Blog series:

Building Technological Capability

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March 2015

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This series of posts focuses on building technological capability in developing countries. I am specifically thinking of Sub-Saharan Africa as I write these posts, but I am sure that some of the ideas will be relevant to my colleagues working in other parts of the world.

Post 1: Building technological capability

What do I mean with technological capability? We see technological capability as going beyond what firms can do, to what societies or parts of society can use or do with technology. It is a capability that is manifest in products and processes, but that arise from a capacity to match a problem or opportunity with technological systems, sub-systems or combinations of systems. This means that technological capability is not only about technological skills (for instance in knowing how to combine different technologies, or what the latest advances are), but also has business and networking skills to identify and recognize opportunities, discover what solutions can fit the context and constraints (like performance specifications, prices, volumes) and how to organize supply, delivery and maintenance. It thus combines all the elements of innovation including product knowledge (understanding components, sub-systems, architectures), process knowledge as well as business knowledge.

To build technological capability in a country or an industry is the result of an ongoing search process where networks of businesses, academia and government officials search for what is possible at reasonable value and margins, what can and what cannot be done within the local context. What can and cannot be done in the local context is a complex issue that is affected by four factors that I will briefly outline below. It is not only an engineering design problem, and it is not only about products and patents. It is not about a lack of knowledge or a lack of PhDs and engineering students. There are several things that must be worked on at the same time but a whole range of actors working towards different goals.

In many instances the public sector is more eager to develop domestic technological capability than the private sector itself. The private sector in Sub Saharan Africa is in most countries fragmented, and search costs as well as coordination costs at the level of products, processes and networks are very high. That is why those that can afford to take risks and that can afford to take a long term view will most certainly benefit disproportionately to those who are driven by short term profits. For instance, local manufacturers of components that invest very little to nothing in R&D cannot be expected to compete in the long run with international or regional competitors who are investing in R&D.

My late friend and business partner, Jörg Meyer-Stamer argued that there are four pillars [1] that technological capability is built on:

1. The skill of the producers to imitate and innovate at product, process and business model levels. This is largely dependent on pressure to compete as well as pressure to collaborate with each other;
2. The economic, political, administrative and legal framework conditions, which determine whether incentives to develop technological capability exist. In the past, it was often not recognised that these incentives do not exist in many developing countries, especially if an import substitution policy relieved companies of all pressure to be competitive or to innovate;
3. Direct support by technology-oriented state institutions or specific types of knowledge intensive service companies - depending on the given development level, the competition situation and the characteristics of a technology branch in the

given country. These organizations disseminate technical and expert knowledge between different actors, knowledge domains and industries and play a critical role in the use of and application of tacit and explicit knowledge;

4. Indirect support by the public and private educational system; in addition to a sound basic education it is important that technical training of a suitable quantity and quality is available at the secondary-school level and also in the universities. The private sector often plays a role in short term training aimed at particular technology applications. Overall the responsiveness of the education sector in identifying and responding to changes in how technology is applied, developed or used in society.

The close interaction between these four pillars creates technological capability. Thus technological capability differs between countries and even within countries because the context differs. A single firm may in the short to medium term manage to get a sophisticated product into the market, but to sustain its position it will sooner or later need to tap into the education system, the knowledge networks of intermediaries and technology experts, or in supplier networks. Technological capability is not measured at the level of patents or products developed (this does not measure the system, it measures a single firm), but is best measured at the level of regional or international competitiveness of industries, entrance of new domestic and international competitors, and exports.

What developing countries fail to achieve is to crowd in many firms and industry networks by creating public goods that intensifies competition and that force firms to collaborate on critical issues like skills development, the development of industry specific infrastructure, etc. Despite being a big buyer in many countries, procurement patterns, priorities and performance criteria are not available to domestic producers (until it is too late). The education sector is mainly funded to provide basic and undergraduate education along strict disciplines, not to constantly upgrade the existing workforce to cope with technological shifts and the integration of different knowledge bases. Universities are funded to do research at a product or process level, not to do applied research that will modernize industries. The importance of various networks of technological intermediaries and knowledge providers are overlooked.

The private sector must also shoulder some blame. Industry bodies are often mainly focused on advocating for favorable conditions to protect existing investment or interests, not on increasing local supplier networks or building industries. Firms would often rather collude than collaborate. Industry associations are typically organized via traditional sub-sector structures, while global production is becoming more integrated, multi-disciplinary and application orientated.

In closing, technological capability is not only created through policy. It is not created through industrial or innovation policy, although it helps. It is not created by individual champion firms, although this certainly makes it easier. Technological capability is built as a result of an innovation system where the context matters. Firms able to manage their own internal technology and innovation are essential, but these typical arise out of public funded investment into technology intermediaries, management capability and the overall performance in the education sector. It is not possible to increase the technological

capability of a group of firms in a particular industry without looking at the broader context where the four areas outlined earlier shape the outcomes in the medium to long term.

From my experience in assisting to promote technological capability in developing countries an ongoing facilitation effort funded by the public sector AND the private sector is needed to broker collaboration, but also to look at ways that local demand can be met by the broader system in the long term. In many countries and industries the best host for such a process is a technology intermediary attached to an university or a development programme, with a mandate to build networks around local opportunities that is not only about engineering, but also about reducing the costs of finding opportunities, suppliers and suitable technologies.

Notes

1 - These four pillars later became the foundation of the RALIS methodology that we use to diagnose and improve innovation systems.

Post 2: Technological capability: enabling enterprises to innovate

This is the second post in this series about building technological capability. I believe that this technological capability is best developed by an innovation systems approach with a particular view on emergent properties of the system. I have written before about the importance of taking a business perspective on an innovation system here and here. In the previous post I explained our concept of technological capability. I argued that one of the elements of technological capability is *"The skill of the producers to imitate and innovate at product, process and business model levels. This is largely dependent on pressure to compete as well as pressure to collaborate with each other"*.

In this post I will look a little deeper into this ability to innovate, collaborate and competition. For the remainder of this post I will take the perspective as a knowledge broker (or facilitator) working with an technology transfer center responsible to promote the upgrading and modernization of a sector.

One of the challenges of promoting an innovation system is that the technological capability in the private sector is not easy to see. Often we have to use proxy indicators such as exports to determine whether our industries are innovative and competitive. But export figures does not tell the whole story.

While the physical attributes of a product or component could tell us something about the sophistication of the product and the process behind it, even a simple metal component could be the result of an extremely sophisticated process that combines different knowledge domains, technological capabilities, materials (combining metallurgy and sand for instance in a foundry) and enterprises. Even if you have access to the premises, the tacit knowledge, experience and networks that are accessed to make a product is not always detectable.

Not only is it hard to determine what companies are able to do, it is also difficult to figure out what they cannot do. The fact that a manufacturer three years ago developed a successful product is not a guarantee that they can still do this. The finding that a particular function or technology is not present in an enterprise does not mean that they do not have access to this technology when they need it. When the entrepreneurs claim that they lack finance to do innovation this is often merely describing a symptom.

Enterprises that are able to adapt, change and improve not only their products but also their processes and business models are essential for any economy. This is about competition, but it is also about unlocking the capability of individuals, being more responsible with resources, and being responsible within a broader socio economic environment.

Finding ways to get enterprises to collaborate is very important for the health and dynamics of an innovation system. At the same time, stimulating competitiveness, not only at the level of price, but in terms of alternative approaches to solve a problem or in terms of different ideas and concepts is necessary. Often business associations and industry bodies are good with some limited collaboration, for instance on advocacy, but not so good at stimulating new (competing) ideas, approaches, models and solutions.

For a broker or intermediary it is still possible to move between and into enterprises to find opportunities for improvement. I am often amazed at how hesitant universities, technology intermediaries and research centres are to

Searching for opportunities for collaboration

embrace this privilege of being able to move around in an industry to see what is possible and what constraints or barriers to innovation exists. I will expand on that in a future post in this series.

For enterprises to find out what other enterprises can or cannot do is a lot more difficult. Firstly, by asking somebody if they can or cannot do something might give them a hint that a specific opportunity exists. Secondly, many companies do not like their competitors on their premises. Thirdly, there are many risks and costs associated with working with a competitor. Lastly, there is a risk that a competitor is able to exploit a joint opportunity better and thus gain more prominence in the market.

The ability of enterprises to find opportunities to work together is important as a means of reducing costs and gaining access to resources that individual enterprises cannot afford independently. For instance, skills development, joint marketing efforts are quite easy to cooperate on.

However, on issues such as joint research and development, procuring scarce and sophisticated equipment, or collaborating in a more intensive way such as a cluster often require an external broker. Often this kind of brokerage is hard to organize at the level of enterprises. Industry associations, Universities, technology intermediaries of government programmes aimed at industry promotion must step in. This is where I earn my bread and butter as many industry support programmes are ill-equipped to diagnose, articulate and facilitate these kind of firm level collaboration processes as part of improving an innovation system.

Let me bring all of this together. Enterprises that are striving to improve their performance, their value add and their overall competitive offering are an important element in an innovation system. These enterprises are expected to compete with each other, not just on price, but with different approaches, solutions and concepts. At the same time, we expect to see that these enterprises cooperate or collaborate on issues where there are benefits to do so. The dynamic of how enterprises interact with each other (collaborating and competing) is a direct contributor to the technological capability of a region, an industry or an economy. Where enterprises are not able to work together and at the same time compete with one another, a key ingredient to the technological capability is weakened. It is not always possible for enterprises to formulate or develop opportunities for collaborating due to many risks, costs and the difficulties associated with forming the cooperation concepts. This is a technology related market failure that sometimes can only be overcome by a broker-like service of Meso-level institutions such as technology intermediaries or education institutions.

Post 3: The role of various organizations involved in education

This is the 3rd post in the series on building technological capability.

Contrary to common belief, building technological capability does not start with education. That being said, education matters and certainly makes any upgrading effort much easier. It is not only about the basic qualifications, but also about the ease with which existing employees can further their education.

With education institutions we include all forms of education, from basic to technical, vocational to post tertiary education. We also include public as well as private providers of education. Education lays an important basis with regards to skills, but also increases the absorptive capacity of a society. Advanced forms of education includes research.

In general, when we assess the role of education in assisting enterprises or industries to upgrade, we want to know how responsive the education system (broadly speaking) is. If a new standard is agreed upon in industry, how long does it take for the technical Universities to include this in their programmes? If a new disruptive innovation takes place, how fast is the curriculum updated? I remember back in the 90s when I studied for the first time, how the software we used at the university was no longer available commercially. Fortunately, all those Lotus 1-2-3 shortcuts still worked on Excel, I still use it today ;-)

While the responsiveness of the education sector is important, what is ideal is an education system that not only responds to the needs of the private sector, but it pre-empts or anticipates what is needed next. This is very important for the manufacturing sector. Graduates must know not only what is now mainstream, but also what is expected or coming soon. This is where large parts of our South African university system lags behind. But this is not unique to South Africa.

A last point I want to make about the education sector is that it is also important to understand the role and contribution of the private sector to the education sector. In many countries there is a close relationship between the private sector and for instance universities. Companies contribute to not only basic education infrastructure, they often fund research positions and projects. An industry that is complaining that they don't get from the education sector what they need is most likely also not contributing through finances or advice.

Post 4: Technological Institutions that disseminate knowledge

This is the fourth post in this series about building technological capability.

In 2011 I explained how we define technology in a broad way. This definition looks beyond hardware to include knowledge and organization of the different elements. For instance, if a company decides to achieve a new standard of compliance, that is seen as a technology. This technology involves the way processes are organized, the knowledge of how to achieve and maintain this new standard, and the physical and knowledge infrastructure involved in the enterprise.

Firms depend on a variety of public and private technology institutions in order to compete, innovate and grow. Examples range from access to basic research all the way to access to technical problem solving. The measurement, standards, testing and quality assurance (MSTQ) of a country is also assessed from this perspective. The density of interaction between various technology institutions, as well as the interaction between the firms and the technology institutions, is an important factor in the innovation trends in a sector. Various kinds of technical services such as knowledge-intensive business services play an important role in knowledge spill-overs between different firms.

We call all these carriers of technological knowledge "technological institutions". While some of these institutions are publicly funded (like a research centre, national standards organization or a start-up incubator), some could also be privately funded (like a supply chain development office at a multinational, a specialized equipment provider that provides training and technical support, etc). Specialist and technical service providers, management consultants, researchers and manufacturing extension experts all fall under this broad category. Some charge full service, others provide public goods, but all disseminate knowledge to enterprises.

An organization like a Technology Transfer Centre hosted by a University is located between an Education Institution (post 3 in this series) and a Technological Institution, and often it behaves like both. The Technology Stations Programme in South Africa is an example of an institution designed to fit the space between technological intermediaries, universities and enterprises.

It is noticeable that in many developing countries, the technological institutions that disseminate technological knowledge and that makes scarce technology available to industry are weak or missing. While some stronger enterprises may require and be able to absorb more technological knowledge, the domestic institutions often provide generic services that do not meet the expectations of these leading enterprises. In middle income countries, leading enterprises may simply disengage from the domestic technological institutions and engage with service provided in other countries, further reducing the scale of knowledge dissemination and weakening the system further. This leads to a situation where most enterprises in the country only have access to generic and low-value services, while leading companies and multinationals connect with global sources of knowledge and technology.

You may be surprised to find out which organizations are identified by enterprises if you asked them where they receive technological and specialized knowledge from. I typically ask

"who do you turn to when you get stuck?". In most cases, equipment suppliers, engineers employed by larger companies, or a junior lecturer with high levels of enthusiasm are identified as the most important sources of knowledge or technological advice. I have found this same pattern in many countries, the most important carriers of knowledge are not formal organizations, but individuals.

The result is that the cost of finding knowledge, or gaining access to scarce technology is high, and that those with broader networks are most likely able to gain access to this important resource while those that depend on public goods or generally available information are unable to access the necessary information.

I will explain in a future post how we can diagnose and improve the domain of technological institutions in order to improve the technological capability of enterprises.

Post 5: Various regulatory and environmental factors that shape the behaviour of enterprises

This is the 5th post on building technological capability. I have written many posts before on the environment in which innovation and technological capability development takes place, so this will only be a short summary.

In this perspective, we investigate how various regulatory and environmental factors shape the behaviour of enterprises. It combines the meta level (sociocultural) and macro level (generic framework conditions) of the systemic competitiveness framework (Esser, Hillebrand, Messner & Meyer-Stamer, 1996).

Specifically, we seek to establish whether or not firms have to innovate through the incentives created in the broader environment. Firms' innovative efforts are not usually the result of enthusiasm for innovation but the outcome of necessity – firms have to innovate because their competitors are innovating too, and because they will get forced out of the market if they do not innovate. In turn, this means that firms that are experiencing little competitive pressure will often not be inclined to put much effort into innovation, which is perfectly rational as innovation always involves cost and risk. It is important to note that the enabling environment is not only a function of different kinds of government policy, it is also affected by private sector policies such as decisions to collectively invest, collude and compete.

While some of these issues can be identified through desktop research, interviews with key industry leaders or experts will quickly reveal which socioeconomic factors affect the investment and experimentation appetite of the business sector.

A second dimension relates to the incentives for other actors in the system to support the development of technological capability in formal and informal institutions. For instance, national-level policies direct universities to offer particular kinds of courses, but do they provide the incentive for academics to develop teaching or research programmes that improves the capacity of enterprises or innovators?

Hint: I have learned that when interviewing entrepreneurs to understand their perspective on the innovation system (a.k.a the technological system) around them, never to start with the regulatory environment and the broader environmental factors. You will hear a million reasons why the whole system is conspiring against entrepreneurs to be competitive, innovative and optimistic.

Gaining a deeper understanding of an innovation system and how to build technological capability is not rocket science. I propose that you start with understanding the enterprise perspective on collaboration on competition first (post 1 and 2 in this series), then continue to better understand the relationship between formal education and the industry (post 3), then the creators and disseminators of informal and technical knowledge (post 2) and only then ask about the regulatory systems and the environmental factors.

In the end it is not about the presence of entrepreneurs, institutions that enable knowledge to flow, institutions that address persistent market failure, or an supportive framework conditions. While all of these matters, it is about how they interact. A checklist approach

will not work. Having a university or a few innovative enterprises does not guarantee that a society or community has institutionalized technological capability. Technological capability is about the dynamism between these different factors, it is about relationships, spill-overs and trust. These are only created over time as a result of positive interaction between individuals, organizations, both formally and informally.

References

ESSER, K., HILLEBRAND, W., MESSNER, D. & MEYER-STAMER, J. 1996. Systemic Competitiveness: New Governance Patterns for Industrial Development. London: Frank Cass.