot-shells, producing and repairing small tools, replacing and removing aluminium-pot superstructures and on-site specialised welding.

In this sense, Mozlink's performance assessment of the 12 firms participating in its capacity building programme reports substantial improvements in the four core competence areas deemed as being critical for the successful participation in Mozal's tendering processes; namely: *(i)* quality assurance and control; *(ii)* business management, *(iii)* maintenance and *(iv)* safety, as summarised in Table 4 below.

Table 4. MOZLINK Performance Assessment Results, 2005

Criteria	% score in relation to required standard at beginning of	% score in relation to required standard five months later
Quality	30	48
Business	40	60
Maintenance	25	78
Safety	40	70

Source: Mozlink (2006)

Similarly, in their impact assessment of Mozal, Castel-Branco and Goldin (2003) report considerable technical capacity building spillovers for firms working with Mozal, derived from their sub-contractual activities with this industrial project, concluding that Mozal *'has the potential to create significant positive industrial externalities by providing a platform for the development of metal engineering and maintenance industries, as well as crucial industrial services, which may greatly reduce marginal cost of investment and, therefore, increase the attractiveness of investing in Mozambique in new productive sectors'*. Still, they find that this project's long-term impact in the Mozambican economic context will '*ultimately depend upon the ability of the economy to take advantage of such externalities, and the policies and strategies that are developed and implemented to materialize potential linkages'* (2003:38).

Interviews with firms subcontracting work with Mozal provided further support to these findings. Hence, these linkages and capacity building programs appear to have lead to a strong interaction between managers and technicians of participating firms and Mozal's staff. For instance, the latter regularly programmed site-visits to these companies' installations to monitor progress with subcontracted work and ensure that production specifications were met. They also provided substantial direct on-site technical assistance in specialised welding, product design and industrial organisation, and supported these companies in key management functions that Mozal considers critical to guarantee the timely delivery of these subcontracted projects, such as production scheduling, human resources or accounting and finance. In addition, these firms received from Mozal detailed work plans of the various tasks and products they were required to produce or service, which, in effect, constitutes a form of technology transfer in the sphere of product development. These products would then be tested by Mozal's engineers to ensure that they met the required standards, contributing to improve the quality of these products, as well these firms' production capabilities and know-how. At the same time, managers of these subcontractor firms would often participate in monthly meetings with Mozal's production team to assess subcontracted work and, when necessary, revise production schedules and devise common solutions to existing technical and production constraints. In this respect, the interaction between subcontractor firms and Mozal appears to have led to significant transfers of technology and know-how, as well as technological upgrading spin-offs in the various relevant production spheres: product development, production technology upgrade, quality control and industrial engineering.

At the time of the survey, some of these firms had further benefited from technology transfers and spin-offs through the establishment of joint partnerships with foreign investors moving into Mozambique to participate in the investment and operational phases of Mozal. This is the case of at least six of the 15 firms in the sample that had work with Mozal. These joint ventures appear to have played a key role in Mozal's investment strategy in Mozambique, given the poor technological and production capabilities in industry that exited in Mozambique at the time this investment took off in 1999.[5] Many of these foreign firms were already providing similar industrial services to other aluminium smelting plants owned by BHP Billiton in South Africa, suggesting some element of coordination with BHP Billiton in their investment strategy in Mozambique. In some cases, the government also appears to have actively encouraged these joint ventures as a way of maximising the spillover benefits from this mega-project to local manufacturing firms. For instance, one of the Mozambican firms entering this type of partnership, was taken by Mozambican investment agency to visit a similar aluminium project owned by BHP Billiton in Richard's Bay, South Africa, to learn about the possibilities of subcontracting work in this type of industrial operations. During this visit, this Mozambican firm was put in touch with the South African firm with which it subsequently formed a joint venture during the initial MOZAL investment phase. On the other hand, two other firms, which had established joint ventures to participate in the investments phases of MOZAL, were partly state-owned at the time these partnerships were established, suggesting an active involvement of the government in encouraging this type of partnerships. In some instances, these have been essentially one-off partnerships, led by specialised foreign firms aiming solely at taking part in the construction of the Mozal project during its two investment phases, and motivated by their immediate need of production facilities in Mozambique. In these instances these partnerships have not led to any substantial greenfield investments in physical capital. Yet, in other cases, these joint ventures have been of a more permanent, long-term nature, leading to considerable spin-offs and acting as an important channel of technology and know-how transfer to their Mozambican counterpart firms.

An illustrative example of the benefits derived from these joint venture partnerships is that of COMETAL, one of the largest industrial units in Mozambique. This firm, originally established in 1957, is currently owned by the Indian TATA industrial conglomerate, with 51 percent of the shares of this company, and the Mozambican state, that owns the remaining 49 percent. During the Mozal-I investment phase, COMETAL established a technological

[5] In this respect, Castel-Branco and Goldin (2003) cite a 1998 inception study by the Mozambican investment agency (CPI) commissioned to appraise the linkage potential of Mozal concluding that 99% of firms examined had serious problems with product quality, 95% did not have the required project experience and portfolio, 92% operated with old and worn out equipment, 90% suffered from serious management deficiencies and inadequate financial structures, and 85% lacked marketing skills and a proactive business attitude.

partnership with GENREC, a South African firm with worldwide operations specialising in steel fabrication and heavy machining, to take part in the construction of several hundred aluminium smelting pot-shells and metal structures. Under the terms of this partnership GENREC made available its product design expertise, specialised welding equipment, as well as several engineers and welding technicians. COMETAL, on the other hand, remained in charge of project tendering, management and execution. To respond to the volume of work generated by Mozal, COMETAL had to employ several dozen specialised welders, including around 40 Thai workers, temporarily employed to work in MOZAL-related contracts. It also engaged in extensive training of its own workers, mostly in specialised welding and engineering services. At the time of the survey, in 2004, several of these workers were still working for COMETAL in other projects. Others had found employment in other firms operating in Maputo, including Mozal, taking with them the skills acquired whilst working for COMETAL, in what constitutes a form of skills transfer. COMETAL, on the other hand, continues its partnership with GENREC, with whom it had recently secured a USD2 million contract to supply similar engineering services for the expansion of the Hillside aluminium smelting plant in Richard's Bay, South Africa, also owned by BHP Billiton. Recently, it has also been approached by a Middle Eastern investor to submit a bid to provide similar services for an aluminium smelting plant being built in Bahrain.

Another such case is that of Agro-Alfa, a firm created in 1955, nationalised after Mozambique's independence from Portugal in 1975 and then privatised in 1996, which, with 135 full-time workers, is the fifth largest metalworking firm in the sample. During the Mozal investment phase, Agro-Alfa, which originally operated as a manufacturer of agricultural equipment and implements, established a partnership with a South African metalworking firm to supply this project with a variety of components and metal structures. The participation in Mozal's investment phase appears to have led to a strategic reorientation of Agro-Alfa's business model, increasingly focusing in the provision of industrial maintenance and engineering services to large industrial units, whilst moving away from its traditional specialisation as a manufacturer of agricultural equipment and tools. A critical element of this strategy was its efforts to continue to modernise its manufacturing plant and other critical production systems (e.g. production management, quality assurance, human resources) with the general aim of improving their capacity of designing and fabricating more complex steel products and becoming the leading engineering company in industrial maintenance in Mozambique. According to its chairman, working for Mozal and other large industrial projects, such as the Beira Port, Cimentos de Moçambique or BAT, had played a critical role in this strategy. Hence, it allowed the company to obtain important contracts and secure their business operations for several years. This, in turn, enabled this company to undertake key investments aimed at modernising its production systems and, eventually improve their competitiveness. At the time of the survey, Agro-Alfa continued to operate as a subcontractor of Mozal, supplying engineering and maintenance services from a new division based in the Mozal industrial free zone, and had moved on to provide similar services to other mega-projects in Mozambique. It also continued to work with its South African partner, of which it had become a minority shareholder. This South African firm continued to provide expertise and training to Agro-Alfa, with one of its technicians working in Agro-Alfa to favour technology transfer and knowledge sharing between both firms.

A third illustrative example is that of METECH, the seventh largest firm in the metalworking sub-sample and also one of the oldest, having been established in 1964 during the Portuguese colonial period. In 1999, whilst still being 75 percent state-owned, METECH established a joint venture with KEMPE International, an Australian-based global engineering corporation, to participate in MOzal's investment phase. This partnership was decisive in enabling METECH to participate in this project, given KEMPE's international specialisation in the provision of engineering services to the aluminium smelting industry, and its past experience in similar projects owned by BHP Billiton in Brazil and South Africa. As a result of its partnership with KEMPE and its work with Mozal, METECH, now renamed as KEMPE-METECH, had modernised its production systems and installations and is currently one of the leading metalworking firms in Mozambique working, as in the case of Agro-Alfa, for other large industrial projects operating in Mozambique. At the time of the survey, it had also recently created a 'sister' firm, KSSM, based in the Mozal industrial free zone, specialising in the provision of metalworking services to this aluminium plant.

4.3. MOZAL, sample technology dynamics and manufacturing performance

The results reported in Tables 2 and 3 indicate that firms that have worked for Mozal have also outperformed other firms in the sample. Thus, this group's sales grew on average by 80.5 percent between 1999 and 2003 in real terms, a level well above the 14.7 percent achieved by the remaining firms in the sample. These differences are even more marked in the metalworking sub-sample, where sales for firms that have worked for Mozal grew, on average, at a similar 79.6 percent rate in real terms during that period, against an average contraction for the remaining metal-engineering enterprises of -37.9 percent, in real terms.

The performance data made available during the survey by firms working for Mozal is insufficient to quantify and assess the exact impact that this mega-project has had on their performance. Consequently, it is not possible to determine whether, when comparing against other firms in the sample, these firms' higher performance between 1999 and 2003 owes only to their operations with Mozal, or whether other projects in their client portfolios might have played a similar or greater role. In this respect, it is important to note that the differences observed in the performance of firms working for Mozal and the remaining firms in the sample are likely to reflect an element of self-selection. That is, firms selected by Mozal to subcontract work during its investment and operational phases might have already been the best performers prior to being chosen to work with this industrial project. The fact that many of these firms were already amongst the largest operating in the two sectors suggests that this is likely to have partly been the case. In this respect, it is not possible to ascribe this heightened performance exclusively to the technological improvements registered in their technological base as a result of their operations with Mozal.

However, there are strong indications that this has partly been the case. Hence, in terms of Mozal's overall impact on these firms' manufacturing performance, the USD13 million worth in contracts that the Mozlink linkges program (Mozlink 2006) reports to have contributed to generate between local firms and Mozal during its 2-year of operation are equivalent to 20.4 percent of the value of sales registered between 1999 and 2003 by the 14 firms reporting performance figures for this survey that had subcontracted work with Mozal during this same period; and around 23.1 percent of the sales reported by the 12 such firms operating in the metalworking sector. Although not directly comparable, these figures give an indication of the magnitude and importance of Mozal's contracts for firms in the metalworking and light chemical sectors.

With regard to the impact that the technological dynamics generated by this mega-project has had on sample firms' performance, it is important to note that Mozal's policy is that the award of contracts is contingent upon subcontractors meeting strict quality and production standards, regardless of whether they are foreign or local firms. In this respect, technological competence would appear to have been a precondition for the successful participation in tendering processes for subcontracts with Mozal. Furthermore, the general feeling amongst those firms in the sample that have been awarded contractual packages with

Mozal is that this work had significantly contributed to upgrade their technological capabilities and know-how, as well as to improve their competitiveness and market reputation, allowing them to enter new markets, sometimes abroad. These claims are further supported by some of the evidence described above of specific instances in which firms that have subcontracted work with Mozal have then gone on to win contracts in other areas or in similar projects abroad.

Beyond these appreciations, it is important to note that the links between technology development and manufacturing performance in firms working for Mozal has not been unidirectional. Clearly, their already relatively high level of technological and production competence, together with the technology development efforts they have undertaken in the context of the various formal and informal initiatives promoted by Mozal and the Mozambican government, have enabled these firms to win relatively important contracts during this mega-project's investment and operational phases. As indicated above, this is likely to have positively impacted on their manufacturing performance and, furthermore, allowed them to improve their competitiveness and ability to enter new markets. Yet, as recognised by several of these firms, these technological efforts would have not taken place without certain guarantee that they would lead to the award of contracts by Mozal. Hence, given the volume of services and work involved and Mozal's prompt payment, the award of these contracts had improved these firms' financial position and cash-flow. It had also provided them with assurance and a more predictable business outlook. Altogether, this has enabled them to invest in the purchase of production equipment and in the acquisition of skills and technological capabilities. These findings highlight the cumulative nature of the links between technology change and manufacturing performance.

5. Reassessing the links between technology and enterprise development

The case study of the cluster of firms subcontracting work with Mozal serves to shed light on the results obtained in the econometric analysis of the (technological) determinants of manufacturing performance undertaken in Section 3. This analysis pointed towards a weak and, to a certain degree, counter-intuitive association between the various technology-related variables under consideration – capturing firms' skills, technological capabilities, technological efforts and their degree of foreign ownership – and their manufacturing performance between 1999 and 2003, as measured by the real growth in sales, with only three technology-related variables identified as being statistically associated with manufacturing performance, two of which presented a negative sign.

As indicated above, these regression findings contrast with much of the industrial technology and technology capabilities literature, which generally finds a strong association between technology development, in its various forms, and manufacturing performance. These results suggest that, in the business context in which Mozambican industrial firms operate, characterised by a poor market environment, a weak institutional setting for industrial development and a narrow industrial base, technology does not play any significant role in shaping patterns of manufacturing performance. The only strong indication of a link between manufacturing performance and technology development are: *(i)* that firms with a higher skill base tend to perform better in terms of their real sales growth, and *(ii)* that under-performing firms tend to engage in greater technology cooperation and quality control/industrial engineering efforts. These latter results suggest that weak manufacturing performance might be pushing under-performing firms to engage in greater technological efforts as a way of overcoming their poor performance.

The case study of Mozal allows the identification of factors underlying processes of technology-lead manufacturing growth and the illustration of how these operate. It also sheds light on key aspects regarding the process of technology accumulation, and on how the various elements involved in this process can interact to support dynamics of technology development and industrial growth. Hence, this case study shows that, in certain circumstances, a strong link may appear between levels of technological competence and dynamism in industry and manufacturing performance, in which technology development can act as an important driver of industrial growth. Typically, in markets that place a premium on quality and competitiveness and which, therefore, generate the incentives to improve levels of technology competence, other things equal, technologically more capable, dynamic and skilled firms are likely to outperform other similar enterprises. The case study presented here provides an extreme example of this, in that there was a purposeful effort by Mozal and the various linkages and capacity building programmes established around this project to select the technologically more capable and skilled firms to participate, as subcontractors, in the investment and operational phases of this industrial project. Also in the sense that Mozal provides a market for hi-tech engineering and metalworking services, in which the only client, Mozal, places a high premium on technological competence and local innovation, closely interacts with its subcontractors to achieve this and ensures a growing and predictable business outlook for subcontractor firms.

However, as discussed in previous research on Mozambique (Warren-Rodriuez, 2008a), beyond this very specific case of Mozal, this is not the case of the market contexts in which most firms in the Mozambican metalworking and light chemical sectors operate. These markets are characterised by a very thin and dispersed industrial base of formal enterprises, which undermines competition and industrial linkage generation. Also, by the collapse of sectors that traditionally provided an important upstream market for these firms and which has led to a fall in the demand for their products. Finally, a generally poor business environment and strong competition from the informal sector and foreign imports make it difficult to do business in Mozambique. All of these factors intertwine to reduce the incentives that firms face to engage in technology-upgrading efforts and, consequently, undermine a possible process of technology-led industrial growth in Mozambique.

The case of Mozal and related foreign investments also illustrates how FDI can play a critical role as a source and channel of technology transfer, positively impacting on both technology and industrial development of host developing economies. Yet, as suggested by this *positive* case of Mozal, as well as by the more pessimistic evidence discussed in previous research regarding the generally weak technological impact of FDI in the two Mozambican manufacturing sectors under consideration (warren-Rodriguez, 2008a), this process is not automatic. Hence, FDI is motivated by a myriad of factors and can take a variety of forms, not always conducive towards a process of technology transfer to the local economy. In the case of Mozal, a series of circumstances led to a certain, yet limited, process of technology transfer, and the generation of some more dynamic technological spillovers. These circumstances include Mozal's social corporate strategy in Mozambique, the immediate need for production facilities in Maputo by some of the foreign investors that Mozal attracted during its investment phase, or the attempts by the government to generate some visible impact on the local manufacturing sector through the set up of purposely created linkages and capacity building programs. However, as this same account of events suggests, these circumstances were very specific to the Mozal project and, therefore, are not given and can not be expected to be replicated automatically for other FDI projects in Mozambique.

Finally, this case study of Mozal also provides insight into the role of government policies in promoting technology development as a source of manufacturing growth. In this respect, the institutional response to BHP Billiton's and its partners decision to establish Mozal in Mozambique appears to have had positive, although somewhat limited, outcomes, in terms of promoting the upgrade of local firms' technological capacities and skills and linking them to tendering processes to subcontract engineering and metalworking services with this industrial project. This success was largely driven by the implementation of a number of very selective and proactive policy or quasi-policy interventions, articulated, amongst others, through the SMEELP and Mozlink linkage and capacity building programmes. These were, in part, aimed at actively promoting the upgrade of skills and capabilities in local firms and the effective transfer of technology. But also, at promoting the participation of these firms in Mozal's tendering processes through specially designed contractual packages. In other words, they included both interventions aimed at providing the required technological inputs as well as an incentive framework that encouraged these technological investments, as determined by the market and demand opportunities that these contracts offered. That is, they generated the appropriate supply-side and demand conditions for effective technology development and industrial growth. On the whole, these efforts appear to have created an environment in which technologically more capable firms have been able to compete in a market-niche from which, otherwise, they would have been ousted by foreign firms with greater capabilities and with experience of working in similar projects abroad, sometimes owned by the same investors behind the Mozal project. However, beyond this very specific experience, the general institutional setting for industrial (technology) development in place in Mozambique remains weak, with poor coordination mechanisms between the different institutions working in this area, as well as between these and other relevant government agencies. It is also characterised by an excessive fragmentation of policy interventions, and a functional, non-selective approach to industrial policy formulation, excessively focused on making available a limited number of business services, and less so on providing the business conditions required for their effective use (Warren-Rodriguez, 2007). These policy factors a likely to have further exacerbated the generally weak association between technology development and enterprise performance identified in the regression analysis discussed in section 3 above, of which the cluster of firm working for Mozal emerges as an exception.

References

Badhuri, Saradindu and Ray, Amit S. (2004) 'Exporting through Technological Capability: Econometric Evidence from India's Pharmaceutical and Electrical/Electronics Firms' *Oxford Development Studies*, Vol. 32, No. 1, March 2004

Benavente, Jose Miguel (2002) 'The Role of Research and Innovation in Promoting Productivity in Chile' *Economics of Innovation and New Technology* Vol. 15, No. 4-5.

Castel Branco, Carlos Nuno and Goldin, Nicole (2003) *Impacts of the MOZAL Aluminium Smelter on the Mozambican Economy –Final Report* Submitted to MOZAL Maputo, 21st September 2003. *mimeo*

CBO (2005) *R&D and Productivity Growth: A Background Paper* Congressional Budget Office Background Paper. Congress of the United States, Washington, D.C., June 2005

Chang, Ha-Joon and Rowthorn, Robert (1995) 'Role of the State in Economic Change: Entrepreneurship and Conflict Management' In (ed.) Chang, Ha-Joon and Rowthorn, Robert *The Role of the State in Economic Change*. Clarendon Press, Oxford

Chudnovsky, Daniel; López, Andrés and Pupato, Germán (2006) 'Innovation and productivity in developing countries: A study of Argentine manufacturing firms' behaviour (1992-2001)' *Research Policy* Vol.35, No.2

Crepon, Bruno; Duguet, Emmanuel and Mairesse, Jacques (1998) *Research, Innovation and Productivity: An econometric analysis at the firm level* NBER Working Paper No. 6696. National Bureau of Economic Research. Cambridge, MA

Deraniyagala, S. (2001a) 'Adaptive Technology Strategies and Technical Efficiency: Evidence from the Sri Lankan Agricultural Machinery Industry' *Journal of International Development*, Vol. 13, No.1: 59-71

Deraniyagala, S. (2001b) 'The Impact of Technology Accumulation on Technical Efficiency: an Analysis of the Sri Lankan Clothing and Agricultural Machinery Industries' *Oxford Development Studies*, Vol.29; No.1: 101-114

Deraniyagala, Sonali (1999) 'Comparative and Pooled Analysis of the Three Countries' in (ed.) Sanjaya Lall *The Technological Response to Import Liberalization in SubSaharan Africa*. MacMillan Press Ltd, London, U.K.

Deraniyagala, Sonali and Semboja, Hagi H.H. (1999) 'Trade Liberalization, Firm Performance, and Technology Upgrading in Tanzania' in (ed.) Sanjaya Lall *The Technological Response to Import Liberalization in SubSaharan Africa.* MacMillan Press Ltd, London, U.K.

Evenson, Robert E. and Westphal, Larry E. (1995) 'Technological Change and Technology Strategy' in (ed.) Behrman, J. and Srinivasan, T.N. *Handbook of Development Economics.* Volume 3A, Chapter 37. Elsevier Science, B.V. Amsterdam,

Ferrantino, Michael J. (1992) 'Technology Expenditures, Factor Intensity and Efficiency in Indian Manufacturing' *Review of Economics and Statistics* Vol.74 No.4: 689-700.

Field, Andy (2005) *Discovering Statistics Using SPSS (and sex, drugs and rock 'n' roll)* Second Edition. Sage Publications, London

Griliches, Zvi (1998) *R&D and productivity: The econometric evidence. Selected essays of Zvi Griliches* Special volume of the NBER. NBER Cambridge, MA

Griliches, Zvi (1979) 'Issues in assessing the contribution of Research and Development to productivity growth' *The Bell Journal of Economics* Vol.10, No. 1: 92-116.

Gujarati, Damodar N. (1995) *Basic Econometrics* 3rd Edition. McGraw-Hill, Singapore

Hasan, Rana (2002) 'The impact of imported and domestic technologies on the productivity of firms: panel data evidence from Indian manufacturing firms' *Journal of Development Economics* Vol. 69:23-49

Hasan R.; Raturi M. (2003) 'Does Investing in Technology Affect Exports? Evidence from Indian Firms' *Review of Development Economics*, Vol. 7, No. 2: 279-293

Hu, Albert G.Z.; Jefferson, G. H.; Jinchang, Q. (2006) 'R&D and Technology Transfer: Firm-Level Evidence from Chinese Industry' *Review of Economics and Statistics* Vol.87, No.4

Iacovone, Leonardo and Hoyos, Rafael (2005) *Economic Performance under NAFTA: A Firm-Level Analysis of the Trade-Productivity Linkages* Paper Presented at Third CEPI/IADB Conference , 9-10 February 2006, Washington D.C.

IFC (2003) Mozambique—*IFC Helps Mozal Expand Successful SME Linkages Program to Daily Operations* IFC Press Release. International Finance Corporation, Washington D.C.

Kathuria, Vinish (2002) 'Liberalisation, FDI and Productivity Spillovers – an Analysis of Indian Manufacturing Firms' *Oxford Economic Papers* Vol.54: 688-618

Katrak, Homi (2002) 'Does economic liberalisation endanger indigenous technological developments?: An analysis of the Indian experience' *Research Policy*, Vol. 31, No.1:19-30

Keller, Wolfgang (2000) 'Do Trade Patterns and Technology Flows Affect Productivity Growth?' *World Bank Economic Review* Vol.14, No.1 (January 2000): 17-47

Keller, Wolfgang (2001) *Trade and the Transmission of Technology* NBER Working Paper No. 6113. NBER. Cambridge, MA, March 2001

Kumar, Nagesh and Siddharthan, N.S. (1994) 'Technology, Firm Size and Export Behaviour in Developing Countries: the Case of Indian Enterprises' *The Journal of Development Studies* Vol.31, No.2: 289-309.

Lall, Sanjaya (1993) 'Understanding Technology Development' *Development and Change* Vol.24: 719-753

Lall, Sanjaya (1992). 'Technological Capabilities and Industrialization' *World Development* Vol.20, No.2, pp.165-186

Lall, Sanjaya (1991) 'Human Resources, Technology and Industrial Development in sub-Saharan Africa' in (ed.) A. Chhibber and S. Fisher *Economic Reform in sub-Saharan Africa* The World Bank, Washington, D.C

Lucas, Robert E., Jr. (1988) 'On the Mechanics of Economic Development' *Journal of Monetary Economics* Vol. 22 pp.3-42

MOZLINK (2006) Website of the MOZLINK linkages and capacity building program e– www.mozlink.co.uk

Narayanan, K. (1997) *Technology Acquisition, De-Regulation and Competitiveness: A Study of Indian Automobile Industry* INTECH Discussion Paper Series Institute for New Technologies, United Nations University. Maastricht, September 1997

PODE (2004) *Aide Memoire from the Supervision Mission – June/July 2004* Enterprise Development Project (PODE) Credit 3317-MOZ. Draft Version. Maputo, *Mimeo*

Rasiah, Rajah (2004) *Foreign Firms, Technological Capabilities and Economic Performance.* Edward Elgar. Cheltenham, UK

Raut, Lakshmi K. (1995) 'R&D spillover and productivity growth: Evidence from Indian private firms' *Journal of Development Economics* Vol. 48 (1995) 1-23

Rodrik, Dani (2004) *Industrial Policy for the Twenty-First Century*. KSG Working Paper No. RWP04-047. Harvard University, Ma.

Scherer, Frederic M. (1982) 'Inter-Industry Technology Flows and Productivity Growth' *Review of Economics and Statistics*, vol. 64, no. 4 (November), pp. 627-634.

Schor, Adriana (2004) 'Heterogeneous productivity response to tariff reduction. Evidence from Brazilian manufacturing firms' *Journal of Development Economics* V.75: 373– 96

Thomas, Rosalind H. (2005) *FDI and SME Linkages –The case of Mozal I and II* Paper presented at IDRC Private Sector Development Task Force Conference, April 2005, Ottawa

Wang, Jiann-Chyuan and Tsai, Kuen-Hung (2003) *Productivity Growth and R&D Expenditure in Taiwan's Manufacturing Firms* NBER Working Paper No. 9724, NBER. Cambridge, MA

Warren-Rodríguez, Alex (2008a). 'Uncovering dynamics in the accumulation of technological capabilities and skills in the Mozambican manufacturing sector'. Department of Economics Working Papers No.156. School of Oriental and African Studies (SOAS), London

Warren-Rodríguez, Alex (2008b). 'An Exploration of Factors Shaping Technology-Upgrading Efforts in Mozambican Manufacturing Firms' Department of Economics Working Papers No.159. School of Oriental and African Studies (SOAS), London

Warren-Rodríguez, Alex (2007). 'Science and technology in the PRSP process; A survey of recent country experiences' *Background Paper for the 2007 Least Developing Countries Report*. United Nations Conference for Trade and Development (UNCTAD), Geneva

Wignaraja, Ganeshan (2002). 'Firm Size, Technological Capabilities and Market Oriented Policies in Mauritius' *Oxford Development Studies* Vol.30, No.1, pp. 87-104

Wignaraja, Ganeshan and Ikiara, G. (1999) 'Adjustment, Technological Capabilities and Enterprise Dynamics in Kenya' in (ed.) Sanjaya Lall *The Technological Response to Import Liberalization in SubSaharan Africa.* MacMillan Press Ltd, London, U.K.