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AN EXPLORATION OF FACTORS SHAPING TECHNOLOGY-UPGRADING EFFORTS IN MOZAMBICAN MANUFACTURING FIRMS

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An exploration of factors shaping technology-upgrading efforts in Mozambican manufacturing firms

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Abstract

This paper presents an analysis of factors shaping technology-upgrading efforts in the Mozambican manufacturing sector. It uses firm-level data to examine these issues for the metalworking and light chemicals sectors, using Logit regression analysis to identify factors associated with firms' decisions to engage in technology-upgrading efforts in three areas: (i) product development; (ii) production technology development aimed at upgrading existing equipment or purchasing entirely new manufacturing technologies; (iii) and process engineering. In line with much of the literature on industrial organization and the microeconomics of technology change, this paper finds that existing production and technological conditions in manufacturing firms do play an important role in shaping their technological efforts. However, this association is not always linear, cumulative or uniform across the various relevant spheres of manufacturing, underscoring the multifaceted nature of technology change at this level. Moreover, factors identified in the literature as being instrumental in shaping technology development efforts, such as skills or foreign ownership, play no role in dynamics of this kind in Mozambique. At the same time, other factors that have received less attention, such as the ability of firms to engage in technology cooperation arrangements or the role played by demand and market conditions appear as important factors shaping these technology-upgrading efforts. Altogether, these findings serve to underscore the importance of defining policy interventions for private sector development that go beyond investment climate concerns and take into account issues such as the promotion of linkages, technology cooperation and demand/market management considerations.

Keywords: Manufacturing; Firm-level Dynamics; Technology Change; Industrial Organisation; Sub Saharan Africa; Mozambique.

1. Introduction

As in other least developing countries, private sector development and manufacturing growth have been receiving increasing attention in Mozambique, given these activities potential they offer as drivers of general economic development and poverty reduction (e.g. GoM, 2005; Lledó; 2007; World Bank, 2005). The importance of these issues are somewhat magnified in the Mozambican context, given the country's past history of relative industrial development, at least from a African perspective, especially during the Portuguese colonial period and in the aftermath of independence. In this context, debates on private sector development in

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Mozambique have tended to focus on investment climate considerations regarding the constraints to business imposed by a burdensome administrative and regulatory framework. Issues relating to industrial technology development, on the other hand, have only occupied a marginal place, despite ample evidence pointing towards a weakening and growing obsolescence of the Mozambican manufacturing sectors' technological and skill base (RPED, 1999, 2002). The absence of any analysis or policy discussion on these issues is ever more striking in light of the vast body of theoretical, empirical and development policy literature that exists on these issues, including at the microeconomic level and in the context of economic developing.[1]

It is against this background that this paper examines technology-upgrading dynamics in the Mozambican metalworking and light chemicals sectors. It does this with the double aim of shedding light on these issues for the Mozambican case, whilst also providing relevant evidence on more general debates on the nature of industrial technology change in developing countries. The analysis presented in this paper takes the form of a series of exploratory exercises aimed at identifying factors that are associated with firms' decisions to engage in technological efforts in key areas of manufacturing. Following previous research in this field, this is done on the basis of several binary logistic (Logit) regression exercises examining firms' decisions to engage in technology efforts to introduce new products, purchase new items of machinery, incorporate new production technologies embodied in manufacturing equipment and introduce ISO 9000 standards of production in their manufacturing lines.

The paper is organised as follows. Section two starts by discussing key methodological considerations regarding the analysis undertaken here and presenting the empirical strategy followed in this paper. This is followed in section three with a brief description of technology development efforts by firms operating in the Mozambican metalworking and light chemical sectors in each of the three spheres of manufacturing under consideration. Section four moves on to examine factors associated with firms' technology-upgrading efforts. It does this in two parts. First, it presents the regression results of the various Logit exercises undertaken for this purpose. This is followed by a discussion of key themes that emerge from these regression analyses and which shed light on the nature of technology development in these two manufacturing sectors. Finally, Section five concludes with a summary of findings and a brief discussion of their implications for understanding manufacturing dynamics in Mozambique and the analysis of firm-level technology change.

2. Empirical Strategy and methodological considerations

2.1. Sampling and data considerations

The analysis presented in this paper is centred on the examination of 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. The survey focused on firms employing ten or more workers operating in the metalworking and light chemical sectors in the capital province of Maputo, which accounts for 60 to 70 percent of industrial production in Mozambique (RPED, 2003). This survey was part of a broader research project examining technological conditions and dynamics in the Mozambican manufacturing sector and their impact on enterprise performance. The analysis of this data is complemented throughout this paper with the discussion of events taking place in Mozambique in the macro, meso economic and policy spheres, based on information obtained from interviews with key informants and other (secondary) sources available in Mozambique.

[1] See Freeman (1994), Evenson and Westphal (1995) or Westphal (2002) for reviews of this literature.

The survey undertaken for this project included a total of 90 firms, 56 in metalworking and 34 in the light chemicals sector, 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). Lall's technology capabilities framework defines spheres of production technology in the various areas of manufacturing production. It focuses in those areas of production 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 coded into a set of questions in a survey questionnaire.

2.2. Approaches to the analysis of technology development

The analysis of firm-level technology change has been undertaken in the literature in a variety of ways. One typical avenue has consisted in using R&D expenditures as a proxy of firms' technology development efforts. Examples of this approach are abundant and can be found in the econometric literature on innovation and productivity growth.[2] This R&D approach presents several advantages. Hence, R&D investments probably reflect the highest level of technology development efforts. Furthermore, from a methodological perspective, it also allows for a precise, value-based quantification of firm-level innovations and the definition of continuous variables to capture them, with the ensuing increase in variability, richness of data and, consequently, in the depth, precision and quality of empirical analyses on these issues. However, this approach also comes at significant analytical costs. Thus, not all technology development efforts are the direct result of formal investments in R&D (Bell & Pavit, 1995) and, therefore, cannot be fully captured through this type of indicators. This will be the case of innovations in the sphere of process and industrial engineering, involving how production is organised or managed, which often result in significant gains in manufacturing efficiency. These types of innovations tend to take place in the management sphere and, consequently, largely reflect specific patterns of leadership, corporate management and structures (Figuereido, 2001). It is also likely to be the case of sectors, firms or countries that are not on the international technological frontier, for which technology change takes the form of the incorporation and adaptation of existing technologies, rather than of R&D expenditures. As a result, R&D investments may not be a good proxy of technology development activities in manufacturing (Calvo, 2006).

An alternative approach to the analysis of firm-level technology development consists in focusing on relevant technological events taking place within the firm and identifying factors associated with their occurrence. This approach typically involves the use of limited dependent variable analysis (e.g. Logit, Probit) to identify factors associated with a certain technology-upgrading events taking place, such as the adoption of a certain technology or the acquisition of new equipment. In contrast to approaches based on R&D investments, this method allows the examination of a greater variety of technology-upgrading efforts. Consequently, it also reduces sampling bias problems, in terms of capturing a greater number of firms engaging in technological development (Calvo, 2006). However, this comes at the cost of loosing detail and quality in the analysis, as limited dependent variables usually convey limited information, other than whether a specific event takes place or not. This

[2] See, for example, Schmookler (1966), Scherer (1982), Griliches (1998) or Crepon *et al* (1998).

approach has been extensively used in agricultural economics to examine factors associated with the adoption of technology packages by farmers in developed and developing countries.[3] However, its use has been less extensive in industrial studies.[4]

2.3. Regression Strategy

Given the nature of the data collected in the survey undertaken for this research and that of sample firms' technology development efforts, this paper follows this second approach to the analysis of technology-upgrading in the Mozambican manufacturing sector. In this respect, it uses Logit regression analysis to examine firms' technology-upgrading efforts in Mozambican manufacturing sector between 1999 and 2003 as defined by four events: (i) the introduction of new products in firms' product portfolios; (ii) the purchase of new items of machinery; (iii) the acquisition of new production technologies to the firm embodied in new equipment; and (iv) initiatives to implement ISO 9000 quality assurance standards in production.

Logit regression analysis is a form of limited dependent variable analysis in which the dependent variable takes a dichotomous form (Pampel, 2000). It is used to predict the odds of a certain event (the dependent variable) occurring, on the basis of continuous and categorical independent regressors, and to determine the percentage variation in the dependent variable explained by these explanatory variables. The use of Logit analysis as a distinctive form of regression analysis arises as the use of dichotomous dependent variables makes OLS estimation inappropriate. This is so because the error term is neither normally distributed nor does it have equal variances for different values of the explanatory variables, leading to inefficient OLS estimates. To overcome these shortcomings, Logit regression applies maximum likelihood techniques to estimate the odds and, indirectly, the probability, of a certain event occurring, after transforming the dependent into a Logit variable: the natural log of the odds of this event occurring or not. In this sense, logistic regression calculates changes in the logarithmic odds of the dependent variable occurring, not changes in this dependent variable itself, as in the case of OLS estimation. Despite these differences, binary logistic regression presents many similarities with OLS estimation. Hence, estimated Logit coefficients correspond to the β parameters in the linear regression equation, whilst the standardized Logit coefficients correspond to β-weights. As in OLS estimation, logistic regression also requires that observations are independent and that the independent variables be linearly related to the Logit of the dependent. It also results in several (pseudo) coefficients of determination that summarise the strength of the relationship between explanatory and independent variables, or goodness of fit. However, unlike OLS estimation, logistic regression does not assume linearity in the relationship between the independent variables, nor does the dependent variable need to be normally distributed. Furthermore, it does not assume homoscedasticity and, in general, its estimation has less stringent requirements.

In all four sets of statistical exercises a backward step-wise Wald variable selection approach is taken to establish the final model specification defining the relationship between the dependent variables, capturing technology development efforts in the different areas under consideration, and the regressors associated with these efforts. Under backward stepwise selection, Logit regression analysis starts by including all potential predictors in the model. The regression analysis then consists in (re)testing whether any of these predictors can be removed from the model without having a substantial effect on its data fit. At each step, the analysis removes variables based on the significance of the score statistic, with removal based

[3] e.g. see Boz & Cuma (2005); Chirwa (2005); Foltz & Chang (2005); Gockowski & Ndoumbe (2004); Payne *et al* (2003); Isham (2002); Diederen *et al* (2003); Popp *et al* (1999); Burton *et al* (1999); or Nichola (1996).
[4] Some notable exceptions are Katrak (1997), Basant (1997), Braga and Willmore (1991) or Pamucku (2003).

on the significance of the Wald Statistic (Field, 2005).[5] The removal criterion was established at a p-value of 0.1 to provide some flexibility in the selection of variables, especially in light of the estimation problems of running logistic regressions on a relatively small sample. This backward stepwise approach is considered particularly useful in exploratory analysis (Field, 2005). This is the case here, where there is no a priori knowledge of the exact model specification for each of the binary variables examined and, thus, of which variables can be expected to be reliable predictors.

It is important to note that the analysis undertaken here is only of an exploratory nature. Several reasons justify this caution. First, none of these exercises is based on the estimation of structural models of enterprise technology development specifying the nature of the relationship between dependent and explanatory variables. In this sense, they should be viewed as tests of association, rather than of causation. Second, many of the explanatory variables considered are difficult to interpret in a precise way and, therefore, to relate to each of the dependent variables under examination. In some instances, this is because they are imperfect proxies of wider economic phenomena. In other cases because they convey relevant but little information. Third, this exploratory approach is justified in light of some of the estimation problems that arise from using a relatively small sample in Logit analysis. Hence, logistic regression uses maximum likelihood estimation to derive the parameters of the regression model, which relies on large sample asymptotic normality, so that the reliability of estimates will decline when there are few cases for each observed combination of independent variables. As a result, estimations based on small samples or using a large number of regressors may result in high standard errors (Garson, 2006) and, thus, in imprecise estimates. In practical terms this might lead to the exclusion of variables from the final estimated regression specifications that might have been included with the use of a larger sample.

Finally, it should be noted that each of these Logit exercises consists of two separate estimations, one performed on data for the full sample of 90 firms and another on the sub-sample of 74 enterprises that reported performance figures for the survey. This twofold estimation allows the examination of the specific links between firms' performance and technological efforts for this group of 74 companies, whilst at the same time maximising the use of the information provided by the full sample of firms. It also provides a simple test of robustness of the different model estimations, in the sense of rerunning each regression exercise over a randomly generated sub-sample and examining whether any significant differences arise in the estimation results.

2.4. Explanatory variables considered in the analysis

The explanatory variables considered for these analyses were drawn from two main sources. First, factors identified in the technology literature as playing a decisive role in the process of technology development. Second, the empirical findings specific to the Mozambican manufacturing sector identified in earlier research undertaken as part of this research project in Mozambique (Warren-Rodriguez, 2007, 2008a). These variables broadly fall into four different categories: (1) variables describing firms' general traits (2) variables capturing technological and production characteristics of sample firms; (3) variables capturing external and market conditions in which these firms operate; and (4) two measures of firms manufacturing performance between 1999 and 2003.

[5] The Wald Statistic is the equivalent of the t-statistic in linear regression analysis, presenting a Chi-Square distribution (Field, 2005).

Table 1: Variables considered in Logit analyses

Variables capturing firm 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. *ONLYMOZ*: Dummy variable capturing whether firms are fully Mozambican owned or not
5. *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.
6. *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. The technology capability dimension directly related to dependent variable, product development capabilities (*PRODEVCAP) production technology management capabilities (PRODTECHCAP) and process/industrial engineering capabilities (PROCESSCAP*)
4. *TECHCAP*: Aggregate technological capabilities index
5. *TECH. COOPERATION*: Technology cooperation index
6. Technology upgrading efforts in other areas of technology development: namely product development (PRODDEV), Production technology development (PRODTECHDEV), and Process/industrial engineering development (QUALDEV).
7. *OVERALL TECH. (TECHCAP x TECHDEV x ALLSKILLS)*: Combined technology interaction index capturing the interaction between these variables.

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

Variables capturing manufacturing performance

1. *GROWTH*: Growth of sales
2. *PRODUCTIV*: Productivity growth

The first group of indicators includes variables commonly found in empirical studies of technology, such as firms' size, age and the degree of foreign ownership, as well as two variables identified in earlier research (Warren-Rodriguez, 2008a) as playing a significant role in shaping technological capabilities and skills patterns in sample firms: the historical period in which these firms were established and whether they were ever state owned or state intervened enterprises.

The inclusion of firms' size in the analysis follows empirical work undertaken within the technological capabilities analytical framework, with most studies of this kind finding a positive relationship between enterprise size, technological capabilities and technology development efforts (Wignaraja, 2002). At a theoretical level, its inclusion aims at capturing the existence of economies of scale in technology development at the firm level, following the debate in the industrial organisation literature on the links between firm size, innovation and market structure.[6] This debate has essentially unfolded around two main themes: whether a positive relationship exists between size and innovation and, if so, the direction of causality between these two variables. Economies of scale in innovation and, more generally,

[6] See Freeman and Soete (1997) or Symeonidis (1996) for a review of this debate.

technology development may arise when these activities involve large and indivisible fixed costs, such as R&D investments, that smaller firms cannot undertake. This results in a concentration of R&D activities and innovations in large industrial firms, often of a multinational nature. However, innovation and, more generally, technological efforts do not always require a minimum size or scale.[7] This is partly because firms' technology development efforts do not always take the form of R&D induced innovations and, consequently, may not necessarily be scale intensive. This is likely to be the case of technology development efforts in developing countries, where technology change usually takes place through the incorporation and modification of existing technologies, activities that may not require any sizeable scale of production for their implementation. It is also important to note that the nature of innovative activities is not uniform, with traits of industrial innovation largely shaped by sector specific considerations, leading to different patterns of innovation, production scale and market structures across different industries (Acs & Audretsch, 1987). In any case, the existence of a positive relationship between firm size and innovation or technology development may not necessarily reflect the existence of economies of scale in technology efforts but, rather, the opposite causal relation, reflecting the Schumpeterian nature of innovation. That is, the fact that technology development efforts confer innovators with a certain degree of market power and, therefore, the possibility of increasing their share (and size) in the markets in which they operate.

In relation to firms' age, the inclusion of this variable presents a weaker theoretical and empirical foundation. Age can be considered relevant for technology development in that experience might make older firms more aware of the importance of engaging in technological efforts as a means of making them more competitive and, thus, as a mechanism of survival in competitive environments. In this case, a positive association between firms' age and technological efforts would reflect technological learning-by-doing effects (Wignaraja, 2002). However, it has also been argued that younger firms tend to be more dynamic, less risk averse and more aware of the need to innovate than older ones (Katrak, 1997). In this case, the association between age and technology efforts would run in the opposite direction. In any case, regardless of its theoretical basis or of the true nature of this association, the inclusion of firms' age is useful for statistical purposes to control for the inherent effects that age will have on technological activities; that is, the fact that older firms tend to have older equipment and product portfolios and, therefore, a greater need to replace them. As a result they are likely to exhibit higher levels of technological dynamism than younger firms, pattern that would not necessarily reflect a greater predisposition to innovate.

The analysis of factors associated with technology efforts also includes two measures of foreign ownership: firms' share of foreign ownership and a dummy variable capturing whether firms are fully Mozambican owned or not. These variables aim at capturing the contention found in the technology and development literature that foreign firms are better able or have a greater predisposition to engage in technological efforts, given their better access to foreign technologies, sources of finance and skills (see Blomstrom & Kokko, 1996)

The second group of variables includes indicators capturing firms' technological traits. These attempt to reproduce the theoretical and empirical findings of the literature on technology change stressing the importance of human capital and technological capabilities as key determinants of technology change (e.g. Bell & Pavitt, 1995). This group includes: two composite skills indices capturing sample firms' managerial and firm wide skills; three technology capability indices capturing firms' technology capabilities in product

[7] In fact, historical evidence indicates that a large proportion of inventions and innovations have historically been introduced by smaller, specialised firms (Freeman and Soete 1997:228).

development, production technology management and process & industrial engineering; an aggregate technology capabilities index which captures technology capability levels across the production process; a variable capturing the degree of technological cooperation with other firms and organisations; and, finally, two indicators capturing the interactions, complementarities and co-evolution between the various technology dimensions under consideration: a multiplicative technology development index and a variable resulting from multiplying the composite skills, capabilities and technology development indices. The use of these various technological variables follows similar empirical work in the technology capability literature (e.g. Lall, 1999; Wignaraja, 2002) and their exact definition can be found in Warren-Rodriguez (2007, 2008a).

In addition to these technology and firm identity variables, the Logit regression analysis also takes into consideration indicators capturing external market conditions in which firms operate, in an attempt to examine the impact of market conditions and demand-side considerations on technology-upgrading efforts. Whilst much of the literature examining the determinants of firm-level technology development has tended to focus on supply-side explanatory factors, the inclusion of these market and demand-side variables can also be found in some earlier literature on the determinants of firm-level technology development. For instance, Braga and Willmore (1991) include the effective level of tariff protection that firms face as a measure of market protection in their analysis of enterprises' technological efforts in the Brazilian manufacturing sector. Similarly, Bertschek (1995) includes measures of import shares in her analysis of German industrial firms' technological efforts.

In the Mozambican case, the inclusion of these variables is justified in that the increasingly adverse market conditions that manufacturing firms face in Mozambique, characterised by the thinning and collapse of important upstream sectors, a strong competition from imports and the informal sector and a poor investment environment, among others, are likely to impinge on firms' technological efforts and investments. In the past, studies on the Mozambican manufacturing sector (e.g. RPED 1999, 2002) have highlighted the various investment constraints faced by firms in Mozambique. These studies have tended to focus on investment climate considerations, such as the cost of finance, the burdens imposed by an over regulated business environment or the investment risks associated with policy uncertainty. Without underestimating the importance of these problems, the focus here is on conditions that are specific to each of the markets and sub-sectors in which firms operate. These conditions refer to demand trends, market sizes and structures, market regulations or lack of them, or the impact of the informal sector. This approach is justified on two main grounds. Firstly, from a methodological perspective, it is impossible to identify the differential impact that business climate problems have on technology development efforts, since these conditions are general to the Mozambican economy, so that any distinctive impact they may have on a specific group of firms will be captured by firm identity variables such as firm size, age or degree of foreign ownership. Secondly, interviews with firms' managers suggested that, whilst business climate considerations do affect their decisions to undertake technology-upgrading investments, it is also market specific problems that constrain this type of investment efforts.

In this sphere, the analysis undertaken here includes two groups of dummy variables: the sub-sector in which firms operate, and the markets they serve, each attempting to capture general external conditions that firms face. The fact they are included as dummy variables means that they can only capture whether systematic differences exist in firms' technological efforts across these various sub-sectors or markets under consideration, but not the exact nature of these differences. Following the debate on the dynamic effects of competition on technology change (see Rodrik 1992 or Krueger, 1997, 1998) The analysis also include an indicator of the degree of competition that firms face, defined as the number of firms operating in each of the sub-sectors considered. Whilst providing some interesting results, it is important to note that this indicator presents some drawbacks that limit its ability to fully capture the precise level of competition. Hence, the number of firms in a given industry cannot capture its exact structure or layout, since within one same sector different firms can hold different market shares. It also ignores the competition exerted by imported goods and the informal sector. This group of market and demand indicators also includes a dummy variable capturing whether sample firms run their production lines on a continuous or on a *made-to-order* basis. The idea underlying this indicator is that, other things equal, firms that are able to run their production lines on a continuous basis have more stable business prospects, facilitating investments and, more generally, technological efforts.

Finally, these various Logit analyses incorporate as explanatory variables two different measures of firms' manufacturing performance: growth of sales and productivity growth. The reason for including these variables is that firms' performance is likely to be an important driver underlying their decision to engage in technology development efforts. For instance, poor performance may take firms to invest in different technological areas of production to improve their competitiveness or enter new markets. Good performers, on the other hand, may invest in these areas as a way of consolidating their market positions.

3. Traits of technology development in Mozambican manufacturing firms

Similarly to what other studies of the Mozambican manufacturing sector report (e.g. RPED, 2002), none of the ninety firms surveyed for this project had engaged since 1999 up to the time of the survey in 2004 in formal R&D efforts. This does not mean that these firms have been technologically stagnant. In fact, the available evidence suggests they actually engage in substantial technological activity. Hence, a total of 71 of the 90 firms surveyed (78.9 percent) had engaged since 1999 in technology-upgrading efforts, either by means of introducing entirely new products, acquiring new items of equipment or participating in programmes to introduce ISO 9000 standards in their manufacturing processes. Furthermore, in some cases, these efforts have involved substantial informal processes of innovation, for instance to adapt technologies to local circumstances, leading to processes of local innovation. In addition to these more substantial efforts, most if not all firms in the sample had engaged in minor technology-upgrading activities, such as modifying existing product ranges or existing manufacturing equipment, among other initiatives.

With regard to product development efforts, in all, around half of the firms surveyed in these two sectors (52.2 percent) engaged in efforts to introduce entirely new products for which they had little or no past manufacturing and marketing experience, whilst 74.4 percent had undertaken major alterations of existing product lines. It is important to note that product development efforts captured here are defined locally; that is, they generally do not involve movements of the international technological frontier, but rather, movements towards or around this benchmark. In fact, in many cases they simply consisted in the introduction of products that have long been manufactured in other countries. In terms of their origin, product development efforts consisting of major alterations of existing product lines were primarily the result of internal efforts, although in the light chemical sector several firms used external technical assistance to undertake product alterations. This was especially the case of paint manufacturers, where firms frequently resort to external consultants or product licenses. On the other hand, there did not appear to be any systematic pattern in the source of acquisition of product development know-how involving the introduction of entirely new product lines. In some cases, new lines were the result of internal efforts based on reverse engineering of similar products already available in the market. For instance, on this basis, three firms in the metalworking sector had developed brick-making machines, and another had recently created an electrically operated small-scale maize-milling machine. Other firms had introduced new product lines by purchasing new specialised production equipment or, in some cases, contracting specialised workers. For instance, one of the main metalworking firms in the sample had started producing plastic recipients in 2001 after purchasing specialised extrusion blow moulding machinery, whilst one of the main Mozambican manufacturers of cleaning and hygiene products heavily relied in the product development expertise of its chief technical engineer, acquired whilst working for a major multinational firm in the sector. In the light chemical sector several firms had employed specialised technicians to develop and introduce new product lines on the basis of know-how acquired in other Mozambican firms or abroad. Finally, many firms relied on product know-how provided by foreign partners, such as mother firms, suppliers of specialised inputs or technological partners.

Table 2. Technology-upgrading efforts in the sample between 1999 and 2003

Firm has	Metalworking		Light Chemicals		Total	
	No.	% Total	No.	% Total	No.	% Total
1. Product Development efforts						
Introduced entirely new product	29	51.8	18	52.9	47	52.2
Substantially modified existing product	47	83.9	20	58.8	67	74.4
Small product modifications	34	60.7	17	50.0	51	56.7
2. Production technology upgrade efforts						
Has purchased equipment since 1994	39	69.6	26	76.5	65	72.2
Purchased equipment since 1999	34	60.7	21	61.8	55	61.1
% Purchased second hand equipment	26.4	n.a.	23.8	n.a.	26.5	n.a.
Purchased entirely new technology embodied in new equipment	16	28.6	9	26.5	25	27.7
Firms modifying equipment	22	39.3	16	47.1	38	42.2
3. Process / Industrial engineering efforts						
Firms taking ISO course	17	30.4	8	23.5	25	27.8
Computerised Inventory System	39	69.6	24	70.6	63	70.0

Production technology development efforts were examined in terms of initiatives by firms in the metalworking and light chemical sectors to upgrade existing manufacturing equipment or introduce production technologies embodied in production equipment that was new them. It also included efforts to adapt these technologies to circumstances that are specific to the environment in which these firms operate. On the whole, outcomes in this sphere of firm-level technology development were mixed. A majority of firms (around two thirds in both sectors) had been involved in purchases of items of manufacturing equipment with a value above USD1000 since 1999.[8] However, this leaves a total of 35 firms (38.9 percent) not having purchased any items since that year, of which 25 had not purchased any equipment since 1994. Furthermore, a significant proportion of purchases of machinery consisted of second hand equipment. Additionally, although a majority of firms had purchased equipment since 1999, the proportion of equipment reported by firms as being less than five years old remained low (See Table 3), with the overall, the proportion of equipment five years of age or less at around 25 percent for both metalworking and light chemicals sectors. In terms of the nature of these acquisitions, only 25 firms, representing 27.8 percent of the sample, had acquired production technologies that were new to them, in the sense of

[8] This somewhat arbitrary value was imposed to exclude purchases of small items of equipment. It follows Deraniyagala and Semboja (1999), who use a value of USD500 in their study of Tanzanian manufacturing firms.

being significantly different to those they already operated. The remaining 30 firms had only upgraded production technologies that they were already using in their production lines.

Table 3. Proportions of equipment less than five years old of sample firms

	Metalworking		Light Chemicals		Total Sample	
	No. Firms	% Tot.	No. Firms	% Tot.	No. Firms	% Tot
0%	20	35.7	13	38.2	33	36.7
0 – 10%	10	17.9	4	11.8	14	15.6
11 – 25%	9	16.1	7	20.6	16	17.8
26 – 50%	8	14.3	5	14.7	13	14.4
51 – 75%	2	3.6	0	0.0	2	2.2
75 – 100%	7	12.5	5	14.7	12	13.3

One third area where technology development efforts were examined is that of efforts in the sphere of process engineering; that is, initiatives to improve manufacturing processes or the organisation of production lines. The economic, business and technology literature identifies these types of technological efforts as a prime source of efficiency gains in production. In fact, the importance of industrial engineering for manufacturing efficiency has been a recurrent topic in the literature on industrial organisation, for instance in discussions regarding different forms of capitalist production, such as Taylorism, Fordism or Toyotism.[9] However, it can be difficult to obtain quantifiable indicators in this sphere of technology development, given that changes in this sphere are often the result of informal or unplanned efforts that are difficult to identify. In this respect, two indicators were considered.

A first indicator captures whether firms were participating or had participated in programmes to implement ISO 9000 standards. The ISO 9000 is a set of standards developed by the International Standards Organisation (ISO) establishing practices of excellence in manufacturing production, in terms of quality management and assurance (UNIDO, 2005). In this regard, participation in this type of course can be considered a good proxy of firms' willingness to engage in technology development in this sphere.[10] Ideally, this indicator should included only firms that are ISO 9000 certified. However, in the Mozambican context the costs of certification impede many firms from doing so, despite complying with ISO 9000 production standards. Hence, as part of the coursework to obtain ISO certification, firms participating in these courses in Mozambique are required to implement ISO standards and practices in their firms, so that these training efforts actually do translate into efforts to improve manufacturing processes. At the time the survey was undertaken in 2004 these courses, which started running in 2001, were being organised by the National Institute of Quality and Standards (INNOQ), the Mozambican investment promotion agency (CPI), as well as by several private consultancy firms, and partly benefited from financial support from several aid agencies. In all, 25 firms, representing 27.8 percent of the sample, had participated or were participating in these ISO 9000 courses and implementing ISO standards in their production lines. In the metalworking sector many of the firms participating in these courses had done so after being awarded contracts with MOZAL, a large aluminium smelter operating outside the capital city of Maputo and which, with annual production accounting for 6.7 percent of Mozambique's GDP in 2005, is by far the largest industrial project in the country. Two reasons explain this: first, MOZAL required local potential subcontractors to conform to

[9] For a recent discussion of these issues, see Figueiredo (2001) and also the special issue on industrial organisation and development in World Development (1995, Vol. 23, No. 1) including Humphrey (1995)

[10] In a similar note, UNIDO's 2005 Industrial Development Report argues that *'together with the more traditional measures of technological effort such as R&D expenditure and patents, ISO 9000 certifications provide quite a robust indicator of capabilities'* (UNIDO, 2005:13).

international production standards in order to be eligible to be subcontracted by this aluminium smelter; Second, as recognised by survey respondents, gaining long term contracts with MOZAL provided firms with large volumes of profitable work and the possibility of obtaining additional contracts with other large projects in Mozambique and abroad, which justified investing on quality control and certification of this form.

A second indicator of process and industrial engineering efforts considered was whether firms operated computerised stock management systems. In this sense, it was assumed that firms with such systems are able to organise and control their stocks in a more precise, timely and efficient way. Moreover, in the Mozambican context where, at the time of the survey, the use IT technologies was quite recent, it was reasonable to assume that efforts to computerise stock inventory systems responded to initiatives undertaken during the relevant period of analysis: 1999 to 2003. In this sphere a total of 63 firms operated computerised inventory systems, 39 in metalworking and 24 in light chemicals industries. Although it was not possible to obtain, on a systematic basis, information regarding the type of software and inventory systems these firms operated, anecdotal evidence suggested that only a small number of them were using advanced software and networked inventory systems, the rest operating simple software spreadsheets to manage their inventories.

4. Factors Shaping technology efforts in the sample

4.1. Presentation of estimation results

Following the estimation methodology outlined above, tables 4 to 7 report the main results of the Logit analyses of factors associated with firms' efforts between 1999 and 2003 to introduce new products in their product portfolios (Table 4); purchase new items of equipment or machinery (Table 5); acquire production technologies involving the incorporation of new technologies for the firm (Table 6); and introduce ISO 9000 production standards in their manufacturing processes (Table 7). Each of these four analyses presents two different estimation models of technology efforts, one for the full sample of 90 firms and another for the sub-sample of 74 firms that reported performance figures for the survey.[11]

From an estimation perspective the results reported in Tables 4 to 7 appear to be reasonably robust, with model specifications remaining similar for the estimations on the full sample of 90 firms and the sub-sample of 74 companies reporting performance figures. The only exception is the model capturing factors associated with the acquisition of production machinery (Table 5), where these two estimations yield very different results, in terms of selected predictors. The estimated models also present a reasonably good fit. This is especially the case of the regression estimations of efforts to introduce new products and to incorporate ISO 9000 standards, with Hosmer & Lemesho's pseudo R^2 statistics ranging from 0.464 to 0.711, whilst the goodness of fit falls for the estimations of efforts to purchase new equipment and new production technologies, with Hosmer & Lemesho's pseudo R^2 estimators in the 0.2-.0.3 range.

[11] Detailed results of these Logit regression results can be provided by the author upon request.

Table 4. Logit regression of product development efforts

Full Sample of firms (Performance not considered)						
N: 90	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	11.344	2.609	18.906	1	.000	84416.63
MANSKILLS	-4.285	1.228	12.180	1	.000	.014
FIRMSKILLS	-4.783	1.374	12.110	1	.001	.008
TECHCAP	-3.221	.990	10.589	1	.001	.040
TECH.COOPERATION	.964	.379	6.462	1	.011	2.623
OVERALL.TECH.	1.093	.261	17.531	1	.000	2.983
CONTINUOUS	-1.364	.694	3.863	1	.049	.256
NBFIRMSIND	-.059	.035	2.853	1	.091	.943
PROCESSDEV	-2.532	.756	11.203	1	.001	.080
PRODDEVCAP	2.108	.840	6.303	1	.012	8.232
POST1987-base period			5.684	2	.058	
COLONIAL	-.935	.756	1.528	1	.216	.393
CENTRALPLAN	-3.780	1.638	5.324	1	.021	.023
Cox & Snell R^2: 0.480	Nagelkerke R^2: 0.646		Hosmer & Lemesho's R^2: 0.482			

Sub-sample firms reporting performance data						
N: 74	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	11.417	3.091	13.642	1	.000	90876.71
MANSKILLS	-5.167	1.565	10.900	1	.001	.006
FIRMSKILLS	-6.385	1.918	11.079	1	.001	.002
TECHCAP	-2.459	.894	7.557	1	.006	.086
TECH.COOPERATION	1.197	.505	5.612	1	.018	3.311
OVERALL.TECH.	1.132	.299	14.379	1	.000	3.102
CONTINUOUS	-1.631	.840	3.775	1	.052	.196
PROCESSDEV	-2.205	.827	7.111	1	.008	.110
POST1987-base period			6.655	2	.036	
COLONIAL	-1.050	.845	1.542	1	.214	.350
CENTRALPLAN	-4.512	1.754	6.616	1	.010	.011
Cox & Snell R^2: 0.456	Nagelkerke R^2: 0.624		Hosmer & Lemesho's R^2: 0.464			

Table 5. LOGIT analysis of production technology efforts to acquire new items of machinery and other production equipment

Full Sample of firms (Performance not considered)						
N: 90	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	2.653	1.146	5.355	1	.021	14.192
MANSKILLS	-1.679	.881	3.635	1	.057	.187
AGE EQUIPMENT	-.165	.065	6.452	1	.011	.848
OVERALL.TECH.	.212	.079	7.158	1	.007	1.236
INDUSTRY	-1.160	.585	3.928	1	.047	.313
NBFIRMSIND	-.041	.022	3.399	1	.065	.960
POST1987-base period			9.822	2	.007	
COLONIAL	3.164	1.054	9.010	1	.003	23.662
CENTRALPLAN	.562	1.194	.222	1	.638	1.755
Cox & Snell R^2: 0.321	Nagelkerke R^2: 0.429		Hosmer & Lemesho's R^2: 0.28			

Sub-sample firms reporting performance data						
N: 74	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	-1.966	1.506	1.705	1	.192	.140
SOE	1.808	.906	3.981	1	.046	6.101
FIRMSKILLS	1.472	.842	3.053	1	.081	4.356
PRODTECHCAP	.504	.254	3.946	1	.047	1.655
AGE EQUIPMENT	-.096	.057	2.842	1	.092	.908
INDUSTRY	-1.834	.770	5.675	1	.017	.160
STATE	1.874	.789	5.650	1	.017	6.517
NBFIRMSIND	-.068	.033	4.206	1	.040	.935
SECTOR	1.705	.884	3.719	1	.054	5.499
Cox & Snell R^2: 0.418	Nagelkerke R^2: 0.558		Hosmer & Lemesho's R^2: 0.478			

Table 6. Logit analysis of efforts to acquire production technologies new to the firm

Full Sample of firms (Performance not considered)						
N: 90	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	-4.518	1.233	13.436	1	.000	.011
TECHCAP	-1.636	.594	7.571	1	.006	.195
SECTOR	1.452	.670	4.693	1	.030	4.273
PROCESSDEV	1.473	.817	3.253	1	.071	4.363
TECH.COOPERATION	.751	.288	6.802	1	.009	2.119
PRODTECHCAP	1.081	.309	12.245	1	.000	2.946
Cox & Snell R^2: 0.229	Nagelkerke R^2: 0.338		Hosmer & Lemesho's R^2: 0.213			

Sub-sample firms reporting performance data						
N: 74	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	-5.468	1.563	12.240	1	.000	.004
TECHCAP	-2.321	.778	8.908	1	.003	.098
SECTOR	2.490	.907	7.539	1	.006	12.060
PROCESSDEV	1.644	.964	2.910	1	.088	5.177
TECH.COOPERATION	.813	.339	5.748	1	.017	2.254
PRODTECHCAP	1.571	.446	12.387	1	.000	4.810
Cox & Snell R^2: 0.300	Nagelkerke R^2: 0.418		Hosmer & Lemesho's R^2: 0.283			

Table 7. Logit analysis of efforts to implement ISO 9000 standards

Full Sample of firms (Performance not considered)						
N: 90	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	-11.718	4.972	5.556	1	.018	.000
FOROWN	-.118	.046	6.681	1	.010	.888
OVERALL.TECH.	1.105	.425	6.768	1	.009	3.020
AGRICULTURE	-5.094	2.436	4.373	1	.037	.006
INDUSTRY	4.456	2.092	4.536	1	.033	86.107
STATE	7.523	3.535	4.531	1	.033	1850.801
EXPORT	12.893	5.286	5.950	1	.015	397601.5
MOZAL	13.256	5.554	5.697	1	.017	571261.8
PRODDEV	-2.017	.772	6.819	1	.009	.133
POST1987-base period			5.584	2	.061	
COLONIAL	8.961	3.792	5.583	1	.018	7794.105
CENTRALPLAN	-16.673	179.686	.009	1	.926	.000
Cox & Snell R^2: 0.586	Nagelkerke R^2: 0.825		Hosmer & Lemesho's R^2: 0.711			

Sub-sample firms reporting performance data						
N: 74	Coefficient	S.E.	Wald stat.	df	Sig.	Exp(B)
CONSTANT	-6.358	2.333	7.425	1	.006	.002
FOROWN	-.042	.019	4.791	1	.029	.959
SOE	6.626	2.355	7.919	1	.005	754.793
OVERALL.TECH.	.815	.293	7.731	1	.005	2.258
AGRICULTURE	-4.787	2.219	4.655	1	.031	.008
STATE	2.781	1.448	3.688	1	.055	16.136
EXPORT	7.449	2.840	6.877	1	.009	1717.707
MOZAL	5.228	2.449	4.557	1	.033	186.363
PRODDEV	-1.362	.571	5.685	1	.017	.256
Cox & Snell R^2: 0.602 Nagelkerke R^2: 0.829 Hosmer & Lemesho's R^2: 0.711						

On the whole, considerable variability can be observed in the selection of statistically significant predictors for these estimated Logit regression models, in terms of selected predictors and their implications for understanding technological dynamics in the sample. This should be interpreted as indicating that factors shaping technology-upgrading efforts vary considerably across different spheres of technology development. Also as underscoring that the importance of these various factors, in terms of their level of statistical significance, intensity and sign, will vary for different types of (heterogeneous) firms, depending on the nature of their production processes, the markets they supply and, more generally, the external conditions in which they operate. These findings highlight the heterogeneous and complex nature of technology change at the firm level in a context in which heterogeneous firms operate different production systems and face a variety of external constraints. These findings are consistent with the industrial organisation literature highlighting the heterogeneity of processes of firm-level technology change (e.g. Acs & Audretsch, 1987).

4.2. Multifaceted nature of technological dynamics in sample firms

In general, technology variables enter these estimated Logit specifications as statistically significant predictors of firms' technology-upgrading efforts in all four of the events analysed. These predictors include variables capturing general skills and technology capabilities, technology development efforts in other areas of production, technology capabilities directly applicable to each of these four technological events, as well as the interactions between all of these technological indicators. The inclusion of these variables highlights the close association that exists between these various technological parameters and firms' technology development efforts; that is, between technological conditions that exist in these enterprises and technological outcomes in the sample. However, these technology variables do not always interact in a positive cumulative way.

Hence, in several instances the various technology variables included as predictors are inversely related with efforts in each of the technology spheres examined. This is for instance the case of technology efforts in the spheres of product development and process engineering, for which there appear to be clear tradeoffs. Hence, as can be seen from the predictors included in Tables 4 and 7, the relative odds of firms introducing new products tend to fall as process engineering efforts {PROCESSDEV} increase, with both coefficients on this variable reporting negative values in the regression reported in Table 4. At the same time, the odds that firms introduce ISO 9000 production standards, which capture industrial engineering efforts, decrease with product development initiatives, with negative values on the coefficients of the product development variable {PRODDEV} of -2.017 and -1.362. This inverse relationship is also present in the case of managerial skills, firms-wide skills and overall technological capabilities {TECHCAP}, which, in all but one case,[12] are negatively associated with technology development efforts whenever statistically significant.

These results need to be interpreted with caution, given the nature of Logit regression analysis. Hence, the negative coefficients and their associated odds ratios do not necessarily entail that more skilled and technologically capable firms do not engage in this type of efforts. Simply, that when they do, they do so with less intensity, so that the odds doing so are lower for these companies than for less skilled and technologically capable firms. On the other hand, whilst these results might appear counterintuitive, they should be viewed within the wider context of the various sources of technology and know-how acquisition available and used by these firms. Thus, firms in these two sectors have other sources technology and know-how acquisition, which can make up for their weak skills and capabilities base. There is also a possibility that they reflect catching up dynamics, by which less skilled and capable firms engage in greater technology-upgrading efforts, in order to catch up with technologically more advanced firms. In the specific case of the composite technology capabilities indicator {TECHCAP}, it should also be noted that this index is constructed as the summation of sub-indices capturing technology capabilities in different spheres of production. Consequently, each of these sub-indices may be affecting these four technology development events with different intensity and sign. This would entail that the impact of technological capabilities on technology development efforts would not be uniform across the different technology dimensions and production spheres, highlighting the heterogeneous nature of technology capability accumulation and development.

In other instances various technology sub-indices and composite technology indicators are positively associated with firms' efforts to engage in these four technological events. This is the case of several sub-indices capturing specific technological capabilities that are directly relevant for each of the technology development areas under consideration, which enter in some of these estimated models as being positively associated with these events. Examples of this are product development capabilities {PRODEVCAP}, which are positively associated with the odds of introducing new products (Table 4); or production technology capabilities {PRODTECHCAP}, which increase the odds of purchasing new production equipment by sample firms (Tables 5 and 6). These results suggest that, in some cases, technological capabilities are important determinants of technology efforts in specific spheres of technology development, as posited by the technology capabilities literature. This is also the case of the variable capturing interactions between firms' skills, capabilities and technology development efforts {OVERALL TECH.}, which is positively associated with the odds that firms engage in technology efforts to introduce new products (Table 4), invest in new machinery (Table 5) and introduce ISO 9000 standards in production (Table 7). The inclusion of this predictor would imply that, beyond the possible tradeoffs that exist between different spheres of technology development, on the whole, technologically stronger firms tend to engage more in technological efforts such as those describe by these four technological events than technologically weaker firms.

Altogether, these results highlight the complex and multifaceted nature of enterprise technology development: that is, on the whole, general technological conditions and dynamics in these firms play an important role in determining technology-upgrading efforts. However they are not all equally important in the various relevant areas of manufacturing production in which technology change takes places; nor do they impact each of these spheres in a linear or uniform way.

[12] That of firm-wide skills in the LOGIT estimation on the sub-sample of 74 firms of efforts to acquire new production equipment and machines (Table 5).

4.4. Industrial heterogeneity and technology change as a heterogeneous process

The above results also underscore the differential impact that enterprises' heterogeneous production conditions have on firms' technology development efforts, in line with the findings by the industrial organisation literature (e.g. Acs & Audretsch, 1987). This result is important in that it highlights the intrinsically multifaceted nature of technology change in the context of heterogeneous firms. In other words, that the nature of production will vary across different firms, even for those firms classified as pertaining to the same (sub) sector, and this will impact on the specific firm-level trajectories that technology development takes.

Several predictors illustrate the importance of industrial heterogeneity for technology development in industrial firms. This is the case of the dummy variable describing whether firms engage in continuous production or, on the contrary, produce on a *made-to-order* basis {CONTINUOUS}, which appears as an important predictor for product development (Table 4). This variable presents a negative value, indicating that the odds of introducing entirely new products for the former group of firms is between four to five times lower than for the latter.[13] The inclusion of this variable partly reflect the fact that firms engaging in continuous production tend to base their business strategies in the mass production of standardised products, leaving little scope for product development considerations. The second group of firms, on the other hand, includes enterprises that produce on a *made-to-order* basis, catering each time for the specific needs of different types of clients, which frequently involves substantial product development. This is, for example, the case of many metalworking firms that produce, at different points in time, a variety of products, ranging from spare parts, repair and reconstruction services, metal furniture or metal structures used for construction purposes, each of which have to be adapted to different client requirements.

The differential technological impact of heterogeneous production conditions in sample firms is also visible in relation to efforts to purchase entirely new production technologies and, to a lesser extent, general efforts to acquire new items of machinery, [14] areas in which there are significant sectoral and, consequently, techno-production differences between metalworking enterprises and firms in the light chemicals sector. Efforts to acquire new items of machinery are also negatively related to the age of existing equipment, indicating that the odds of engaging in such purchases increase with the average age of the production equipment used by these firms. Interestingly, the age of equipment is not a significant predictor of firms' efforts to acquire new items of equipment that involve the incorporation of entirely new technologies in production (see Table 7). This would suggest that this type of decisions respond to more strategic considerations, which take place regardless of the age of firms' manufacturing equipment.

Finally, it is also evident in the apparent tradeoffs identified above between technology development efforts in the spheres of product development and process/industrial engineering. One possible interpretation is that these tradeoffs reflect a budget or resource constraint on technology development, which impedes firms from engaging in technology-upgrading efforts simultaneously at both these levels; that is, firms either devote their efforts to introducing new products or to participate in ISO 9000 programmes. However, interviews with these firms suggested that, beyond the need for certain product development capabilities, often already present in these firms, product development activities do not usually involve large expenditures. On the other hand, programmes to introduce ISO 9000 production

[13] Hence, the odds reported in the last column of Table 4 are of 0.256 for the estimation on the full sample of 90 firms and of 0.196 for the estimation over the sub-sample for 74 firms reporting performance figures.
[14] In this latter model the dummy variable is only significant in the estimation done over the sub-sample of 74 firms but not for the estimation over the full sample (See Table 5).

standards have been in all cases, at least, partly subsidised in Mozambique. In this respect, the possibility that these tradeoffs between product development and process/industrial engineering efforts reflect a budget constraint loses weight. Another more plausible interpretation is that these tradeoffs reflect intrinsic differences in the nature of the manufacturing processes of firms that engage more intensely in product development activities and enterprises that are more intensive in process/industrial engineering efforts.

4.5. Technology cooperation as a source of technology development

Beyond these technological and production considerations regarding the multifaceted nature of firm-level technology development and the impact of industrial heterogeneity, it is important to highlight the role that technology cooperation arrangements plays in technology development efforts in the four areas examined here. These, refer to sample firms' interactions with other private companies, technology institutions or specialised consultants aimed at acquiring new production technologies or know-how. The importance of these channels of technology transfer has been recognised in the technology capabilities literature (e.g. Lall, 1992; Kagami *et al*, 1998), although its applied analysis has been scant.

In the analysis undertaken here technological cooperation enters directly as an important predictor of efforts to introduce new products (Table 4) and to incorporate new production technologies embodied in purchases of machinery (Table 6). In particular, firms engaging in technology cooperation arrangements appear as being considerably more likely to introduce entirely new products than firms that do not, as well as to incorporate new technologies embodied in machinery and other production equipment. Indirectly, the role of technology cooperation is also present as a predictor of efforts to incorporate ISO 9000 standards, since all firms subcontracting work with the MOZAL aluminium smelter (which is a significant predictor in the Logit specification reported in Table 7) have benefited from substantial technological 'coaching' by this industrial project, including support to introduce ISO 9000 standards in their manufacturing processes.

These results largely reproduce the findings identified in earlier research on industrial and technological development in Mozambique (Warren-Rodriguez, 2008a) indicating that for many firms, linkages with partner companies, suppliers, independent consultants and business service providers constitute a key source of technology and know-how acquisition. For instance, several firms engaging in product development were doing so on the basis of prototypes, formulas and product licenses developed by foreign firms and institutions, as well as on the basis of the services offered by specialised consultants. Similarly, firms acquiring new production technologies embodied in new items of machinery have, in several occasions, benefited from critical support from external agencies and firms in the specification and installation of this equipment. In some instances this support has come directly from international suppliers of key inputs and equipment. In other cases, it is the mother company abroad who has provided these services. Finally, all firms participating in programmes to introduce ISO 9000 production standards have done so under the auspices of one of the various business development initiatives currently running in Maputo.[15]

Still, these results should be viewed within the general context of the relative few cooperation arrangements between sample firms and external organisations, with only 42 firms in the sample (46.7 percent) reporting having arrangements of this kind. Moreover, of these 42 firms, only 24 have participated or benefited from the various business development and linkages programmes that exist in Mozambique, in many instances not on a regular basis and, frequently, for training purposes not directly related to manufacturing production, for

[15] See Warren-Rodriguez (2008a) for a more detailed discussion of these issues.

instance for secretarial or accountancy training, underscoring the limited reach of this type of technology extension programmes have in Mozambique.

4.6. Market related constraints on technology development efforts

Market and sectoral conditions in which firms operate also appear to play an important role in shaping technology development efforts in the sample, with all but one[16] of the model specifications reported in Tables 4 to 7 including at least one variable of this nature. These variables include several dummy variables capturing the specific conditions that firms face in the markets in which they operate, as well the competition indicator, constructed as the number of local competitors that firms confront in their respective sub-sectors. These results are suggestive that technological development in the Mozambican manufacturing sector is not only constrained by supply side factors, such as the availability of technological inputs (e.g. skills, technological capabilities) or the effectiveness of the different sources of technology and know-how acquisition, but also by demand side considerations.

Market specific conditions appear as being particularly relevant for efforts to invest in the acquisition of machinery (Table 5) and those to introduce ISO 9000 production standards (Table 7). In the first of these cases, which typically involves large investment expenditures, it is interesting to note the very different impact of participating in government procurement contracts {State} and supplying other industrial firms {Industry}, two markets which in the past two decades have experienced very different fortunes in Mozambique. Hence, the odds of investing in the purchase of equipment are around one third lower (odds ratio of 0.313) for firms supplying other industrial firms (over those that do not), a sector which has experienced several negative shocks in the past decades that have lead to the closure of many industrial firms, the collapse of key sectors and a general thinning of its productive base (Castel-Branco, 2002; Warren-Rodriguez, 2008a). In this respect, poor market conditions in the industrial sector may have undermined sample firms' technology development investments. At the same time, these odds are over six times higher (Exp(B): 6.517) for firms regularly participating in government procurement contracts (over those that do not), a market which has experienced a very significant growth as a result of the large inflows of aid that Mozambique has received since the mid 1990s, a large proportion of which has been directed to fund government programmes in priority sectors.[17] It is also worth noting that, whilst these two market dummy variables {State and Industry} play and important role in shaping firms' decisions to invest in purchases of new equipment, they (as well as other market dummy variables) hold no significant impact on more strategic decisions to invest in the acquisition of entirely new production technologies (see Table 6), which can be considered as a specific case of the former type of investments. Unfortunately, the available information does not allow a precise assessment of the factors underlying these divergent results. Still, these differences could be read as indicating that, whilst general purchases of machinery are negatively affected by the budget constraints imposed by the specific market conditions that sample firms face, decisions to acquire entirely new production technologies respond to more strategic motives.

Dummy variables capturing market conditions that firms face also play a relevant role in the specification of the efforts to introduce ISO 9000 standards. In this case, the odds of doing so are substantially higher for firms working for MOZAL, exporting, participating in government procurement contracts and supplying other industrial firms. Conversely, they are considerably lower for firms selling their products to the agricultural sector than for other firms. Lack of information on firms' reasons to undertake such efforts impedes an exact

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[16] That is, efforts to introduce new production technologies embodied in new items of machinery (See Table 6).

[17] Sample firms participating in government procurement contracts typically supply school and hospital equipment (metal chairs, desks and beds, foam mattresses, medical gases etc.), among other products.

assessment of their motives in doing so. Nonetheless, the nature of some of these markets and technology efforts provides some hints of plausible explanations. For example, the inclusion of the variable capturing whether firms sub-contract work with MOZAL is simple to interpret, since these firms were required to participate in ISO 9000 programmes as a precondition for obtaining contracts with this aluminium firm. On the other hand, the export dummy variable could be interpreted as providing support to the trade literature highlighting the role of exports as a source of technology transfer (see Krueger, 1998; Westphal, 2002 or Bhaduri and Ray, 2004). Hence, the fact that efforts in this sphere have been largely subsidised weakens the self-selection argument that exporting firms have greater odds of introducing ISO 9000 standards only because they are in a better financial position of doing so. Consequently, there would appear to be some intrinsic aspect regarding export activities that makes exporters more likely to engage in this type of technology-upgrading efforts than firms that do not export. For instance, it could be that this type of certification has become a standard requirement for firm operating in international markets of manufacturing goods.

Market competition, captured as the number of firms that operate in each sub-sectors {NBFIRMSIND}, is also a statistically significant predictor of efforts to purchase new items of equipment and, to a lesser extent, to introduce new products.[18] In all these cases, estimated coefficients are negative, implying that the odds of engaging in this type of effort fall as competition increases in each of these sub-sectors. In all three cases, market competition enters as a significant predictor with a very small negative coefficient, meaning that the odds of engaging in this type of effort only marginally falls as competition increases. Still, it should be noted that these odds also refer to marginal increases in competition; that is, to the impact on technology-upgrading efforts of increasing competition by one firm.

Market conditions faced by these firms are also partly captured in the variable denoting whether firms produced on a continuous or on a *made-to-order* basis, which is an important predictor of efforts to introduce new products. As indicated above, this variable partly captures intrinsic differences in production in sample firms, which are likely to affect the nature and intensity of their technological efforts. In particular, firms producing on a *made-to-order* basis are more likely to engage in product development, as they often need to design different products for different clients. However, discussions with managers of these firms indicated that, in several cases, they had been led to produce on this basis as a result of adverse external conditions, for instance in terms of insufficient demand for their products. This is the case of several metalworking firms, which in the past operated continuous production lines producing spare parts, equipment or metal tools. These firms have had to diversify their production as many of the sectors they supplied have shrunk or collapsed, so that they currently produce a wide variety of products and services to clients of a varying nature. For these firms product diversification can be seen as a survival strategy aimed at maintaining their operations and maximising the use of their installed production capacity by entering new markets or, simply, taking any orders they can reasonably fulfil.

4.7. Absent variables in the determination of technological efforts

Finally, it is worth commenting on some of the variables initially considered for the analysis that are absent from the final estimated Logit specifications reported in Tables 4 to 7. In this respect, a first common feature in all the models estimated on the sub-sample of 74 firms is the absence of performance variables (sales growth or productivity growth) as statistically significant predictors of firms' efforts in each of these four areas of technology development. Two interpretations can possibly explain this. Firstly, the absence of performance indicators

[18] In this latter case, the competition variable is only statistically significant for the estimation on the full sample of firms, not in the estimation of 74 enterprises that reported performance figures for this survey.

in these Logit estimates could simply indicate that firms' performance has no predictive power, positive or negative, over the four technology development events examined here. Second, that the impact of firms' performance on these four technology-upgrading events is partly captured by other statistically significant predictors included in the final model specifications reported in Tables 4 to 7. For instance, it is likely that significant predictors describing firms' main markets (e.g. Export, Industry, or MOZAL) capture, among other factors, specific market traits, such as the evolution of demand or the degree of competition, that also affect manufacturing performance of firms operating in these markets.

Other in theory relevant variables are also absent in all four Logit specifications. Amongst these it is worth highlighting the absence of variables capturing the impact of foreign ownership, enterprise age and size, which feature prominently in the literature on firm-level technology change. The exclusion of these variables is line with the findings discussed in earlier research on this topic in Mozambique (Warren-Rodriguez, 2008a) and strengthens the observation that, unlike other studies on firms' technology efforts in developing countries (e.g. Wignaraja, 1998, 2002; Deraniyagala & Semboja, 1999; Rasiah, 2004), in the Mozambican case these factors have not had a differential impact on firm-level technological dynamics, including technology-upgrading efforts in the spheres examined here. Yet, whilst the exclusion of variables such as age and size is likely to reflect specific traits of the various technology development events examined here, it is necessary to reflect on the potentially more profound implications of the absence of foreign ownership variables in the above Logit regressions. Hence, in a context in which the Mozambican manufacturing sector is well below the international technological frontier, FDI would appear to be an obvious channel of technology transfer. In this sense, its absence in the present analysis of technological efforts in the metalworking and light chemicals sectors could be seen as a reflection of the poor nature of FDI projects in these two sectors, as well as of the weak institutional framework for investment and linkages promotion that exists in Mozambique.

5. Concluding comments

The exploratory analysis presented in this paper has provided valuable insights of factors shaping technology development efforts in the two manufacturing sectors under consideration, metalworking and light chemicals, during the period under analysis, 1999 to 20003. It has also served to assess of the validity of various propositions found in the literature on industrial technology change and development.

In line with much of the literature on industrial organisation and the microeconomics of technology change, the analysis presented in this paper suggests that existing production and technological conditions in manufacturing firms do play an important role in shaping the nature and intensity of their technology-upgrading efforts, underscoring the path dependent and idiosyncratic nature of technology change. That is, paths of technology development in manufacturing firms are, to a certain extent, influenced by the type and nature of their production processes, as well as by their levels of technology capability skills. However, this association between existing technological conditions and technological outcomes is not always linear, cumulative or uniform across the different areas of manufacturing, underscoring the multifaceted nature of technology development ay the enterprise level. From a methodological perspective, this would suggest that the analysis of technology dynamics in manufacturing firms needs to take into account these complexities and, in particular, the different technological dynamics that exist in the various spheres of manufacturing, as well as their interdependencies. In this respect, whilst these complexities are widely acknowledged in studies of technological dynamics in industrial economies, it is more rare in similar analyses undertaken for developing countries, especially in the applied technology capability literature, which has tended to focus on the examination of aggregate features of firm-level technology change (see, Lall & Latsch, 1999; Wignaraja, 1998, 1999, 2002; Deraniyagala & Semboja, 1999; Rasiah *et al,* 2004, Yoguel & Milesi, 2006). From a policy perspective these results also suggest that manufacturing development and the formulation of industrial (technology) policies cannot be approached under the assumption that industrial firms constitute a homogenous group of economic agents engaged in standardized manufacturing processes.

A particularly striking finding is the role played by skills in the various Logit estimates presented in this paper, which, whenever relevant, are negatively associated with firms' technology development efforts. Although the available information precludes an indepth analysis of this somewhat counter-intuitive finding, these results suggests that firms in these two sectors have other mechanisms or sources of know-how acquisition that compensate for their lack of skills. They also suggest that skills, as usually understood and measured in the technology (capabilities) literature, may not be a particularly relevant factor underlying firm-level technological dynamics. Similar conclusions can be drawn with respect to the weak role played by foreign ownership as a source and catalyst of technology development efforts. These results and the prevalence and weight of the variable capturing technology cooperation between sample firms and external agents suggests that these alternatives sources of technology and know-how acquisition have played a critical role in shaping technology development efforts in Mozambique. Conversely, it can also be read as an indication that the potential technological benefits of FDI have not been maximised in the Mozambican manufacturing context.

The analysis presented here has also provided some interesting insights into the role played by demand side considerations in shaping technology development efforts in the Mozambican metalworking and light chemicals sectors. In general, the available evidence suggests that, whenever relevant, adverse market conditions undermine technology-upgrading efforts in the various production spheres examined here, underscoring the demand-side nature of (technological) manufacturing investment. The lack of information that exists in Mozambique regarding specific conditions and trends in the various markets in which these firms operate, as well as the empirical approach taken in this paper impedes a precise and comprehensive assessment of the role played by market and demand conditions in shaping technology development efforts in Mozambique. In this respect, these results should only be taken as indicative of the importance of these issues. Yet, the relevance of this finding should not be underestimated. First, because, although microeconomic theory of production, the firm and technology change recognises the importance of these considerations, the empirical analysis of technology in developing countries has tended to overlook these issues. In some cases, taking them as given, for instance in the examination of the role of technological capabilities and efforts on manufacturing performance or export decisions (e.g. Wignaraja, 1998, 2002; Rasiah, 2004; Bhaduri & Ray, 2004, Yoguel & Milesi, 2006), which tend to obviate the fact that market and demand dynamics will simultaneously affect manufacturing performance and, consequently, decisions regarding technology investments. In others, by focusing only on firm's traits (e.g. ownership, size, age) in the analysis of factors shaping their technology development efforts. Second, because from a policy perspective it highlights that efforts to promote technology-upgrading in manufacturing firms cannot be limited to initiatives aimed at overcoming market failures in the provision of key technology inputs, for instance through the creation of business development services or vocational training programmes. Nor to general investment climate considerations; and should also take into account market specific demand conditions shaping technology development efforts.

References

Acs, Zoltan and Audretsch, David B. (1987) Innovation, market structure and firm size. *Review of Economics and Statistics,* 69(4), pp. 567-574.

Badhuri, Saradindu and Ray, Amit S. (2004) Exporting through Technological Capability: Econometric Evidence from India's Pharmaceutical and Electrical/Electronics Firms. *Oxford Development Studies*, 32(1), pp. 2004

Basant, Rakesh (1997) Technological strategies of large enterprises in Indian industry: some explorations. *World Development,* 25(10), pp. 1683-1700.

Bell, Martin and Keith Pavitt (1995) The Development of Technological Capabilities, in: ul Haque, Irfan (ed.) *EDI Development Studies,* Economic Development Institute (EDI) of the World Bank. The World Bank. Washington, D.C.

Boz, Ismet and Akbay, Cuma (2005) Factors Influencing the Adoption of Maize in Kahramanmaras Province of Turkey. *Agricultural Economics*, 33(3), p. 431-40

Burton, Michael; Rigby, Dan and Young, Trevor (1999) Analysis of the Determinants of Adoption of Organic Horticultural Techniques in the UK. *Journal of Agricultural Economics,* 50(1), pp. 48-63

Braga, Helson and Larry Willmore (1991) Technological imports and technological efforts: An analysis of their determinants in Brazilian firms. *Journal of Industrial Economics*, 29(4), pp. 421-32

Calvo, José L. (2006) ¿Son las Actividades de I+D una buena aproximación a la Innovación Tecnológica? *Economía Industrial*, 358, pp.173-184

Castel-Branco, Carlos Nuno (2002) *An Investigation into the Political Economy of Industrial Policy: The Case of Mozambique*. PhD Thesis. School of Oriental and African Studies (SOAS) University of London. London

Chirwa, Ephraim W. (2005) Adoption of Fertiliser and Hybrid Seeds by Smallholder Maize Farmers in Southern Malawi. *Development Southern Africa,* 22(1), pp. 1-12

Diederen, Paul; van Meijl, Hans and Wolters, Arjan (2003) Modernisation in Agriculture: What Makes a Farmer Adopt an Innovation? *International Journal of Agricultural Resources, Governance and Ecology,* 2(3-4), pp. 328-42

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

Evenson, Robert E. & Westphal, Larry E. (1995) Technological Change and Technology Strategy, in: Behrman, J. & Srinivasan, T.N. (eds.) Handbook of Development Economics Volume 3A, Chapter 37. Elsevier Science, B.V. Amsterdam

Figueiredo, Paulo N. (2001) *Technological Learning And Competitive Performance* Edward Elgar, London

Field, Andy (2005) *Discovering Statistics using SPSS.* Second Edition. Sage Publications Ltd., London

Foltz, Jeremy D. and Chang, Hsiu-Hui (2002) The Adoption and Profitability of rbST on Connecticut Dairy Farms. *American Journal of Agricultural Economics*, 84(4):1021-1032

Freeman, Chris and Soete, Luc (1997) *The Economics of Industrial Innovation*. 3rd Edition. MIT Press, Cambridge, Massachusetts

Garson (2006) Statnotes: Topics in Multivariate Analysis: Logistic Regression PA765 *Quantitative Research in Public Administration; Internet Resources.* North Carolina State University (NCSU). Raleigh, NC

Gockowski, James and Ndoumbe, Michel (2004) The Adoption of Intensive Monocrop Horticulture in Southern Cameroon. *Agricultural Economics,* 30(3), pp. 195-202

Humphrey, John (1995) Industrial Organization and Manufacturing Competitiveness in Developing Countries: Introduction. *World Development,* 1(1), pp. 1-7

Isham, Jonathan (2002) The Effect of Social Capital on Fertiliser Adoption: Evidence from Rural Tanzania, *Journal of African Economies*, 11(1), pp. 39-60

Kagammi, Mitsuhiro; Humphery, John and Piore, Michael (1998) *Learning, Liberalization and Economic Adjustment*. Institute of Development Studies, Tokyo, Japan

Katrak, Homi (1997) Developing Countries' Imports of Technology, In-house Technological Capabilities and Efforts: an Analysis of the Indian Experience. *Journal of Development Economics*, 53, pp.67-83

Krueger, Anne O. (1997) Trade Policy and Economic Development: How We Learn. *American Economic Review*, 87(1), pp. 1-22

Krueger, Anne O. (1998) Why Trade Liberalisation is Good for Growth. *Economic Journal* 108, pp. 1513-1522

Lall, Sanjaya (1992) Technological Capabilities and Industrialization. *World Development* 20(2), pp.165-186

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

Lall, Sanjaya and Latsch, Wolfram W. (1999) Import Liberalisation and Industrial performance: Theory and Evidence, in: Lall, Sanjaya (ed.) *The Technological Response to Import Liberalization In Subsaharan Africa*. MacMillan Press Ltd. London

Nichola, T. (1996) The Decision to Adopt and the Intensity of Adoption of Technology: A Double Hurdle Model Application in the Adoption of a Sorghum Hybrid. *Journal for Studies in Economics and Econometrics*, 20(3), pp. 49-57

Pampel, Fred A. (2000) *Logistic Regression: A primer* Sage Publications Ltd.. *Quantitative Applications in the Social Sciences.* London

Payne, James; Fernandez-Cornejo, Jorge and Daberkow, Stan (2003) Factors Affecting the Likelihood of Corn Rootworm Bt Seed Adoption. *AgBioForum,* 6(1-2), pp. 79-86

Popp, Michael P.; Faminow, Merle D. and Parsch, Lucas D. (1999) Factors Affecting the Adoption of Value-Added Production on Cow-Calf Farms. *Journal of Agricultural and Applied Economics*, 31(1). pp. 97-108

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

RPED (2002) Mozambique. Industrial Performance and Investment Climate 2002: Pilot Investment Climate Assessment. Prepared by John Nasir, Manju kedia Shah, Chad Leechor, Pradeep Srivastava, Alan Harding and Vijaya Ramachandran. CTA, CPI, RPED, Africa Private Sector Group, The World Bank. Washington, D.C., March 2003

Rodrik, Dani (1992) Closing the Productivity Gap: Does Trade Liberalization Really Help? In: Helleiner, Gerald K. (ed.) *Trade Policy, Industrialisation and Development: New Perspectives* Chapter 6. Clarendon Press, Oxford.

Symeonidis, George (1996) Innovation, Firm Size and Market Structure: Schumpeterian hypotheses and some new themes. *OECD Working Paper No. 161*. OECD. Paris

UNIDO (2005) *Industrial Development Report, 2005. Capability building for catching-up: Historical, empirical and policy dimensions*. UNIDO. Vienna

Wignaraja, Ganeshan (2002) Firm Size, Technological Capabilities and Market Oriented Policies in Mauritius, in: Katrak, Homi & Strange, Roger (eds.) *Small-Scale Enteprises in Developing and Transitional Economies.* Palgrave, Basingstoke, UK

Wignaraja, Ganeshan (1998) *Trade Liberalisation in Sri Lanka: Exports, Technology and Industrial Policy* Macmillan. London

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

Yoguel, Gabriel and Milesi, Darío (2006) Technological and Organizational Capabilities for the Development of Competitive Advantages -The Case of Successful SME Exporters in Argentina, Paper presented at *Globelics 2006: Innovation systems for competitiviness and shared prosperity in developing countries*, 4-7 October, Trivandrum. Kerala, India.