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THE ROLE OF RESEARCH UNIVERSITIES IN CREATING A CLEAN-TECH INDUSTRY: THEORY, INTERNATIONAL EXPERIENCE AND IMPLICATIONS FOR THE UNITED ARAB EMIRATES

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1. Introduction

The Government of the United Arab Emirates (UAE) has recently announced plans to develop a knowledge-based economy with renewable energy innovations at its core. Having conducted an empirical examination of the current UAE Solar Innovation System and identified the potential key opportunities and challenges to attaining such an ambitious goal (Vidican et al., 2011), an effort has been made to examine - in more detail - the key components and processes that are of importance when considering the prospects for the successful establishment of a renewable energy industry in the UAE. One of the highly important and relevant tasks of such an endeavor is investigating the potential role of research universities in the UAE (e.g. the Masdar Institute) in facilitating a transition towards renewable energy innovation in the country. In this report, we investigate two main research questions:

1) How do research universities contribute to the creation of new industries in general?
2) What guidelines can be developed to support the creation of a renewable energy industry in the UAE where research universities are at the core of an innovation-led transformation?

This report starts by providing a succinct background on the theoretical perspectives available to study the potential roles played by research universities in innovation and industrial development. Next, a literature-based examination is provided with regard to the ways in which research universities have contributed towards fostering innovation in the renewable energy field around the developed world. This overview is supplemented with empirical data collected in earlier research (conducted in collaboration with scholars from the MIT) on the formation of the US and German solar photovoltaic (PV) industries. This joint research project has a particular focus on the way US and German universities have contributed towards the creation of national solar PV industries. Here, it is important to recognize that the role of research universities is highly dependent on the industrial transition pathway followed by the respective country, in addition to its current stage of development (Lester, 2005). Therefore, as part of the cross-national literature review, it has been decided to look into the experiences of a selection of rapidly-developing Asian countries, namely Korea, Taiwan, Malaysia and Singapore. Since the latter countries do not have thriving renewable energy industries, an effort has been made to reflect on the roles that their research-intensive universities have played in establishing new (although not necessarily energy-related cleantech) industries. A focus on these countries is deemed more logical than considering the other oil-rich Gulf countries, as although they resemble the socio-economic characteristics of the UAE to a greater extent, the role of research universities and renewables (and hence the supporting published data) in these countries is still very limited. After attaining a thorough understanding of the roles already played by research universities in establishing innovative industries around the world, the last part of this report examines closely the case of the UAE, using both primary and secondary data, whilst taking into account relevant policy-oriented lessons that can be drawn from international experience.

2. The Role of Research Universities in Innovation: Theoretical Perspectives

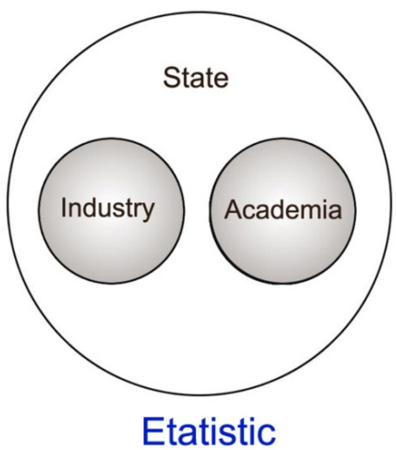
One of the influential attempts to conceptualize the role of academic research is known as the 'linear model of innovation process'. This model is usually associated with a report entitled *Science: The Endless Frontier* by Vannevar Bush which outlined, to the US President, proposals for post-war science and technology policy (Bush, 1945). This report called for a need to expand funding for basic research within US universities in order to promote innovation and economic growth[1]. In essence, the linear model of innovation process prioritizes scientific research as the

[1] Adopting this linear approach and assuming that patenting intensity can provide a true reflection of national innovation capabilities, several studies (e.g. Margolis and Kammen, 2001; Nemet and Kammen, 2007) reported that the total number of US patents and funds allocated for R&D activities were highly correlated in the 1980s and 1990s – both roughly doubled between 1976 and 1996. A similar correlation was reported for energy-related patents and related R&D investments.

basis of innovation, whilst overlooking the role of other actors and interactions in the innovation process. This simple model has been widely criticized for failing to capture, let alone appreciate the existence of, the great deal of feedback and loops that occur between the different actors and stages of the process (e.g. Rogers, 2003). Mowery and Sampat (2005) mention that, in the 1970s, many US policy makers cited Japan as a case to argue that basic research may not be either necessary or sufficient for a nation to improve its innovative performance.

An alternative conceptual framework to analyze the role of academic research in contemporary industrial societies has more recently been proposed by Michael Gibbons and colleagues (Gibbons et al., 1994), who argued that research strategies could be described in terms of Mode 1 and Mode 2 knowledge production. Their work claims that Mode 1 is discipline-based research that is only executed in universities and specialized research centers, with little interest in its practical application. Mode 2, on the other hand, is associated with a more interdisciplinary and pluralistic type of research that is carried out through intensive interaction with industry. The implications of accepting such a 'mode-ist' approach are that (i) it announces the increased importance of networks in knowledge production; (ii) it gives the impression that Mode 2 is better, or more modern, than Mode 1. Policy makers may take this for granted and direct the lion's share of public research funds to applied research and networks, whilst overlooking the importance of funding the research institutions themselves. It is apparent, however, that there has been a tremendous interest in the work of Gibbons and his co-authors. According to the Google Scholar search engine by August 2011 this work had around 4,235 citations in numerous books and journal articles. A further investigation reveals that the vast majority of those who cited their work agreed to some extent with the 'mode-ist' concept. Whilst most of the scholars suggest that research strategies should follow Mode 2, i.e. with an emphasis upon network-based practical application, others argue that both theoretical and practical work are important (e.g. Easterby-Smith et al., 2002). Huff (2000) went further, and pushed for a compromise they call the 'Mode 1½' position. It does appear, however, as argued by some scholars (including Boden et al., 2004; Shinn, 2002), that the 'mode-ist' concept has not been rigorously tested and is, therefore, a part of the research vocabulary as opposed to being a solid methodological foundation.

Another analytical framework that could be used for studying the role of universities in fostering innovation towards knowledge-based societies is the Triple Helix of academic-industry-government relations (Etzkowitz and Leydesdorff, 1997). Figure 1 shows three different models of such relations. The first model is called the Etatistic (statesman) model, where the government not only encompasses academia and industry, but also controls the relations between them. The second model (Sabato's triangle) shows a clear institutional separation of the three spheres, with the government in the upper vertex of the triangle. Etzkowitz and Leydesdorff (2000) mentioned that most countries are currently trying to attain some form of the Triple Helix III, with overlapping institutional spheres and hybrid organizations emerging at the interfaces. Whilst the Triple Helix provides an interesting framework for analyzing the relationship between universities, industry and government, it is often argued that it devotes little attention to transformations in industry and government, which essentially complement those taking place in universities (e.g. Mowery and Sampat, 2005).



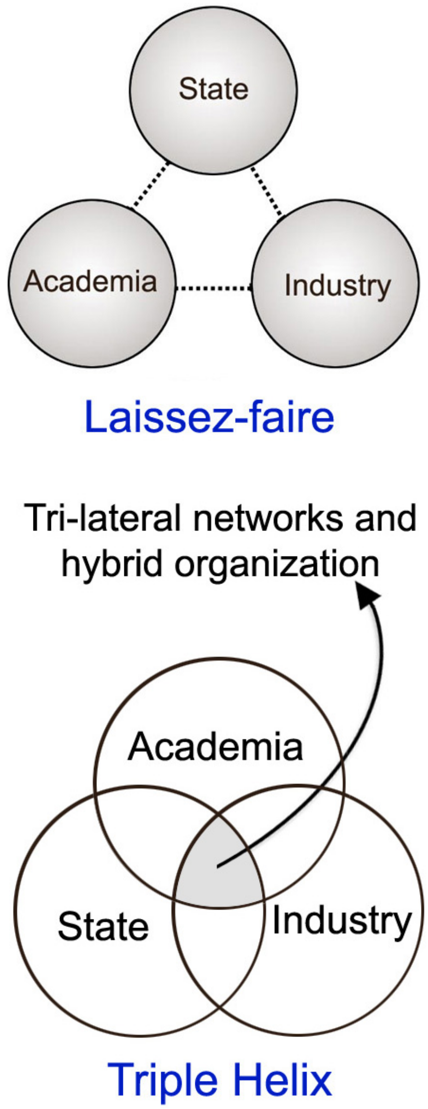


Figure1: Three different models of university-industry-government relations (Adapted from Etzkowitz and Leydesdorff, 2000)

A more appropriate framework for conceptualizing the role of research universities within the innovation process of knowledge-based economies is the systems of innovation (SI) concept, which was introduced in the mid-1980s by Freeman (1987) and Lundvall (1988), and then followed by others (e.g. Edquist, 1997; Nelson, 1993; OECD, 1997). Whilst demonstrating a conceptual shift from its neo-classical predecessors, The SI concept is still emerging and its definitions vary considerably depending on the characteristics of the system being considered. One of the most frequently cited definitions, provided by Lundvall (1992), is “The elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge" (pg. 2). A further review of the SI literature reveals that mechanisms of learning are at the heart of the evolutionary theory-based SI approach. In this regard, Lundvall (1992) believes that "The most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning" (p. 1). Edquist (1997) further argues that it is important to analyze the knowledge base and learning aspects of SI, including – where possible – systems of formal research and development (R&D), patents, education and training as well as learning processes that are embedded in routine economic activities. In a later work, Edquist (2005) went further and argued that we should transcend the traditional SI approach and think along the lines of 'Systems of Learning' rather than 'Systems of Innovation'. This call came after admitting that despite the fact that 'competence building' is an important activity for both universities and systems of innovation, it has not yet been thoroughly analyzed as part of an SI study.

It should be remembered that the roles of research universities vary from one country to another, and one cannot understand such roles without knowledge of the country's specific historical and current development (Larédo and Mustar, 2004; Lester, 2005). Therefore, in order to investigate the potential role of the UAE research universities (e.g. the Masdar Institute) and provide policy recommendations to enhance their role in terms of establishing a national renewable energy industry, it is important to keep in mind the National Innovation System (NIS) of the UAE. This consists essentially of a group of actors that share common 'national' knowledge, institutional and political infrastructures. The NIS framework does not just look at research institutes performing R&D and the level and source of R&D funds; it also considers policies (e.g. licensing and IP rights) that affect technology development and industry creation.

Mowery et al. (2004) examined the important contributions that American universities offered to fostering industrial innovation, with a particular empirical focus on the role of patenting and licensing of academic inventions in supporting technology transfer between universities and industry. Counter to the prevailing belief that the Bayh-Dole Act of 1980[2] was the principal driver of the economic boom in the 1990s, it has been argued that academic patenting and licensing played a lesser role than other channels in knowledge dissemination and exchange between academia and industry. Similar empirical findings on university-industry links in the US were provided by Cohen et al. (1998) and in the United Kingdom (UK) they were presented by D'Este and Patel (2007) who all highlighted the increasing role of publications, conference presentations, internships, training, contract research and consultancy. A recent international innovation benchmarking project, conducted by the Cambridge-MIT Institute, further confirms these findings and adds that informal contacts are the most prevalent university-industry activity in both the US and the UK (Cosh et al., 2006). Such 'knowledge transfer' channels are referred to as 'networks', which are important elements of any NIS. Edquist (1997) affirms that "Not only is the creation of new knowledge crucial but so is its accessibility, i.e. its distribution and its utilization within systems of innovation" (p. 16). The fundamental purpose of such knowledge-based networks, within the NIS framework, is to exchange information and diffuse both explicit and tacit knowledge, which will eventually facilitate the development of a knowledge-based economy for a country. To sum up, the NIS concept examines which elements and relationships exist and how they currently interact and contribute to the process of producing, diffusing and using new, and economically useful, knowledge within a nation. It is true that an NIS cannot be purposively designed from scratch, as it is shaped by several factors including the history of industrialization in the country, together with its laws, style of politics, research background, education and training systems. However, considering the workings of the respective NIS is seen as paramount for the design of suitable public policies, which would effectively assign roles to the different actors (e.g. research-intensive universities) towards

[2] The Bayh-Dole Patent and Trademark Amendments Act deals with intellectual property arising from US government-funded research. The act permits the performers of such research (and their respective universities) to file for patents on their research and retain the property rights to their inventions. There have been extensive debates in the scholarly literature on the effects of this act on academic research (e.g. see Sampat, 2006; Rafferty, 2008). In the words of Nelson (2008): "University research was contributing importantly to industrial innovation long before Bayh-Dole and much of what industry was drawing on was in the public domain, not patented" (pg. 10).

enhancing the technological capabilities of a nation. Such aspects will be borne in mind when providing policy-oriented recommendations, towards the end of the report, to support the creation of a renewable energy industry in the UAE. The following section provides a cross-national review of both the general role of universities and the ways in which research universities have contributed towards establishing renewable energy industries within advanced industrialized countries that have already developed knowledge-based economies with R&D-intensive industries and large science-driven enterprises. This will be followed by a review of the roles played by universities in terms of new industry creation within industrializing Asian countries.

3. The Role of Research Universities in Developed Countries

During the 1990s, a large number of studies were conducted in the USA and Europe in order to estimate the benefits and local impacts of a university on its local territory (e.g. Armstrong et al., 1997; Bleaney et al., 1992; Harris, 1997). The economic and social benefits of universities have long been recognized as an important source of industrial innovation. Whilst recognizing that the rationale for academic research extends far beyond the sort of narrowly defined economic benefits considered in most of these studies, May and Perry (2006) mention that the generic impacts of universities are twofold: (i) Direct impact of initial investment, job creation, effects of student and staff spending and the university's operating expenditure on their local and national economies; (ii) Development of local human capital as universities carry out their mission of providing higher education, training and knowledge production dissemination. In another study, Varsakelis (2006) argues that education provided by universities affects national innovation productivity in four direct ways: (i) Scientists and researchers employed by these universities are considered to be inputs in the knowledge production function of NIS. In fact, these scientists are also outputs of the education production function; (ii) Universities are also responsible for creating a highly-skilled workforce pool in the industry; (iii) Education helps to create a national pool of risk-taking entrepreneurs who demand innovation, new products and services and more efficient production methods that increase the national competitiveness; (iv) Education improves the cognitive abilities of the public and helps in creating a sophisticated quality-demanding local customer base. To that end, Porter (1990) emphasized the role of demand conditions as a key driver for innovation and international competitiveness.

Moreover, it should be mentioned that in recent years there has been extensive discussion about whether universities can encompass a third mission of promoting entrepreneurial-based economic development, in addition to their conventional missions of competence building and scholarly research (Branscomb et al., 1999; Geiger and Sá, 2005). In fact, universities are becoming increasingly viewed as economic assets that, unlike firms, are relatively permanent entities and therefore 'safer' for implementing regional development policy measures (Srinivas and Viljamaa, 2007). Greenaway and Haynes (2000) argue that the increasing policy pressure on universities to help improve national economic competitiveness has contributed to a growing involvement of universities with industry. Subsequently, universities are increasingly perceived to be vehicles not only to provide education and conduct R&D, but also as mechanisms for patenting, licensing and spin-outs. The impact of universities on the creation of high-tech firms is often epitomized in the literature by success stories along Route 128 with the MIT and in Silicon Valley with Stanford University (Saxenian, 1998). Michael Porter's Clusters Theory, articulated in Porter (1990), triggered a worldwide interest in building clusters anchored by universities. For example, based on a large dataset of startup firms in Germany, Audretsch et al. (2005) confirm the that new high-tech firms prefer to locate themselves close to universities in order to access knowledge spillovers. Similarly, using the MIT as a case study, Agrawal (2000) argued the importance of geographic distance and direct interaction between university scientists and company scientists to the successful transfer and commercialization of patented university inventions[3]. It appears that much public scrutiny on government policies aimed at encouraging knowledge transfer in the developed world has been devoted to measuring rates of patenting and spin-off activities (Geuna and Nesta, 2006; Landry et al., 2006; Langford et al.,

[3] Other studies that have provided convincing evidence supporting the importance of proximity in the transfer of knowledge between universities and firms, include Adams (2002); Arundel and Geuna (2004); Mansfield (1991); Mansfield and Lee (1996); Varga (2009).

2006; Smith and Ho, 2006; Shane, 2004). Nonetheless, as mentioned earlier, several scholars, including D'Este and Patel (2007) and Mowery et al. (2004), highlighted the fact that an increasing number of American and European university researchers are interacting with industry through another set of potentially revenue-making channels (or 'networks' as per the SI vocabulary), namely consultancy, contract research, joint research and training[4].

Jong (2006) assures us that, through the abovementioned range of SI networks, research universities[5] have been central to the industrial development of capitalist economies, having contributed to the growth of most of today's important industries. For instance, such universities played a key role in the formation of the high-tech electronic industry in the USA during the post Second World War period (Mowery and Rosenberg, 1998), the chemical industry in Germany during the second half of the nineteen century (Beer, 1959), and more recently the biotech industry (Kenney, 1986; Nelsen, 1991). In general, companies that have become involved with research universities are likely to earn substantial benefits in increased productivity, profitability and innovation (Coopers and Lybrand, 1995). Whilst universities have shown a significant potential in supporting the creation of innovative science-based industries, countries vary in terms of the extent to which their universities achieve this potential. In an attempt to explain the cross-national variations in this regard, some scholars attribute this to the different organizational set up of national university structures. For example, Whitley (2003) – a British scholar – examined the comparative success of the American academic system in fostering the growth of new science-based industries since the Second World War. He argued that the relatively competitive nature of the American academic system and its higher

[4] A major work conducted by Lester (2005) broke down the role of universities into four broad categories: education and training (undergraduate, postgraduate and executive education); adding to the stock of codified knowledge (publications, patents); increasing the local capacity for scientific and technological problem-solving (venture mentoring programs, start-up clinics, incubators, contract research, joint research, faculty consulting and technology licensing); providing public spaces for open-ended conversations(university-hosted meetings and conferences, business plant contests, alumni networking activities and curriculum development committees involving local industry practitioners).

[5] Based on the work of Tijssen (2006), the term 'research university' is defined here as a university that does not only place an emphasis upon research, but also a one that has become entrepreneurial through time, during which it will engage in intensive university-industry collaboration.

level of flexibility and intellectual pluralism have resulted in producing scientific knowledge that is more radically innovative. In another study, Gittelman (2001) highlighted the importance of individual researchers and suggested that the entrepreneurial spirit of university scientists who happened to be working in the USA then, played a key role in the emergence of new science-based industries during the post Second World War period. It is perhaps worth mentioning here that the NIS approach takes such analysis a step further and, by assuming that knowledge is not produced in a vacuum, looks at the macro-level and stresses the role of institutions, actors and their interactions in the process of new knowledge production[6].

David (1994) argues that university science is to the knowledge-based economy of the 21st Century what the machine tool sector was to the economies of the 19th and early 20th centuries. It is not surprising, therefore, to find a genuine effort on the part of NIS scholars (e.g. Lundvall, 1992; Edquist, 1997) among others, to highlight the importance of knowledge production and utilization in fostering innovation and economic growth. Nevertheless, it appears that while the role of universities in establishing new industries – so their importance in promoting innovation and economic growth – has been rigorously established in the literature, the potential contribution of research universities in both fostering sustainable energy innovations and to the creation of renewable energy industries has not been sufficiently researched to date. Given the emerging nature of these industries, one would assume that not only are most incremental technological innovations being developed by companies in-house, but also the mechanisms through which universities contribute to renewable energy innovation are different (Vidican, 2009).

To begin with, and given that the conventional role of universities is the provision of education and competence building, it is worthwhile highlighting the fact that a number of international alliances have promoted commitment on the part of universities and colleges towards teaching subjects related to renewable energy and sustainability in general (Selby et al., 2010). In 1990, a

[6] It is unfortunate that, as noted by Bozeman and Dietz (2001), most research policymakers and analysts continue to spend little time conceptualizing the NIS, trying instead to develop a limited understanding of its subsystems such as national laboratories, federal agencies and state government technology development programs.

document – composed at an international conference in Talloires, France – spelled out the actions that universities and colleges needed to take as part of their responsibility towards forging a sustainable future. This document is now known as the 'Talloires Declaration' and it identified important areas that need addressing including curriculum development, teaching and outreach. For example, commitments were made to establish programs to "Teach environmental literacy to all undergraduate, graduate and professional students" and "To develop interdisciplinary approaches to curricula, research initiatives, operations and outreach activities that support an environmentally sustainable future". As of August 2011, the Talloires Declaration has been signed by the presidents and chancellors of some 433 universities in 52 countries around the world. To date, no university from the oil-rich Gulf region – the UAE included – has signed this declaration, which in essence commits universities to enhance their inputs towards the development of clean-tech energy industries (University Leaders for a Sustainable Future 'ULSF', 2011). Many scholars, including Rappaport and Creighton (2007), support the view that universities are more suited – than the government or the private sector – to effectively involve the local community in developing and promoting sustainability principles.

Next, by drawing on earlier empirical evidence, an effort is made here to reflect on other roles played by research universities in supporting the establishment of leading renewable energy industries. It was decided to focus on US and German solar PV industries, as their formation has been the subject of extensive research recently conducted in collaboration with the MIT. As part of this joint research project, a total of 115 interviews were conducted: 23 interviews in Massachusetts; 40 interviews in California, 2 interviews in other US states, 24 interviews in Germany and 26 interviews in the UAE with companies, researchers and public policy actors. Eastern Massachusetts and Northern California have emerged as instructive and highly relevant regions to investigate in the USA as they have the largest concentration of firms involved across the value chain of solar PV technology. It is estimated that there are 65 companies involved in Massachusetts and more than 200 companies in California, most of which are located in the Silicon Valley (Vidican, 2009).

Our examination of the historical development of the solar PV industry in both these leading countries indicates that research universities have been active – though at varying intensities – in pursuing new knowledge, pushing the technological frontier, setting the agenda for future research and in fostering strong collaborative networks between academics, the business community and relevant governmental agencies and officials. When compared to private firms, however, it has become apparent that universities have a different attitude towards transparency and exchange of information. Whilst universities are usually committed to exchanging ideas and knowledge, firms tend to be extremely parsimonious when it comes knowledge sharing. One of the notable differences is that Germany has enjoyed high and consistent R&D funding for joint projects between industry and research labs. On the other hand, there was high R&D funding in the USA initially, but this was lowered after the 1980s and was provided on a less consistent basis. Considering the evolution of the PV industry in California, we found that although the role of national research laboratories played a minimal role during the early years, their contributions increased from the late 1970s with regard to supporting the development of solar PV technology. It should be noted that from 1980, and particularly after 2001, research universities have played a major role in establishing the PV industry in California. Stanford University is often accredited for the development of almost every technological innovation in the Silicon Valley. The role of this university has indeed been instrumental during the formative phase of the computer and semiconductor industries, which in turn provided a fundamental resource for the development of PV technology. In general, we found that US universities have contributed much in terms of developing scientific ideas, attracting individuals with scientific expertise to the region and in providing access to networks of entrepreneurial resources that enable the formation of startups (Colatat et al., 2009).

Marinova and Balaguer (2009) examined the development of the solar PV industry in Australia using the NIS theoretical perspective. It was pointed out that, unlike the cases of Germany and Japan which have a strong industrial fabric, manufacturing expertise and history, the Australian PV industry was started in an academia-scientific environment. They argued that although the first Australian organizations involved in PV were in academia from the 1970s, strong institutional-related barriers have prevented Australia from becoming a leader in the PV field. It was suggested that the limited number of active actors involved with the Australian PV industry has failed in influencing the policy agenda. This situation seems to largely contrast with the German case where the influence of interest groups and public support for renewables has been active in provoking change in the incumbent institutional set up and in policy frameworks. One of the reported limiting institutional factors is the nature of research funding. More specifically, it was pointed out that the Australian Research Council has had the tendency to allocate funding on the basis on previous scientific excellence. Consequently, most of the funds went to research groups who already had a good track record in academia as opposed to newer or smaller research groups. Considering the case of Japan, the structure of funding for the Japanese PV-related R&D programs followed a pragmatic approach that gives priority to fund projects on the basis of technological development for mass manufacturing and innovative solar cell technologies. Such a pragmatic institutional set up strongly contrasts with the 'good science' approach adopted in Australia. Another limiting institutional factor is a lack of sustained policy support for R&D activities in general. According to academic researchers working at Australian universities, forming a research group that is able to produce significant research outcomes requires at least ten years of continued work and a critical mass of dedicated researchers and equipment, all of which were limited due to a lack of a stable source of funding. Moreover, it usually takes several years before knowledge generated through successful R&D projects may be absorbed by the industry and hence produces a noticeable impact, if any at all, on the economy. For example, econometric estimates by Adams (1990) suggest that it may take as long as two decades before additions to the stock of US academic knowledge generate a minor, yet measurable, effect of 0.5% on US macroeconomic productivity growth. According to another study conducted by Mansfield (1991), the average time lag between the successful conclusion of the relevant academic research and the first commercialization of the innovations based on the findings of that research is estimated to be around seven years, with the period being longer for large firms than for small ones.

Many studies have shown that sustained public research support is crucial in establishing renewable energy industries. Moreover, it appears that the success of R&D programs is more related to how the funding is managed and directed than to the total amount of funds allocated. For example, although the US has put more money into wind power-related R&D than any other country; the story of the US wind industry has not been as successful as that of their Danish or German counterparts. In addition, renewable energy R&D has been found to be most effective when there is a strong degree of collaboration and coordination between the private sector, national laboratories and universities (Lewis and Wiser, 2007). This underscores the importance of having research-driven entrepreneurial universities that maintain strong links with the private sector[7]. However, our earlier research has revealed concerns regarding the increasing emphasis on applied research, at the expense of fundamental research, when the research funds come from private sector (Vidican, 2009). In this regard, Welsh et al. (2008) highlighted the need for intelligent and creative policies, set by the both universities and their respective governments, which not only facilitate university interactions with the industry but also protect the autonomy and operational freedom of university scientists. As a final note to this section, it is should be borne in mind that the degree of university autonomy varies from one country to another. In some countries, most universities and their activities fall directly under the responsibility of the national government. For instance, consider the source of research funds. In the USA there exist a number of public research institutes (i.e. national laboratories) and most of the research funds come from the Federal government, yet the vast majority of German Universities tend to be financially independent. In the UK, academics rely

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[7] Quite often, universities need brokers to create windows of opportunities for strategic partnerships with the private sector. For example, the Stanford Photonics Center was established at Stanford University in order to facilitate communications with the private sector and leverage cross-disciplinary knowledge. More specifically, a former entrepreneur was brought to identify interesting ideas and research projects, and then link researchers across different departments together and with potential collaborators from the solar PV industry (Vidican, 2009).

heavily on research councils that award R&D funds based on a competitive basis (Edquist, 2005).

4. The Role of Research Universities in Industrializing Asian Countries

Universities in developing countries have long devoted almost the entirety of their resources to undergraduate education, which mostly utilizes knowledge imported from advanced countries. Given this situation, one would expect to find the role of research universities to be well established within western countries, which tend to enjoy competitive advantage in terms of cutting-edge scientific research that is primed to produce discoveries and new insights. With their close ties to industry, such leading universities in the west are also suited to commercial exploitation of the outcomes of their academic research (Tijssen, 2006). However, as noted by Etzkowitz et al. (2000), the pattern of transformation towards entrepreneurial research-driven universities is becoming “a global phenomenon with an isomorphic development path, despite different starting points and modes of expression” (p.313). The authors went further to suggest that the creation of MIT-like research universities has always been a strategy for latecomers or lagging regions to build up industrial clusters and a collective identity. Observers including Robertson (1999) and Vela (2007) have noted a rapidly growing interest with regard to setting up university technology transfer policies, mechanisms and practices around the world. For example, it has been noted that many developing countries have attempted creating policy frameworks that emulate the Bayh-Dole Act and have also established university technology transfer offices, science parks and business incubators. These have been initiated together with policies intended to foster the universities’ role in economic development, the formation of clusters and of public-private R&D agreements that facilitate North-South and South-South cooperation. Nonetheless, transforming existing universities to embrace a ‘third mission’ is neither an automatic nor a painless journey, as local circumstances can sometimes hinder a smooth transformation (Srinivas and Viljamaa, 2007). To the best of our knowledge, there has been no systematic study, NIS-based or otherwise, of the role played by research universities in earlier experiences of industrial catch-up. What seems to be available in the literature is a scattered collection of individual cases, described at different levels of detail. Drawing from the limited sources available in the literature, the following is a brief review of the contributions played by universities within some of the industrializing Asian nations.

An instructive case to consider here is that of Korea, which has made phenomenal economic and industrial achievements over the past four decades under the most unfavorable socio-economic circumstances. This Asian country inherited an economy distorted by 36 years of colonial rule (1909-1945) and its industrial base was utterly flattened during the Korean War (1950-1953). Therefore, when Korea started its drive towards industrialization in the early 1960s, it had to face all the problems and challenges that poor and developing economies have to address. The Korean modernization journey relied heavily on education and human resource development. Enrolment at various levels of formal education has increased rapidly, which has served as an excellent source for the development of indigenous scientific and technological capabilities. For example, enrollment in elementary education reached 100% by 1970. In addition, the number of researchers with Ph.D. degrees increased more than tenfold from 3,417 to 36,106 over the period 1980-1996 (Chung, 2001).

However, Kim and Leslie (1998) pointed out that educational programs in science and engineering within Korean universities during the 1960s were insufficiently matched to the reality and needs of the industry. Indeed, an emphasis was initially placed upon developing theoretical knowledge that appeared to be geared to preparing students for either careers in academia or admission to foreign universities. As a result, it was estimated that over 2,000 Korean scientists and engineers were living abroad in 1968. However, a reverse brain drain has occurred over the last quarter century due to a growing demand for scientific talents in the private sector in addition to massive R&D investments as well as the creation of public research organizations and entrepreneurial academic establishments. One example of this is the Korea Institute of Science and Technology (KIST), established in 1966 as a result of several years of negotiations between the Korean and US governments. In order to keep close the scientific objectives of its research agendas to domestic development needs, the KIST was charged with carrying out contract research for both industry and government, along the lines of the Battelle Institute in the USA. KIST's initial staff consisted of Korean expatriate scientists and engineers, most of whom were appointed and trained in conducting contract research at Battelle, which in turn served as a KIST's sister institute during the first years of operation. Prior to the establishment of the KIST, discussions were held with Korean firms in order to identify the technology areas that were of crucial importance to Korea. Subsequently, five broad technical areas were decided upon: food technology, mechanical engineering, chemical engineering, materials science and electronics. The KIST became heavily involved in research activities aimed at various industries namely shipbuilding, steel, chemicals and industrial machinery (Mazzoleni and Nelson, 2009).

Kim and Leslie (1998) criticized the KIST's desire to win Nobel Prizes when its mission clearly stated the intention "To satisfy the needs of Korean industry and Korean industrial establishment for highly trained and innovative specialists, rather than to add to the world's store of basic knowledge" (p. 170). Whilst the KIS was responsible for the development of several patented technologies, this should not denigrate its vital contribution to the development of indigenous capabilities through collaboration in technology transfer projects with local and foreign firms, as well as reverse engineering projects. Moreover, together with a number of other public research institutes, the KIST played an important role in both training personnel and demonstrating the importance of R&D activities to private corporations. Interestingly, there has been a dramatic shift in the balance of funding from the public to the private sphere. Whilst the Korean government provided more than 80% of national R&D funding when the KIST was first established, the private sector contribution to national R&D exceeded 50% in 1977 and rose to over 80% in 1988[8] (Mazzoleni and Nelson, 2009).

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[8] The ratio of 20% public-80% private has more-or-less maintained ever since. It is also interesting to note that during the mid-1960s, when Korea's per capita income was not much higher than that of Ghana, its R&D spending was just 0.5% of the country's Gross Domestic Product (GDP). The share of R&D expenditure increased 2.7% by the year 2004 (Dahlman, 2010).

Nonetheless, as pointed out by Chung (2001), the vast majority of Korean R&D performers, and recipients of national R&D funds, were public research institutes as opposed to universities. It is apparent that whilst Korea has achieved significant economic and industrial achievements when compared to other developing countries, its universities are not as actively involved in research activities as their foreign counterparts are. Consequently, university research, and its contribution towards the development of basic science, is significantly weak. Moreover, the interactions between major actors in the Korean NIS (such as universities, research institutes and industries) are nowhere near that level of collaboration witnessed in advanced countries. According to NIS scholars (e.g. Lundvall, 1992; Edquist, 1997), fruitful collaboration between such actors involved in R&D activities is key for international competitiveness.

As with the case of Korea, Taiwan faced the problem of mass migration of Taiwanese students to foreign higher education during the 1960s. However, a large number of these foreign-trained nationals were then critical to the later development of the Taiwanese higher education system by staffing emerging R&D institutes in the public and private sector. Moreover, following the establishment of the Hsinchu science-based industrial park in 1980, a large number of foreign-trained Taiwanese returned home to found, or invest in, most of the new firms based in this park (Science and Technology Information Center, 1997). Mazzoleni and Nelson (2009) noted that Taiwanese public research institutes played a more important role than their Korean counterparts. Whilst only 20% of national R&D funding was provided by the Korean government in 1987, the Taiwanese government contributed to around 60% of its national R&D spending. As a result of the generous spending of the Taiwanese government, several public research institutes were created including the Industrial Technology Research Institute (ITRI), which was established in 1973 through merging three existing research laboratories namely the Union Industrial Research Laboratories, Metal Industrial Research Institutes and the Mining Research and Service Organization.

In subsequent years, the ITRI created a new laboratory dedicated to research in electronics and semiconductor technology, named the Electronics Research and Service Organization (ERSO). The latter was active in licensing technologies from foreign firms, creating pilot plants to master the technologies and, at the same time, provide training for local personnel. When an ERSO research project was concluded, the leapfrogged technologies often transferred to spin-off firms whilst the trained engineers went out into the industry and provide industrial firms with the technical expertise needed to draw fruitfully from that research. In essence, Taiwanese industrialization has been based on learning as opposed to invention, Governmental support for R&D activities at both public research institutes and universities has played a key role in promoting an inward transfer of technologies that typically takes place through foreign direct investment, subcontracting with foreign firms and joint-ventures between local and foreign firms.

In a somewhat similar vein to most industrializing Asian nations, tertiary education has taken precedence over academic research in Malaysia and Singapore. Most university research has also focused on developing an ability to adapt and apply foreign technologies for the local market. In Malaysia, in particular, entry to university has long been regarded as the principal mean to attaining well paid high-level jobs in the public sector, as opposed to becoming scientists or researchers. Another observed trend there is the expansion of private universities and vocational training establishments. Psacharopoulus (1980) described Malaysian universities as 'failed change agents', citing studies that argue inappropriate transfer of university structure and planning models from the west and lack of university contribution to academic research or consultancy. For example, it was reported that a consultancy offer for a principal manufacturer in that region, named the 'Klang Valley development project', was turned down by the University of Malaya on the basis of a lack of sufficient technical skills and managerial expertise. In general, workers employed in the Malaysian private sector seem to be less educated than their public sector degree-holding counterparts. The situation is different in Singapore, whose public and private sectors seem to be staffed with relatively highly-educated and skilled individuals. In addition, despite the fact that foreign university programs run within Singapore as well, balance and control are considerably less distorted than in the case of Malaysia. It is true that the development of Singapore as a regional financial center cannot be attributed to the role of its universities, but rather to the monitoring and increased openness of the Singaporean economy. However, many of its universities – including the National University of Singapore – have followed established practices in academic excellence such as evaluating academic research on a peer-review basis. They were also active in easing tension during periods of labor shortage through implementing training programs for old workers (Milne, 1999).

Although the industrializing experience of each Asian nation is different, there are common features that have been noted in the review above. Mutual interests between government and industry, development of human capital and openness to the international economy have all been driving forces. In addition, an emphasis has been placed on conducting engineering-based and applied R&D as opposed to basic research. In fact, it has been reported even countries as advanced as Japan still do relatively little basic research. Despite the fact that the USA used to conduct more basic research than any other country, its share of basic research has been declining with cutbacks in government spending. In this regard, one could argue that developing indigenous capabilities in the basic sciences, even for developing nations, is important for training purposes since, for example, engineers need to have solid training in physics and mathematics. Moreover, whilst a few Asian countries have recently achieved significant economic achievements, their universities are less developed than western ones in terms of scholarly research activities, R&D investment, research facilities and equipment as well as in entrepreneurial undertakings. Compared with other developing countries, however, Korean universities appear to be performing relatively well. One way to quickly assess the strength of universities in R&D is to examine a global ranking of the best universities. Whilst the significance and validity of such classifications and ranking leagues are largely contentious due to the heterogeneity of the methodologies and standards used, the most comprehensive ranking – with a strong focus on research capacity and quality – appears to be the one developed by Shanghai's Jiao Tong University. According to its recent rankings of the world's top 500 universities, China is the best developing country performer with 30 universities, followed by Korea with eight universities (Dahlman, 2010). For the foreseeable future, however, it is apparent that various actors within developing countries will need to engage with the global R&D research community to keep up to date with rapid advances in science and technology in order to support both the creation and sustained development of their local industries. In this regard, significant contributions could be provided by universities within the developing world if they transform themselves to entrepreneurial research-driven universities.

5. Concluding Remarks and Policy Implications for the UAE

Prior to commenting on ways in which universities in the UAE could contribute towards the creation of a renewable energy industry, it is useful to highlight the current standing of the K-12 sector (i.e. primary and secondary education), which is an important constituent of the NIS that has not been discussed yet in this paper. To that end, we believe that the learning framework of K-12 education needs to be geared forward toward subsequent higher education in the field of sustainable energy. It is worth mentioning here that the Masdar Institute of Science and Technology, (a private, research-based and non-profit university established in Abu Dhabi in collaboration with the MIT), has recently signed memorandums of understanding with both the Abu Dhabi Education Council and the Ministry of Education in order to raise the level of instruction in subjects related to both energy and the environment[9]. Nevertheless, not only does the education system in the UAE need to work on enhancing energy and environmental awareness among the younger generation, it also needs to develop their scientific knowledge and entrepreneurial skills.

[9] A promising initiative, which has recently been initiated by the Masdar Institute, is known as 'Young Future Energy Leaders' (YFEL). This program aims to increase the awareness of students and young professionals with regard to renewable energy and sustainability. The YFEL program offers young students, from the UAE and abroad, an opportunity to engage – with leaders of today – in debate and discussions about the future of energy and seek sustainable solutions to the challenges of climate change (Masdar Institute, 2011).

One effort worth highlighting here is that of the Technology Development Committee (TDC), established by the Abu Dhabi Government in 2009. According to our research, the TDC has been involved in launching extensive outreach campaigns for young Emiratis, with the aim of developing their interest with regard to S&T and the engineering fields. Recent empirical research conducted by one of students at the Masdar Institute suggests that exposure to S&T subjects during school time could positively influence students' aspirations and hence increase the likelihood that they will consider applying for S&T and engineering degrees (Aswad, 2011). Of course, the abovementioned initiatives will not produce results overnight, raising awareness and enhancements to education in general may well take a generation to bear fruit. According to current official statistics, only 7% of Emirati nationals are employed in S&T and innovation-related industries (Calily, 2011). Aswad (2011) highlighted the significant misalignment that currently exists between labor market demand and the specialization of university students in the UAE. In spite of the abundant availability of jobs in the S&T and engineering fields, there is a growing oversupply of graduates in the humanities and social sciences. The situation is more pronounced among female Emiratis, most of whom prefer to study non-technical subjects with the hope of securing relatively permanent office-based jobs in the public sector.

Given the focus of this paper, a primary search was conducted to identify universities and colleges in the UAE that offer S&T or engineering-based curricula, which could ultimately provide inputs for knowledge production in the UAE renewable energy industry. In total, thirty-two universities and colleges were identified, 70% of which are located in Abu Dhabi and Dubai. However, it became apparent that the Masdar Institute of Science and Technology is the only academic establishment that focuses its curriculum on renewable energy technologies. It is also perhaps the only university in the UAE that could come near to the classification of a research university – as per the developed world's standards. In fact, with the obvious exception of the Masdar Institute, the sole purpose of establishing all the universities and colleges in the UAE was teaching as opposed to research, let alone fulfilling the third mission of promoting entrepreneurial-based economic development. This situation is somewhat understandable given the need to provide tertiary education and vocational qualifications to a rapidly growing young population in this developing country. A disappointing fact reported in our earlier research is that whilst more than 67% of the total UAE population is younger than 30 years old, enrolment in higher education and postgraduate education is very low compared to other developing countries. The UAE, therefore, continues to be characterized as a resource-rich developing country with a small scientific research community that has a limited access to research funds (Colatat et al., 2009).

Unlike the other UAE universities, however, the Masdar Institute was established with the vision of “becoming a leading worldwide research and academic hub, and a main source for locally generated intellectual property”. Prior to their appointment, faculty members receive special training at MIT and engage in long-term research collaborations with MIT academics. Moreover, not only has the institute established partnerships with other leading universities and research institutes internationally, it has also been equipped with cutting-edge laboratories, with the intention of enabling researchers to make scientific breakthroughs. However, given the country’s limited technological capabilities and industrialization history, a more realistic target could have been an attempt to adapt foreign technologies to the local context instead of the announced intention of focusing on basic research for technological development. In effect, it is suggested that rather than trying to ‘reinvent the wheel’, the UAE should adopt the technological adaptation approach that was followed by the Asian Tigers during their early days of industrialization. One of the efforts undertaken by the Masdar Institute in this respect has been a large-scale field study where the performance of solar panels, produced by several worldwide manufacturers, was tested when operating in the harsh weather environment of the UAE. In essence, an attempt was made to examine how different technologies endured the effects of heat, dust and humidity over a period of eighteen months. This experiment was indeed a promising step that could provide input for future undertakings to adapt foreign technologies to the local conditions of the UAE (Vidican et al., 2011)

Currently, the Masdar Institute offers eight cross-disciplinary graduate programs in chemical engineering, electrical power engineering, mechanical engineering, water and environmental engineering, engineering systems and management, microsystems engineering, material science and computing and information science. In effect, the institute was founded to set an example by moving away from the old model where universities were discipline-centered and used to teach subjects as if they were arranged in tiny and isolated boxes. Such disciplinary boundaries limit creativity and collaboration potential, not to mention the fact that most real-life problems (especially energy-related ones) are not disciplinary by nature. At the moment higher education in the UAE – and in most of the world as pointed out by Cortese (2003) – is by and large organized into highly specialized areas of knowledge and traditional academic disciplines. Such a setting stresses the importance of individual learning and competition, resulting in researchers who are ill prepared for cooperative efforts.

It appears that whilst the Masdar Institute has done a terrific job – since its establishment in 2009 – on the education and research fronts, there is still the potential to do more in terms of fostering networks of collaboration between the relevant government agencies, industry and academia. For instance, whilst the institute has been working closely with the recently established International Renewable Energy Agency, it is noted that the institute does not currently have a technology transfer office, a science park or a spin-off incubator. Building such networks (not to mention advocacy groups that are strong enough to advance the renewables agenda) in the UAE is seen as instrumental in supporting the creation of a national renewable energy industry in such an oil-rich country. Such limited interaction between the different NIS actors appears to be a common feature in the UAE even in non-energy related fields. Therefore, there is an urgent need to coordinate the efforts of all relevant actors and their capabilities, and to bring them together to function as an integrated system. In this regard, the Masdar initiative has strong potential to not only develop advocacy groups but also to act as a catalyst for guiding and organizing the establishment of the UAE renewable energy industry. The previous Provost of the Masdar Institute went further and suggested that the aim of this initiative is to create a new 'Silicon Valley' around sustainability and renewable energy in Masdar City, with the Masdar Institute acting as the centre of gravity in a similar fashion to the pivotal role that Stanford University played in the formation of the Silicon Valley (Perkins, 2009). Indeed, no initiative – even one as ambitious as the Masdar initiative – will be able to create a sizable renewable energy industry on its own, not without readjusting and redirecting all relevant actors and institutions towards accomplishing this massive task. We believe that this will need to be accompanied by a fundamental shift in the way renewables are traditionally viewed by all stakeholders including the UAE national oil companies, leaders of local society and the general public of this oil-centered country. To quote Albert Einstein, "The significant problems we face cannot be solved at the same level of thinking we used when we created them" (Calaprice, 2000: 317).

Before concluding this paper, it is definitely worthwhile revisiting the work of Richard K. Lester on the role of university in innovation. Having conducted large-scale research that examined multiple industries within different countries, Lester (2005) argued that the role played by universities varies to a large degree according to the type of industrial transformation pathway being followed in the country where the universities operate, in addition to its current stage of development. More specifically, four potential innovation-led pathways were identified as part of this work: (i) Creating new industries that are entirely new with no technological antecedent in the regional economy; (ii) Transplanting industries from elsewhere; (iii) Diversifying into technologically-related industries; (iv) Upgrading existing industries. Lester (2005) went further to suggest the kind of contributions that are expected from universities under each of the different pathways (see Figure 2).

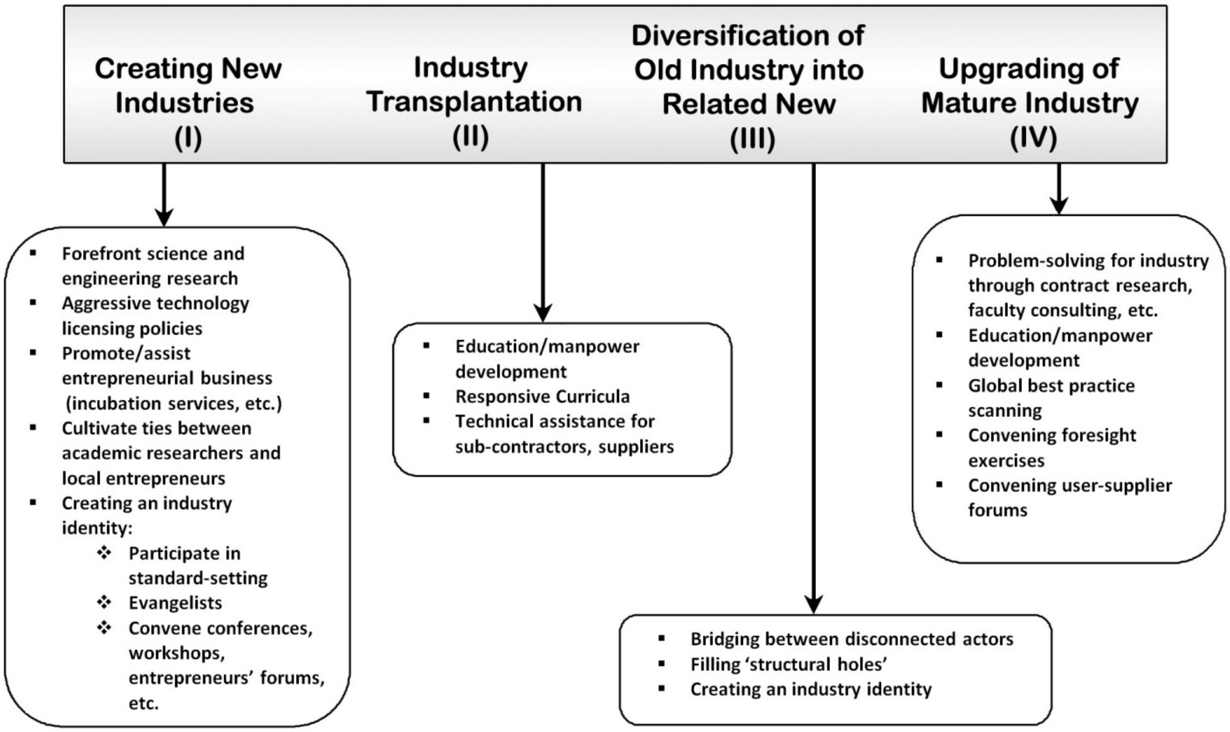

Figure 2: University roles in alternative innovation-led growth pathways (Lester, 2005)

Whilst these types of growth pathways are not mutually exclusive, one type usually emerges as the most dominant for a particular development occasion. Considering the case of the UAE, the adopted transformation process underway involves creating a new renewable energy industry. However, given that the renewable energy industry is already well established in other locales, the UAE could be classified as undertaking an industry transplantation innovation-led growth pathway. Consequently, key roles for universities include the provision of education, development of local manpower and responding to the needs of relocating firms through developing customized curricula and continuing education programs. Additionally, universities could provide technical assistance to both local suppliers and sub-contractors. Universities in the UAE also need to model sustainability into all their functions, operations and engagements with both local and national communities. However, whilst research universities (such as the Masdar Institute) are positioned to contribute towards a move from an economy based on natural resources into a knowledge-based era in the currently hydrocarbon-rich UAE, one needs to be realistic and careful not to overstate the potential roles to be played by these universities. For instance, an emphasis should be placed on the exploration, adaptation and commercialization of technologies as opposed to generating new scientific knowledge from scratch. A compromise needs to be struck somewhere between local industry needs, national absorptive capacity and the internal capabilities of these universities. As argued by Lester (2005) himself, "…[U]niversities cannot be all things to people, and a failure to formulate and clearly articulate an institutional strategy for economic development risks underperformance in this domain, interference with other institutional goals, increased conflict within the university, and disappointed external constituencies" (p. 29).

In this paper, we have built on these arguments and suggested here that as long as the capacity of other NIS actors in the UAE is not sufficiently leveraged, the role of research universities is likely to be curtailed. To that end, one cannot overemphasize the importance of embracing NIS thinking in national S&T planning and public policy in order to both understand the innovation dynamics of the UAE's local context and guide its transition to a knowledge-based economy with an emphasis on renewable energy innovations. It is unlikely that these long-term goals will be achieved if the government chooses to continue its overreliance on short-term consultants for policy work. Rather than believing in the principle of 'getting the incentives right and everything will follow', attaining a thorough NIS-based understanding of the status quo should be a policy priority.

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