Role of linker units in academia -industry-government relations

The cases of the internet in Zambia and genomics in Brazil

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This article uses the cases of the development of internet in Zambia and of genomics in Brazil to highlight the important role of units in the Triple Helix (TH) model. These are the "linker units" that mobilize university, government and industry/partner resources to create and incubate businesses. It argues that these units break down traditional boundaries to create a more porous community, where individuals or teams with competing or common interests work together.

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Introduction

National systems of innovation (NSI) are composed of various institutions that influence the generation, dissemination, use and marketing of knowledge, products and services. The institutions that make up an NSI - research and development (R&D), financial, manufacturing, and professional and regulatory institutions, among others - may however be at different levels of development, especially in new and emerging technologies or industries. In some cases, they may be unable to function fully at a certain stage of development.

In order to overcome such institutional bottlenecks and accelerate technology development and diffusion, countries have developed specialized institutions with coordinative functions, often termed centres of excellence. Although there is no single agreed definition, a centre of excellence is supposed to be a well-established institution with a critical mass of skilled personnel, a stable and adequate funding base, highly motivated staff and state-of-the-art facilities. In addition, it has a clear objective and mandate, as well as good links with its clients and other specialized centres, inside and outside the country, and act as technology generators and transferors.

In a way, centres of excellence can be seen as 'institutional systems of innovation'. For example, entrepreneurial universities are said to possess at least five main characteristics:

- Independent, strong and efficient managerial systems;
they do not have research teams or large numbers of students. Sometimes, management; and overwhelmed by the lack of financial support from man-

erm of excellence. This is not surpris-
ing, in view of their underpaid academic

economic and political realities.

In poor countries, a university that helps communities improve their living standards and enables marginalized individuals to become entrepreneurs and create jobs may be just as entre-

dermanial universities engage in the pro-

As already mentioned, entrepre-

Universities in many developing

countries are generally the main or-

amount, well-equipped facilities and a sta-

funding base. Industries, especial-

ly in developing countries, are unlikely
to pool enough skills in any one area of
technology that would enable them to
remain competitive in emerging in-

derdisciplinary fields of technology. It is
for this reason that the relationship
between industry, university and gov-

erminal units, industry and government.

This article uses the cases of the
Computer Centre at University of Zam-
bia (UNZA) and FAPESP’s Organiza-
tion for Nucleotide Sequencing and
Analysis (ONS A) to demonstrate the
important role linker units play in the
triple helix (TH) model.

The two countries, at different lev-
els of economic and technological de-

development, acquired, adapted and
used, what at that point in time, might
have been advanced technologies for
these countries. Zambia became the
first country in sub-Saharan Africa, out-
side South Africa, to get on the Internet
and Brazil became the first country in the
world to sequence a genome of a plant pathogen. The cases also high-
light, in their humble way, the impor-
tance of government support and the
demonstrative impact in spurring in-
dustrial interest and development.

Zambia and the internet

UNZA - entrepreneurial university

The University of Zambia (UNZA) has
a long standing tradition of working
with industry and public institutions and
runs several business ventures (e.g.
farms, bookshops, guesthouses and
clinics). For instance, UNZA owns near-
ly 50 per cent of the share of York Farms,
Zambia’s second largest horticultural
producer and exporter, with an annual
turnover of about $13.5 million and
brings the UNZA roughly $1 million in
dividends a year (2000 estimates).

UNZA also runs a Technology De-
velopment and Advisory Unit (TDAU), a
semi-autonomous unit that designs
and fabricates machinery for small and
medium-sized enterprises (SMEs),
conducts research and provides train-
ing to its users (industry, institutions,
government and donors). Through a
memorandum of understanding (MoU)
with the UNZA, TDAU is required to re-
fund half the salary it draws from UNZA
and meet its operational expenses, but
has the freedom to invest its resources
and declare bonuses for its staff. TDAU
is another linker-unit as it often brings
together expertise in different UNZA
units, industry and government to ac-
complish its tasks.

More importantly, UNZA has an
established tradition of not duplicat-
ing teaching, research and experimental
courses. This encourages interdiscipli-
ary and interdepartmental interaction.
For example, students admitted to the
Schools of Engineering, Agriculture,
Medicine, Mining and Veterinary Med-
icine spend a year or more taking
courses in the School of Natural Sci-
ences; and either many lecturers teach
in more than one school or department,
or the courses are designed to be tak-
en by students from more than one
school.

These characteristics are impor-
tant in understanding why interdiscipli-
nary teams seem to form without for-
mal agreements by the different units
and why UNZA has good working re-
lations with the Government and the
private sector, even though it is often
seen as a purely teaching university.
Although it does not have an estab-
lished technology or business incuba-
tor, the university plays an important
role in technology adaptation and
transfer, and business development.

Internet development in Zambia

In 1990, the Director of the Computer
Centre (CC) at the University of Zam-
bia, Mark Bennett, connected a few per-
sonal computers that could exchange
e-mails within the institution, and with
Rhodes University in South Africa, and
The collaborative spirit within the university community was also important in the development of the networks. For example, the School of Engineering manufactured a unit that Bennett described as, “a device that allows the central PC to be connected to both internal and external phone systems and answering whichever calls first”. This concentrated the limited resources and social networks of the different projects to successfully implement the projects.

**Importance of good and effective relations with government**

The University of Zambia benefited from its relationship with the Government, since the CC was one of the main domestic advisors to government on national computing and networking initiatives. Therefore, UNZA did not experience the problems other universities faced in the establishment of ESANET (Eastern and Southern Africa Network), which included the Universities of Nairobi, Zimbabwe, Dar-es-Salaam and Mozambique. For example, the University of Nairobi in Kenya was initially denied a licence to operate the radio link to the satellite. In Zambia, government interests (in HealthNet) were represented by the Deputy Minister, HealthNet was inaugurated by the Republican President of Zambia.

The goodwill that government showed towards HealthNet also benefited other projects at the Computer Centre and may have facilitated the development of Zamnet. For example, Zamnet was the first firm to be allowed to operate private satellite links for data transfers, cutting off the national telecommunication firm. As a result, all new entrants into the internet market in Zambia were able to easily establish satellite links. Therefore, good working relations with government are possibly one of the university’s main advantages and assets.

**Management and commercialization**

There is no doubt that donor support for e-mail-type of projects was high. However, support for developing an internet connection was very low. Mark Bennett summed up the attitude of many people at the time as follows:

“By 1993, we had decided that we wanted ‘the real thing’ ... full internet access ... There were plenty of people who said that Africa had other priorities - after all, wasn’t Fidonet (e-mail) working - or that Africa needed its own systems of communication ... but with the relevant bits of string and sticky tape ... The continent has gone from Zambia being one of the only countries with a connection to no country being without”. 

On the basis of the success of the projects implemented, the Vice Chancellor of UNZA, the Deputy Minister for Health and the Director of the CC believed the sustainability of these projects required full internet access. The first idea was to form a self-sustaining internet provider based at UNZA. But this was of no interest to any funding agency or industry. In 1994, UNZA decided to establish a campus-based company called Zamnet (www.zamnet.zm) to provide service to commercial customers. This decision was not surprising as UNZA had learnt to operate a “quasi firm” serving ‘clientele’ (selected hospitals, NGOs, government institutions) as far as Ndola (450 kilometres from UNZA) with email services.

The UNZA provided space, management and most of the manpower for Zamnet, while the World Bank provided a $122,000 loan through the Institutional Development Fund in 1994 - covering 80 per cent of the cost for the first year. The Director of the Computer Centre became the first Managing Director of Zamnet, while the Vice Chancellor became the Chairman of the Board, which included the Deputy Minister for Health.

The number of commercial accounts grew from 5 to 165 between January and June 1995. Seven months before the end of the World Bank loan, Zamnet was making enough money to buy new equipment. Zamnet also provided “free” internet access to the University Community and partners in the project.

**No losers**

As noted earlier, UNZA benefited from the goodwill of several partners that
were at the Computer Centre to meet their own needs, and not to attain full internet access or development of a company. For instance, HealthNet was deemed successful once the satellite-based link was established, and its next step was to provide e-mail-based search capabilities.

Most projects entered and exited the Computer Centre through the intersection of the three parties: university, government and partners. HealthNet exited from the Computer Centre to be based at the Medical School, ZangoNet exited to be managed by a network of NGOs, and UN-ZANET remained the main networking unit of the University of Zambia community and the country. However, the Computer Centre remained the main gateway for the three networks and Zamnet their common link to the world.

Each of the projects coordinated or participated in brought new challenges and opportunities as well as partners and technologies and resources. For instance, the Computers for Administrative, Management and Academic Support (CAMAS) project that laid fibre optic cables throughout the university and provided every office with a digital telephone line and internet point, and each department with computers, a scanner and printer (1994-1996) transformed the CC into a network. This project gave birth to the Consultancy and Training Unit (CTU) at CC.

**Demonstrative impact**
The commercialization of Zamnet demonstrated that provision of Internet services was good business even in poor countries. Other institutions soon followed the example of Zamnet. CopperNet, Zambia’s second largest Internet Service Provider (ISP), formerly a networking unit of the Zambia Consolidate Copper Mines (ZCCM) was formed as a private firm, and Zambia Telecommunication Corporation (Zamtel), developed Zamtel Internet services. Today, Zambia has over a dozen ISPs of all shades.

The CC too, following the successful commercialization of Zamnet, formed another unit called “Consultancy Training Unit” (CTU). The CTU was initially formed to train and support university staff and departments with IT services. Once that was achieved, it opened its doors to the wider public, and now provides commercial networking services. It has carried out training for organizations such as Common Market for Eastern and Southern Africa (COMESA), Chilanga Cement PLC, Zambia Sugar PLC, Zambia Telecommunication Cooperation and Caltex, and provided software systems support to a number of organizations, such as Micro Banker’s Trust (MBT) and the Dutch embassy.

**Genomics in Brazil**

**History, rationale and funding**
Genome sequencing is a highly specialized biotechnology field that was seen largely as a preserve of large and sophisticated organizations, such as The Institute of Genomic Research (TIGR) and the Sanger Center, among others. Genome sequencing required a high level of sophistication and organization in preparation and tracking samples and analysis of the voluminous genetic data generated.

However, the Organization for Nucleotide Sequencing and Analysis (ONSA) captured the headlines when they announced that they had successfully completed the sequencing of Xylella fastidiosa (an organism with a genome size of 2.7 megabases that infects oranges and causes Citrus Variegated Chlorosis) two months ahead of time and $ 2 million within their budget. They had, within the same period, built a genomics institution from scratch that was unique: a virtual institute involving some 34 laboratories located in geographically distant places and belonging to different institutions.

When the São Paulo State Research Support Foundation (FAPESP) decided to fund the genome sequencing project, it also wished to expose as many laboratories as possible to modern biotechnology tools. Plans to create a single centre were rejected. They settled for a virtual institute that was web-managed. It was also cheaper than building one large concrete block institute and required little time to erect or reorganize. This project is estimated to have trained at least 200 young geneticists.

FAPESP is estimated to have spent about $ 45 million on the ONSA project. The initial $ 11.6 million budget was used to fund the purchase of equipment and reagents for the selected laboratories: two central sequencing laboratories, a bioinformatics unit and 27 independent sequencing laboratories and sequencing of the first genome. Rather than appoint agencies, the project requested interested laboratories to apply, and these were selected based on their experience. This involved the filling of internet-based forms identifying areas of competence as well as research, funding and publication track records.

The project developed rapidly. The idea of bacterial genome sequencing was proposed in May 1997. By mid-November 1997 the project had been announced, the project structure defined, a steering committee formed, the organism chosen and the participating laboratories selected. The first sequence was deposited in March 1998 and the sequence completed in February 2000. The initial success of the project attracted some Brazilian nationals based abroad to return home. At least three firms were developed out of ONSA; industry began to seriously consider investing in genomics; and several laboratories were equipped with modern equipment.

**Choice of genome and institutions**
The choice of the organism was based on its economic importance, industrial interest, scientific adventure and genome. Xylella fastidiosa causes losses of approximately US$ 100 million to the citrus industry in the State of São Paulo, which accounts for about 87 per cent of Brazil’s orange production or 30 per cent of world production. The size of the genome was reasonable and attainable with the limited resources and was the first plant pathogen (until then none had been sequenced completely).

The laboratories involved were largely from institutions of higher learning, principally universities and research institutions. Teams within the in-
stitions organized themselves and submitted bids to the project managers. The project managers selected the teams based on the information provided by the bidding laboratories. The project did not involve any significant international collaboration. Above all, it was limited to laboratories within Sao Paulo, as FAPESP is a Sao Paulo State initiative and not a Federal Government body.

ONSA and its partners have contributed three genomes to the public genetic databases; Xanthomonas axonopodis, Xanthomonas campestris and Xylella fastidiosa. The level of genome sequencing that the Brazilian Team has achieved is unparalleled among developing countries. It has attracted the attention of the United States Department of Agriculture (USDA), which contracted the Brazilian Team to sequence a train of X. fastidiosa that afflicts California’s grapevines.

Management of ONSA

The team had a steering committee consisting of three experts from Europe and two from Brazil, that also served as an advisory body to FAPESP. A DNA coordinator was responsible for the distribution of DNA samples (clones) to the sequencing laboratories; and two heads for the central sequencing laboratories were responsible for key sequencing and training of some of the participating laboratories. The Bioinformatics Centre coordinated the flow, management and analysis of the data.

The DNA Coordinator, the two Heads of the central sequencing laboratories and the Heads of the bioinformatics centre formed a working executive committee. It was this team that managed the daily activities of the project. The steering committee visited the team once every six months, prepared a report to the funding agency (FAPESP) and made relevant recommendations. Further, the representatives of the participating laboratories, 230 in total, met once every four to five weeks in person to review progress and make fresh plans. This was important as daily management was performed via the Internet.

The management of the institute was tailored to encourage generation of high-quality data in the shortest possible time. The selected laboratories agreed to generate a minimum number of high quality sequences in a fixed time. Laboratories that deposited more good quality sequences got more money as a result. These measures partly enabled the project to be completed within time and within budget. More significantly, the sequencing laboratories were paid based on the quality of sequences generated.17

Achievements and benefits

The project developed its own genome sequencing and analysis methods. For example, they developed a number of bioinformatics tools and a polymerase chain reaction method targeting the amplification of the central portion of expressed genetic material (mRNA) called ORESTES. These tools are now being used to generate about one million expressed sequence tags in the Human Genomes Cancer Research. The organization also became the single largest contributor of human expressed gene sequences currently available in public databases and of the annotation of the human genome.18, 19 This initiative was supported by funding from the Ludwig Institute for Cancer Research and FAPESP.

Following the success of the ONSA, the Federal Government of Brazil decided to fund the Virtual Institute of Genomic Research in 2002. Approximately 25 laboratories distributed across Brazil were selected to sequence Chromobacterium violaceum with a genome size of about 4.7 Mb. The organism is abundant in the waters of the Amazon, and could cause a fatal disease. The organism also produces violacein, a purple coloured pigment with trypanocidal and antibiotic properties, as well as molecules that resemble propylene and polyethylene, which may be of interest to industry.

It is important to note that there have been increased genome-related research activities in Brazil since the initiation of the ONSA projects beyond the State of Sao Paulo.20 For example, the Virtual Institute of Genome Research has sequenced Mycoplasma synoviae, an organism that infects chicken. In combination with other organisms, Mycoplasma synoviae causes fatal respiratory diseases in poultry. Brazil is the second largest producer of poultry, and export earnings stand at roughly US$ 1.3 billion as of 2004.

Demonstrative impact of ONSA

The success of ONSA attracted support from private firms and non-Brazilian agencies that enabled the project to expand. For instance, the Ludwig Institute for Cancer Research and FAPESP co-funded the Human Cancer Genome Project (contributing $ 5 million each), the USDA provided $250,000 to ONSA to sequence a related organism, and the sugar industry contributed to the sequencing of the sugar cane genome project.

The ONSA project spun-off three companies, of which two were Allelyx Applied Genomics and Scylla Bioinformatics. Scylla Bioinformatics (http://www.scylla.com.br/) received funding from Votorantim Ventures and has strategic alliances with Hewlett Packard and AMR. Allelyx Applied Genomics was funded by Votorantim Ventures and both firms were founded by molecular biologists and bioinformatics experts that worked with ONSA.

Fernando de Castro Reinach, who suggested the first organism that ONSA sequenced, joined Brazil’s largest private venture capital fund - Votorantim Ventures - which has invested in the biotechnology firms above and in Canavials, a plant breeder (http://www.canavials.com.br).

Case analysis

ONSA could be considered to be a centre of excellence, with units that are distributed throughout the state. They planned together, shared human and financial resources and management via the web, just like a single institution made of bricks and concrete. On the other hand, ONSA may be seen as a unit that brought together several scientists and laboratories, government and industry to meet its own goals.

Virtual centres are faster to build, and easy to be abandoned, rearranged and recreated to meet new challenges. They expose a large number of centres and professionals to new tech-
niques and quickly concentrate limited expertise. They render geographical isolation irrelevant, foster collaboration and stimulate quality research activities. The individual participating laboratories expand their research activities based on the lessons learnt and use the tools acquired to create and attract new partnerships and sources of funding. ONSA is one such unit.

The case of UNZA, at first glance, seems to be the complete opposite. But the Computer Centre equally concentrated the skills, scant resources, support and goodwill drawn from various units of the university, government and industry or partners to build a centre that did innovate, had a clear mandate, leadership, clientele and delivery mechanism.

All the projects had different funding and support agencies but the proposals, plans and designs were developed together to avoid use of incompatible software systems, as at the University of Harare, where the projects were run in two centres - the Computer Centre and Computer Studies Department using two different systems.

Both cases demonstrate the importance of government support. In Zambia, the freedom to operate was the greatest contribution that government made. Such government support and participation may have been instrumental in securing the loan that enabled Zamnet to take off.

In the case of ONSA, FAPESP, which is entitled by law to receive 1 per cent of all taxes collected by the Government, was not the only financier but also the driver of the projects. Without such government measures, the Brazilian genomics research status might have remained fragmented and largely unnoticed as that of other developing countries.

The cases demonstrate that even LDCs could easily achieve a critical mass of technologists to meet the challenges posed by new technologies. They also demonstrate that advanced technologies were not the preserve of developed country institutions to transfer or adapt on behalf of developing countries. Both projects only emerged as models once they either developed a commercially viable firm or published an entire genome sequence.

The role of local innovation and learning are often overlooked. In the case of ONSA they developed software and protocols of genetic data analysis and amplification of expressed sequence tags (ESTs). In Zambia they manufactured their own devices to compensate for the lack of imported ones, developed software for billing customers, and had to find ways of strengthening the weak signal that was leading to massive loss of data.

Both projects benefited from the knowledge of those that had advanced systems or used similar methods, but also undertook measures to improve the skills of its people.

In addition to developing an independent department of computer sciences, it sent a number of young Zambians abroad for training. ONSA also had to send a technician to France to learn how to culture the organism in vitro and benefited from its external advisory board members, who were familiar with managing similar projects.

The two cases are similar in many respects but differ significantly in design, complexity, technological advancement, purpose and types of players. Zamnet benefited greatly from international resources (equipment, funding and advice) but ONSA got its funding from the state.

ONSA was designed to train and build local capacity in the state, and partly demonstrate to the world that Brazil has the capacity to carry out cutting edge research. In Zambia, the goals were simple: implement the projects.

Perhaps, with regard to TH, both cases demonstrate that when a technology is still emerging, industry partners are likely to first watch until researchers demonstrate the technical and economic viability. The birth of Zamnet, which remains wholly owned by UNZA, catalyzed the emergence of ISPs in the country. In Brazil, they attracted contracts from as far as the USA, and established new alliances with, and funding from, private firms specializing in genomics.

However, if innovation is seen as the application of knowledge to development, then the firms that emerge or are attracted to the emerging industry complete the model. On the other hand, if the model is applied to science parks and incubators, where government, industry and academia are playing their respective roles in technology and business development, then it may not be applicable and will become static. The fluidity, after all lies, in the premise that the roles are interchangeable: universities can create firms and regulations, industries may be a source of knowledge and education, and government may be an investor and basic researcher.

This also depends on one’s definition of government, industry and academia. For instance, one may argue that FAPESP played the role of government, while ONSA played the role of academia, but one wonders if the State of São Paulo would have actually funded the project directly if FAPESP did not exist, given that the glamour associated with the success of ONSA led the government to fund the national genomics initiative.

Similarly, my lumping of the technical and professional assistance that Computer Centre received from Zambian Telecommunication Corporation with donors that provided financial and technical support may not be seen as a fair characterization. If the fluidity of the model, where acts could interchange roles, makes it appealing, then we may have to define industry, government and academia based on their roles at the point in time.

Conclusion

Andy Simpson, who headed the ONSA project wrote, “It is wrong to suggest that technology can only be transferred downwards from well-meaning laboratories in the developed world.” It is unlikely that scientists in developing countries would neglect well-funded projects targeting solutions for the rich, and concentrate on uncoordinated and often poorly financed problems of countries that lack purchasing power.

Of course, technological capabilities are concentrated in the north but

Special Feature : The Triple Helix Model for Innovation
local specialization may remain a major competitive edge that could be advanced by increased globalization and connectivity. Centres in developing countries could tap into knowledge bases located beyond their borders. The success of the centres may be determined by how well they serve as links between their institutions and their institutions with industry and government.

It is these units that undertake entrepreneurial activities and have all the characteristics associated with entrepreneurial universities. In many ways, they exist almost as 'independent units' within the university.

For example, TDAU at UNZA is headed by a Manager supported by two Project Engineers, a Business Advisor, an Information Officer and a Chief Technician. It is a hierarchy that mirrors those of private engineering units rather than a university department or school with titles like Dean, Head or Chairman.

Therefore, a few key characteristics are important at the university level if they are to function as useful partners in the university:
- The ability of staff to work across schools, especially when supported by internal rules;
- The efficient utilization of existing, and/or developing, relationships with government and industry;
- The existence of units dedicated to support enterprise development; and
- The extension of the concept of excellence beyond teaching and research.

Universities whose regulations promote teaching and research across schools or departments may facilitate a wider exchange and combination of knowledge. This could be achieved either through units such as incubators or consultancy centres, or through financing projects across schools. The centres should serve as channels through which the rest of the university community could potentially work with industry and government.

Although ONSA may not qualify as academia in the way we traditionally define universities, it served the same purpose as the Computer Centre or TDAU. Between 1997 and 2003, ONSA had completely sequenced nine genomes and was sequencing an additional four genomes either by itself or with other Brazilian centres. ONSA may be described as a linker-unit that accessed, mobilized and effectively utilized the independent laboratory of universities or R&D centres to accomplish the assigned tasks.

References

Notes
a. For example, TDAU was hired to identify a way of producing affordable agricultural lime for farmers whose land was acidic. It brought in expertise from Schools of Agricultural Sciences and Mines, Mount Makulu (Agricultural) Research Station and partnered with the British Geological Society. This team worked with producers of lime and farmers.

b. ‘Partners’ refers to the collection of donors, institutes and the Zambia Telecommunication Company that provide financial, technical and professional support. In effect, taking over the role of industry.