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University-Industry Collaboration as a Determinant of Innovation in Nigeria

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Abstract: This paper examines the types, intensity, and impact of collaboration and learning in Nigeria. Two separate studies are used to examine on the one hand, the way universities collaborate with other actors within a national system of innovation (NSI) framework and how firms collaborate with universities and other actors on the other. Descriptive statistics and Probit regression confirm some of what we know from the literature about collaborative learning. The size of organizations and firms, infrastructure, and human capability proxied by number of PhDs all tend to influence the types and intensity of collaboration that result in innovation.

Keywords: learning, national system of innovation, size, university-industry collaboration

JEL classifications: D83, D85, O32, Q55

1. Introduction

Recent scholarship underscores the importance of industry-universities collaboration as an important organizational form for knowledge creation within the national system of innovation (NSI), especially in stimulating new technologies (Rosenberg and Nelson, 1994; Lundvall, 1992; Fagerberg *et al*., 2005). There are two broad assumptions underlying the establishment and management of universities. The first one is that universities are set up to perform certain well defined functions such as teaching, research and knowledge production and could remain outside the broad national, cultural and political influence. Second, and specific to the research function, the notion of research and development (R&D) without much attention to downstream activities that involve commercialization, limits the relevance of university research (Etzkowitz and Leydesdorff, 2000). But these assumptions have come under considerable criticism, given the highly contextualized methods of knowledge production (see Gibbons *et al*., 1994), where the innovation processes are intricately characterized by constant feedback in a heuristic learning process. The "basic" versus "applied" research dichotomy that was applied to universities (where the former is more curiosity oriented and the latter is more tailored to practical industrial applications) may therefore not be that distinct from each other (Johnston and Blumentritt, 1998, *cited in* Beesley, 2003).

Technological developments and their institutional environments co-evolve, thereby bringing about changes in the knowledge structure gradually (Nelson, 1993). The policies and practices of a country with respect to its universities, in turn, are shaped to a very large extent by the country's singular historic development (Bartholomew, 1997a: 244). In addition to these policies and practices, institutional behavior and cooperation patterns between universities, firms and other counterparts in the NSI is decided to a large extent by social factors that are institutionalized over time (Bartholomew, 1997b). Therefore, factors that motivate inter-organizational interactions are not only localized, they can differ radically from one social and institutional context to another. The focus of analysis in this study will be less on which kinds of formal institutions exist in a country and how they perform, and more on how the different components of an innovation system interact in the process of knowledge generation, use and transfer and how social institutions, norms and policy frameworks condition these interactions (Beesley, 2003).

The paper is organized as follows: after a brief review of some of the factors that potentially influence the rate and intensity of university-industry collaboration (U-IC) in Nigeria, section two provides a framework for organizing the study. Sections three and four present elements of research and innovation collaborations in universities and public research institutes (PRIs) as well as firm-level capacities based on empirical evidence from surveys. The final section presents a synthesis of our findings, along with key conclusions.

1.1 Factors Affecting University-Industry Collaboration in Nigeria

Main Obstacles to U-IC and the Innovation Process

This paper draws on a study designed in a way that allows us to track the different stages of work in which the universities and firms were engaged and the institutional environment in which they operated. There were three main reasons for this approach. First, an understanding of the process gives an insight into the motives and limits of the organizations' capacity. Second, it provides some insight into the value that an organization is able to add to the process and the main constraints it faces in moving products to the market. Third, the nature of activity and the locus of the organization's work in the process might also suggest the relevance to, and the perceived importance of the product by, the market. One of the persistent complaints of policy makers, which is also confirmed by the findings of this study, is that several research projects remain at incipient stages because there is no immediate demand for them. University researchers defined the problems and designed projects that were not necessarily signalled by the market.

The literature on U-IC collaboration has identified three factors why the innovation process remains at the level of pre-commercialization. First, lack of facilities and financing to move the research to the concluding stages. Second, there are situations where significant research results had been collected, with evidence of possible utility of the process and product, but no demand by the end-users.[1] Third, failure to commercialize sometimes results from institutional rigidity, much of which relates to the ways traditional universities are set up. There are two issues that recurred in our interviews namely, who initiates the process (the university or a firm/entrepreneur?) and what form of formal or informal contract guides the process? In advanced developing and highly industrialized countries, two broad types of formal contract are common, which are, academic entrepreneurship, and spin-off companies from public research or universities.[2] These are largely absent in Nigeria because university professors are, because of labour conditions of employment, unable or disinclined to pursue commercial ventures. Relatedly, the cost in time and money to pursue such a line of activity is too high and as such acts as a disincentive.

Systemic and Institutional Weaknesses

The general problems of the university system in Nigeria and the lack of funding for research facilities and programmes both contribute to physical and institutional infrastructure problems, which more or less are the same across the various universities surveyed in this study. In very specific terms the main institutional constraints are as follows:

Physical Infrastructure and Knowledge Infrastructure

Autonomous telecommunications facilities, such as telephone, fax and internet in the universities, largely fall below what may be required for good research and teaching work, getting to know and linking up with similar programmes in other universities and institutions in Nigeria or Africa or the rest of the world and for dissemination of research efforts. There is a critical shortage of power and water, a situation that calls into question the commitment of governments to research investment. The situation in the communication sector has however improved quite significantly since 2000, deriving from a liberalized telecommunication sector that allowed several players into the sector, thereby raising the penetration rate of telephone and internet several fold. For instance, the number of lines in 2000 was less than one million but rose to over ninety million by the end of 2009 due in large part to Global System for Mobile Communications (GSM).

High quality research requires equipment, such as an Infrared Spectrophotometer, Gas Liquid Chromatograph (GLC), and Freeze Dryer. For most universities these facilities are not available. Even laboratories that were deliberately created for high level research to facilitate collaboration between different departments such as the Central Research Laboratory (CRL) and Obafemi Awolowo University (OAU) depend on the availability of foreign grants for their survival. Basic chemicals and reagents are hard to find and graduate students often have to rely on their own funding to carry out experiments. Even if the university wishes to engage in U-IC, these are the basics in addition to the intellectual capital that universities are known for.

2. University-Industry Linkage: A Systems Framework

The debate on the role of universities and public research institutions (UPRIs) in generating innovation for economic use continues to engage scholars in developed and developing countries alike. While the mandate and responsibility of these organizations to society would seem fairly clear, the process of knowledge generation and transmission is complex. In broad terms, university-based research apart from generating new knowledge is geared towards manpower production through teaching, while public research and development (both basic and "other types of pre-competitive") is primarily aimed at correcting market imperfections (Drejer and Jorgensen, 2005). As Schartinger *et al*. (2002) elaborate, universities are meant to play three distinct roles:

1) They conduct fundamental and applied research that shift the knowledge frontier of industry over time.
2) They generate innovations that are of immediate relevance to industry.
3) Universities produce human capital through the training of scientists, engineers and researchers.

An important human capital function includes the general mobility of scientists from universities to industry, and through a variety of collaborative arrangements between universities and industry. Systemic interaction (SI) is an important element of the systems of innovation framework within which this study is carried out and we will be examining the modes of exchange between universities and other actors within the SI from the perspective of learning, seeking new knowledge and innovation.

This paper is about systemic collaboration and specifically university-industry linkage. There are a variety of reasons why firms look to create linkages with other actors and why universities themselves increasingly seek to commercialize their inventive activities. One, firms and organizations increasingly seek external knowledge because of the growing complexity of production (Howell, 2000). Two, they do so because of the interactive nature of learning (Lundvall, 1988; Freeman, 1987). In knowledge intensive domains such as biotechnology where research and application take place almost simultaneously, the role of universities assumes added importance within the system of innovation (Fontes, 2003; Orsenigo, 1989).

The literature on public research and university-industry interaction is considerable and scholars address different aspects of the transfer process.[3] This review is evidently partial and limited to issues of particular relevance to learning in a developing environment context. In what follows we provide a set of stylized facts on issues related directly to this study.

First, the nature of knowledge generation and transfer of U-IC is complex, highly systemic and context-specific, particularly as a result of the significant but hardly acknowledged tacit content of scientific skills required which will therefore require more than codified format. In other words, countries will need to develop domestic scientific capabilities suited to their own context.

Second, there is a wide gap between the motivation, scope and purpose between academic research and industrial research and production. This complicates the transfer process and restricts the scope for policy incentive (Dasgupta and David, 1994). The widely debated Bayh-Dole Act of 1980 was a watershed in U-IC in the US. The Act allowed US universities to exercise property rights over federally funded research results and has been credited with a surge in university patenting and licensing although this assertion has been equally contended (Reichman, 2005). According to Mowery *et al*. (2001), the Act was more an effect rather than a cause of the intensified university patenting. However, adapting the Bayh-Dole Act model to a developing country context will need considerable examination because the historical paths as well as the knowledge infrastructure bases of the two environments are very different. What can be said in broad terms is that an institutional mechanism such as this Act demonstrates the importance of policy action in stimulating U-IC.

Third, firms seek external collaboration such as linkage with universities for purposes of learning because autonomous efforts are costly, and innovation outcomes are uncertain. Moreover collaboration releases firms from additional financial commitments, thereby allowing firms to share risks and spread sunk cost (Bougrain and Haudeville, 2002). Again, learning results in new ideas from combining experiences (Hakansson, 1987), while Teece *et al*. (1990) suggest that inter-firm cooperation results in the exchange and dissemination of knowledge. It is well known that face-to-face interaction between individuals in a knowledge environment results in mutual exchanges of information and knowledge that benefit the organization in the long run (Saxenian, 1994). Whatever the context however, there are several advantages of university-industry-public research institute interfaces and these include:

1. Lower R&D costs for firms: Recent research conducted on university-firms alliances shows that such collaboration is critical to bringing down the R&D costs of firms while achieving a higher innovative output.[4]
2. For the universities, collaboration enhances sources of public and private funding as well as helps participation in technology transfer and human training activities (see for example, Barnes *et al*., 2002). It also helps enhance focus on secondary research of immediate industrial relevance.
3. Universities interact with PRIs to perform a supportive role in research and patenting. In research, universities collaborate with PRIs in providing the requisite knowledge base to the industry or higher research institutions. At the same time, they also utilize the supportive services provided by PRIs, to structure research more toward industrial applications.

Three sets of factors guided our study of U-IC interactions namely, organizational features, incentives structures and the nature of interaction and collaboration. The organizational features include: (1) level and quality of human skills (number and quality of researchers) available to train new man power, and to conduct research; (2) facilities and physical infrastructure to train students and carry out research; (3) human interaction and coordination between researchers in various departments and universities and good channels of dissemination of research results within Nigeria and abroad.

Again, the dynamics of reward systems and collaboration incentives are an important mechanism that shapes the ways inventions are translated to the market although researchers interviewed in the studies tend to rank lack of facilities and research funding as one of the most critical factors that affect university performance (Oyelaran-Oyeyinka and Gehl Sampath, 2006). Incentive systems tend to develop from more fundamental institutional roots such as labour laws and even the national constitution. Terms of employment and work environments, both tangible (research and teaching facilities) and intangible (possibilities for institutional collaboration, quality of networks and colleagues) play a pivotal role in retaining skilled professionals.

The intensity of interaction between the university and other components of the national system will be conditioned by the type of mechanisms of interaction such as:

1) Mobility of scientists and technology in the labour market.
2) Collaboration mechanism (formal and informal) between enterprises.

3) Links between national institutions such as universities and the productive sector.
4) Informal mechanisms which have become extremely useful in a user-producer arrangement. To this end networks have become substitutes for formal markets and for organizational integration.

2.1 Size of Firms and Organizations

Size of operation and of organizations is considered a major driving force behind technological change or innovation, as it influences the nature and type of financial support for adopting new technologies and the firm's ability to successfully adapt such products and processes. As well, the size of operation has implications for the capacity to utilize these technologies (Oyelaran-Oyeyinka and Lal, 2005). This is particularly important for the sort of organizational form we have in developing countries which is largely small and medium sized enterprises (SMEs). In the initial phase of technological adoption, learning to master new systems leads to capacity under-utilization of new technologies which quite often, small firms can ill-afford. Several studies (Lall, 1982; Lal, 2002) have found a positive relationship between firms' size of operation and the level of their innovative activities including the propensity to collaborate. Larger sized firms tend to possess the human resources required to establish and sustain lateral relational interactions while small firms look more to the state as well as to professional associations for support. Lal's study in 2002 suggests that size played an important role in the adoption of new technologies by Indian SMEs.

Firms with larger size of operation are generally more innovative due in large part to greater resources (knowledge and skills), to modify product specifications. Changes in product design would require changes in production technologies and processes that in turn can require greater training for the users of new technologies. In firms where the product profile remains static, the need for new learning tends to be less frequent. Such firms generally operate in markets with little competition and tend to exist in the lower end of SME skills spectrum. We argue in this paper that large firms are likely to adopt more modern learning processes. The decisions by the firms' owners regarding acquisition of technologies are hypothesized to be influenced by size of operation.

2.2 Technological Learning

One of the most prevalent forms of skill acquisition in firms is learning-by-doing. However, this form of learning may not be effective or useful where there is a paradigm shift in technological development such as that brought about by advances in new technologies. Therefore, learning-by-doing should theoretically not have a significant impact on the adoption of new technologies. However, several activities in new manufacturing configurations progress by imitation and do not require formal training. This study investigates the role of learning in the process of innovation and the mastery of technologies. It is expected that different forms of learning such as learning-by-doing, conducting R&D, producing and acquiring skills might affect the adoption of new products and processes. Other forms of collaborative learning include learning by exporting, learning within a dense network of clusters where there are multiple forms of interactions with laboratories, machine shops, input and intermediate suppliers, and, within very advanced developed economies, learning that takes place in R&D networks.

2.3 R&D Activities

The sample of firms here, as is the case in many developing countries, do not have the resources required to establish their own R&D units, however, several firms possess the capability to make appropriate changes in product design. Some firms collaborate with universities in consultancy arrangements particularly in materials specifications and for minor machinery and product modifications mediated by various kinds of university consulting and technology transfer units. In low technology sectors such as garment manufacturing, product design changes seasonally, particularly in international markets and it may be difficult for firms to survive in export markets if they are not capable of implementing new designs. As a result, most firms engage in some form of innovation in order to remain competitive. There are frequent design alternations in the electrical and electronic goods sector as new design features are added to products and often the changes require the reconfiguration of the manufacturing processes. Hence, firms in this sector need to be innovative to accommodate the changes in product designs. As production based on new technologies fosters relatively easier and cheaper reconfiguration of production processes, we hypothesize that firms that adopt more advanced technology tend to assign higher weight to innovative activities.

2.4 Technological Collaboration with Foreign Firms and Universities

Access to the latest technologies is very crucial for firms to remain competitive and one way to gain access to new technologies is through technological collaboration with foreign firms. For organizations such as universities and public research and development institutes (RDIs), collaboration with partner universities to acquire new techniques, to gain access to research funds and to build human skills and research capacity in their home countries is not uncommon. The liberalization of markets in the last decade has made this much simpler in almost every country. Technical collaboration is as important for firms operating in the domestic market as it is for export-oriented firms. Several scholars (Stiglitz, 1989; Evans and Wurster, 1997) have emphasized that new digital technologies play an important role in the exchange of information, knowledge, and product designs between manufacturers and the suppliers of technology. Improved coordination of manufacturing activities is a major contribution of new technologies to the business environment. Local collaboration centres largely on small firms collaborating with universities and research institutes, on collaboration between small firms, professional associations, input and intermediate suppliers, contractors and customers. The broad objective relates largely to plant maintenance whereby local suppliers provide parts and ancillaries, and to trade-related interaction between firms and customers. This relationship should not be underestimated as firms tend to rely on their customers and input suppliers for market information that bigger firms spend considerable resources to collect through market surveys. Hence, we hypothesize a positive relationship between the types of internal capability and skills of firms and the degree of technological collaboration (Oyelaran-Oyeyinka and Gehl Sampath, 2006).

3. Empirical Investigation into University-Industry Collaboration (U-IC) in Nigeria

In this section we articulate the data sampling process and the actors that we sampled. We employed different techniques primarily questionnaire administration to interrogate the different research questions. Specifically, we probe the nature of innovation capacity, the determinants of research capacity as well as the nature of university-industry collaboration. In the final analysis using both univariate and bivariate methods, we found the most significant variables to be human capital, foreign collaboration and proportion research funding devoted to innovation activities.

3.1 Data and Methods

This paper draws largely on data collected in surveys and interviews carried out in 2005 and 2006 studies[5] of three universities, two Public Research Institutes (PRIs) and seventy five firms with a view to understanding their collaborative behaviour within the system of innovation. The sample units of measurement are university departments and units within PRIs. These included agriculture among others, and life sciences such as biology, biotechnology, biochemistry, microbiology and pharmacy. One set of questionnaires was administered in universities and research institutes, while another set was administered in industrial firms. We interviewed deans of faculties, heads of departments and university administrators to get a perspective of the issues and what challenges they face. Secondary data was collected from libraries and relevant institutions. A total of 210 questionnaires were completed out of the 250 that were administered. The industrial firms were selected on the basis of the outcome of the data obtained and interviews conducted with the universities and research institutes. However we only analyzed the firms qualitatively based on interview notes rather than detailed questionnaires. Firm selection was also based on sectoral consideration and firm size.

More specifically, we seek to answer the following questions: What is the pattern of University-Industry Collaboration (U-IC)? How do we measure the effectiveness of U-I collaboration through the nature of innovation involving universities? Which government policies support innovation and which ones hinder it? How does U-IC among agents affect innovation performance? How does learning affect innovation and performance? Finally, how do policies and human capital affect U-I collaboration?

Due to the qualitative nature of the data, we make use of discrete choice type models to answer our questions. More specifically, we employed descriptive as well as a Bivariate Probit to study the determinants of product and process innovation, which also allows us to investigate the extent to which the two types of innovation are associated with each other. Innovation capacity (read research capacity of these universities) is measured by the commercialization of product innovation (technological innovation), and its determinants are investigated using a standard Probit model. Finally, we use a Bivariate Probit to study the determinants of local and foreign collaboration, and to what extent they are correlated. Three types of explanatory variables are used, namely U-IC and collaboration variables, learning variables and government variables as described in the Appendix.

3.2 The Determinants of Research Capacity and Innovation Performance

The variable of interest is binary indicating whether or not a firm has commercialized product innovations. It is explained, in a standard probit model, by U-I collaboration and learning variables as in Table 1. "0" means no collaboration while "1" means "very strong" linkage.

The table presents descriptive statistics for technological performance and the collaboration explanatory variables. The percentage of universities and research institutes (URIs) that have recorded commercial success regarding their product innovations is rather small (10.5 per cent), as in row 1. Most of them rank the intensity of collaboration with other universities fairly strong, strong or very strong (53.3 per cent), compared to U-IC with other types of institutions (e.g. 11.9 per cent with agricultural machinery suppliers).

Table 1: Descriptive Statistics – U-IC and Innovation Capacity

Variable	Mean	(Std. Dev.)	Min.	Max.
Technological performance	0.105	(0.307)	0	1
Col. With Res. Inst.	0.362	(0.482)	0	1
Col. With Farm. Ass.	0.376	(0.486)	0	1
Col. With Univ.	0.533	(0.500)	0	1
Col. With Priv. Lab.	0.176	(0.382)	0	1
Col. With Ext. Agen.	0.295	(0.457)	0	1
Col. With Agr. Mach.	0.119	(0.325)	0	1
Col. With Agr. Coop.	0.152	(0.360)	0	1
Col. With Seed Comp.	0.157	(0.365)	0	1
Col. With Others	0.043	(0.203)	0	1
N	210			

Source: Authors' survey (2005).

The estimation results of a standard probit (not reported here) suggest that none of the variables of Table 1 and of the learning variables plays a role in technological performance. Indeed, a standard Wald test with $\chi^2_{(12)} = 16.26$ and probability value of 0.180 suggests that these variables are jointly not significant in the probit regression.

3.3 Types of U-IC

We next explored the specific types of U-IC: whether it is foreign or local and if so, if it is related to teaching, production, product development, or local R&D collaboration. Table 2 shows the mean values.

The U-IC types are measured in binary variables indicating whether a firm has foreign collaboration in production and in research, and local collaboration in research, teaching, product development, in R&D and in extension services. The descriptive statistics are reported in Table 2. Unlike the collaboration variables of Table 1, those of Table 2 are jointly significant in the estimation of the standard probit with a Wald statistic of 22.95 and probability value of 0.002. The estimation results of the best specification are reported in Table 3 and suggest, for instance, that foreign collaboration in production affects positively and significantly research performance. In other words, the more foreign collaboration a URI develops in translating invention to production, the more likely it is to commercialize product innovations. In other words, local collaboration with industry is less likely to result in innovation.

Table 2: Descriptive Statistics – Types of U-IC

Variable	Mean	(Std. Dev.)	Min.	Max.
Foreign col. in production	0.086	(0.281)	0	1
Foreign col. in research	0.319	(0.467)	0	1
Local col. in research	0.605	(0.490)	0	1
Local col. in teaching	0.176	(0.382)	0	1
Local col. in pdt. dev.	0.414	(0.494)	0	1
Local col. in R&D	0.414	(0.494)	0	1
Local col. in ext. serv.	0.105	(0.105)	0	1
N	210			

Source: Authors' survey (2005).

Table 3: Probit Estimates – The Effect of U-IC on Innovation Performance

Variable	Coefficient	(Std. Err.)
Foreign col. in production	0.925*	(0.396)
Foreign col. in research	0.335	(0.293)
Local col. in research	0.656†	(0.361)
Local col. in teaching	0.074	(0.352)
Local col. in pdt. dev.	0.785	(0.517)
Local col. in R&D	-1.125*	(0.564)
Local col. in ext. serv.	0.658†	(0.369)
Intercept	-1.992**	(0.302)
N		210
Log-likelihood		-58.966
$\chi^2_{(4)}$		22.945

Note: Significance levels: † : 10%, * : 5%, ** : 1%.
Source: Authors' calculation from survey data.

In sum, the probit results show that in the models of performance, the following comes out statistically significant in achieving innovation outcomes from research:

1. Human capital represented by the proportion of PhDs.
2. Foreign collaboration in funding research.
3. Research as share of overall institutes' activities.

3.4 The Determinants of U-IC

The variables of interest are binary indicating whether a firm has local and/or foreign collaboration. We estimate a bivariate probit model that allows us to estimate the correlation between foreign and local collaboration. The variables of interest are explained by human capital and the policy variables.

We start by estimating a bivariate probit with human capital and all the policy variables as regressors. Using a standard likelihood ratio with $\chi^2_{(13)} = 18.55$ and probability value of 0.138, we do not reject the restricted model whose estimates are reported in Table 4. These results suggest, for instance, that human capital affects positively and significantly both foreign and local collaboration. In other words, the more higher degrees, particularly PhD holders are present in an organization, the greater the propensity for collaboration and linkages. Government innovation incentives also affect positively and significantly both types of collaboration. The remaining

Table 4: Bivariate Probit Estimates – The Effect of Human Capital and Policies on U-IC

Variable	Coefficient	(Std. Err.)
	Foreign collaboration	
Human capital	0.398*	(0.184)
Gvt. Innov. Incentive	0.686**	(0.239)
State of power supply	0.973**	(0.351)
State of water supply	-0.539*	(0.271)
Intercept	-0.540**	(0.150)
	Local collaboration	
Human capital	0.503**	(0.193)
Gvt. Innov. Incentive	0.673*	(0.289)
Technical collaboration	0.562**	(0.181)
Intercept	-0.041	(0.167)
	Correlation	
P	0.644**	(0.095)
N		210
Log-likelihood		-230.483
$\chi^2_{(26)}$		35.519

Note: Significance levels: † : 10%, * : 5%, ** : 1%.
Source: Authors' calculation from survey data.

parameters are interpreted similarly. For instance, infrastructure proxied by power and water supply are both significant determinants of U-IC.

Clearly, a wide variety of factors combine to determine the nature of innovation, innovation capacity, research performance and collaboration in the Nigerian universities and PRIs. We find that product and process innovations have different determinants in terms of policy and learning variables. Both types of innovations are significant, albeit to a small extent, correlated. Furthermore, U-IC has not been adequate and hardly affects technological performance. Finally, unlike innovation, foreign and local collaboration are highly, positively and significantly correlated. They also share more determinants than in the case of innovation.

4. Empirical Analysis of Firm Level U-IC

To complement the view of the research community, seventy firms were served questionnaires. Forty five of these were returned and analyzed. Table 5 provides a summary of firm characteristics. The firms were all selected from within the South Western area of Nigeria, specifically from Ibadan and Lagos industrial areas. The sample was drawn from the Manufacturers Association of Nigeria (MAN) Directory and we purposively mixed small, medium and large enterprises in order to obtain a representative sample of all size categories. Based on our earlier interviews with universities, two sectoral groups were deemed relevant namely, foods and beverages and machinery, metals and repairs. These are the industrial groups that are most frequently associated with U-I collaboration.

4.1 Inter-firm Collaboration over Time

While the focus of this research is on U-IC, we included in the questionnaire questions related to collaboration with other actors consistent with the systems

Table 5: Demographics of the Firms

Variable	Mean
Range of firm size (no. of employees)	13 to 75
% of Output exported in 2005	15.0
% Profitability 2005	2.8
% of owners with University Degrees	43.8
Proportion of owners with High School Certificate	75.0
Proportion of staff with Elementary Certificate	100.0

Source: Authors' calculation from survey.

of innovation approach. The main actors are universities, input suppliers, subcontractors, and intermediate input suppliers, local and foreign buyers. Firm interaction with these actors was analyzed in a dynamic framework. The time dimension for "change" questions is five years and we pose the question as follows: "How has your relationship changed over the last five years with universities"? An ordinal scale with three categories was employed to reduce the margin for complication in the answers provided by the enterprises. In the three-scale answer, 1 denotes "decrease", 2 and 3 mean "remain the same" or "increase" respectively. In order to simplify the tables we constructed indices by assigning equal weight to responses using weighted averages.

4.2 Linkage with Different Actors

Table 6 shows the computed indices for the key actors as well as the types of changes undertaken by firms. Quality improvement was rated fairly high on the linkage scale, in other words raising product quality has been a major preoccupation of firms over the five years period. There is also increasing tendency to exchange information with suppliers, but joint training and joint marketing decreased on average in the period. The pattern of linkage is similar to that with other actors, namely input and intermediate input suppliers. In effect firms interact more frequently to raise quality and many of the incremental innovations are efforts to produce products with higher quality to meet competition. On a few of the activities however, firms rely on universities for training, quality improvement, joint R&D as well as laboratory testing. However, these activities are done on a systematic basis

Table 6: Inter-Firm and Organizational Linkages

Collaboration Variable	Input Suppliers	Univer-sities	Intermediate Input supplier	Sub-contractors	Local Buyers	Foreign Buyers
Exchange of Information	2.25	1.0	2.48	1.93	2.36	2.33
Product Quality Improvement	2.75	1.7	2.79	2.52	2.59	2.47
Joint Training	0.0	2.1	-0.0	2.31	-0.0	2.00
Joint marketing	0.0	0.0	0.0	0.0	0.0	1.8
Joint R&D	0.0	1.5	0.0	0.0	0.0	0.0
Laboratory Testing	1.8	1.5	1.0	0.0	0.0	0.0

Note: 1 = decrease, 2 = remain the same, 3 = increase.
Source: Authors' calculation from survey data.

through long-term partnerships, but firms tend to approach universities as the need arises. There are a few instances where collaboration is carried out for a considerable period of time particularly when there is a fairly complicated problem involved that requires experimentation and testing.

4.3 Technological Capability of the Firms

A very important factor affecting U-IC is the managerial and technological capability of the firms. This is important because it determines to a considerable extent whether firms in fact seek for collaboration and if so, what the sources are. The nature of available knowledge (for design, R&D and production), skills and experience required to carry out innovation is crucial to the survival and growth of each firm.[6] While firms in this study do not carry out "major" innovations, they have accumulated capabilities for minor innovation in managing the process of *copying* foreign designs and in managing to produce several designs simultaneously. Minor innovation capability often holds the potential for far-reaching impact on the growth of the firm in the form of machinery maintenance and re-tooling to cope with a market that is in constant flux. Most firms have acquired in-house skills to keep machines working at reasonable levels of capacity utilization. Although our interest centred largely on product innovation, we posed a set of questions to find out the sources and nature of design changes involving the whole spectrum of the innovation process, namely, inputs, process, and products. Table 7 shows that firms invest mainly in machinery and equipment and in the design of new products. There was less investment emphasis on process change as well as on modification to inputs' properties largely because cheaper products and inputs continue to flood the market from Asia. The emphasis is to compete and survive on a daily basis.

There are significant differences in the behaviour and linkage attitude of the firms. Medium sized firms are more eager to interact and seem more aware and informed on the benefits of U-IC. They have need for more

Table 7: Types of Investments in the Last 5 Years

Types of Investments	Firms Investing (%)
Machinery & equipment	85.0
New products	60.9
Process change	9.3
Improvement in raw materials	25.4
Others	3.8

Source: Authors' survey (2006). Firms gave multiple answers.

complex innovation activities, they tend to have more highly qualified and experienced staff and for this reason, they have had a much longer history of carrying out modifications through for instance, reverse engineering, product copying processes and product designs. Smaller firms are more involved in very minor product innovations and their linkage activities are largely with local maintenance organizations because they lack internal capacity in machinery and equipment for repairs and for product changes. Another reason is that small firms tend to compete in less quality-demanding markets and are subjected to far less pressures to upgrade. Their central activities are production and their machinery and equipment well adapted to local needs and fairly familiar to local machine shops in terms of repairs and maintenance. The medium and large firms with a focus on the regional export market tend to invest more in design changes and are more likely to engage in U-IC through training and laboratory testing of inputs. They also sometimes initiate collaborative R&D efforts.

4.4 U-IC, Innovation and Human Capital in Firms

This is related to firm level capability and the overall assets of the enterprise. The quality of human capital in industrial firms speaks to the overall research and production capabilities available in such firms. In order for industrial firms to effectively relate with and use information generated from universities and research institutes, they require a certain threshold of qualified personnel, especially for R&D and innovative activities. From our interviews, firms that conduct some semblance of R&D have a larger proportion of PhD holders, in most instances combined with MSc degree holders. While 55% of firms claim to have research laboratories, only large firms seem to engage in systematic research particularly in the testing and generation of new products using local raw materials. These firms are the ones that turn to universities for collaboration. Other forms of "R&D" departments are devoted to improving quality and monitoring competitors' products.

Although most firms tend to rely on price as a competitive factor this is certainly underlined by internal capacity for making quality products that can rival both local and imported products. Qualified skills are required for designing and implementing innovation but they are expensive for small firms and this was one of the factors hindering the recruitment of highly qualified personnel both in the short and medium term. Some firms rely on arms-length relationship with universities by which they engage individuals to work on short term assignments to solve specific product and process innovation problems. Table 8 shows sources of innovation. U-IC certainly is important, but is likely to become more important as firms engage in more complex production and innovation activities.

Table 8: Sources of Innovation

Sources of Innovation	Firms' Response (%)
Machinery acquired in the national market	9.4
Machinery acquired in the international market	18.2
Technology developed internally in firms	44.8
Technical adaptation through university-industry linkage	12.6
Developed/adapted in collaboration with repair shops	13.5
In cooperation with RDIs	16.6
Technology through university R&D collaboration	7.7
In cooperation with buyers	1.4

Note: Multiple responses were given.
Source: Authors' Survey (2006).

4.5 Why Firms Collaborate

We asked firms to indicate their motives for investing in any sort of technical or non-technical U-I linkage activity. This question was to assist in answering the question as to why firms do not patronize local universities and to validate the earlier answers on inter-firm cooperation. In discussions with firms, it is clear that inter-firm linkage is driven not by strategic concerns but the need to *maintain production regime in order to remain competitive*. Firms do not see universities regarding solutions to these sorts of immediate challenges, but this answer is qualified by the differentiated responses based on firm size as we discussed above. What was evident from discussions with enterprise owners is that competitive pressure raises the propensity to learn and in the process leads to accumulation of capability and experience in firms. However the sources of interactive learning vary widely and universities are not always central to this process in early phases of industrialization. Learning to improve products is firms' central activity, the main actors are buyers and suppliers of components, materials and machinery. Universities play a part when firms need new knowledge that helps them move to a new and potentially higher production regime. This is precisely what firms confirm they require, but they are hardly able to pay for the services of university academics, they often are not able to spare the time and some are unable to properly define the problem that requires solution in the language of the academics.

Table 9 summarizes the motives for collaboration and helps explain the particular pattern of U-I linkages.

Table 9: Reasons for U-I and Other Linkages

Reasons for Investing in Technical Change	Firms (%)
To improve local raw materials	32.8
To achieve greater operational efficiency	35.2
To make changes to imported technologies	51.6
To improve product design	78.3

Source: Authors' survey (2006).

The survey shows that enterprises make explicit investments to build up capabilities, and they do so in different ways. Training is an important source of capability building and confirming earlier findings, improving product quality has attracted a lot of concern. It is in this area that universities could play an important part. However, we find that firms turn to other private actors rather than universities for a myriad of reasons. Clearly R&D as it is traditionally known and carried out within university and RDI laboratories was not the main requirement of the sample firms and as we set out in our earlier hypothesis, while advanced industrial firms invest heavily in R&D and seek ways to lower R&D costs, firms in the category we analyzed are more focused on routine production and maintenance issues.

4.6 Reasons for Low Rate of Commercialization

An important point of debate is about how to commercialize inventive activities of universities. We sought the views of both university administrators as well as firm owners and we summarize these below. Our findings and interviews show a low rate of commercialization on the part of universities and research institutes and concomitantly, a low uptake of new inventions by industrial firms. Six main factors that tend to hinder commercialization were identified by both firms and universities. They include:

1) Weak or lack of interest by university researchers towards commercialization – firms claim that researchers do not market their skills sufficiently well and firms do not have the resources to do so.
2) Poor specification of remunerations that attend researchers' job specifications such as incentives in the form of research grants, part-ownership of patents resulting from inventions/research results and the promotion of technical entrepreneurship within their institutions/institutes.
3) Firms lack information on what universities have to offer – there is a lack of bridging institutions for instance, technology brokerage offices such as Industrial Liaison, Technology Transfer or Patent Management Offices.

4) Mismatch of interest and lack of complementary assets such as R&D facilities on the side of firms to encourage collaborative research, design skills, and facilities for building prototypes.
5) Lack of finances (investment and production) and venture capital to promote risky investments which has slowed the rate of birthing of new firms.
6) Poor support systems to assist firms (particularly small and medium) define and engage in U-I linkages.

5. Conclusions

In this concluding section we pose the question: what do the above narratives as well as the interviews tell us regarding the behaviour of firms' collaboration, particularly U-I collaboration? To answer this question, we return to our original one, that is, what is the pattern and role of U-IC in developing countries and for Nigeria such as we have in this study? The evidence from our sample is that such collaborations are episodic and differentiated by types of technological and managerial knowledge possessed by firms. It is also differentiated by firm size as well as industry sector and university discipline. For instance many of the challenges that firms face relate to production and how to keep up with the intense competition in the local market, they have little to do with strategic long term concerns of new products and processes for which R&D might be a solution, which in turn is the key role of universities. Of necessity, universities have faced intense scrutiny and pressures to change and adapt to accommodate the needs of enterprises. This issue has generated debate in the literature on what precisely the response should be (Howells and Nedeva, 2003).

In brief we combine insights from the questionnaires and the interviews to provide a summary of our findings. The sample size is not large enough to do the sort of quantitative analysis that we did for the university questionnaires, but the responses we obtained are sufficiently representative.

1) Firms have multiple sources of knowledge and different avenues for innovation which include their internal or firm-level assets, sources close to their immediate production environment such as local repair and machine shops.
2) The sources of innovation sought by firms are very much correlated with internal firm assets such as owners' education (firms with a high number of PhDs, and university degrees tend to relate with universities), experience and skills.
3) The propensity for U-IC is correlated with firm size because larger firms tend to have many resources and personnel for R&D and other tools of collaboration.

4) U-IC is influenced by geographic consideration. Firms that are closer to universities incur less transaction cost in reaching out to university resources. This was an important consideration raised by the firms we interviewed. In order of priority, they seek knowledge in their most immediate geographic and cognitive bases (buyers and suppliers are closer to them intellectually – according to a firm owner "we speak the same language"); then they seek others within the national system and finally knowledge sources outside the national system mostly the international market.
5) The most frequently used sources are machinery/component suppliers that operate both within and outside their production locus. This is due to the fact that most of these small and medium firms are focused largely on production on a routine basis and are less concerned with long term strategic issues. They face intense competition at the local level due to the increasingly prominent role of Asia (particularly Chinese presence) in the market. Foreign suppliers and buyers largely from the African region such as Ghana, Benin, Cameroon, etc. are also very prominent actors.

In addition to the problems of physical infrastructure and rigidity to the labour terms of employment, this section highlights three additional challenges and opportunities to U-IC in the Nigerian case study which may well have implications for collaborations learning in other developing countries.

Commercializing Research Results

The exclusive focus on publication as an end of research programmes is a major disincentive to translate research into product innovation. In addition, lack of mobility and research links between university researchers and private firms constitutes a barrier to turning inventions to innovation. These institutional weaknesses among others, affect the capacity of the universities to engage in systematic translation of research to products and processes.

Collaboration between Universities and Other Actors in the NSI

All potential channels of interaction that could otherwise provide positive impetus to innovation are constrained in Nigeria. Industry involvement is low, owing to the fact that private sector research in Nigeria is itself in need of basic support such as sources of finance (e.g., venture capital), better infrastructure and technology diffusion activities that could enhance their internal capacity. There is also a historical lack of collaborative interactions between industry and public research. Interactions between the various university departments itself is weak as a result of lack of information and absence of incentives amongst researchers to indulge in joint research. Universities also do not collaborate sufficiently with users of knowledge. Due to these problems encountered in local collaborations and funding possibilities, the universities rely largely on external funds.

Lack of Adequate Incentives to Motivate Researchers

Academic entrepreneurship can be promoted through various forms of incentives such as (a) involvement in collaborative research that can foster mobility of labour between research and industry, (b) consultancy possibilities to augment income, (c) patenting possibilities and (d) full-scale commercialization of research results (Aaltonen, 1998). But institutional rigidity that is common to PRIs and universities generally across countries has resulted in an environment with a pervasive lack of incentives to researchers in Nigeria.

Persistent decline in research activities due to economic problems in the country that follow from misguided priorities such as diversion of funds from tertiary education into primary education on the advice of international monetary institutions, and the enrolment explosion have all adversely affected Nigerian research culture over the past decades. These factors add to the rigidity of the system and its inability to adapt to dynamic prospects brought about by new technologies such as ICTs.

Appendix: Definition of Variables

Variable	Definition
Learning explanatory variables	
Human capital	Indicator with value 1 if having a PhD degree
Foreign training programme	Indicator with value 1 if a firm has benefited from overseas training and development programme
Local training programme	Indicator with value 1 if a firm has benefited from local training and development programme
Government policy explanatory variables	
Government innovation incentive	Indicator with value 1 if government incentives for innovation are deemed fairly strong, strong or very strong
Skilled manpower	Indicator with value 1 if scientific/skilled manpower is deemed fairly strong, strong or very strong
Technical collaboration	Indicator with value 1 if local universities' competence for technical and R&D collaboration is deemed fairly strong, strong or very strong
Laboratory facilities	Indicator with value 1 if laboratory facilities are deemed fairly strong, strong or very strong

Appendix (continued)

Variable	Definition
IP protection	Indicator with value 1 if intellectual property protection is deemed fairly strong, strong or very strong
Quality of ICT	Indicator with value 1 if the quality of ICT services is deemed fairly strong, strong or very strong
State of power supply	Indicator with value 1 if the state of power supply is deemed fairly strong, strong or very strong
State of water supply	Indicator with value 1 if the state of water supply is deemed fairly strong, strong or very strong
Other policies	Indicator with value 1 if other policies are deemed fairly strong, strong or very strong
Government funding	Indicator with value 1 if a firm's innovation and research funding sources are from the government
Collaboration and networking explanatory variables	
Col. with Res. Inst.	Indicator with value 1 if collaboration with research institutions is fairly strong, strong or very strong
Col. with Farm. Ass.	Indicator with value 1 if collaboration with farmers' association is fairly strong, strong or very strong
Col. with Univ.	Indicator with value 1 if collaboration with universities is fairly strong, strong or very strong
Col. with Priv. Lab.	Indicator with value 1 if collaboration with private laboratories is fairly strong, strong or very strong
Col. with Ext. Agen.	Indicator with value 1 if collaboration with extension agencies is fairly strong, strong or very strong
Col. with Agr. Mach.	Indicator with value 1 if collaboration with agricultural machinery suppliers is fairly strong, strong or very strong
Col. with Agr. Coop.	Indicator with value 1 if collaboration with agricultural cooperatives is fairly strong, strong or very strong
Col. with Seed Comp.	Indicator with value 1 if collaboration with seed companies is fairly strong, strong or very strong
Col. with others	Indicator with value 1 if collaboration with others is fairly strong, strong or very strong

Notes

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1. As Jolly (1997) correctly observed, technologies and for that matter, products and process inventions fail not so much for an absence in skills of the inventor and the lack of market, but because no one promotes or gets sufficiently interested in them.

2. Academic entrepreneurship takes several forms namely: (a) Involvement in large-scale externally funded research; (b) consultancy to earn supplementary income; (c) university-industry research and transfer of technology; (d) patents and trade secrets; and (e) commercialization which might involve holding equity in private enterprises by scientists. (See Aaltonen, 1998).
3. See Schartinger *et al*. (2002) and their references to different shades of the issue: academic research and biotechnology spin-offs from UPRIs (Fontes, 2003); transfer between university research and industry (Lee and Win, 2004); on the overall impact of university research on industrial production (Jaffe, 1989; Anselin *et al*., 1997); and personnel mobility (Bania *et al*., 1992; Almeida and Kogut, 1995).
4. George *et al*. (2002) analyze 2457 alliances undertaken by 147 biotechnology firms, in order to arrive at these findings. However, as the authors themselves note, it is not clear as to how much such collaborations influence (or enhance) the financial performance of the firms.
5. The study was jointly coordinated by the authors and funded in part by the IDRC (International Development Research Council (Canada)).
6. The literature on technological change, which is quite considerable, shows that technical change in developing countries does lead to significant increases in firm-level productivity (Lall, 1992; Ernst *et al*., 1998).

References

Aaltonen, M. (1998) "Academic Entrepreneurship, Technology Transfer and Spin-offs: Companies in Different European Regions – Comparisons and Best Practices", Turku School of Economics and Business Administration, Business Research and Development Centre, Series A1/1998.

Almeida, P. and Kogut, B. (1995) "The Geographic Localization of Ideas and the Mobility of Patent Holders", paper presented at the Small and Medium-Sized Enterprises and the Global Economy: Trends and Patterns in Foreign Direct Investment Seminar, CIBER, University of Maryland, 20 October.

Anselin, L., Varga, A. and Acs, Z. (1997) "Local Geographic Spillovers between University Research and High Technology Innovations", *Journal of Urban Economics*, 42(3): 422-448.

Bania, N., Calkins, L.N. and Dalenberg, D.R. (1992) "The Effects of Regional Science and Technology Policy on the Geographic Distribution of Industrial R&D Laboratories", *Journal of Regional Science*, 32(2): 209-228.

Barnes, T., Pashby, I. and Gibbons, A. (2002) "Effective University-Industry Interaction: A Multi-Case Evaluation of Collaborative R&D Projects", *European Management Journal*, 20(3): 272-285.

Bartholomew, S. (1997a) "National Systems of Biotechnology Innovation: Complex Interdependence in the Global System", *Journal of International Business Studies*, 28(2): 241-266.

Bartholomew, S. (1997b) "The Globalization of Technology: A Socio-cultural Perspective", in Howells, J. and Michie, J. (eds), *Technology, Innovation and Competitiveness*, Cheltenham: Edward Elgar, pp. 37-64.

Beesley, L.G.A. (2003) "Science Policy in Changing Times: Are Governments Poised to take Full Advantage of an Institution in Transition?", *Research Policy*, 32(8): 1519-1531.

Bougrain, F. and Haudeville, B. (2002) "Innovation, Collaboration and SMEs' Internal Research Capabilities", *Research Policy*, 31(5): 735-47.

Dasgupta, P. and David, P.A. (1994) "Towards a New Economics of Science", *Research Policy*, 23(5): 487-521.

Drejer, I. and Jorgensen, B.H. (2005) "The Dynamic Creation of Knowledge: Analysing Public-private Collaborations", *Technovation*, 25(2): 83-94.

Ernst, D., Ganiatsos, T. and Mytelka, L. (eds) (1998) *Technological Capabilities and Export Performance: Lessons from East Asia*, Cambridge: Cambridge University Press.

Etzkowitz, H. and Leydesdorff, L. (2000) "The Dynamics of Innovation: From National Systems and 'Mode 2' to a Triple Helix of University-Industry-Government Relations", *Research Policy*, 29(22): 109-123.

Evans, P.B. and Wurster, T.S. (1997) "Strategy and the New Economics of Information", *Harvard Business Review*, September-October, pp. 71-82.

Fagerberg, J., Mowery, D.C. and Nelson, R.R. (2005) *The Oxford Handbook of Innovation*, Oxford and New York: Oxford University Press.

Fontes, M. (2003) "The Process of Transformation of Scientific and Technological Knowledge into Economic Value Conducted by Biotechnology Spin-offs", *Technovation*, 25(4): 339-347

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*, London: Pinter Publishers.

George, G., Zahra, S. and Wood, D. (2002) "The Effects of Business–university Alliances on Innovative Output and Financial Performance: A Study of Publicly Traded Biotechnology Companies", *Journal of Business Venturing*, 17(6): 577-609.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994) *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, London: Sage.

Hakansson, H., (1987) *Industrial Technological Development*, London: Routledge.

Howells, J. (2000) "Knowledge, Innovation and Location", in Bryson, J.R., Daniels, P.W., Henry, N. and Pollard, J. (eds), *Knowledge, Space, Economy*, London: Routledge, pp. 50-62.

Howells, J. and Nedeva, M.N. (2003) "The International Dimension to Industry-Academic Links", *International Journal of Technology Management*, 25(1-2): 5-17.

Jaffe, A.B. (1989) "Real Effects of Academic Research", *American Economic Review*, 79(5): 957-970.

Johnston, R. and Blumentritt, R. (1998) "Knowledge Moves to Centre Stage", *Science Communication*, 20(1): 99-105.

Jolly, V.K. (1997) *Commercializing New Technologies: Getting from Mind to Market*, Boston, Massachusetts: Harvard Business School Press.

Lall, S. (1982) *Developing Countries as Exporters of Technology: A First Look at the Indian Experience*, Houndmills: MacMillan Press.

Lall, S. (1992) “Technological Capabilities and Industrialization”, *World Development*, 20(2): 165-186.

Lal, K. (2002) “E-business and Manufacturing Sector: A Study of Small and Medium-sized Enterprises in India”, *Research Policy*, 31(7): 1199-1211.

Lee, J. and Win, H.N. (2004) “Technology Transfer between University Research Centers and Industry in Singapore”, *Technovation*, 24(5): 433-442.

Lundvall, B.-Å. (1988) “Innovation as an Interactive Process: From User–producer Interaction to the National System of Innovation”, in Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L. (eds), *Technical Change and Economic Theory*, London: Pinter Publishers.

Lundvall, B.-Å. (ed.) (1992) *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning*, London: Pinter Publishers.

Mowery, D.C., Nelson, R.R., Sampat, B.N. and Ziedonis, A.A. (2001) “The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980”, *Research Policy*, 30(1): 99-119.

Nelson, R.R. (ed.) (1993) *National Innovation Systems: A Comparative Analysis*, New York and Oxford: Oxford University Press.

Orsenigo, L. (1989) *The Emergence of Biotechnology*, London: Pinter Publishers.

Oyelaran-Oyeyinka, B. and Lal, K. (2005) “Internet Diffusion in sub-Saharan Africa: A Cross-Country Analysis”, *Telecommunications Policy*, 29(7): 507-527.

Oyelaran-Oyeyinka, B. and Gehl Sampath, P. (2006) “Rough Road to Market: Institutional Barriers to Innovations in Africa”, United Nations University-MERIT Working Paper Series #2006-026.

Reichman, J. H. (2005) “University-Industry Collaboration: The United States Experience”, WIPO Conference Paper, 23 June.

Rosenberg, N. and Nelson, R.R. (1994) “American Universities and Technical Advance in Industry”, *Research Policy*, 23(3): 323-348.

Saxenian, A. (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Cambridge, MA: Harvard University Press.

Schartinger, D., Rammer, C., Fischer, M.M. and Frohlich, J. (2002) “Knowledge Interactions between Universities and Industry in Austria: Sectoral Patterns and Determinants”, *Research Policy*, 31(3): 303-328.

Stiglitz, J.E. (1989) “Economic Organisation, Information and Development”, in Chenery, H. and Srinivasan, T.N. (eds), *Handbook of Development Economics*, 1(1): 93-160.

Teece, D.J., Pisano, G. and Shuen, A. (1990) “Firm Capabilities, Resources and the Concept of Strategy”, Consortium on Competitiveness and Cooperation, Working Paper 90-98.