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National Centre for Technology Management, Inderscience Publishers

2009

A Model for the Design and Development of a Science and Technology Park in Developing Countries

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Abstract

This paper presents an appropriate model for Science and Technology Parks (STPs) with a view to helping policy makers and STP managers implement and manage STPs. The authors reorganize and prioritize the Cabral-Dahab Science Park Management Paradigm. We identify three critical groups of actors (determinants, reactors and executors) and develop four sub-models from different trajectories of the groups of actors. We place more emphasis on the "determinants" as the most important actors in the establishment and management of STP. A critical evaluation of the sub-models reveals that the sub-model in which government, industry and university/research institutes are all jointly involved in decisive policy direction is the most appropriate for the developing country. The paper concludes that economies in

transition should see STPs as having a distinctive organizational structure as a result of its myriads of collaborations and partnerships.

KEYWORDS: Enterprise Development, Science and Technology Park, Model, Developing countries, Cabral-Dahab Paradigm, Determinants, Management

Biographical Notes

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1.0 Introduction

The establishment of institutions to support high technology firms and other instruments of technology diffusion is imperative to national and regional development (Amsden, 1989). Among other things, these institutions help to develop endogenous science and technology (capabilities). A particular type of institution that most transition economies establish to develop such internal capabilities is Science and Technology Parks (STPs). A STP can be described as a property-based economic strategy (Zhang, 2004a) with basic focus on the transfer of technological know-how and industrialization. STPs usually have technological entrepreneurial biased tenants with infrastructure such as advice and service firms, financing institutions and relevant government agencies. STPs constitute an integral part of a successful National Innovation Systems (NIS) (Xue, 2006). And in most transition economies, the establishment of STPs constitutes part of economic development strategies.

These countries indeed realize that growth and achievement of innovation targets require an appropriate level of science and technology infrastructure in the country (Al-Sultan, 1998). Such infrastructure should have the capacity to add value to knowledge base, create employments, encourage re-industrialization or urban renewal, promote commercialization of emerging technologies, stimulate commercial and industrial innovation, promote the use of locally produced goods and services and entrepreneurial ventures, provide high return on investment in knowledge creation and promote national/regional economic development (OECD, 1992). The STP is one of these infrastructure.

Since the late 20th century, it has been clearly understood that knowledge production is a major driver of sustainable growth and development; as such, most nations have embarked on the creation of high-technology industries of various geographical scales (Goldstein and Luger, 1993). These are called by different names such as science cities when they occupy a particular region or city (e.g. Japan Technopolis); or innovation centres, technology incubators, research, science or technology parks when they occupy a smaller property (e.g. Silicon Valley and Route 128 in USA) (Bass, 1998). The nomenclature notwithstanding, there are three common characteristics of these schemes: they are property-based schemes; involve knowledge-based and technology-intensive firms; and they assist in the growth of knowledge-based industries & technology transfers (Zhang, 2005). In this paper, therefore, the term *science and technology park (STP)* is used to refer to a geographical agglomeration of high-tech industries that is confined to a defined property not large enough to be called a city or a region. This conceptualization acknowledges three main assumptions. First, externalities that occur in industrial agglomerations vary in scope and intensity with the geographical scope of the agglomeration. Second, when an industrial agglomeration occupies a whole city or region, then it cannot be referred to as a park. Third, by virtue of its being focused on high-tech firms, an STP is a specialized kind of cluster. A cluster is simply taken to mean a geographical agglomeration of enterprises (Oyelaran-Oyeyinka, 2006).

The concept of external economies like knowledge spillover, strong labour market, backward and forward linkages within a local market is a critical factor in explaining industrial concentrations in a particular geographical region (Marshall, 1920). Recent literature (Romer, 1990 and Lucas, 1993) have also linked increasing returns to scale yielded by externalities within a defined geographic location to rapid growth rate of some industrial concentrations. There are also evidences which point to the fact that R&D and knowledge spillovers generate externalities and such knowledge spillovers are bounded in the region where they were created (Feldman, 1994; Audretsch and Feldman, 1996). All these have been used to explain the factors responsible for the spread of high-technology firms in Technology Parks (TPs) such as the Silicon Valley, USA; Kyoto Research Park, Japan and the Cambridge Science Park, UK, among others. For instance, studies like Krugman (1993) and Black and Henderson (1999) have used the idea of Marshal to analyze the reasons why firms agglomerate. The existence of Marshallian externalities in the concentration of high-technology firms may also be the justification why many tertiary institutions, research institutes and policy institutions promote technology parks.

Furthermore, there are opinions which suggested the ‘anchor tenant’ hypothesis as an important factor in the agglomeration of technological firms in a region. Here, an anchor, (in form of a large, established firm) creates externalities that benefit agglomerations of high-technology industries (Feldman, 2003). The relationships between the externalities in themselves may not be as important as the way they are entrenched in the economic activities of these high-technology industries. Thus, externalities are said to be path-dependent (David, 1997) or follow specific knowledge trajectories (Feldman et al. 2006).

Several scholars have studied the concept of science parks (e.g. Dahab and Cabral 1993; Al-Sultan, 1998), its history and development (e.g. McQueen, 1998; Zhang, 2005), important factors for its establishment (e.g. Cabral and Dahab, 1998 and Zhang, 2004b), its role between industrial R & D and high-tech development (e.g. Stuart, 2000) and the role of science park members of staff and intellectual capital optimization (e.g. Gibb, 2007). Furthermore, countries and regions have adapted this technological policy instrument to their economies so as to promote sustained growth. In so doing, several models have been developed for the establishment and management of science parks. One of the most common of these models is the Cabral-Dahab Science Park Management Paradigm (Cabral and Dahab, 1998) which has been validated in both developing and developed countries. Specifically, it has been validated for Science Parks in Europe, the Americas, Arab countries, Asia and Australia (Cabral, 1998, 2004) (see Box 1).

However, it has been noted that developing countries should be wary of merely adopting such propositions in order to sustain growth and development of STP. Al-Sultan (1998) explained some of the reasons for this caution. Three of the key reasons are lack of support to the general educational system, brain drain and difficulties at the level of the civil society. The latter is very important because it makes innovators focus on other money-making activities instead of development of products and processes. It is within this context that this paper prioritizes the ten-point Cabral-Dahab Science Park Management Paradigm with a view to modifying and refining the concept so as to make them more readily applicable to the developing country context. The paper also presents a more appropriate model that could be used by developing countries in establishing a viable STP which could become an important pillar within their various NIS. This model sits on the strong framework of the Cabral-Dahab Paradigm which was empirically developed after observations of the IDEON Science Park in Lund, Sweden and the ff Science Park in Rio de Janeiro, Brazil.

Insert Box 1 approximately here

2. Models of Science and Technology Parks

This paper conceptualises an STP as a deliberate scheme to develop and accommodate high-technology cluster of firms which engage in commercialization of high-technology products and services. The idea is to evolve a general model for the design and development of an idealized STP with a focus on developing countries. The model spans the critical four-phase developmental process of STPs: start-up, growth, maturity and diversification (Kirk and Catts, 2004); and is informed by the fact that there has been a paradigm shift in the design and establishment of STPs. The onus of designing and establishing a STP now rests on collaboration/partnership among academic institutions/research institutes, national/regional governments, non-governmental organizations, international organizations, private sector organizations and local communities.

We propose that for the successful design and implementation of a STP, three critical groups of actors would have to be taken into consideration. These actors in consecutive order are: determinants, reactors and executors. Our model is centered on these actors. The personnel/institutions at the level of "decisive policy direction" are termed determinants. Those who are involved in the location, preparation, building, management and expansion of the STP are called reactors. The executors are basically those who manage the output of the STP which could be the commercialization of high-technology goods and services, technology transfer, knowledge spillover, spin offs and innovations. This category of actors is supposed to profitably manage the park and create wealth for both the immediate local community and ultimately for the national economy in the global market. The model that arises from the combination of these actors (Figure 1) recognizes the determinants as the most important factor to successful implementation of STPs. This is because they determine the focus of the STP (for instance, whether it should adopt a single technology/business, a multi-sectoral or sector neutral approach), the reactors and executors. The role of the determinants is highly dependent on the demand created by the local communities where the STP is located and which surround it. Besides, determinants' structures have significant effects on the service attributes, principles, objectives and goals of an incubator (or science park) and as such constitute important factor in establishing a successful incubator (Sun et. al., 2007). More importantly, it has been found out that many incubators in science parks require different support systems during their various developmental stages and as such these support systems should be prioritized according to the stages of development cycle (Chan and Lau, 2005). Within the context of the functions of the determinants in this paper, the best group of people to do this is the 'determinants'.

Insert Figure 1 approximately here

From the general model, four trajectories, leading to four distinct sub-models, are possible depending on who is at the level of "decisive policy direction" which could be government, academic/research institutes, organized private sector (including non-governmental organization/international organizations) or a combination of the three (see Figure 1). The sub-models (Sms) are SmA (Government trajectory), SmB (Academic/research institutes trajectory), SmC (Organized private sector trajectory) and SmD (the three-determinant trajectory). Each of these is discussed in greater detail in the sections that follow. To facilitate the discussion, the ten-point Cabral-Dahab Science Park Management Paradigm is first prioritised in line with the three crucial groups of actors in the models. The points are listed in order of importance together with the actors (in brackets) who will organize and execute each of the operations at each stage of the STP development. In other words, each point is listed, together with the most relevant actor, to correspond with the phase of development when it needs to happen to ensure maximum impact (Box 2).

Insert Box 2 approximately here

2.1 SmA: The Government trajectory

A scenario whereby government is at the level of decisive policy direction or as determinant is shown in Figure 2. Contrary to what had always existed, government's roles in this scenario will follow the prioritized ten-point management paradigm. Particularly, government will take the initiative to establish the STP, provide the fund and hire the STP board of management. It also decides whether the STP should adopt a single technology/business, a multi-sector or sector-neutral approach -as the case in Kecskemet Business incubator in Hungary- (UNPAN, 2007) in implementing its objectives. This is done with a view to increasing competitiveness, promoting innovations, commercializing cutting edge technologies, creating spinoffs which should ultimately lead to employment generation and wealth creation for the citizenry. This sub-model has been operated successfully in the developed countries and some emerging economies across the world where there are well established level of infrastructure. In China, for instance, the successful stories of the establishment of STPs are intrinsically linked to industrial development and Science and Technologies policies of the national government (OECD, 1992). Moreover, the creation of world-class research centres plays an important role in the formation of research networks and clusters and the subsequent creation of STPs as evidenced in places such as BioRio in Brazil, Silicon Valley in USA and Laval Science Park in Canada. A good example is the business incubator managed by the local authority of the Kecskemet in Hungary. This incubator provides services such as modern ICT infrastructure, including integrated services digital network telephones, asymmetric digital subscriber line, internet connections and videoconferencing (UNPAN, 2007). Another successful example of this model is seen in the management of Kulim High Tech Park in Malaysia. The park is owned by the State Kedah government and has been the engine of growth in the Indonesia-Malaysia-Thailand triangle (Kirk and Catts, 2004).

Insert Figure 2 approximately here

Indeed, evidences from this heterogeneous group of countries support the fact that the national government can play an important role in the development of the economy, particularly through policy action. For instance, the enactment of the Bayh-Dole Act of 1980 by the United States of America had a tremendous impact on the rate of technology transfer in the country (OECD, 2000). Government action can really strengthen competition, facilitate networking and co-operation, strengthen links between science and industry, increase returns to investment in R&D and protect intellectual property. These roles have a direct bearing on the establishment of STPs; and governments with a stronghold on the foregoing activities are more likely to promote viable STPs. For instance, USA, Britain and Japan have high returns to investment in R&D and are also known to have successful STPs, partly due to a high level of business consciousness attached to these. Governments in the developing countries could also promote the growth of technological firms by having science and technology-biased policies and sufficient funds to manage such infrastructure (Sun et. al., 2007).

In contrast, most government-funded research in developing countries is directed towards public goals such as education, improvement in social amenities, health care service delivery and energy. Consequently, these governments tend to provide more funds for the provision of social infrastructure than to prosecute R&D. For instance, Nigeria's government only spent 1.3% of its budget on research in her federal universities (Harnett, 2000). Moreover, government establishments in developing countries are not seen as a business venture. In other words, they are not meant to be run as profit-oriented organizations but as service-providing institutions and this usually lead to their eventual death. STPs are capital intensive and property-based institutions that should be run as a business organization.

Another problem with the workability of this scenario in the developing countries is that of instability of civil society. Most of the government policies in the developing countries have been truncated in one way or the other as a result of unstable political environment. STPs, as other long term investments, need a stable political environment to thrive in. It is known that most STPs do not have any positive significant impact until about 15-20 years (Kirk and Catts, 2004) after establishment. Furthermore, experiences have shown that most government enterprises in developing countries do have a very low probability of success. For example, in Nigeria, government enterprises such as the former National Electric Power Authority (NEPA), Nigerian Telecommunications Ltd (NITEL) and Nigeria Airways failed mainly because government lacks the adequate capacity and commitment to maintain such infrastructure and as a result of wrong policies - as it is the case in Tanzania (van Engelen et al., 2001).

According to Portelli (2006) the removal of government intervention in the productive economy might be responsible for the slight growth in some developing countries in East Africa. If these issues in developing countries are not addressed, it is not likely that STP which has government as its main determinant will perform optimally or succeed in most developing countries.

2.2 SmB: Academic/research institutes trajectory

This sub-model describes the trajectory of developing STP to leverage on the assets of the academic/research institutes – the so-called knowledge centres (Figure 3). For instance, although the first sets of STPs in Russia were set up under the state programme “Technology Parks and Innovations”, the main purpose is to promote the scientific potential of universities (Kihlgren, 2003). It is becoming increasingly common for communities in which there are research centres or universities to develop a research/science park to leverage on academic and laboratory resources so as to promote economic well being of the community. This is based on the fact that major research centers can be key drivers of technology-based economic development. This is a common phenomenon in developed countries. The “determinants” at the level of decisive policy direction are the universities or research institutes with inventions or new/emerging technologies which are ripe for commercialization. A good example of this model is seen in the establishment of La Trobe University R&D Park in Australia which is owned and managed by the La Trobe University (Kirk and Catts, 2004). This is distinguished from STPs stimulated by government’s establishment of universities or research centres – in which case government is the determinant.

Insert Figure 3 approximately here

In addition to their roles in the prioritized management paradigm, the knowledge centres also take responsibility in appointing/employing the actors in the “reactors”. The output usually involves inventions, entrepreneurships, employments, promotion of industrial R&D and developing high-tech industries as well as wealth creation in and around their environments (Xue, 1997). Specifically referring to universities, those that have the tendency of establishing such capital intensive park with a view to running them as profit-making infrastructure have been categorized as "universities of innovation' while those whose primary function is to carry out research and training are called 'universities of reflection' (Cowan et. al., 2008).

The types of STPs formed by 'universities of innovation' are usually called Research Parks (RP). It is useful here to characterize a research park in order to distinguish it as a specific type of STP and to better appreciate what its objectives, functions are within the economy. The Association of University Related Research Parks (AURRP, 1997) has defined Research Park or Science Park as a property-based venture that has:

i. existing or prospective land and buildings intended primarily for private and public research and development facilities, high-technology and science-based companies, and support services;
ii. a contractual and/or formal ownership or operational relationship with one or more universities or other institutions of higher education, and science research;
iii. a role in promoting research and development by the university in partnership with industry, assisting in the growth of new ventures, and promoting economic development; and
iv. a role in aiding the transfer of technology and business skills between the university and industry tenants.

The third and the fourth roles differentiate research parks from other types of STPs and really put them forth as being driven by knowledge centres. There is quite a number of successful RPs in developed countries. Some of the most popular ones are the Stanford Industrial Park, in the Silicon Valley of northern California, Research Triangle Park, Waltham Industrial Centre, and Boston's Route 128 (Miller and Cote, 1987). It is assumed that most universities and research institutes will be willing to attract companies that wish to leverage the expertise and resources of the laboratory/researchers in order to gain access to highly specialized, and often unique, facilities and equipment. A good example of research parks that developed by or located close to research institutes are Sandia Science and Technology Park, the National Aeronautics and Space Administration (NASA) Research Park at Ames and East Tennessee Technology Park at Oak Ridge National Laboratory. Another example of such parks in Russia is that of the technology park of the Technical University in St. Petersburg. This park was set up in 1994 to promote start-ups from university staff (Kihlgren, 2003).

Looking at the success stories of these RPs, and believing that the development of a RP is an important medium for moving economies forward in the advent of global market place (Malecki, 1991), many developing countries have started or are starting to employ the same concepts, apparently without looking critically at the appropriateness of such models within the contexts of their own economic development. Unfortunately, the expectation in most developing countries that the shelves of researchers in the knowledge centres have inventions and technologies that could be readily commercialized is merely an assumption. The truth is that a lot of the public universities in the developing countries do not support entrepreneurship like the institutions in the developed countries. For instance, Oxford University is known as the UK's most entrepreneurial university and it has demonstrated this leadership by supporting academic entrepreneurship (Feldman et. al. 2006). On the other hand, the lack of resources in developing countries forces university personnel to carry out external work and consultancies, thus doing a “forced” technology transfer. However, the fact remains that employing this model of establishing STP hook, line and sinker may not be the best of options for the developing countries for so many reasons. Some empirical findings even suggest that some STPs in the developed countries with this model are not effective. For instance, very few tenants in the technology park of the Technical University in St. Petersburg are prospering basically because the university does not have enough funds to manage the park (Kihlgren, 2003).

Most of the researches in the developing countries are not demand-driven (Igwe, 1990; Bako, 2005) and majority of them usually end up in journals for the purpose of career advancement (Musa, 1988, Oyewale et al. 2007). Majority of the developing countries have a very low rate of return on investment on higher education and researches. For instance, between 1960 and 1980 the return on investment on higher education and researches range between 15% and 46% in most sub-Saharan countries with Nigeria having the highest rate and Somalia recording the lowest rate (Hincliffe, 1987). Another problem is that of inadequate fund for the universities and research institutes to conduct researches (Donwa, 2006). It was noted that most of the investments in R&D in many countries could be as high as 6 to 10% of the GDP while that of Nigeria is less than 1% (Donwa, 2006). Some of other problems which are peculiar to most of the developing countries are lack of research skills in the modern methods, constraint of equipment for carrying out state-of-the-art researches, difficulty in accessing research funds, diminishing scope of mentoring junior researchers by seasoned and senior researchers due to brain drain (Okebukola, 2002). In addition to these difficulties, Hales and Kivleniece (2003) suggested that an existence of a university (or research institute) is not a pre-condition for the establishment of STP. In sum, these problems suggest that an attempt for these developing countries to adopt SmB to establish STP without addressing the basic difficulties could be a futile effort and a waste of resources.

2.3 SmC: Organized private sector trajectory

This model considers "determinants" to be the organized private sector which includes industrial players and NGOs/international organizations (Figure 4). This is probably the least common form of STP in the developing countries. It also incorporates a university or other research organization either by affiliation or actual ownership, but the operational control lies with a commercial developer. One of the main roles of the park is that it could act as an interface to bring the researchers and industry together to work for mutual benefits and for benefit of the society at large. It could also provide training and consultancy services to all levels of government and the private sector.

A good example of a successful STP under the management of a property development company is that of Brisbane Technology Park in Australia. Although it was established in 1986 by the Queensland Government's Department of State Development, it was actually given to Graystone Group as the original development manager of the park. In order to achieve the objective for which the TP was set up, the Department of State Development of Australia contracted Zernike Australia Pty to provide specialized management services to resident companies and attract more companies that will embrace the objectives of the Park (Kirk and Catts, 2004). Zernike Australia engages in activities such as provision of experts in technology innovation and commercialisation, facility management, seed capital and technology park management (Kirk and Catts, 2004). This park demonstrates how private developers are given the role of a determinant in the management of the park. There are few examples of these models in the less developed countries. However, a critical look at them shows that they are very small in scale and majority of them are into Information and Communications Technology (ICT)-related services. Examples of such STPs include Viasphere Technopark in Armenia, SODBI Business Incubator in Kazakhstan and Information and Telecommunication Technologies Development Association in Azerbaijan support ICT-related business (InfoDev, 2008).

Insert Figure 4 approximately here

While this might have worked in some developed countries, the peculiar situations in the developing countries would make it almost impossible to work. The problem with this type of model in the developing countries is that most of the indigenous private developers do not have the competence to manage this type of property-based venture. This constraint is more evident in the management of high-tech companies in Tunisia as shown by the study of Harbi, et al. (2008). Moreover, foreign investors who could have shown interest in managing the park see this as a very “risky business” to dabble into. Another problem of this model with the developing countries is that there is the tendency for the developers to lose focus on the main objective of the park and focus more on the quantity rather than the quality of park (Kirk and Catts, 2004). Other problems which could make this model unviable for the developing countries include unstable political systems, inadequate legal and regulatory framework, lack of coherent public private partnership strategy and processes and contractual and payment risks. This problem will ultimately lead to ineffective management of the park with grave negative consequences on its survival.

2.4 SmD: The three-determinant trajectory

This model (Figure 5) explores the possibility of the three stakeholders (government, knowledge centres and the private sector) coming together to establish a sustainable STP. The word "three" here only recognises the distinction of each stakeholder. The functionality of the model requires that working relationship be formed among them such that they appear as "one". In a way, SmD is basically similar to the "triple helix" model which emphasizes the triadic relationships among the institutional spheres (i.e. university-industry-government) (Henry Etzkowitz, 2002); but it transcends the "triple helix" model in that, beyond the simplistic triadic basis, it actively involves other unique stakeholders such as NGOs and international donors which do not necessarily belong to any of the triad.

The stakeholders in the proposed sub-model include the national/state/local governments, research institutes, universities, private developers, financial institutions, international organizations, non-governmental organizations, private investors, etc. The rationale for this sub-model is the fact that the establishment of an STP has a high probability of success when these stakeholders pool their resources together for the establishment of STP. For instance, the knowledge centres will bring in their expertise in the area of research, training and consultancy; the government will provide counterpart funding and infrastructure (including, notably, intangible components such as favourable policies) while the organized private sector will provide additional fund, consultancy and other specialized services. The sub-model puts all or a combination of some of these actors at the level of "determinants" where they are responsible for taking decisions on various aspects of the STP; and is perhaps more widely applied than the other three models in developed countries. The output of the park will depend on the decisive policy direction that the "determinants" have chosen with the ultimate goal of wealth creation and economic development.

Insert Figure 5 approximately here

A successful example of this model is that of the Delaware Technology Park. This park is a partnership among the state of Delaware, the University of Delaware and the private sector. The main goal of the park is to attract established industries and provide an incubation and acceleration for start-ups in high-technology fields, specifically those in biotechnology, information technology and advanced materials. It also provides networking access to services and resources to the clients. Another good example is that of the the Wrocław Technology Park which has the State Treasury, the City of Wrocław, the Wrocław University of Technology, the University of Wrocław, the Agricultural University of Wrocław, the Foundation for the Development of the Wrocław University of Technology, the Lower Silesian Chamber of Commerce, Dolmel Investment Association, and Bank Zachodni SA as its stakeholders. Other successful STPs like Silicon Valley, Route 128 also have collaborations with other stakeholders.

This model is most highly recommended for developing countries. This is because all the stakeholders have a role to play at all stages of the park's development. These roles span the inception, completion and smooth running of the STP as well as marketing of the output, expansion and management of the park. A summary of the relationship between the determinants and the actors is depicted in Table 1. The sub-model SmD encapsulates all the typical actors and roles shown in the table. Participation of each of these stakeholders would have taken care of most of the peculiar challenges identified to be typical of developing countries and hinder successful development of STPs.

Insert Table 1 approximately here

The proposition of this model is premised on the strength and significance of the collaboration of the determinants as well as the successful stories of well established STPs that have adopted this model. For instance, it has been established that there is a strong correlation between clusters of high-technology firms and a number of factors which promotes university–industry and firm-to-firm communications and collaboration (Barker, 1995). Those factors include a strong regional knowledge-base (universities, colleges and research laboratories), local government and other agencies of the government which provide leadership, vision, infrastructure and collaboration among research institutions for formal and informal exchanges and networking (Barker, 1995).

A specific example of the application of this model in a developing country is the International Technopark of Panama (ITP). ITP is the first technology park in Panama. The park received special support from Panamanian government and economic cooperation programs developed by the European Commission. The park is sector-neutral but makes its selection based on specific requirements. Some of the tenants are Xerox and Citibank. ITP is located in Panama's "City of Knowledge". The City of Knowledge is under the supervision of the City of Knowledge Foundation, a private non-profit foundation created in 1995 (Briggs and Watt, 2001). It is directed by a Board of Trustees comprised of representatives from the academic, business, labour and government sectors. Other partners of ITP include University of Panama, Gorgas Memorial Institute for Health Studies, Smithsonian Tropical Research Institute, Santa Maria La Antigua University and Technological University of Panama. The Panamanian government has been able to support the park by establishing a free trade zone and 20-year exemptions from import duties, fees for construction materials and equipment, income, real estate and other taxes (Briggs and Watt, 2001). The telecommunication infrastructure in the park is provided by organized private sector such as the Pan American, Global Crossing, Maya, Project Oxygen, Arcos etc (Briggs and Watt, 2001). Considering the age of the park, it may be difficult to measure its success at present. However, according to the report of the Panama's Council for Investment and Development, the investment climate of the park has resulted in flow of foreign direct investment worth millions of dollars and over 2,000 jobs have been created (Briggs and Watt, 2001). Another example of the application of SmD is seen in the National Technology Park in Limerick, Ireland. The park is managed by the National Technological Park Plassey Ltd, a wholly owned subsidiary company of Ireland's Shannon Region but its establishment rests on the involvement of the host institution (University Limerick), organized private sector and local economic development agencies.

It is important to note that while adopting SmD, each developing country should understand what works within their political and economic environments. For instance, China has been able to use the SmA model successfully under her Torch (*Huoju*) Program. She exempts tenants from corporate income tax for two years, waiving license for the import of materials and parts used in producing goods for export and not imposing tax on firm's revenue from technology transfer below 300,000 Yuan (Hu, 2007). The tenants in themselves have collaborated with other interested parties and this has led to the improvement in the good and services of the STPs. Government in developing countries can borrow from this example by instituting a preferential policy to promote technology-based businesses. Given the fact that it could be difficult for all the interested parties to come together at the same time, governments in the developing countries could make themselves rallying points for bringing the other determinants into play. This systematic approach would ensure entrenchment of SmD and eventually brought about sustainability of the STP. A critical look at some of the structure of the other sub-models revealed that even when the park adopts a single determinant model (SmA, SmB and SmC), the management and administration are usually left with the board of management with representatives from all the stakeholders. For instance, the Board of Management of the La Trobe University R&D Park has representatives from private sector, the University, State and Local Governments (Kirk and Catts, 2004). Governments in the developing countries could solve the problem of non-demand driven research in the public institutions by subsidizing or contract research organizations to undertake R&D activities that address specific industry demand in their countries.

Insert Table 2 approximately here

3.0 Conclusion and Directions for Future Research

A summary of the evaluation of the different sub-models is contained in Table 2. It comes out clearly that SmD is most appropriate for developing countries. Within the SmD, the university/research institute provides majority of the human capital, the government provides the basic amenities, infrastructure as well as conducive policy environment while the organized private sector brings in its expertise and financial muscles. In view of these, STP impacts in developing countries will depend significantly on input factors like ownership structure, conducive policy environment, and adequate provision of hard and soft infrastructure as well as supply of competent human capital.

Following the discourse so far, we recommend that:

i. STP determinants and policy makers in developing countries must see the establishment of STPs as a long term investment which requires a proper design;

ii. developing countries must recognize the importance of the determinants, reactors and executors where determinants are the most important for effective STP management for a significant impact on their economies;

iii. economies in transition must see STPs as having a distinctive organizational structure as a result of its myriads of collaborations and partnerships; and

iv. policy makers in developing countries must make sure that the establishment of STP is demand driven.

The sub-models that we have presented are all interesting, and particularly so is our recommendation of SmD for developing economies. However, not many examples of the application of this model have been reported. In this light, case studies that put together and draw an evaluative framework of the applications of the different sub-models are welcome. Additionally, our SmD framework can be validated using identified successful cases from developing countries. Specifically, existing STPs or incubators in developing countries could be assessed. It is also desirable to extend our study by carrying out surveys to examine STPs in several economies to shed light on their development process. This improves understanding of how STP programmes can be developed and assessed from the development perspective among the developing economies. Indeed, the findings from such studies would be very useful for policymaking.

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Box 1: The Refined Cabral-Dahab Science Park Management Paradigm

A successful science park must:

1. Have access to qualified research and development personnel in the areas of knowledge in which the park has its identity.
2. Be able to market its high valued products and services.
3. Have the capability to provide marketing expertise and managerial skills to firms, particularly SMEs, lacking such a resource.
4. Be inserted in a society that allows for the protection of products or process secrets via patents, security or any other means.
5. Be able to select or reject which firms enter the park. The firm's business plan is expected to be coherent with the science park identity.
6. Have a clear identity, quite often expressed symbolically, as the park's name choice, its logo or the management discourse.
7. Have a management with established or recognised expertise in financial matters, and which has presented long term economic development plans.
8. Have the backing of powerful, dynamic and stable economic actors, such as a funding agency, political institution or local university.
9. Include in its management an active person of vision, with power of decision and with high and visible profile, who is perceived by relevant actors in society as embodying the interface between academia and industry, long-term plans and good management – Mr./Ms. Science Park.
10. Include a prominent percentage of consultancy firms, as well as technical service firms, including laboratories and quality control firms.

Source: Cabral R., 1998

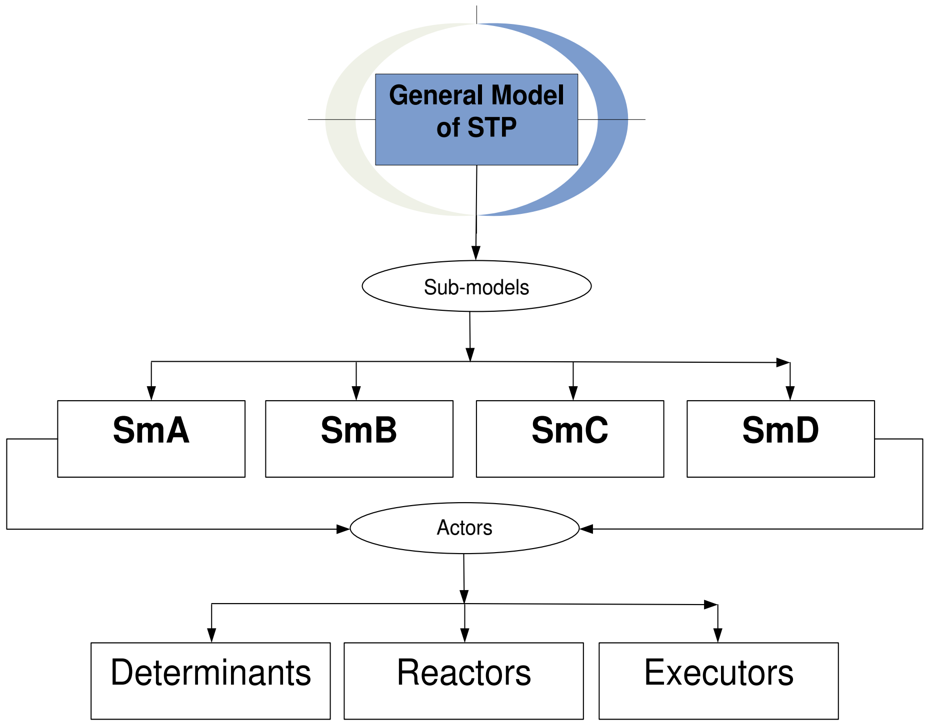

Figure 1: General Framework for the establishment of Science and Technology Parks

Box 2: The Refined and Prioritized Cabral-Dahab Science Park Management Paradigm

A Science/Technology Park should:

1. Have the backing of powerful, dynamic and stable economic actors, such as a funding agency, political institution or local university (Determinants).
2. Include in its management an active person of vision (a group of people), with power of decision and with high and visible profile, who is (are) perceived by relevant actors in society as embodying the interface between academia and industry, long-term plans and good management – Mr./Ms. Science Park (Determinants).
3. Have a clear identity, quite often expressed symbolically, as the park's name choice, its logo or the management discourse (Determinants).
4. Be inserted in a society that allows for the protection of products or process secrets via patents, security or any other means (Determinants).
5. Have a management with established or recognised expertise in financial matters, and which has presented long term economic development plans (Reactors).
6. Be able to select or reject which firms enter the park. The firm's business plan is expected to be coherent with the science park identity (Reactors).
7. Have access to qualified research and development personnel in the areas of knowledge in which the park has its identity (Reactors).
8. Have the capability to provide marketing expertise and managerial skills to firms, particularly SMEs, lacking such a resource (Reactors/Executors).
9. Include a prominent percentage of consultancy firms, as well as technical service firms, including laboratories and quality control firms (Executors).
10. Be able to market its high valued products and services (Executors).

<table>
<tr><th></th><th>Determinants</th><th>Reactors</th><th>Executors</th></tr>
<tr><td>Start-up</td><td rowspan="4">1, 2, 3, 4</td><td>5, 6</td><td></td></tr>
<tr><td>Growth</td><td rowspan="3">7,8</td><td>8, 9, 10</td></tr>
<tr><td>Maturity</td><td rowspan="2">9, 10</td></tr>
<tr><td>Diversification</td></tr>
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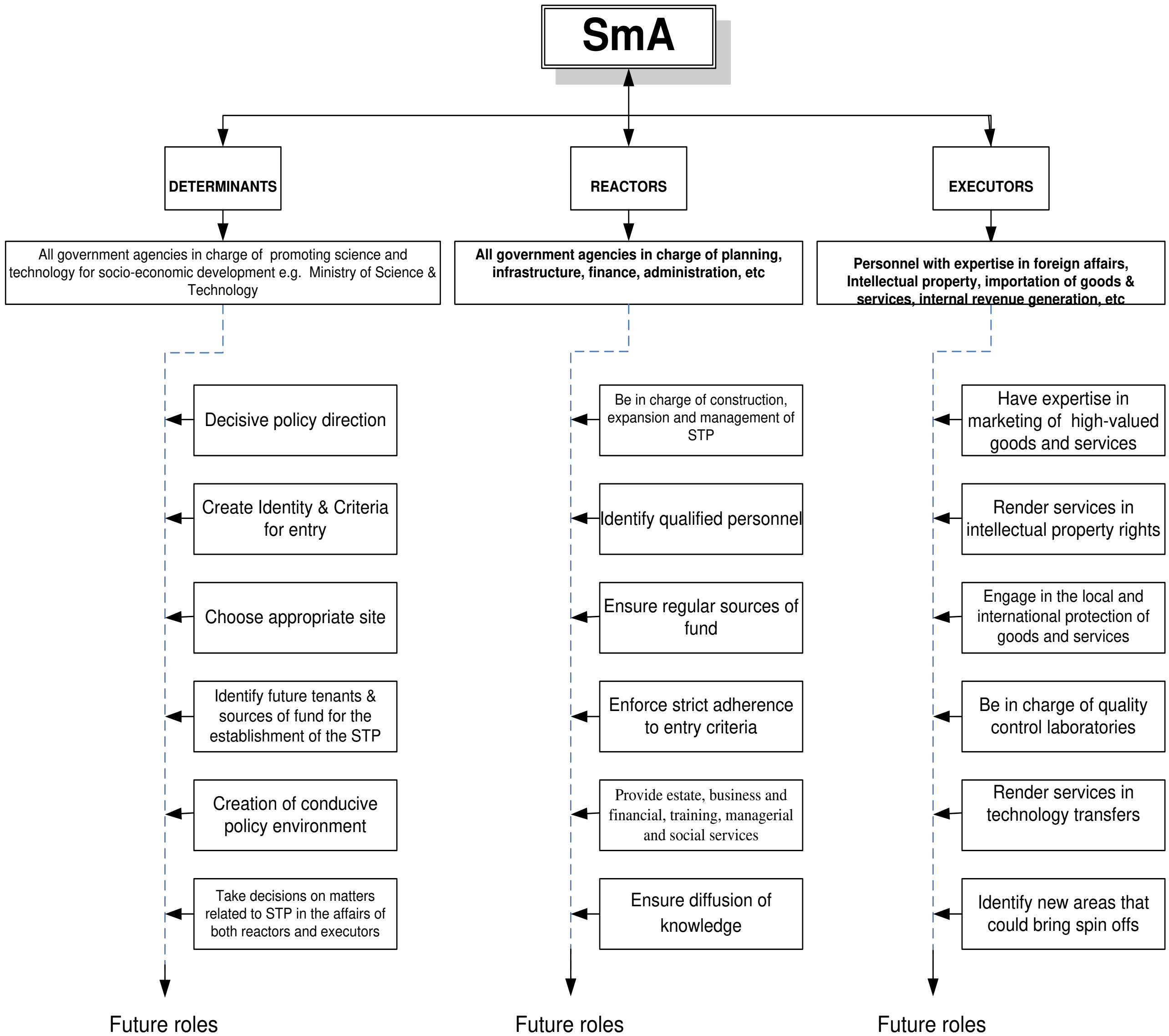

Figure 2: SmA: The Government trajectory

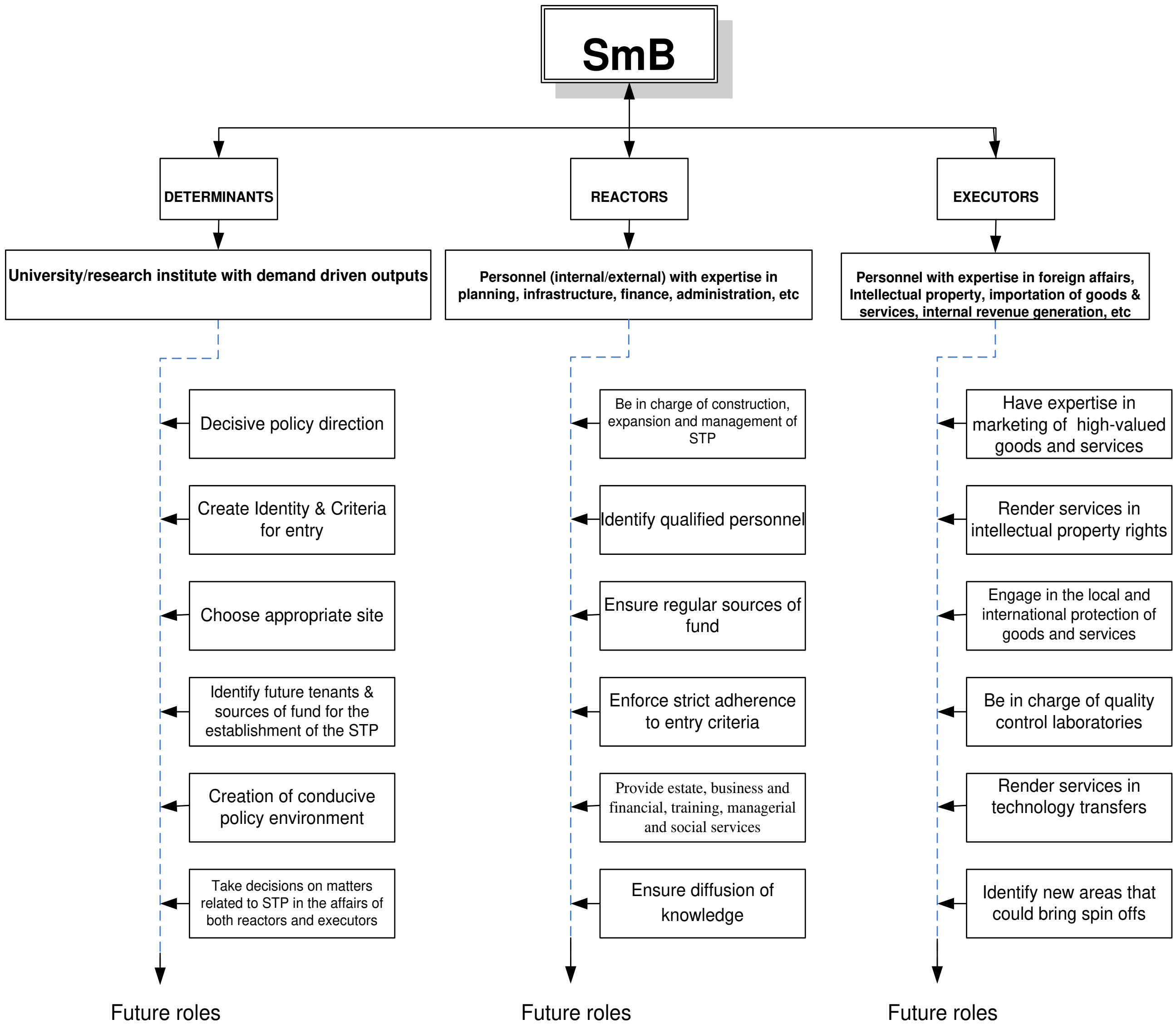

Figure 3: SmB: Academic/research institutes trajectory

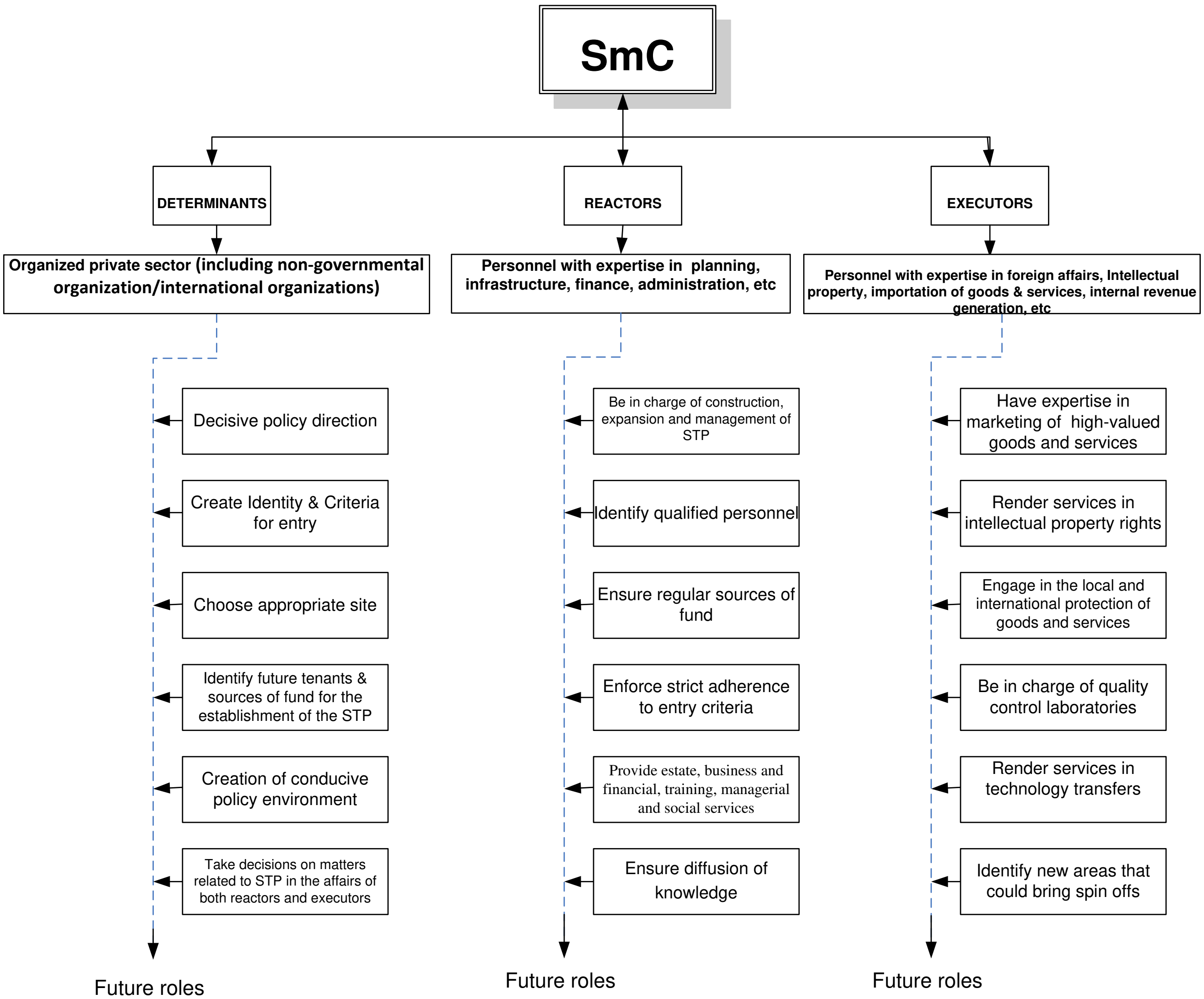

Figure 4: SmC: Organized private sector trajectory

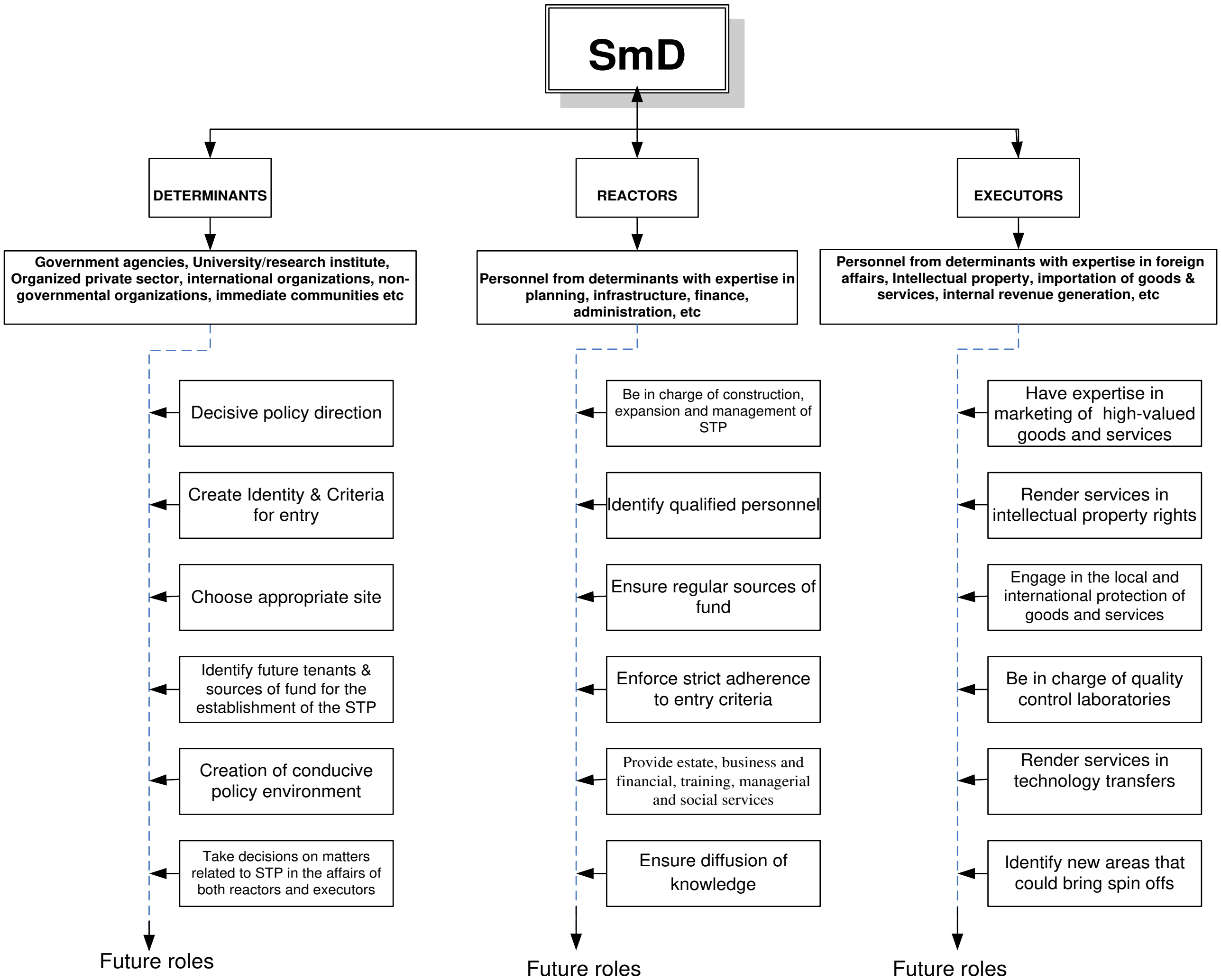

Figure 5: SmD: The three-determinant trajectory

Table 1: Summary of the relationship between the determinants and the actors

Actors	SmA	SmB	SmC
	Government	Research Institute/University	Organized private sector (including non-governmental organization/international organizations)
Determinants	X	X	X
Reactors	X	X	X
Executors	X	X	X

Table 2: The Positive and Negative Points of the STP Sub-Models (Sms)

Sub-Model	**Pros**	**Cons**	**Examples**
SmA	Government mostly provides basic amenities	Bad history of government enterprises poses a threat	The Kecskemet Science and Technology park (Hungary); Kulim High Tech Park (Malaysia)
SmB	Has been successfully implemented in developed countries	Required infrastructural network is largely absent. Most of the R&Ds in the developing countries are not demand-driven (Bako, 2005)	Sandia S&T Park (USA); East Tennessee Technology Park (USA)
SmC	High potential for innovation since there is easy access to R&D outcomes from knowledge centres	High cost of production of goods and services (Gerald, 2002) and instability of civil society in most developing countries. Designing and developing STPs is not attractive to the organized private sector.	Brisbane Technology Park (Australia)
SmD	All the determinants at the level of decisive	The well-known challenge of bringing the	Delaware Technology Park

	policy direction are in themselves major stakeholders in the design and development of STP	stakeholders together	(USA); Wroclaw Technology Park (South Africa)