# KNOWLEDGE-BASED DEVELOPMENT: THE CONTRIBUTION OF UNIVERSITY-FIRM INTERACTION IN SOUTH AFRICA[i]

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## INTRODUCTION

Over the past two decades, there have been substantive shifts in the social compact between higher education and society. Unlike the centuries old tradition of the autonomous pursuit of knowledge and science, universities are now expected to be more accountable to society, the state and the market - in particular, more responsive to the demands of a global knowledge-based economy (Salmi 2007, Maassen 2006, Newman et al 2004, Audretsch and Phillips 2006, Jacob and Hellstrom 2000, Delanty 2000, Van Vught 2000, SAUVCA 2004). A decade ago, a world higher education declaration (1998) set out a key premise that has been influencing policy, research and university practice:

> Without adequate higher education and research institutions providing a critical mass of skilled and educated people, no country can ensure genuine endogenous and sustainable development and, in particular, developing countries and least developed countries cannot reduce the gap separating them from the industrially developed ones.

The broad concern is with this changing role of higher education in relation to knowledge-based economic growth, innovation and development, for the countries of the South, which experience these new global imperatives under very different, often disadvantageous, conditions (Sagasti 2004).

The specific concern of this paper is to explore the contribution universities make to national development goals through their growing emphasis on interaction with firms in South Africa, as a middle income country. It adopts a systemic lens to investigate universities as critical institutions in the South African national system of innovation, and focuses specifically on their direct role in supporting technological upgrading and firm learning. This choice of focus does not imply that a normative or reductive argument, to promote a single, narrow role for universities as 'handmaidens' of the economy or of firms. On the contrary, the multiple roles of universities, and the significance of universities as knowledge generators for the long term health of a science and technology system and for a national system of innovation are fundamental assumptions for the research approach (Nelson 2004).

What the paper proposes to do by way of analytical focus is to place firms at the fulcrum of investigation, to address a gap in our current understanding of university-firm interaction in South Africa (Kruss 2007, Lorentzen 2009). Previous research on university-firm interaction in South Africa analysed the diverse ways in which different types of university are responding to and engaging with the global and local challenges, and developing strategies to link university-firm interaction with their institutional goals and mission (Kruss 2005a, 2005b, 2006). This work highlighted a tension between the financial and intellectual imperatives driving universities' interaction with firms, and the potential consequences of different ways of resolving this tension for individual universities and for the higher education system as a whole. The present research accesses an emerging literature in relation to analysis of developing countries, framed in

terms of national systems of innovation and 'catch-up' approaches, and foregrounding firm technological upgrading. In this manner, new insights may be injected into debate around higher education, innovation and sustainable development appropriate to South Africa.

Section I of the paper will briefly set out the framework and datasets on which the analysis is based. Section II demonstrates that there has been a degree of maturing of the South African system of innovation, but significant system weaknesses, particularly in relation to education and human resource capabilities. Section III problematises the contribution of universities to goals of economic growth through technological upgrading and diversification of firms' production activities in these conditions. The analysis is aggregated across the system and between specific industrial sectors, analyzing the extent and nature of firm demand for co-operation with universities in relation to their innovative and R&D practices. Section IV focuses on cases of university-firm interaction in health biotechnology, a sub-sector which South Africa has targeted as a priority, to explore the manifestation of contextually specific constraints and possibilities. The conclusion draws out implications for the changing role of the university in South Africa.

## SECTION I. SYSTEMIC ANALYSIS OF UNIVERSITY-FIRM INTERACTION

A vast literature has emerged on the nature and impact of university-industry linkages as new organizational forms. In a systematic and comprehensive review, Klitkou et al (2007) have demonstrated that numerically, there is a predominance of research based on the experience of large, developed countries. Much of the research is empirically rather than theoretically driven, and in general, the levels of theoretical development in the field are underwhelming. A third distinctive feature of this literature is that in emphasis, it tends to focus on the university perspective and dynamics of interaction, rather than that of firms. Empirical research attention is typically paid to understanding the dynamics of a specific form of university-industry interaction, whether the extent of co-patenting or co-publication, the optimal conditions for promoting spin-off firms, technology transfer offices or science parks, and so on. There is also considerable focus in the higher education literature debating the merits and demerits of the related conception of the entrepreneurial university (Clark 1998, 2003, 2004, Etkowitz 2003, Douglass 2005, Cargill 2007) and the impact of new imperatives on the traditional contribution of universities to knowledge (Slaughter and Leslie 1997, Amaral and Magalhaes 2003, Dzisah 2007, Rip 2004, Harpur 2006, Tadmor 2006).

In counterpoint to this higher education-oriented literature, evolutionary economists have paid increasing attention to the central role of education and knowledge institutions to the ability of an economy to 'catch-up' or fall behind the leading economies (Nelson 2007b, Fagerberg and Verspagen 2007). Research is beginning to problematise the role of universities in economic 'catch-up' in developing countries (Mazzoleni 2008, Albuquerque 2001, World Bank 2008). A high level of R&D investment and high-level skills is widely hypothesized to explain the ability of some developing countries, typically newly industrializing countries such as South Korea, Taiwan and Malaysia, to succeed in 'catching-up' with leaders in the developed countries (Nelson 2007a, Abramovitz 1986). This raises questions for developing countries, about system failures in the development of innovative capabilities in the industrial sector and in the knowledge infrastructure, to overcome which require dynamic, integrated and differentiated policy approaches (Sercovich and Teubal 2008, UNIDO 2005).

While it has long been assumed that universities' contribution in developing countries is limited to their educational role, both academics and policy makers are now focusing on their potential role in technological upgrading in firms, to a more direct contribution to national industry and hence, competitiveness, growth and development (Liefner and Schiller 2008). There is increasing research attention paid to the potential contribution of universities as knowledge producers interacting with firms to build learning and technological capabilities in a national system of innovation, and hence, contributing to sustained economic growth and structural change. The interest is in how knowledge institutions may be a source of innovation and change for firms in distinct sectors, and how the interaction among actors in networks plays a role in catch-up (Malerba and Nelson 2008).

In developed economies, with the increase in knowledge-intensity of innovation, availability of venture capital, greater mobility of knowledge workers and a reduction in product lifecycles, innovating has become a very expensive and risky activity that makes co-operation essential for competitiveness. No longer is a firm's internal R&D facility on its own its main strategic asset. Innovation is increasingly a networked activity, and a firm's ability to organize and manage the innovation process - including strategic partnerships and sourcing knowledge and discoveries (such as licenses or patents) from elsewhere, including universities, or outsourcing R&D - is seen as imperative for its competitiveness (Chesbrough and Crowther 2006). University-firm interactions in developed economies, mainly Europe and the United States, have been characterized as increasingly displaying such features, a model of 'open innovation systems' (Chesbrough, Chesbrough and Crowther 2006, Gassmann 2006, Lichtenthaler and Ernst 2006, van de Vrande et al. 2008).

The question is whether such open innovation systems that include universities are becoming evident in developing countries. Do firms draw indirectly on the publicly available products of universities – such as conferences or publications - or are they engaging directly with universities to support technological upgrading through outsourcing R&D or engaging in innovative networks? To what extent are universities sources or cooperative partners for innovation and R&D, to what extent is there a match between the capabilities of universities and firms, and in which key sectors? Are firms in developing countries interacting with universities to substitute for missing capabilities, or to complement their own internal R&D capabilities? And it is significant to question whether interaction is to mutual benefit of universities and firms, to address the human development needs of developing countries, or whether it is limited to the short term immediate benefit only of specific firms.

In developing countries, the diffusion of new forms of interaction across firms and sectors is typically limited and uneven. There may be uneven evidence of open innovation activity, with cooperative interaction primarily between cutting edge firms and with only sections of an emerging science and technology system. One may also find that a larger number of firms use innovation-related design and engineering capabilities to enhance competitiveness (Sercovich and Teubal 2008). The source of such innovative product selection and development is often user/supplier relationships, rather than universities or other scientific institutes. As Rapini et al (2009) have proposed in relation to Brazil, there are a limited number of 'spots of interaction' where local university research strengths in specific science and technology fields match firms' technological specializations and needs. Questions of the scale of university-firm

interaction across a national system of innovation and across key industrial sectors are thus significant.

A study by Cohen et al (2002) on the links between and impact of universities on firm R&D in the United States informed the methodology for empirical research to address such questions in a range of middle-income catch-up countries. Cohen et al surveyed the fields and sectors, the channels, and the outcomes and benefits for firms of interaction with universities. Albuquerque et al (2005) first adapted this survey instrument to study the nature of interaction between universities and firms in the Minas Gerais region of Brazil, characterized as an 'immature' national system of innovation (see also Albuquerque et al 2008, Rapini et al 2009). The instrument was subsequently adapted for use in other Latin America, Asian and African countries (Arza and Lopez 2008, Lee et al 2009, Dutrenit and Fuentes 2009, Torres et al 2009). The key questions for this research relate to determining the nature of university-firm interaction in diverse catch-up contexts, here, in relation to the South African case.

**Data sources**

The paper presents a synthesis of trends evident from the analysis of three data sources utilized in the study, to investigate the extent and nature of university-firm interaction in South Africa. First, the paper draws on a contextual analysis of higher education, innovation and development challenges (Kruss 2008a), supported by analysis of key indicators of economic, education, innovation and social performance (Petersen 2008).

Second, given difficulties in conducting a firm survey, the study relied on an examination of firms' cooperative practices in general and with universities specifically, drawing on new analysis of two national datasets (Petersen and Kruss 2009):

A. The South African Innovation Survey 2005, based on the Oslo Manual, measured firms' innovation-related activities for the period 2002 to 2004. A total of 981 responses from a random stratified sample of 2 627 companies was garnered, and of these, 603 firms that responded to a question on co-operation were included in our dataset – that is, a sample of innovative firms with cooperative practices (see DST 2008, Blankley and Moses 2009).

B. The South African R&D survey 2005/06, based on the Frascati Manual, obtained responses from 607 firms, of which 327 responded to a question on firm collaboration, forming a sample of R&D performing firms with cooperative practices (See CESTI 2007).

Third, nine case studies were conducted in two very different universities, focusing on the form, intensity and performance of interaction with firms in one key sector targeted by national policy, the health biotechnology sub-sector (Kruss 2008b).

## SECTION II. SOUTH AFRICA: POTENTIAL AND CONSTRAINT

Since 1994, with the transition to a democratic government in South Africa, there have been dramatic changes in governance, in the economy, in science and technology policy and in higher education. Unlike many other countries where change has been more gradual, the political transition was an opportunity for rupture of the fragmented system of the past, towards a systematic attempt on the part of the new state to put in place new

policy, structures and mechanisms to promote growth and development to meet democratic goals in a globalising economy (Hirsch 2005). The challenges of effecting structural change of course, are formidable.

Trends in global benchmarking systems suggest that South Africa has a great deal of innovation potential but may not be succeeding in 'keeping up' with the pace of global development (Petersen 2008). This is typical of an observed 'Red Queen' effect (Ribeiro et al 2006, Bernardes and Albuquerque 2003), in which catch-up countries need to exert extensive effort merely to ensure that they do not fall further behind. The following sections provide a broad overview of the South African economy and national system of innovation, highlighting the long history of structural inequality that places major constraints on catching-up.

**The South African economy: a broad overview**

Over the past few decades, there has been a strong shift towards the services sector such that taken together, the services sector in total contributed 69.2% to GDP in 2005, while industry contributed 27.9% (Table 1). A broad sectoral breakdown shows that the economy is relatively diverse in structure (Figure 1). In 2005, finance and business services (21.4%) and manufacturing (18.6%) each accounted for about a fifth of GDP. The third and fourth largest sectors are government services, and wholesale and retail trade, restaurants and hotels, while primary commodities, agriculture (2.7%) and mining 7.3%), contributed far less than in the past.

South Africa's ability to catch-up with other middle income countries is constrained. The OECD (2007: 27) indicates that even though South Africa's economy has become more diversified in recent years, global exports continue 'to be dominated by "mineral-based" items', such as mining, basic iron and steel, and advancing the diversification of exports is still identified as a key challenge (Presidency 2008, Edwards and Lawrence 2006). The expected FDI inflows after 1994 have not materialized to any significant extent (and indeed, the current recessionary conditions in 2009 make this an even more significant constraint), constrained by skills shortages and lack of infrastructural development, which may act to limit growth of a national system of innovation.

South Africa's structural deficiencies, systemic weaknesses and potential failures relate to its nature as a dual economy, to the as yet unresolved problems of human development, poverty and inequality. The highly unequal concentration of income leads to limited demand in home markets, and hence, may act as a constraint on technological progress (Albuquerque 2007). High levels of poverty, unemployment and exclusion from education and health benefits co-exist with growing opportunity and wealth. Innovation is thus inextricably bound up with addressing the human development issues (health, housing, education, nutrition) required as a necessary enabling condition for economic shifts. The potential for (parts of) the South African national system of innovation to compete in the global knowledge economy is evident (NACI 2006, OECD 2007), but human development demands operate as a potential binding constraint and require critical efforts to ensure change.

**A policy framework centred on promoting a national system of innovation**

The innovation challenges are reflected in a dualism in national policy goals – aimed at meeting human developmental needs and addressing poverty, at the same time as

achieving competitiveness and technological advancement in a globalizing knowledge economy.[1] An ambitious, comprehensive science and technology policy framework was elaborated, which aims explicitly to promote the transition from a resource to a knowledge-based economy (DACST 1996, DST 2002, DST 2007). The framework has clear direction, embodies a formal commitment to coordination across relevant government departments, and initiates a set of funding incentives and strategic mechanisms and programmes. The explicitly stated policy goals and 'national system of innovation' framework[2] have drawn heavily from and are imitative of, the cutting edge of theory and practice in developed economies. The policy framework aims to bring about structural change in the existing patterns of linkages and interactions between institutions, sectors and firms. One successful example is a funding mechanism that provides matching-funding as incentive to promote collaboration on research and graduate training between universities, public research institutes and firms (THRIP[3]). Other examples are programmes to promote innovative research that can lead to commercialization, such as the Innovation Fund (HSRC 2003), or the establishment of incubators and science parks, or programmes to enhance technology transfer and upgrading of SMMEs. Formal policy thus reflects the aspiration to catch-up in productivity and income, and in practice has tended to prioritize technological upgrading to promote comparative advantage and global competitiveness, while largely paying lip service to technology for poverty reduction.

**Higher education expansion, diversity and flexibility in South Africa**

There is an expressed policy commitment to enhance the responsiveness of the higher education system, both economically but also in terms of general social responsiveness to widen access and address inequality (CHE 2004, SAUVCA 2002, and Favish 2003). However, there are indications of weaknesses in the higher education system.

A rapid acceleration of global standards of educational achievement has occurred over the past two decades (Brundenuis et al 2008), an exponential expansion to create mass higher education systems (Mazzoleni 2008). South African universities are challenged to produce more graduates with more of the kinds of qualifications and skills required by firms, particularly those in priority sectors. Table 2 reflects the total enrolment of the higher education system over the past decade, showing a period of decline after 1994 related partially to funding constraints, followed by rapid growth from 2001, and then a slow annual growth to a system with around 750 000 enrolments (See Cloete et al 2002, OECD 2008 for further analysis). The system is growing, but the participation rate is low relative to countries at similar levels of development, currently around 15%. The data also reflects the slow progress with respect to the policy-driven attempt to shift the balance of enrolments to be more economically responsive (DoE 2001, Moja and Hayward 2000), away from education, the social sciences and humanities and towards science, engineering and technology, as well as business studies (CHE 2004).

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[1] These goals have received differing emphasis in specific strategic policies, incentives and steering mechanisms, and differ in terms of the degree of effective implementation and delivery, over the past fifteen years.

[2] The national system of innovation is defined as 'the means through which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve their individual and collective goals' (DACST 1996: 15).

[3] Technology and Human Resources for Industry Programme initiated by the Department of Trade and Industry. For an analysis of the beneficiaries and outcomes of the programme, see HSRC 2003.

A major system weakness in South Africa relates to unresolved inefficiencies and inequalities in the schooling system that limits access, throughput and further growth of the higher education system. There is not a large enough pool of school-leavers with the required certification to enter higher education, particularly in the critical fields of science and mathematics, in order to grow science, engineering and design fields (Reddy 2006). Human resources and skills development are receiving increasing policy priority, but the low-level equilibrium lock-in in the schooling system has yet to be resolved (Fiske and Ladd 2004). Higher education is directly affected in terms of quality and throughput, as universities grapple with the consequences of expanding access rapidly in line with equity goals, with large numbers of under-prepared students (Luescher and Symes 2003). Table 3 reflects the low level of graduations and outputs from the higher education system, and that graduations are more focused in the humanities, social sciences and education than are enrolments. Over the past few years the national department of education has imposed a cap on growth in order to focus on the quality of the system, motivated by the systemic inefficiencies reflected in high drop-out and low graduation rates across many institutions (Steyn and De Villiers 2006). A recent OECD (2007) review thus reiterated the concern that it may not be possible to sustain current levels of R&D in universities, let alone expand the system significantly (Koen 2006, 2007, COHORT 2004, Kahn et al 2006).

*Diversity and flexibility of the system*

Mazzoleni (2008) cautions against 'over-blown expectations' of the developmental possibilities inherent in an expansion of national enrolments in higher education, as a return on the investment is only likely in the long term and will not immediately lead to the accumulation of technological capabilities. He instead proposes that institutional diversity and flexibility are key. South Africa has a historically differentiated higher education system (Cloete et al 2002, Kahn et al 2007) which is potentially positive. Unfortunately, there has been a high degree of segmentation between historically-defined types of university, which militates against flexibility and change across the system. A high degree of segmentation can discourage researchers from undertaking a wide variety of research and from moving between different types of university, without loss of reputation (Whitley 2003). A lack of flexibility and articulation can slow down the rate of knowledge and skills transfer and diffusion across the higher education system.

A restructuring process since 2005 has created new institutional types that aim to provide a more diverse mix of academic, research, technological and occupational focused institutions in the system (Ministry of Education 2002, CHE 2004). This policy-driven change may serve to shift the tendency to segmentation, and promote greater differentiation, openness, flexibility and exchange.

## SECTION III. UNIVERSITIES CONTRIBUTION TO FIRMS' INNOVATION AND R&D ACTIVITIES

This section will show that in such conditions, given the dual nature of South Africa's economy, there is evidence of a set of technologically sophisticated firms interacting in open innovation networks, including with universities, akin to the trend in developed economies. However, in scale, these represent but fragmented 'spots of interaction' in relation to the total landscape of firms, and activity is stronger in relation to technological exploration but virtually absent for technology exploitation. Some of the potential 'spots

of interaction' are then identified by means of a sectoral analysis of firm's cooperation with universities on their innovation and R&D activities.

**Firms' propensity to conduct R&D and innovate in South Africa**

South Africa reported gross domestic expenditure on R&D of R14 billion in 2005/6, which represents 0.92% of GDP, close to the target set to attain 1% by 2008 (DST 2007), and a steady increase from 0.76% reported in 2001/2 (DST 2004). This is low relative to developed economies but similar to other middle income economies such as Brazil. Notably, the R&D survey 2005/6 covered a small total number of 607 firms, and business enterprises were responsible for 58.3% of the total expenditure, followed by higher education (19.3%), science councils (14.9%), government (6%) and not-for-profit organizations (1.6%) (CeSTII 2007).

In the three-year period 2002 to 2004, a comparatively high 51.7% of South African firms reported that they were engaged in innovation activities, with a total expenditure of R28 billion, representing 3.2% of their turnover (DST 2008, Blankley and Moses 2009). The main type of innovative activity tends to be the acquisition of machinery, equipment and software (54.1%), but equally, intramural R&D is an activity for 51.7% of innovative firms, while 28.3% engaged in the acquisition of other external knowledge such as purchase of patents, and 19.3% engaged in extramural or outsourced R&D.

**Firms' propensity to cooperate on innovation and R&D activities in South Africa**

The research literature on open innovation networks in developed economies suggests that firm size, technological intensity and degree of insertion into global networks are associated with the propensity of firms to use open innovation practices, and cooperation with universities in particular (Laursen and Salter 2004, Cohen et al. 2002, Fontana et al. 2006, Tether 2002).

Analysis of South African Innovation Survey data suggests that local innovating firms that co-operate on their innovation activities with any partner - whether other firms, universities or research institutions - similarly tend to be larger in size (in terms of employee numbers), have a higher turnover, a higher innovation expenditure (particularly on intra-mural R&D) and a higher level of knowledge intensity in personnel (contributing to absorptive capacity) than those firms that do not cooperate at all (Table 4 and 5). Large firms thus appear to co-operate to seek complementary capacity for their innovation activity, rather than to substitute for lack of capacity.

The trends in relation to R&D performing firms are similar but more marked. Firms that cooperate in general are larger in size, spend significantly more on R&D, with a far higher research complement and report less basic and experimental research than the firms that do not cooperate (Table 6 and 7). These trends likewise suggest that firms seek to cooperate to complement internal R&D capability.

**Firms' propensity to cooperate with universities specifically**

Firms' propensity to cooperate with universities specifically follows a similar pattern. Analysis in this section compares three groups of firms – those that cooperate with universities (which may be in addition to other partners), those that cooperate with other

partners but not with universities, and those that do not cooperate on their innovative and R&D activities at all.

*Cooperation with universities for technology exploration*
Drawing on the Innovation Survey data, of 264 innovating firms that co-operate on their innovation activities, 108 reported that they partner with South African universities. Only two of the firms that collaborate with foreign higher education institutions do not also collaborate with local higher education institutions.

There are 120 R&D performing firms that cooperate with local universities (the largest group of cooperative partners), and 98 firms that cooperate, but not with local universities.

Innovating firms with higher employee numbers and greater turnover – the larger firms – show a greater propensity to co-operate with local universities (Figure 2). Innovating firms that cooperate with universities spend twice as much on their R&D than the non-university cooperators, and four times more than the firms that do not cooperate at all (Figure 3). This expenditure may be concentrated in a few large 'big spender' firms, as when we consider the frequency of firms, in relative terms, fewer university cooperating firms conduct in-house R&D, suggesting that there is also a group of firms that seek partnerships with universities to substitute for their own intra-mural R&D capacity.

While the firms that cooperate with universities have higher innovation related expenditure overall, they show lower innovation intensity than the non-university cooperators. This may be related to the large proportion of expenditure on the acquisition of machinery, equipment and software (47% of the university-cooperating firms' expenditure and 65% of the non-university-cooperating firms' expenditure).

The propensity to cooperate with universities on innovative activities also appears to be stronger for firms with higher levels of technological intensity (that is, a larger highly-skilled workforce and those with higher levels of R&D intensity). A higher frequency of these firms engage in the more knowledge intense innovation activities, and tend to rely more on external sources for their R&D to complement their internal R&D activities. It may also be that they rely on external sources to substitute, as in the case of the 21.3% of the university-cooperators that do not conduct intra-mural R&D.

The university-cooperators and non-university cooperators interact with a range of different partners on their innovation and R&D activities, and analysis shows distinct networking patterns.

Market-related resources - particularly their clients or customers, suppliers and other firms – are most important for the non-university-cooperators (Figure 4). Public research institutions are least important to them. This is in stark contrast to the cooperative tendencies of the university-cooperators, for whom consultants, commercial laboratories or private R&D institutes are as important as the firms' clients or customers; and government or public research institutes are as important as the firms' suppliers. More of these university-cooperators also cooperate with other firms, including their competitors.

Thus, the firms that cooperate with local universities on their innovation activities show a propensity to co-operate with knowledge institutions and rate knowledge intensive sources of information more highly than firms that co-operate with other kinds of

institutions. The non-university cooperators typically may be firms that use innovation-related design and engineering capabilities to enhance competitiveness, for which suppliers and users are the most important sources of selection.

*Insertion in global networks*

The non-university cooperators however, tend to connect more in global networks than the university-cooperators, with foreign partners outside of South Africa. In general, the innovations reported by firms originated mainly in South Africa. The larger proportion of the non-university cooperators report innovations originating abroad, followed by the group of firms that do not co-operate on their innovation activities at all. The university-cooperators are less likely to report innovations that originated abroad, suggesting that for this group of firms, local universities play a key role.

Analysis of the R&D Survey data shows similar trends, with the non-university cooperators preferring to cooperate with firms, but these firms do not show propensity to seek knowledge institutions abroad. The R&D firms cooperating with local universities show similar tendencies to the firms in the innovating sample when seeking partners abroad.

There is a small group of 31 R&D performing firms that cooperate with foreign universities, and this group shows a propensity to cooperate with foreign partners generally, concentrated in two sectors – mining and agriculture. The 31 firms represents a specific group of 'big spenders' on R&D, representing 14% of the cooperating sample but 21% of the total R&D expenditure, and accounting for more than a third of the total spent by firms cooperating with universities (locally and abroad). The high level of these 31 firms' R&D activity and cooperation activity generally implies that firms are more likely to engage international higher education institutions once a certain level of R&D expenditure is reached, and also when co-operation frequency with other partners is already high. Here are clear instances of innovative activity – and they are inserted into global networks.

*Outcomes of cooperation with universities*

The university-cooperators report considerably larger proportions of total turnover that comes from innovating goods and services new to the market or new to the firm than the non-university collaborators and the firms that do not co-operate at all.

The level of firm exploitation of new discoveries is generally very low in South Africa, and collaboration with universities does not appear to offer any significant advantage (Figure 5). Less than 10% of all firms in the total sample were awarded patents in South Africa in the period 2002 to 2004, 6.4% applied for patents abroad, 5.4% registered industrial designs, 19.5% registered trademarks, 7.6% claimed copyrights, and only 3.6% received license grants.

For the total sample, product outcomes are of high importance for most firms, in rank order: improved quality of goods or services (42.9% of firms), increased range of goods and services (39.4%) and the ability to enter new markets (34.9%). The firms that co-operate on their innovation activities, particularly those that report co-operation with local universities, share these perceptions, but more firms rate them as highly important (Figure 6). The university-cooperators reported slightly higher levels of success in entering new markets or increasing their share in the market and higher levels of success in improving the quality of their goods or services.

Across all sectors, the firms reported that, on average, the most successful process outcome was increased capacity for production or service production. The university-cooperators generally reported average levels of success on process outcomes higher than the non-university cooperators, and the most distinctive difference between the groups is the importance of reduced environmental impact or improved health and safety, and the meeting of governmental regulatory requirements.

Firms' propensity to co-operate with local universities may be influenced by their assessment of the obstacles to innovation (Figure 7). On average, the greatest obstacle to innovation reported by firms is a lack of qualified personnel. The university-cooperating firms rate other knowledge related obstacles as slightly more significant constraint on their innovation activities than the non-university cooperators. Cost factors, namely lack of funds within the enterprise or group, are also highly significant. Of note, as a group, the firms that do not cooperate with universities identify a distinct set of obstacles to innovation, rating lack of funds within the firm and lack of qualified personnel as the most important obstacles, followed by a lack of finance from outside sources, and market saturation. The fact that these firms do not seek complementary networks with universities suggests an area of latent potential that requires further exploration.

**Emergent open innovation networks and 'spots of interaction'**

The analysis suggests that universities are playing a role in open innovation networks to support technological upgrading and firm learning in South Africa – at least, for some firms. The proportion of firms that cooperate with universities on their innovation, 15% across the system, is comparable with that of many developed economies, with the EU-27 average standing at 8.8% (DST 2008). Firms' propensity to draw on local universities as co-operation partners is associated with larger firms and higher levels of technological intensity, and more with high-technology industries. More important, firms' propensity to co-operate with universities appears to be associated with higher levels of open innovation practices in general, that is, of cooperation networks with other firms, suppliers and customers or external knowledge actors.

This is an encouraging trend in terms of the potential contribution of universities to firm technological upgrading, and the prospects of catch-up in South Africa.

The diffusion of such open innovative practices across the national system of innovation is critical, and here, the trends in relation to the total number of firms involved, to the scale of interaction, and the spread across sectors, particularly emergent sectors in which South Africa may develop competitive advantage, reflect the immature national system of innovation.

The scale of co-operation on innovative and R&D activity in terms of the absolute number of firms involved is very small, particularly in comparative terms with catch up countries or developed OECD countries (Table 8).[4] The propensity of small and medium

[4] We do not know if there is any overlap between these datasets. Moreover, these numbers are not weighted to the total population of firms in South Africa.

firms to cooperate with universities is quite limited, and there are strong sectoral differences in the propensity to use open innovation practices.

Firms that cooperate on innovation are more likely to be in the manufacturing sector (50.4%), followed by wholesale and retail (20.5%), financial and business services (13.6%) and few in the mining sector (4.2%) (Table 8). Sectoral differences are evident in the types of innovation expenditure of cooperating firms. Mining firms tend to outsource R&D, while financial and business services firms tend to conduct their R&D in-house to support their innovation activities, and the wholesale and retail services reported the lowest levels of R&D intensity and innovation intensity.

Similarly, cooperating R&D firms are concentrated in the manufacturing sectors, with 92% of firms in high-technology sub-sectors reporting collaboration. Half of the R&D performing firms in financial and business services cooperate, and few wholesale and retail firms are included in the sample. Striking is that although there is a small number of firms in the traditionally strong resource-based mining and agriculture sectors, 100% report cooperation on their R&D activities (Table 8).

Innovating firms in industry – the manufacturing and mining sectors - show a higher propensity to co-operate with universities specifically than do those in the services sector – financial and business and wholesale and retail sectors - and may rely more on universities for successful operation. Higher R&D intensity and innovation intensity are associated with higher levels of interaction with universities for industry, particularly mining firms. The analysis suggests that the wholesale and retail sector relies more on external sources – although on universities to a lesser extent – for their R&D and innovation needs. The financial and business sector firms that cooperate with universities have lower levels of R&D and innovation intensity than the non-university cooperators, suggesting that firms in the sector tend to rely on in-house capacity for their innovation needs, and prefer partners other than universities.

The university-cooperators in sectors other than manufacturing reported a smaller proportion of goods and services that were unchanged or only marginally changed, in comparison to the non-university cooperators. This suggests that for the mining and services sector firms, co-operation with local universities is associated with higher innovation capability.

Opportunities and failures in technological upgrading through interaction with universities differ between the industrial and services sectors. It is possible to identify ‘spots of interaction’ where universities are matching firm demand, and sectors in which there are latent opportunities or system weaknesses. In South Africa, it seems universities as knowledge producers are aligned with the technology needs of large firms as knowledge users in the traditional resource-based mining and agriculture sectors, particularly in terms of complementing firms’ R&D capacity. The financial and business services sector appears to be an area of potential competitive advantage, but it has a weaker ‘match’ with what local universities offer, seeking to meet its knowledge and technology needs from clients and suppliers locally and abroad, and even foreign universities. The manufacturing sector tends to have the greatest number of firms that cooperate with local universities for technological upgrading, whether innovation or R&D, but trends at sub-sectoral level remain opaque.

The small absolute number of firms and the uneven sectoral spread of interaction between firms and the knowledge subsystem suggest that the innovating and R&D performing firms that cooperate with universities represent the cutting edge of what is possible. Far more in-depth research and analysis of specific emergent sub-sectoral systems of innovation is required, in order to distinguish within the broad categories used in this analysis. For instance, a high proportion of high-technology manufacturing firms interact with universities, and it would be useful to analyse specific sectoral dynamics that facilitate the match of capabilities and interactive activity.

The following section takes a modest step in that direction, through a focus at the micro-level on university-firm interaction in a single sub-sector, health biotechnology, which could be a potential 'spot of interaction' in South Africa.

## SECTION IV. UNIVERSITY-FIRM INTERACTION IN CREATING THE CONDITIONS FOR THE EMERGENCE OF A 'MODERN' HEALTH BIOTECHNOLOGY SECTOR IN SOUTH AFRICA

Section IV examines whether and how open innovation networks including universities have emerged in health biotechnology, which we may expect to be a sector in which there is significant interaction between university and firms.

This is because early in the process of transition in South Africa, influenced by and imitative of global policy trends, a national foresight process selected three horizontal technologies as priority targets for future expansion and competitive advantage – biotechnology, ICT and new materials development (DACST 1996). Great weight has been placed on the promise and potential of the development of a 'modern' biotechnology sector in South Africa, both as a major growth industry enhancing global competitiveness and in terms of addressing social and environmental problems (Gastrow 2008, Gabru 2008a and 2008b). A targeted biotechnology policy framework was initiated, with a high degree of borrowing from the developed economies (DST 2002, Burton and Cowan 2002, Klerck 2005, DST 2007). Public initiatives aimed to stimulate innovation and commercialisation in the biotechnology sector, by establishing a network of regional and national innovation centres and incubators, creating national technology platforms (for bioinformatics and genomics, for example), setting strategic priorities and committing considerable public funding and investment. Biotechnology policy represents an instance of a state-driven attempt at stimulating the growth of new knowledge-based sectors:

> ….based on the successful development of a technology-specific infrastructure that 'nurses' key precursor firms, which then get metamorphosed into a new sector or industry (Sercovich and Teubal 2008: 13).

Universities may be expected to contribute centrally to such R&D, open innovation networks and commercialization endeavours.

However, on investigation, it became evident that the challenges are considerable (DST and eGolibio 2004). The emerging biotechnology system is not co-ordinated, funding is insufficient, there is a lack of private venture capital (Akermann and Kermani 2006) and difficulty attracting highly skilled scientists (see also Cloete et al 2003, Ernst and Young 2006, Lorentzen and Petersen 2008). The biotechnology sub-sector, it appears, is in its

infancy[5], with conditions of limited research and technology capacity, a virtually non-existent industrial sector and significant gaps in the value chain.

Case studies of interaction were conducted at two universities based in a single province, one of two geographical clusters of biotechnology activity nationally. The provincial bioeconomy is extremely small, with potential in a small set of 20 core commercial firms, 12 public research institutions, 9 industry development and venture capital companies and 4 universities (Coetzee 2005). Table 9 presents a brief overview of 9 cases of university-firm interaction investigated in the field of health biotechnology in these very different universities, in the context of an immature regional and national bioeconomy. The universities display evidence of cutting edge scientific production that is attracting global firms and research partners in open innovation networks, but an evident lack of interaction with local firms and gaps in the local value chain suggest that in this targeted sub-sector, universities are in advance of firm capabilities.

**Academic entrepreneurs and global firms as customers of university-based micro-enterprises**

The first institution is a historically disadvantaged, relatively young university with a strong national developmental and transformation agenda, part of a middle group of research-capable universities with strengths only in niche areas, and with a '*laissez faire* aspirational' approach (Kruss 2005) to managing university-firm interaction. With regard to *health biotechnology* specifically, given its historical strengths and areas of focus, there was a very small scale of university-firm interaction. Where it did exist, the scope and intensity of interaction was very limited, essentially taking the form of university-based spin-off micro-enterprises offering bioinformatics consultancy services, and all the clients were foreign firms.

The staff of the micro-enterprises was academics located in the university. A failed spin-off company was more strongly inserted into the universities' knowledge generation activities, but in two other current cases, the micro-firm and the interaction did not rely on university funding, legal support nor involve post-graduate students, and the claim was made that the firm does not involve the university's time or intellectual property. One micro-firm offers bioinformatics consulting and customizing as its core business, with but two members of a close corporation; the other is a start up venture with three or four partners in a network structure[6].

This form of micro-enterprise is found in many South African universities, and is a typical form of university-based commercial endeavour. It is essentially a vehicle for consultancy work on the part of academics, used to supplement their salaries by spending a proportion of their time on private work. The university's main concern is to protect core academic business and satisfy the entrepreneurial demands of researchers. The impact on the university's research reputation and academic profile is likely to be minimal, as consultancy does not typically lend itself to knowledge generation, or

[5] There are those who would argue that the lack of commercial success may not be a uniquely South African phenomenon, given that globally the biotechnology sector is not yet profitable (Ernst and Young 2006).

[6] Both are owned by the same academic, a recent immigrant to South Africa from Europe with experience of working in universities in a number of countries.

publications or the involvement of post-graduate students, the typical university benefits of firm interaction (Kruss 2006b).

The scope for growth beyond a micro-enterprise, generating employment and significant products is questionable, as is the potential economic impact in the region or nationally. One reason is the absence – or at least, the very small size - of local markets for health biotechnology services and the difficulties of accessing global markets. For example, a spin-off company was initially hailed as an exemplar and succeeded in attracting venture capital funding, had some early successes with its bioinformatics software, and claims of significant earnings by the university. Nevertheless, within a short period of time, the company collapsed, primarily due to difficulties in accessing international markets (Kruss 2008).

The cases of interaction in health biotechnology at this university, then, represent fledgling, small-scale experimental academic entrepreneurial activity. The benefits for capability building of the university are minimal, and the absence of local markets is a constraint on the potential growth of the micro-enterprises.

**Translational research: health biotechnology and interaction**

The second institution is a long-established, historically advantaged, well resourced university with strong research capability and reputation locally and even globally. The university has developed policies and internal management structures to promote research niche areas, innovation and technology transfer, although there have been recent shifts away from commercialization and towards promoting academic excellence. The university has a long-established Faculty of Health Science, which, under strong academic leadership the past few years, has grown its research reputation, performance and budget. Potential constraints arise from multiple demands on academic clinicians to balance good research, teaching as well as clinical work.

Of note are trends towards translational research and new hybrid organizational forms that promote open innovation networks. One example is the creation of an independent university owned company in which commercial research ventures are used to cross-subsidise strategic and translational community-based health research with a social development goal. For this proprietary limited company wholly owned by the university itself, the dividends are not declared, and any surplus generated is used to fund the company goals – strategic research. The strategic research is informed by a clear view of the specific health needs of South Africa and a commitment to community-based research, translating medical advances with a clinical bent into applications. To ‘pay the rent’ and find resources for research, both human and financial, the unit’s ‘opportunistic’ work is commercial clinical drug trials for foreign pharmaceutical companies. This institute is thus a hybrid public-private venture, with positive outcomes in that the purpose and expertise of the research institute, the university, the firms and the patient communities interact to mutual benefit.

A similar case of research oriented to public health needs is an HIV/AIDS vaccine development programme that involves indirect interaction with large local energy, transport and mining firms, government and the European Union, as sponsors and donor firm partners to fund research critical to national health agendas, through the vehicle of a national funding umbrella body. The research group has worked as an open innovation

network, building a multi-disciplinary team to collaborate and contribute their specific expertise to extend their reach, achieve critical mass and create new technology platforms. After a number of years, the project is now at a point where they are ready to test two vaccines. If successful and commercialized, the vaccine could be marketed elsewhere, but the research group holds the rights in South Africa, to ensure that there is access to the intellectual property and sharing in the interests of public health.

At a critical point in the process of moving to clinical trials, the research group experienced severe constraints related to a lack of maturity in the national system of innovation – a lack of predictability in the flow of critical public research funds, constraints in relation to gaps in the local supplier value chain such as manufacturing for trials and reliable local Good Practice Lab (GLP) facilities, problems in contracting reliable foreign suppliers of services exacerbated by distance, and immature vaccine manufacturing capability. Nevertheless, the case illustrates the strength of local scientific expertise in interaction with global and local research networks, and the ways in which universities can contribute to national development by addressing a health need that is a significant constraint on future development in South Africa.

There are other cases that reflect commercialization and entrepreneurial activity through open innovation networks. After many years, and based on global collaborative research and funding networks, a research group solved the problem of identifying the three dimensional structure of a protein critical to the causes of hypertension. On this basis, the group proceeded to identify a suitable compound to develop a new second generation drug, also through global and local research networks. At this point the research group encountered significant systemic weaknesses, in the difficulties of raising sufficient funding for an early stage venture in South Africa. With strong university support, the group succeeded in obtaining funding from a public biotechnology regional innovation centre. In terms of this agreement, the group will form a new South African based subsidiary spin-off company to which the IP will be assigned, rather than the university, and a US based company the group formed earlier will fund research for the development of new generation drugs. It is likely that this small spin-off company will take the group through refining the compound and perhaps Phase 1 trials, but thereafter, they will need a pharmaceutical or major biotechnology company partner to develop and license out the product. The main aim for this company then, is to develop the intellectual property and sell, to realize the initial investment. This research group has been successful in terms of its goals of proceeding through the translational pipeline, but it is now entering a high risk stage. The case highlights the complexity of remaining within the university environment once there is a move beyond basic research towards commercialization, in which case, issues of intellectual property rights, financing and business management become paramount, as well as the difficulties facing high technology start-ups in South Africa.

**Health biotechnology as an emergent 'spot of interaction'**

The trends are very specific to the health biotechnology sub-sector, but the case studies provide insight into the complexities of universities' contribution to firm technological upgrading and to building a national system of innovation in middle income countries like South Africa.

The potential of the scientific advances to address critical human development needs, to tackle health problems for which there are insufficient solutions globally and regionally, is irrefutable. The research conducted has intrinsic value, and the notion of 'translational' research provided a focus for developing a new research culture and enhancing strategic capability in the university, while the university benefited reputationally in terms of publications, students and evidence of its contribution to address national health priorities. At this stage, however, health biotechnology represents cutting edge innovation activity *within the higher education system* that enables insertion into global scientific and research networks. The different forms of interaction found in the two universities raise questions about the lack of diffusion and depth of scientific capacity across the segmented higher education system. The concentration of capacity (and the fact that so many key research group leaders are foreign), reflects that science and technology thresholds have not yet have been reached sufficiently across a differentiated, flexible higher education system.

At the same time, the cases reflect that the higher education system does have levels of 'new to the world' scientific production that are sufficiently strong to attract global firms as sponsors, customers, suppliers or partners, but the local productive sector is not able to take advantage of the latent opportunity inherent in this research and knowledge generation capability. And it is unlikely that university-led commercial ventures can drive the process without a core local productive sector with key capacities along the value chain – at least, to the benefit of the South African economy. At this point in time, the presence of open innovation networks is uneven, and there is still a mismatch between the capabilities of local universities and local health-related firms.

## CONCLUSION: UNIVERSITY-FIRM INTERACTION AND THE CHANGING ROLE OF UNIVERSITIES IN SOUTH AFRICA

South Africa is a country attempting to create conditions to access global markets, to strengthen emergent networks and innovation activity - and simultaneously, to resolve historically determined lock-ins in human development, evident in high levels of unemployment, poverty and inequalities in education and health. In this context, the demands on higher education are multiple, but the study has focused specifically on the demand for higher education to contribute to firm's technological upgrading.

Analysis of university interaction with firms on their innovation and R&D activities revealed patterns of open innovation networks akin to those of catch-up and developed countries, particularly on the part of larger, more technologically intense firms with evidence of absorptive capacity. Unlike many other developing countries, where the productive structures do not demand sophisticated knowledge and technology, (some) universities are contributing to (some) firms' technological upgrading in some sectors.

Tese innovation networks are not widely diffused across the economy to a large number of firms or entire sectors. There is evidence of strong sectoral differences that require a great deal of further research: historical patterns of interaction between local universities and firms in mining and agriculture, inter- and intra- firm interaction with both local and foreign firms in the financial and business services sector, and emerging new complex patterns in the manufacturing sector that require disaggregation by sub-sector and field to identify specific 'spots of interaction' that can be nurtured.

Case studies in health biotechnology, an emergent sub-sector targeted for public policy support, suggest that at this stage, it does not represent a 'spot of interaction' between universities and local health-related firms. The levels of scientific production within the higher education system are sufficiently strong to enable insertion into global scientific networks and to attract global firms, so that the higher education system is ahead of the local productive sector, which is still in its infancy with significant gaps in critical value chains. The analysis identified systemic failures in the institutions of the national system of innovation that constrain the development of capabilities that could support the emergence of a dynamic, competitive health biotechnology sub-sector.

Such contextually specific analysis of the nature of university-firm interaction in general and in specific sectors can inform policy interventions in developing countries. A full analysis of policy implications would require engagement with the detail of present national and sectoral policy structures and mechanisms relative to interactive practice, which of necessity is the subject of a separate study. Here, the evidence in support of a combination of horizontal and targeted policies (Sercovich and Teubal 2008) is briefly marshaled.

**Horizontal and targeted policies**

Horizontal policies are increasingly recognized as important to support the conditions for knowledge-based development in countries like South Africa to avoid stagnating rather than catching-up. High income concentration and uneven income distribution are identified as a critical lock-in on technological progress in immature national systems of innovation (Albuquerque 2007, Altenburg 2008) that block diffusion through the economy. Horizontal policies to address inequality, poverty reduction and social welfare could break binding constraints on the national system of innovation in South Africa. In particular, the analysis highlights the significance of horizontal policies to grow and strengthen knowledge institutions across the higher education system, both quantitatively and qualitatively, to reach levels of critical mass. The small scale of interaction, and the differential capability of universities with distinct legacies to interact with firms points to the significance of diffusion of scientific and organisational capabilities more widely across the higher education system, so that the system has the capacity to reproduce itself and produce more graduates with the skills required by firms. Recent analysis of stagnation in South Africa's innovation performance has led to a call for better policy sequencing and prioritization, beginning with a horizontal policy focus on the development of high-level skills to address this major constraint on technological innovation (Kaplan 2008). Ongoing policy effort on the part of government, individual institutions and higher education associations to grow and strengthen knowledge institutions have yet to take effect. The case study analysis highlights the importance of identifying and addressing systemic failures and disjunctures on a regular basis. In short, the strategic level of policy-making required in a dynamic and rapidly changing local and global environment needs to be developed more strongly in South Africa. Strategic policy-making requires ongoing re-assessment in the light of new strategic priorities and system failures, based on knowledge of institutional and contextual specificity (Sercovich and Teubal 2008, UNIDO 2005).

The study's analysis of patterns and trends of firms' cooperation with universities on their innovative and R&D activities across the national system was only a first step towards informing the kinds of targeted policy support required. It highlights the importance of detailed studies of selected priority sub-sectors with potential and existing comparative

advantage, particularly sub-sectors in which it is evident that there is an existing group of highly capable firms that cooperate with universities on their innovation and R&D activities, or that display features of open innovation networks more strongly. It also highlights the importance of identifying and problematising the potential opportunities where innovation chasms exist, where there are scientific specializations and latent opportunities in the universities that the productive sector is not using sufficiently. That large firms are more likely to cooperate with universities highlights yet another area for investigation and strategic re-examination of existing targeted policies - the contribution of universities to support technological upgrading in small and medium firms. Moreover, the case studies highlight the complexity of identifying targeted incentives appropriate to specific national or regional conditions.

**A responsive university**

The main conclusion from the study is that in order to contribute to 'keeping-up' and catch-up, universities in South Africa should focus more strongly on consolidating their traditional strengths as a basis for expanding their contribution to build a more mature national system of innovation.

The global shift to a new 'third mission', of a role for universities in economic and social development, and the notion of an 'entrepreneurial' university (Clark 1998, 2003, 2004) impacted in South Africa since the 1990s. A lively debate ensued at the time, as to the most appropriate new model for the changing university in South Africa (Subotzky 1999, Kraak 2000, Muller 2001, Singh 2001, Gewers 2001, Favish 2003, Ravjee 2002, CHE 2002). A few universities explicitly adopted and actively pursued new models of the entrepreneurial university (Kruss 2005a). More generally, in practice, the 'third mission' tended to be interpreted in terms of a narrow vision of entrepreneurialism, in terms of short-term, market-driven commercial goals, to raise income for the university in the face of public funding cuts. Such commercialization strategies carry high risk, even in developed countries (Cargill 2007), exacerbated under conditions of scarce resources as in South Africa. The differential capacity and segmentation of the higher education system means that very few universities have the capabilities required for launching successful high technology start-ups and commercial ventures.

At this stage of South Africa's development, given multiple demands and imperatives, universities would be better served by proceeding on the basis of what they do best – teaching and research – to build open innovation networks with firms and other knowledge producers. Universities are already key cooperative partners in a number of sectors, responsive to firm demand, complementing firm capacity and contributing to firm upgrading – but there is considerable scope to expand this role.

The key is to expand the complementary role of university-based research and teaching where there is latent opportunity, where potential firm demand matches existing or emerging university scientific strengths. The analysis provides a first step to identify such spots of interaction. It is important for higher education institutions themselves to develop the capability for strategic 'intelligence gathering', for analyzing where the potential matches are between their scientific strengths and local firm demand, and how they can access public and private support. The emergence of new hybrid forms of private-public research institutions illustrate one possible mechanism whereby universities can cooperate with firms in a mutually beneficial manner, and contribute to social and human development goals, as does the notion of 'translational research'.

Such institutional innovations are informed by understanding of local conditions. Unreflective imitation of 'best practice' from universities in the United States and United Kingdom or Europe will not promote university-firm interaction that serves South Africa. Rather, a new national model of a *responsive university,* with research and teaching as a foundation for interaction, encompassing the core developmental tasks, can be elaborated as a more contextually appropriate alternative.

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## TABLES AND FIGURES

**Table 1. Shifts in % GDP by sectors, South Africa 2000-2005**

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | 3.27 | 3.08 | 3.16 | 3 | 2.83 | 2.84 |
| Mining and quarrying | 7.56 | 7.34 | 7.14 | 7.21 | 7.1 | 6.98 |
| Manufacturing | 18.98 | 19.04 | 18.85 | 18.05 | 18.08 | 17.93 |
| Construction | 2.52 | 2.57 | 2.62 | 2.72 | 2.88 | 3.02 |
| **Total Industry** | 29.06 | 28.95 | 28.62 | 27.98 | 28.06 | 27.93 |
| Electricity, gas and water | 2.72 | 2.55 | 2.54 | 2.51 | 2.46 | 2.38 |
| Trade, catering and accommodation | 14.64 | 14.5 | 14.29 | 14.77 | 14.95 | 15.12 |
| Transport, storage and communication | 9.65 | 9.93 | 10.44 | 10.72 | 10.74 | 10.81 |
| Finance, insurance, real estate and business services | 18.64 | 19.6 | 20.07 | 20.29 | 20.9 | 21.45 |
| Community, social and personal services | 22.02 | 21.39 | 20.89 | 20.72 | 20.07 | 19.47 |
| **Total Services** | 67.66 | 67.97 | 68.22 | 69.01 | 69.12 | 69.23 |
| **TOTAL** | 100 | 100 | 100 | 100 | 100 | 100 |

Source: South African Reserve Bank OECD 2007: 31.

| Table 2. Tertiary Education Enrolments in South Africa 1996-2007 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** |
| | | | | | | | | | | | | |
| | 134,301 | 141,531 | 143,425 | 148,417 | 163,023 | 169,257 | 176,729 | 193,864 | 202,552 | 210,707 | 211,585 | 214,690 |
| **SET** | 24% | 25% | 26% | 27% | 28% | 27% | 26% | 27% | 27% | 29% | 29% | 28% |
| | | | | | | | | | | | | |
| | 112,512 | 122,968 | 130,983 | 127,002 | 140,660 | 184,165 | 200,193 | 215,065 | 238,532 | 214,485 | 223,036 | 228,860 |
| **Business and Management** | 20% | 22% | 23% | 23% | 24% | 29% | 30% | 30% | 32% | 29% | 30% | 30% |
| | | | | | | | | | | | | |
| | 63,825 | 61,949 | 59,760 | 69,123 | 78,332 | 100,029 | 108,830 | 105,598 | 112,064 | 105,826 | 98,476 | 106,367 |
| **Education** | 11% | 11% | 11% | 12% | 14% | 16% | 16% | 15% | 15% | 14% | 13% | 14% |
| | | | | | | | | | | | | |
| | 243,903 | 228,885 | 213,799 | 207,532 | 194,233 | 173,187 | 181,429 | 190,723 | 191,332 | 204,053 | 207,923 | 211,172 |
| **Humanities&Social Sciences** | 43% | 40% | 38% | 37% | 34% | 28% | 27% | 27% | 26% | 28% | 28% | 28% |
| | | | | | | | | | | | | |
| | 10,605 | 13,332 | 12,598 | 1,727 | 1,886 | 640 | 1 | 6 | 0 | 2 | 360 | 0 |
| **Unkown cesm** | 1.9% | 1.9% | 1.9% | 0.3% | 0.3% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| | **565,146** | **568,665** | **560,565** | **553,800** | **578,134** | **627,277** | **667,182** | **705,255** | **744,479** | **735,073** | **741,380** | **761,090** |
| **Total** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

**Table 3. Tertiary Education Graduations in South Africa 1996-2007**

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | 21,682 | 22,904 | 22,506 | 23,269 | 24,244 | 25,088 | 27,177 | 29,805 | 31,490 | 33,506 | 35,542 | 36,429 |
| **SET** | 25% | 26% | 26% | 25% | 26% | 26% | 27% | 27% | 27% | 28% | 29% | 29% |
| | | | | | | | | | | | | |
| | 13,915 | 15,049 | 15,960 | 17,754 | 19,937 | 23,020 | 24,676 | 27,213 | 29,323 | 28,153 | 30,096 | 31,064 |
| **Business and Management** | 16% | 17% | 18% | 19% | 21% | 24% | 24% | 25% | 25% | 23% | 24% | 25% |
| | | | | | | | | | | | | |
| | 19,060 | 17,065 | 17,027 | 19,056 | 18,174 | 20,979 | 23,271 | 25,175 | 29,360 | 29,348 | 28,523 | 28,337 |
| **Education** | 22% | 19% | 20% | 21% | 20% | 22% | 23% | 23% | 25% | 24% | 23% | 22% |
| | | | | | | | | | | | | |
| | 31,556 | 33,205 | 31,132 | 32,106 | 30,401 | 26,833 | 26,136 | 26,206 | 27,092 | 29,368 | 30,398 | 30,811 |
| **Humanities&Social Sciences** | 37% | 38% | 36% | 35% | 33% | 28% | 26% | 24% | 23% | 24% | 24% | 24% |
| | | | | | | | | | | | | |
| | | | | 314 | 118 | 158 | 10 | 53 | 3 | 10 | 56 | |
| **Unknown cesm** | 0.0% | 0.0% | 0.0% | 0.3% | 0.1% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| | **86,213** | **88,224** | **86,625** | **92,499** | **92,874** | **96,076** | **101,271** | **108,452** | **117,268** | **120,385** | **124,615** | **126,641** |
| **Total** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

**Table 4. Firms and sectors that innovate and cooperate or not**

| | Total sample (N=981) | Cooperation (N=264) | No cooperation (N = 339) |
|---|---|---|---|
| **Firm size (no. of firms) (2004)** | | | |
| Micro (1-9 employees) | 148 | 21 | 37 |
| Small (10-49 employees) | 271 | 72 | 74 |
| Medium (50-249 employees) | 353 | 92 | 145 |
| Large (250+ employees) | 181 | 78 | 71 |
| **Employees with university or technikon degree or diploma in 2004** | | | |
| Mean | 19.3% | 22.0% | 18.1% |
| Median | 10.0% | 10.0% | 10.0% |
| **Turnover in 2004 (in rands)** | | | |
| Total | 424,160,908.0 | 269,101,827.0 | 83,324,157.0 |
| Mean | 461,044.5 | 1,059,456.0 | 259,576.8 |
| Median | 60,517.5 | 83,719.0 | 65,300.0 |
| **Sector (no. of firms)** | | | |
| Agriculture | - | ‘- | ‘- |
| Mining | 45 | 11 | 13 |
| Manufacturing | 367 | 133 | 133 |
| Electricity, gas & water supply | 21 | 11 | 5 |
| Construction | - | - | |
| Wholesale & retail | 320 | 54 | 112 |
| Transport, storage & communication | 79 | 19 | 25 |
| Financial intermediation, real estate & business services | 147 | 36 | 51 |

*Data source: Innovation Survey 2005 dataset (unweighted), CESTII*

## Table 5. Innovation activities by cooperation

| | Total sample (N=607) | | Cooperation (N=264)* | | No cooperation (N=339)* | |
|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No |
| **Intramural (in-house) R&D** | 396 (65.2%) | 211 (34.8%) | 202 (76.5%) | 62 (23.5%) | 192 (56.6%) | 147 (43.4%) |
| **Extramural or outsourced R&D** | 230 (38.0%) | 375 (62.0%) | 147 (55.7%) | 117 (44.3%) | 83 (24.6%) | 255 (75.4%) |
| **Acquisition of other external knowledge** | 200 (33.0%) | 406 (67.0%) | 119 (45.1%) | 145 (54.9%) | 81 (23.9%) | 258 (76.1%) |
| **Innovation expenditure (in '000 rands) in 2004** | | | | | | |
| Total | 7,002,475.0 (N=557) | | 5,488,225.0 (N=247) | | 1,510,750.0 (N=304) | |
| of which: | | | | | | |
| Intramural (in-house) R&D | 1,595,530.0 | | 1,386,322.0 | | 208,708.0 | |
| Mean | 3,116.3 | | 5,899.2 | | 761.7 | |
| Median | 100.0 | | 300.0 | | 65.0 | |
| Extramural or outsourced R&D | 688,703.0 | | 570,399.0 | | 118,304.0 | |
| Mean | 1,481.1 | | 2,703.3 | | 467.6 | |
| Median | 0.0 | | 50.0 | | 0.0 | |
| Acquisition of machinery, equipment and software | 4,147,716.0 | | 3,047,470.0 | | 1,097,246.0 | |
| Mean | 8,022.7 | | 13,366.1 | | 3,823.2 | |
| Median | 300.0 | | 500.0 | | 200.0 | |
| Acquisition of other external knowledge | 570,526.0 | | 484,034.0 | | 86,492.0 | |
| Mean | 1,314.6 | | 2,444.6 | | 368.1 | |
| Median | 0.0 | | 0.0 | | 0.0 | |

**Table 6. Profiles of the total sample, and cooperative and non-cooperative R&D performing firms 2005/6**

| | Total sample (N=327) | Cooperation (N=218) | No cooperation (N = 109) |
|---|---|---|---|
| **Firm size (no. of firms)** | | | |
| Micro (1-9 employees) | 39 | 16 (41%) | 23 (59%) |
| Small (10-49 employees) | 88 | 47 (53.4%) | 41 (46.6%) |
| Medium (50-249 employees) | 59 | 42 (71.2%) | 17 (28.8%) |
| Large (250+ employees) | 141 | 113 (80.1%) | 28 (19.9%) |
| **Sector (no. of firms)** | | | |
| Agriculture | 12 | 12 (100%) | - |
| Mining | 14 | 14 (100%) | - |
| Manufacturing of which | | | |
| Low-technology | 31 | 23 (74.2%) | 8 (25.8%) |
| Medium-low technology | 34 | 25 (73.5%) | 9 (26.5%) |
| Medium-high technology | 43 | 29 (67.4%) | 14 (32.6%) |
| High-technology | 36 | 33 (91.7%) | 3 (8.3%) |
| Electricity, gas & water supply | 4 | 4 (100%) | - |
| Construction | 2 | 1 (50%) | 1 (50%) |
| Wholesale & retail | 4 | 2 (50%) | 2 (50%) |
| Transport, storage & communication | 9 | 5 (55.6%) | 4 (44.4%) |
| Financial intermediation, real estate & business services | 128 | 63 (49.2%) | 65 (50.8%) |
| Community, social & personal services | 10 | 7 (70%) | 3 (30%) |

*Data source: R&D Survey 2005/06 dataset (unweighted), CeSTII.*

**Table 7. R&D expenditure of R&D performing firms**

| | Total sample (N=327) | Cooperation (N=218) | No cooperation (N = 109) |
|---|---|---|---|
| **R&D expenditure (in rands)**: | | | |
| Mean total R&D expenditure | 18,374,165.14 | 25,530,105.5 | 4,062,284.4 |
| Median total R&D expenditure | 3,190,000.0 | 6,384,500.0 | 1,474,000.0 |
| **By type of research (mean %):** | | | |
| Basic research | 15.1 | 13.7 | 20.4 |
| Applied research | 38.9 | 39.4 | 37.4 |
| Experimental research | 67.3 | 61.8 | 78.2 |
| **R&D personnel:** | | | |
| Mean R&D personnel (headcount) | 32.9 | 42.9 | 13.0 |
| Mean FTE | 25.7 | 34.4 | 8.4 |
| R&D personnel intensity (R&D personnel/total employees) | 0.30 | 0.26 | 0.38 |

*Data source: R&D Survey 2005/06 dataset (unweighted), CeSTII.*

**Table 8. Comparison of innovation and R&D interaction by sector**

| | Innovation Survey 2005 | | | | R&D Survey 2005/06 | | |
|---|---|---|---|---|---|---|---|
| | **Total no. of firms** | **Innovating firms** | **Innovating firms with interaction** | **Interaction with SA higher education** | **Total no. of firms** | **R&D firms with interaction** | **Interaction with SA higher education** |
| **Total no. of firms** | **981** | **603** | **264** | **108** | **327** | **218** | **120** |
| of which: | | | | | | | |
| Manufacturing | 367 | 266 (72.5%) | 133 (36.2%) | 59 (16.1%) | 144 | 110 (76.4%) | 67 (46.5%) |
| Financial and business services | 146 | 84 (57.5%) | 36 (24.7%) | 14 (9.6%) | 128 | 63 (49.2%) | 26 (20.3%) |
| Mining | 45 | 24 (53.3%) | 11 (24.4%) | 5 (11.1%) | 14 | 14 (100%) | 10 (71.4%) |
| Wholesale and retail | 320 | 166 (51.9%) | 54 (16.9%) | 26 (8.1%) | 4 | 2 (50.0%) | - |
| Agriculture | - | - | - | - | 12 | 12 (100%) | 7 (58.3%) |

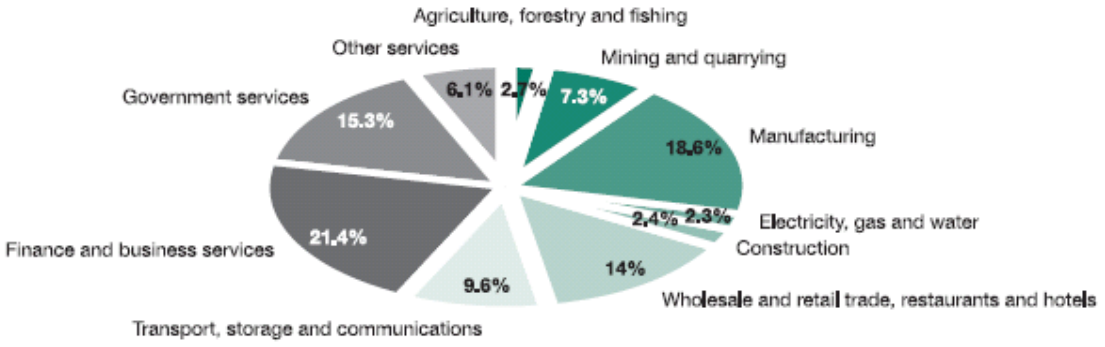
*Data source: Innovation Survey 2005 dataset, and R&D Survey 2005/06 dataset, CESTII (unweighted)*
Note: 1) Proportion of total number of firms within sector in brackets. 2) The analysis is restricted by limitations in the data as the Innovation Survey 2005 dataset does not include any firms in agriculture and the R&D Survey 2005/06 dataset includes only four firms in the wholesale and retail sector in comparison to the 93 firms included in the innovation dataset that reported in-house R&D capacity.

**Table 9. Cases of interaction between university and firm in the biotechnology sector in two South African universities**

| | Nature of interaction with university | Nature of interaction with firms | Outcome in terms of goals set |
|---|---|---|---|
| **UWC** | | | |
| Collaboration between research institute and its spin-off company | Sharing facilities, staff and knowledge products, sub-contracting university to conduct research for firm | Clients were global biotech firms and academic groups | Difficulties in accessing global markets and integrating the marketing function left firm vulnerable to disruption of capital flows following an IP dispute, leading to failure |
| Consultancy micro-firm used to subvent academic salaries | No knowledge-intensive involvement with university in terms of students or publications, little direct support | Clients are global small biotech firms and academic groups | Small turnover, generating small profit for two academics |
| Network micro-firm to offer a chain of services | University professor involved only in personal capacity on consultancy basis | Clients will be global firms | In the process of formal establishment |
| **UCT** | | | |
| Institute conducts commercial drug trials with 'knowledge translation' models and strategic community-based research, based in a hybrid public-private venture | A university-owned company that operates not-for-profit, yields publications and post-graduate students; reputation | Global and local corporates as sponsors and donors of facilities<br>Global pharmaceutical firms as clients of clinical trial services | Growth of commercial work, research income, staff and community-based work |
| Public interest multi-disciplinary HIV/AIDS Vaccine research network | GLP compliant laboratory developed that can be used to generate revenue; publications; patents; post-graduate students; reputation | Government and parastatal firms as donors through a public funding vehicle<br>Global small biotechnology firms as suppliers of manufacturing services to support drug trials | Two vaccines ready for Phase 1 trials |
| Institute conducts contract research for global firm | Cutting edge research laboratory, funding for post-graduate students, publications, reputation | Multinational company as donor of facilities<br>MNC as contract research funder, owns and exploits all IP but no direct collaboration on research<br>Start up micro-company in process of being established with UK collaborator, in anticipation of | Patents<br>First product in final stage trials, rights sold to a new company |

| | | | |
|---|---|---|---|
| | | end of contract | |
| Research group and its spin off company to fund strategic research | Group supported as part of university research niche area, university stakeholder in firm<br>Post-graduate students, publications, patents, reputation | A US- based investment shell and a SA-based company in process of being established to hold IP and sub-contract research group to conduct drug development research, with investment by public funding vehicle | Frontier Science basic research (first to publish in Nature)<br>Compound identified<br>Drug development research in process |
| Research group based in a technology platform funded by public biotechnology vehicle, multi-disciplinary research network driven by commercial goals | Group supported as part of university research niche area<br>Technology platform a service<br>Post-graduate students, publications, reputation | US-based spin-out firm as investment vehicle, will pay research group to conduct research<br>SA-based company in process of being formed | In the process of establishment |

**Figure 1. A breakdown of the South African economy, 2005**

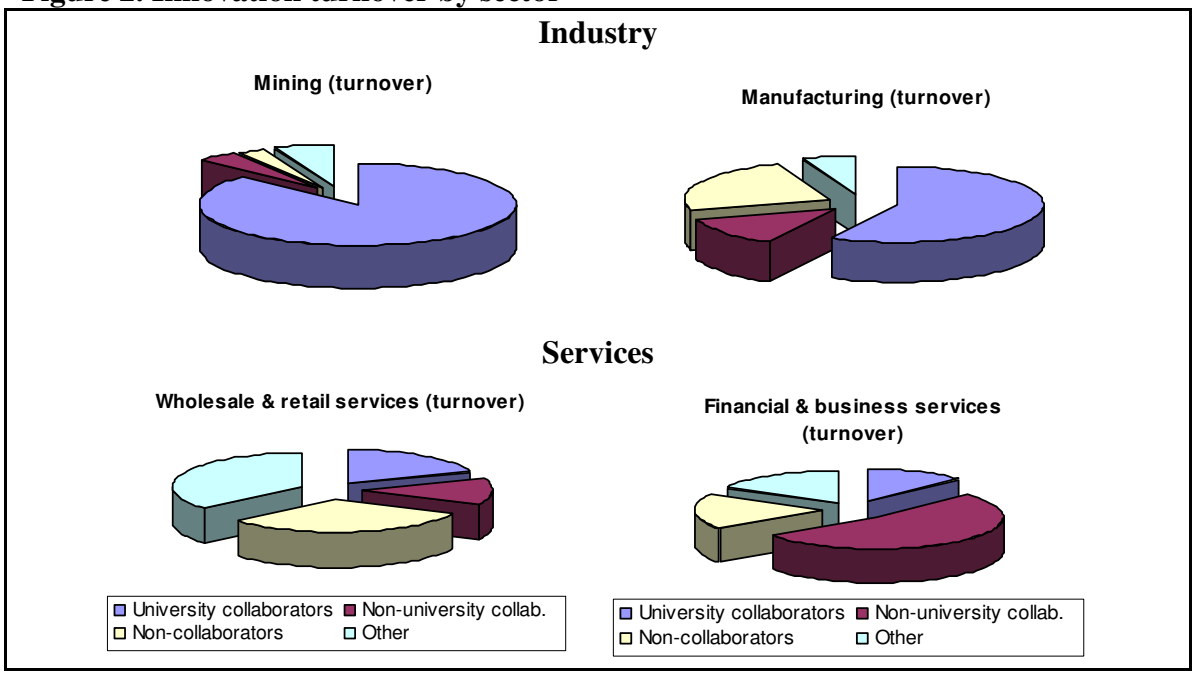



**Source:** Authors' estimates based on National Institute of Statistics data.

http://dx.doi.org/10.1787/247765010430

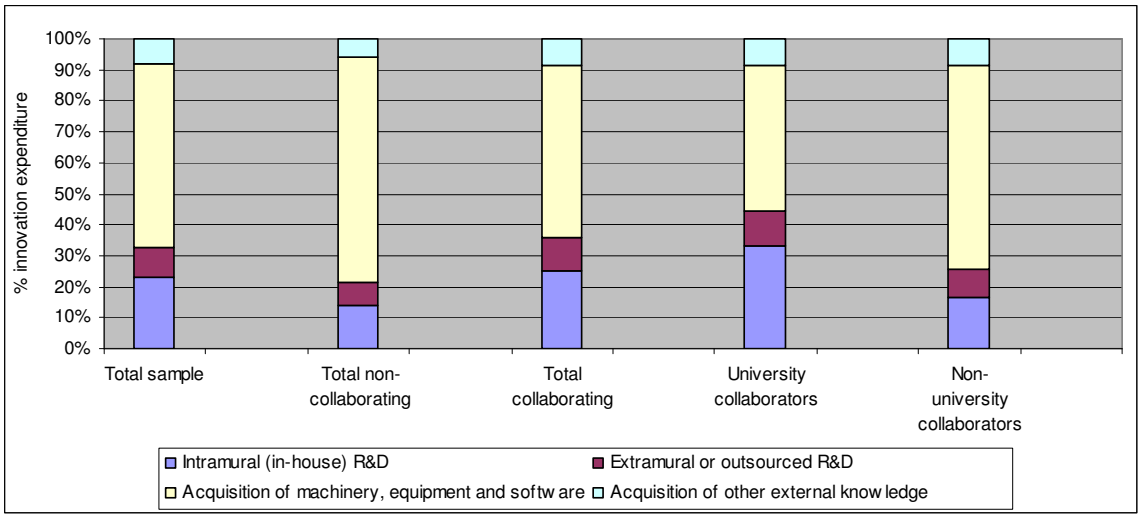
Source: extracted from the African Economic Outlook 2007: 489

**Figure 2. Innovation turnover by sector**



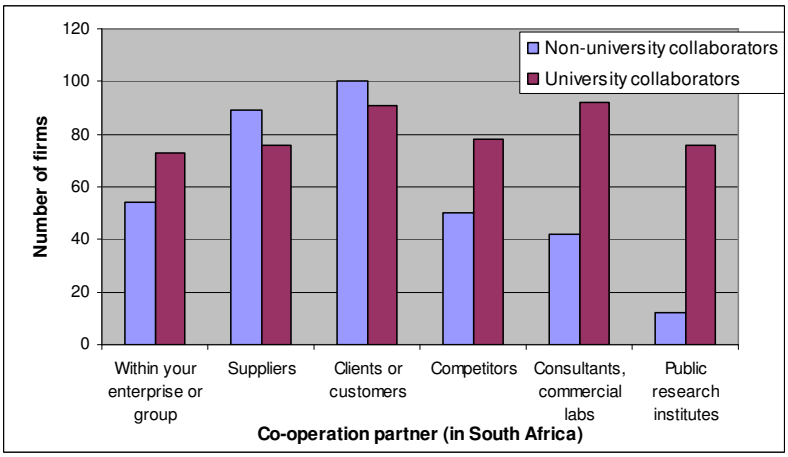

Data source: Innovation Survey 2005 dataset (unweighted), CESTII

**Figure 3. Firms' innovation expenditure in 2004**



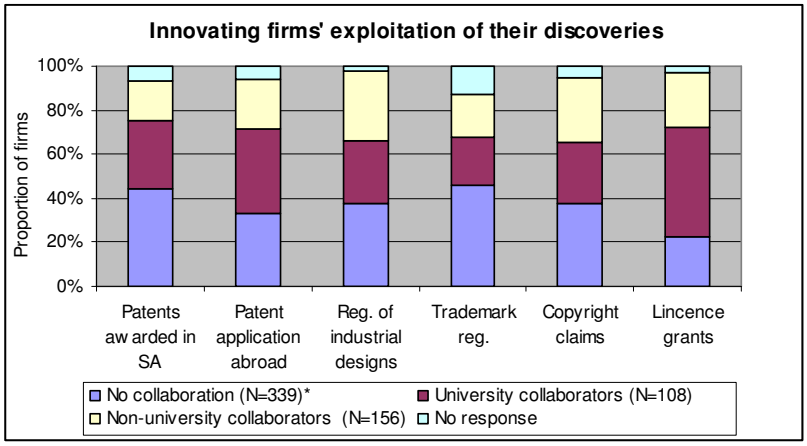

Data source: Innovation Survey 2005 dataset (unweighted), CESTII

**Figure 4. Local co-operation partners for innovation: university-cooperators in comparison with the non-university cooperators**



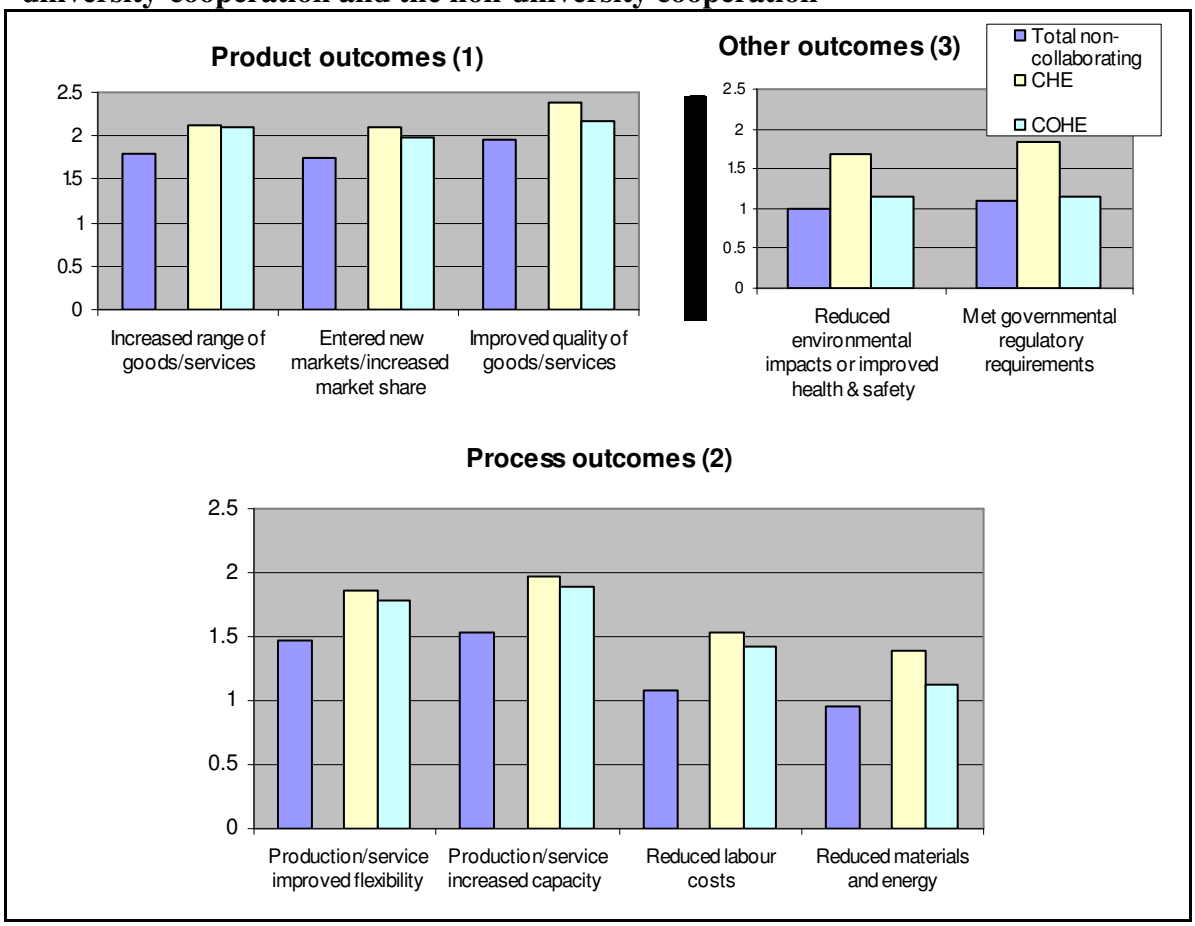

Data source: Innovation Survey 2005 dataset (unweighted), CESTII

**Figure 5. Technology exploitation by cooperation with local universities**




Data source: Innovation Survey 2005 dataset (unweighted), CESTII

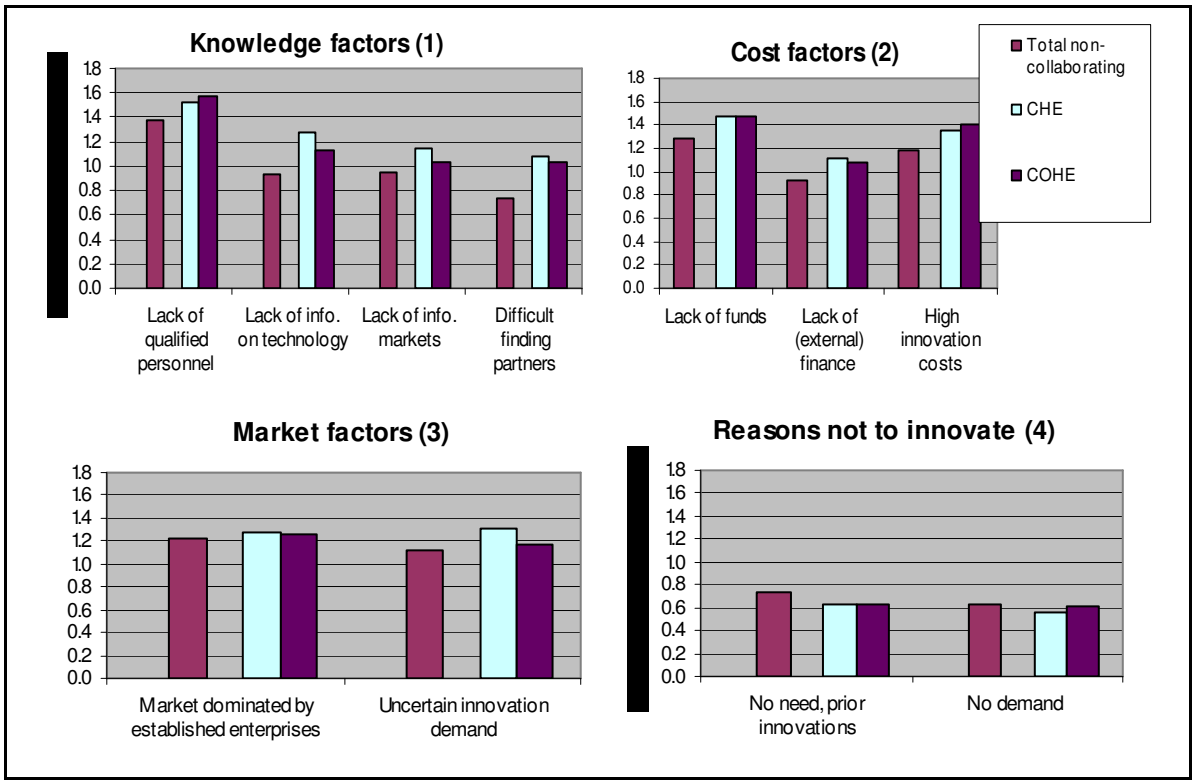
**Figure 6. Average levels of success of innovation outcomes: non-cooperation, university-cooperation and the non-university cooperation**




Data source: Innovation Survey 2005 dataset (unweighted), CESTII

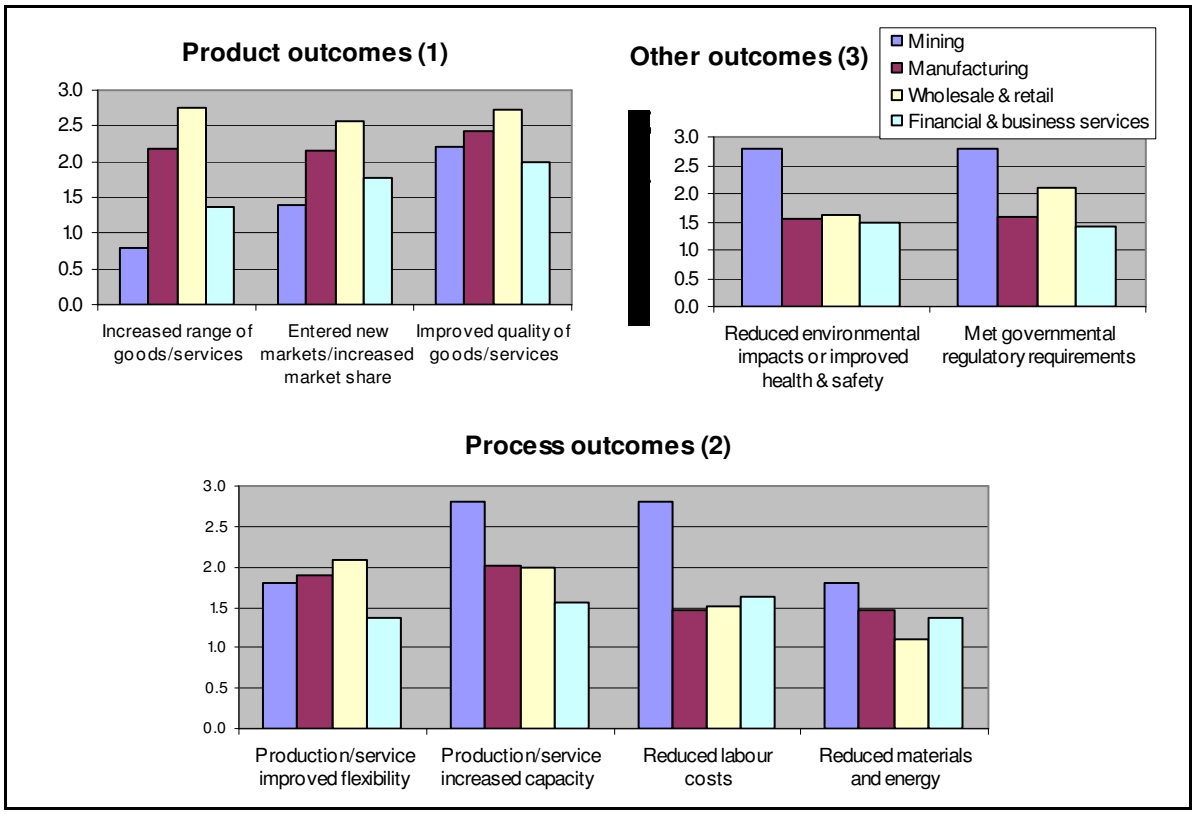
Note: 1) Not relevant = 0, low degree of success = 1, medium degree of success = 2, and high degree of success = 3.
2) CHE = University collaborators and COHE = Non-university collaborators.

**Figure 7. Average degree of importance of specific obstacles to innovation: non-cooperation, university-cooperation and the non-university cooperation**




Data source: Innovation Survey 2005 dataset (unweighted), CESTII

**Figure 8. Average levels of success of innovation outcomes by sector: firms cooperating with local universities**




Data source: Innovation Survey 2005 dataset (unweighted), CESTII

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