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Contents

An Investigation on Input-Output Indicators of Innovation Strategies of Singapore and UAE

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Abstract

This paper exhibits the salient properties of innovation and scrutinizes the innovation strategies of Singapore and UAE. The term innovation can be engaged broadly in various economic terms whereas this study specified the generalized form of innovation for a country to achieve the economic and social wellbeing. The study focused on the case study approach by using descriptive statistics. Some significant indications of advanced innovation setting are seen in Singaporean economy in contrast to UAE. Possession of huge in land natural resources in UAE region could not assist the sound development of innovation condition whereas it is visible in Singaporean economy with very low natural resources in proportion of UAE. Singapore's exports of high tech products are 10 to 5 times larger than those of UAE which signal the better innovation and investment condition of the former. The business incubation is appreciated and banks are found broad toward the startups. The South-Eastern country also identified in better situation than the gulf country in knowledge based innovation—in account of patents and scientific articles published by the residents. The study found innovation as a thrust in economic activity for a country. UAE is a better performer in cost of doing business compared to Singapore. Some more effective policies should be in operation in order to prolong the continued development trend of Singapore, whereas UAE needs more engrossment on business incubation, openness of trade and proper utilization of natural resources.

Keywords: UAE, Singapore, innovation, input-output variable

1. Introduction and Literature Review

Singapore and UAE have already assured their position in the world economy. The indicators of economic wellbeing and economic sovereignty vary in the context of these two countries. One of the most influential factors is innovation for sustainable growth strategy of these countries. Innovation has always played a critical role in predicting the long-term survival of organizations. Afzal and Siddiqui (2015) inquired national innovation systems' (NIS) input-output components and formed an efficiency measurement using the partial frontier order-α technique.

In their paper the countries were ranked based on outliers-corrected estimation while this paper uses descriptive analysis to exhibit the current status of Singapore and UAE innovation strategies. In that study, Afzal and Siddiqui (2015) recommended some policies to the efficiency performance of NIS activities in the transformation of knowledge economies.

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Zemplinerová and Hromádková (2012) postulates that innovation input significantly increases innovation output, with increasing firm´s size, *ceteris paribus*. The paper exercised four stage model (CDM) over the period 2004-2007. Pursuant to Wong and Ho (2007) locally produced new knowledge although insignificant and growing is a source for innovation in Singapore.

Wan et al. (2005) investigated the relationship between firm innovation and six of its potential determinants using data from 71 companies in Singapore. The result showed that firm innovation had significant and positive correlations with its determinants. Keivani et al. (2003) described that Dubai has a highly developed ICT infrastructure and suggested to develop its local and community ICT networks as the logical extension of its ICT development program.

According to WCY-2014 data, Singapore and UAE have high HDI index with 0.91 and 0.85 respectively, decent financial mobilization, low poverty rate, port facilities while the overall higher education system is high with indexed 8.20 in Singapore and low with 5.20 in UAE currently. There are common determinants of innovation in these two countries.

Both Dubai and Singapore enjoy great strategic locations and are located in the midst of economically well-off geographies; Dubai in the midst of rich gulf states and Singapore in the midst of South East Asian tigers. A stronger economic environment ensures liquidity for business, ease of establishing and doing business, investments in infrastructure, etc.

Both UAE, especially Dubai, and Singapore are economically well off, enjoying a high GDP growth and per capita income.

According to Shamel Janbek, Chief Technology officer at China's ICT giant Huawei: "By no means is Singapore the leading smart city in the world, but Dubai is determined to take over this role in the coming years." He said: "I think Dubai is very close to surpassing Singapore soon."

A closer look would bring into focus the many similarities shared by these two dynamic and cosmopolitan maritime and aviation hubs of Asia and the Middle East. Taken together, these make Dubai and Singapore fascinating models for studies of comparison, contrast and benchmarking. Historically, both Singapore and Dubai emerged from humble beginnings near internal waterways. Both were originally simple trading settlements, with Dubai rising near its shallow creek, and Singapore founded near the mouth of its main river. Singapore's founding ideas were simple—to protect property, to enforce contracts and to open its doors for the movement of goods and of people.

However, very few studies have done to compare innovation status of UAE and Singapore using a broad range of innovation input-output indicators. Both the countries are heading towards innovation based growth strategy. Therefore, it is immensely important for the researcher and policy makers of both these two countries to get an idea where this two important port based countries stand in recent time in the context of innovation determinants. This paper is an attempt to compare and discuss the innovations features of these two countries with available data and point out the where the gaps lie.

2. Objectives of the Study

a. Detecting the salient features of innovation
b. Entrenching facts of UAE and Singapore innovative strategies

3. Theoretical Background

According to Schumpeter (1942), in each period there is one person (the entrepreneur) who has an opportunity to attempt an innovation. If she succeeds,

the innovation will create a new version of the intermediate product, which is more productive than previous versions. Specifically, the productivity of the intermediate good in use will go from last period's value A_{t-1} up to $A_t = gA_{t-1}$, where $g > 1$. If she fails, then there will be no innovation at t and the intermediate product will be the same one that was used in t - 1, so $A_t = A_{t-1}$. In order to innovate, the entrepreneur must conduct research, a costly activity that uses the final good as its only input. As indicated earlier, research is uncertain, for it may fail to generate any innovation. But the more the entrepreneur spends on research, the more likely she is to innovate. Specifically, the probability μ_t that an innovation occurs in any period t depends positively on the amount R_t of final good spent on research, according to the innovation function $\mu_t = \Omega (R/A^*)$, where $A_t^* = \gamma A_{t-1}$ is the productivity of the new intermediate product that will result if the research succeeds. The reason why the probability of innovation depends inversely on A_t^* is that as technology advances, it becomes more complex and thus harder to improve upon. So, it is not the absolute amount of research expenditure R_t that matters for success but the productivity-adjusted expenditure R_t/A_t^*, which we denote by n_t. n_t consists of factors that improve the productivity of innovation. In this paper, we have classified these as input-output factors of innovation.

3.1 Determinants of Innovation

Innovation process is one of the main drivers for knowledge-based economic growth. It can be influenced by demographic structure (population structure), ICT structure (computer uses etc.), financial structure, education (secondary, tertiary, etc.), research and development, trade openness, business startup costs, incubation costs, education, market circumstances, governance or regulatory quality, natural resource endowments, etc. Locally produced new knowledge even can contribute towards innovation.

Recent studies indicate that patent counts, patent applications, scientific and technical journal articles, high tech exports as a percentage of total manufacturing exports, etc. are innovation output variables to represent economically valuable knowledge creation. That is innovation is measured with these variables.

Observing, analyzing and comparing the input and output variables of innovation might count evaluate innovation activities. According to Schumpeter (1942), one method of assessing innovation is to distinguish between the outputs of innovative activity and the inputs to innovative activity.

4. Singapore and UAE

4.1 Singapore

Singapore is one of the Asian Economic Tigers. This country with an area of 719.1 square kilometers and a population nearly 5.6 million people has very effectively interwoven its development strategy within the global economy ring. A few simple organizing ideas and immediately, money and people and goods and services flowed in and Singapore grew very rapidly. From what has been called an "improbable nation" with little chance of survival at birth, Singapore bloomed into Asia's first global city. Singapore, a small island nation with five million residents in South East Asia, is one of the biggest success stories in Asia. After getting freedom in 1963, the tiny island state took strong initiatives toward industrialization and opening up of economy. In contrast to Dubai where oil played an important role in building up the economy, Singapore's economy is built on technology and labor skills. During the 70's, Singapore's focus on modern industries such as electronics, petrochemicals and

precision machines coupled with foreign investment helped the tiny state to transform itself into an industrial nation. Its liberal economic policies, industrious and highly skilled workforce and other natural advantage such as vast seaports and strategic location helped it attract a huge amount of MNCs to have their base in Singapore along with large amount of foreign investments. From 1963 to present, Singapore has recorded an average GDP growth of 7.9%.

Today Singapore is considered as one of the most liberal states in the world enjoying high per capita income, state of the art infrastructure and a robust economy. It had successfully diversified into services sector and is the financial and export hub of South East Asia. It is also considered as one of the most innovative, liberal and business friendly nations in the world where it takes only three days to start a business in, much lesser than the world average that stands at 34 days.

4.2 UAE

The United Arab Emirates or the UAE in the Middle East is a federation of seven emirates namely Abu Dhabi (serves as the capital), Ajman, Dubai, Fujairah, RAS al-Khaimah, Sharjah, and Umm al-Quwain. It is bordering the Gulf of Oman and the Persian Gulf and borders with Oman to the east and Saudi Arabia to the south. It comprises an area of 83,600 square kilometers. Among all emirates Dubai receives the utmost importance.

Dubai is the second largest emirate in the UAE with an area of 3,885 square kilometers comprising a population of 2.69 million. Dubai has a growth rate of 2.4%. Although being situated in a petroleum resourceful location, Dubai recently imposed immense focus on the other sectors like trade, services and finance. Dubai stands on a geographically lucrative hub area which has given a boost to the economic development through the expansion of its market in Asian and European region. The well-established infrastructure, the finance centers, various industries are all the initiatives of the Al Maktoum family who have ruled Dubai since 1833. The present ruler of Dubai is Sheikh Mohammed Bin Rashid Al Maktoum who is also the vice president and prime minister of the UAE.

An article in the Economist (2006, P1) summarizes this ambition well; “Ruled by a wealthy and ambitious family the Al-Maktoums, it (Dubai) makes no secret of its wish to become the main financial center between Europe and Asia.” HH Sheikh Hamdan Bin Rashid Al Maktoum’s statement to the board of governors in Dubai, during the 2003 Annual Meetings brings light to their present situation. “We realize that as we move forward and try to accelerate growth, we will have to diversify further our economy and export base. As part of this strategy, the government is working to create a suitable investment climate that will enable Dubai to become an international financial center as well as a popular tourist destination in the years to come.” (International Monetary Fund, 2003, p.2)

Sheikh Mohammed bin Rashid Al Maktoum launched a National Innovation Strategy on October 2014 targeting to make UAE one of the most innovative nations in the world within 7 years.

The strategy aimed at energizing innovation in the 7 sectors—renewable energy, transport, education, health, technology, water and space.

5. Methodology

This research applies descriptive analysis to compare the innovation input-output indicators. Non-experimental studies describe and analyze researchable problem without any manipulation or intervention of the situations. Here we attempt to identify the salient features and factors of innovation and describe the current status of Singapore and UAE in this regard.

5.1 Data and Variables

The factors of innovation are demographic structure, financial structure, research and development, market circumstances, openness and natural resource endowments. We express innovation as economically valuable knowledge creation. Moving averages has been used to fill the gaps for missing data. Due to lack of availability of data, we have to cope with existing data to sketch the comparison. The innovation input-output indicators are observed from various literatures (Afzal & Siddiqui, 2015; Afzal, 2015; Hsu, 2011).

The demographic structure affects innovation because young people are thought to have greater potential and be more creative than the older people. Trade openness would stimulate the speed and scope of knowledge dispersion. The credit expansion provides the base and security for innovation process. The cost of business startup procedure helps to setup the business plan with administrative procedures. Overdependence on natural resources may reduce innovation capacity. Singapore and UAE are compared basing on these variables.

Table 2 and Table 3 show the descriptive statistics for Singapore and UAE for the time period 2000-2015.

Table 1. Input output factors of innovation and their proxy indicators

Input factors	Proxy indicators	Abbreviation	Source of Variable
Demographic Structure	Labor force participation rate, total (% of total population aged 15-64)	LFP	World Development Indicators (WDI)-2015
Financial Structure	Domestic credit to private sector by banks (% of GDP)	DCB	World Development Indicators (WDI)-2015
Research and Development	R&D expenditure (% of GDP)	RDE	World Development Indicators (WDI)-2015
Market Circumstance	Cost of business startup procedures (% of GNI per capita)	CBS	World Development Indicators (WDI)-2015
Openness	Trade (% of GDP)	TDO	World Development Indicators (WDI)-2015
Natural Resources Endowment	Total natural resources rents (% of GDP)	TNR	World Development Indicators (WDI)-2015
Output factor	**Proxy indicators**	**Abbreviation**	**Source of Variable**
Economically valuable knowledge creation	High technology exports (% of manufactured exports)	HTE	World Development Indicators (WDI)-2015
	Patent applications (Residents)	PAR	World Development Indicators (WDI)-2015
	Scientific and technical journal articles	STJ	World Development Indicators (WDI)-2015

Table 2. Descriptive statistics of the input output variable (UAE)

Tests / Variable	LFP	DCB	CBS	TDO	TNR	HTE	STJ	PAR
Mean	78.16	54.78	14.2	136.9	24.64	2.71	950.1	23.27
Std. Dev.	1.36	16.98	3.07	32.65	4.16	1.96	506.6	1.9
Min	77	31.27	11	89.86	17.41	0.70	293.8	18
Max	80.8	84.4	18.8	180.47	32.39	8.46	1679.1	26
Obs.	16	16	16	16	16	16	16	16

Table 3. Descriptive statistics of the input-output variable (Singapore)

Tests / Variable	LFP	DCB	CBS	TDO	TNR	HTE	STJ	PAR
Mean	71.8375	104.9	.080	379.67	0.00	52.45	8073.1	816.56
Std. Dev.	1.58	15.05	0.16	31.44	0.00	6.28	2297.4	263.26
Min	69.4	84.7	0.6	326.1	0.01	45.15	4249	516
Max	73.7	132.1	1	439.6	0.0007	62.79	10658.5	1303
Obs.	16	16	16	16	16	16	16	16

6. Result Analysis and Interpretation

6.1 Input Variables

The input variables affect innovation in different ways. We determine the effects of these variables in case of Singapore and UAE.

6.1.1 Labor Force Participation Rate

Figure 1 illustrates the labor force participation rate in Singapore and UAE from 2000 to 2015. It is measured in percentages of total population ages (15-64). It can be seen that the participation rate of labor of UAE remained at a higher rate than Singapore throughout this time.

At the beginning of the period in 2000, the participation rate in Singapore was 71% whereas the participation rate in UAE exceeded this, at just 77%. The participation rate in Singapore dropped slightly over the next two years but from 2003 it started to rise again and 2012 onwards showed to some extent similar results.

Throughout this time the participation rate in UAE ranged between 77% and 81% and a slightly increasing trend can be seen. At the end of this period, the labor force participation rate in UAE was almost 6.8% higher than that of Singapore.

6.1.2 Domestic Credit to Private Sector by Banks

Figure 2 illustrates the domestic credit to private sector by banks as a percentage of GDP in both Singapore and UAE from 2000 to 2015. Much volatility is seen for both countries. Overall it can be seen that domestic credit provided by banks is higher in Singapore than in UAE.

Figure 1. Labor force participation rate, total (% of total population aged 15-64)

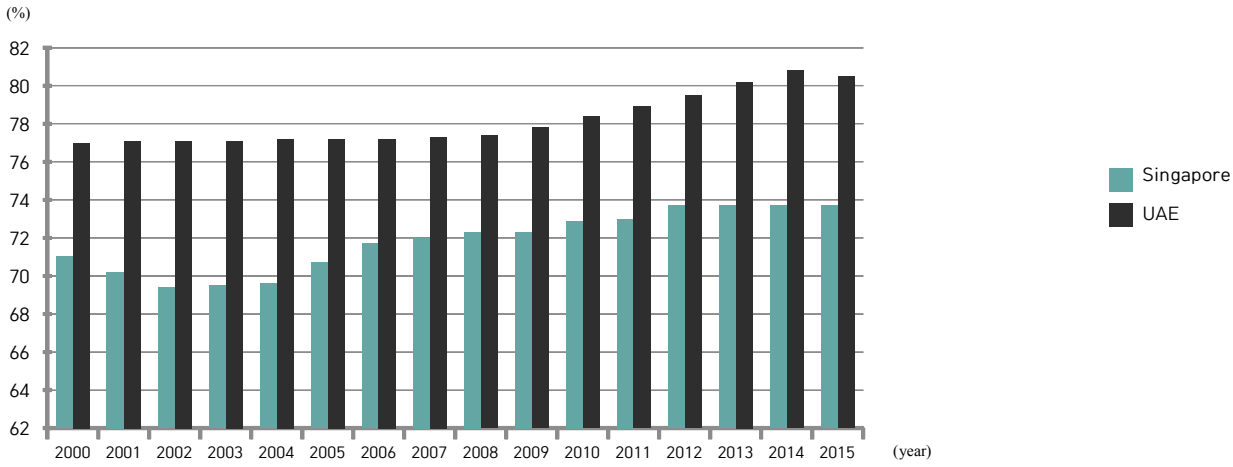
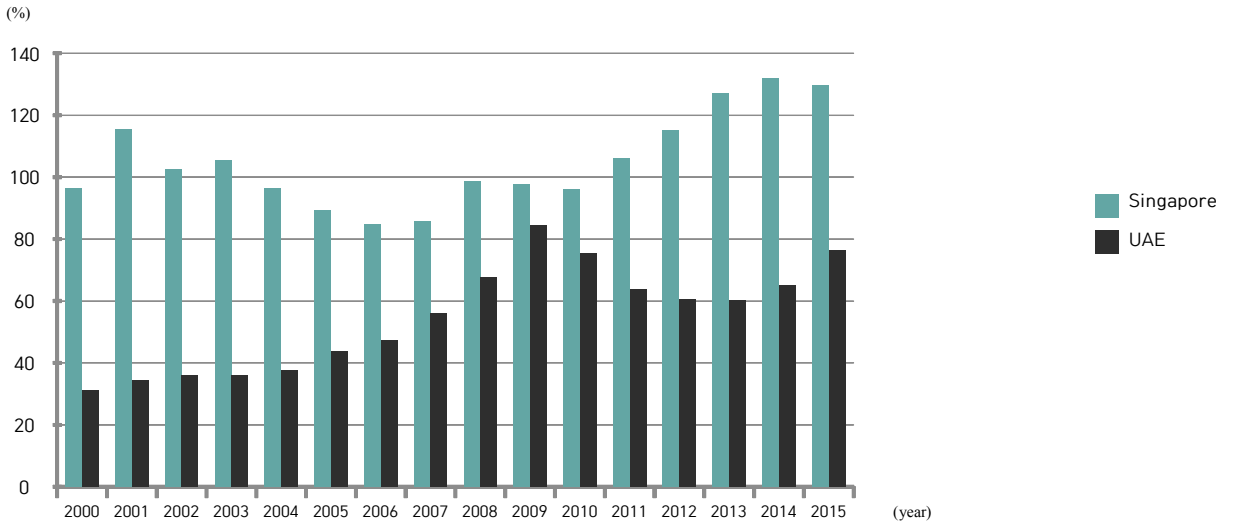


Figure 2. Domestic credit to private sector by banks (% of GDP)



An increasing trend can be seen in case of UAE during the years 2000 to 2009 but in case of Singapore there are fluctuations. A sharp increase in the domestic credit was seen from 2006 to 2009 in UAE and then started to fall until 2013 and rose again. A downward trend could be seen from 2003 to 2006 in Singapore but it remained steady over the next three years and showed an upward trend in the following years. The differences of the percentages are minimized at the year 2009 and maximized in the year 2001. There was a great recession during 2008-2009 which was a reason for the increase of domestic credit in both the countries. Singapore kept injecting capital in the following years as an aid of recovery process to the private sector but a drop was seen in case of UAE till 2013. An increase in domestic credit was seen afterwards.

6.1.3 Research and Development Expenditure

Figure 3 illustrates Research and Development expenditure as a percentage of GDP in Singapore from 2000 to 2015. The data for UAE was only available for 2011 and 2014. In comparison to Singapore, the percentage of R&D expenditure was quite low in UAE in these two years. Data is unavailable for the other years of UAE. The contribution of R&D in GDP for Singapore fluctuated between 1.8 to 2.7 percentages. It contributed highest in the year 2008, 2.62% of GDP.

6.1.4 Cost of Business Start-up Procedures

Figure 4 illustrates the cost of business start-up procedures as a percentage of GNI per capita from the year 2000 to 2015 for Singapore and UAE. Throughout the whole time the cost in UAE is very high compared to that of Singapore. Singapore maintained a very low share of GNI per capita throughout the whole time in business incubation cost ranging from 1 to 0.6 whereas the percentage was around 18% during the first four periods in UAE and then started to decline gradually with a little rise during the year 2007 and maintain trend for the next two successive years. During the last four periods UAE could maintain a cost 11% of GNI per capita. At the end of the period the differences between the results though decreased but still can be considered quite high.

Figure 3. Research and development expenditure (% of GDP)

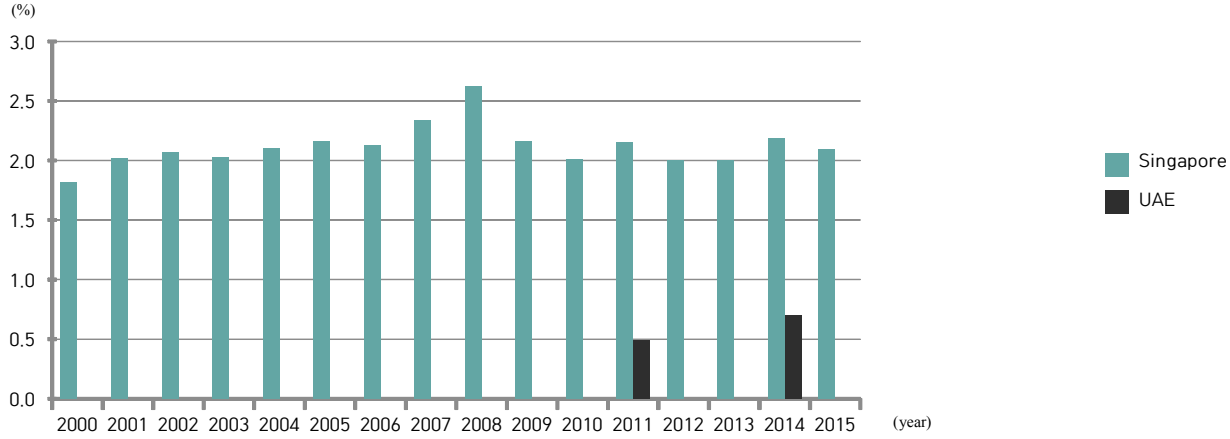
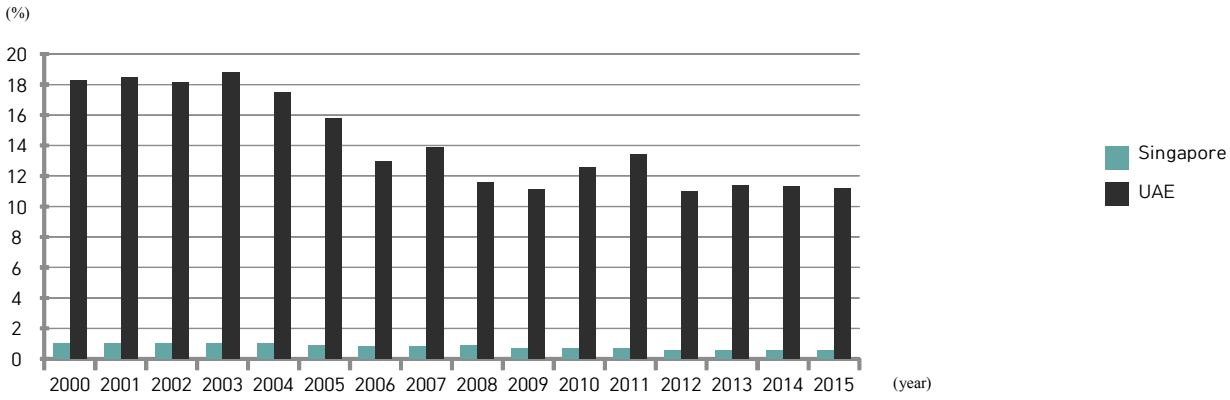


Figure 4. Cost of business start-up procedures (% of GNI per capita)



6.1.5 Trade

Figure 5 illustrates trade of Singapore and UAE as percentage of GDP from 2000 to 2015. Throughout the time, share percentage of Singapore is higher than that of UAE. UAE maintained an upward trend whereas fluctuations are seen in case of Singapore. At the beginning of the period, the trade for Singapore was 366.07 percent of GDP whereas UAE's trade share was 89.86 percent. Over the following years the patterns of the two countries were noticeably different. A sharp fall in trade is seen during 2008 to 2009 during the recession time in Singapore but UAE could maintain the same level. Both the lines converged at the end of the period minimizing gaps but still the trade in Singapore was almost twice that of UAE.

6.1.6 Natural Resources Rents

Figure 6 illustrates the total natural resources rents for Singapore and UAE between the years 2000 to 2015. It is measured in percentages of GDP. From the diagram it is very clear that UAE is a resource based country and Singapore is a resource scarce country. There are fluctuations seen for UAE ranging from 15% to as high as 32.4%. the case for Singapore is negligible in comparison to UAE. Singapore earned the highest natural resource rents during the year 2008 and due to recession, a sudden drop was seen in 2009.

Figure 5. Trade (% of GDP)

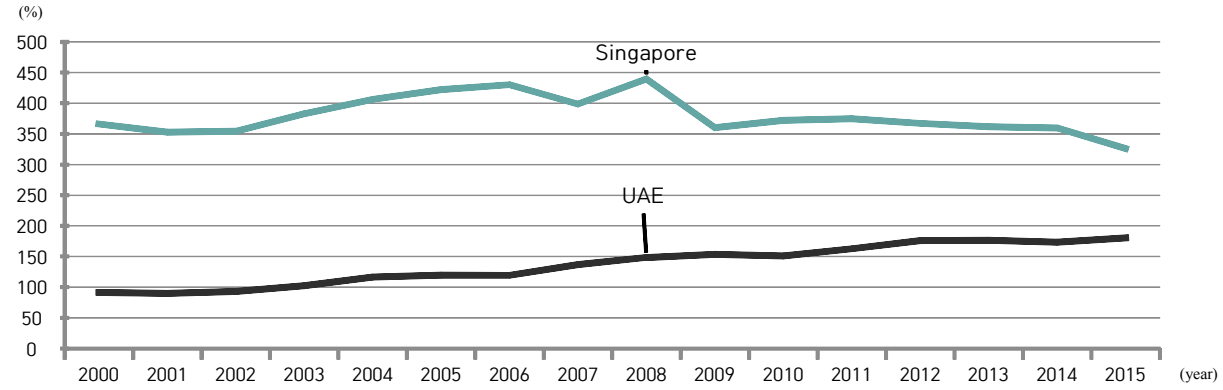
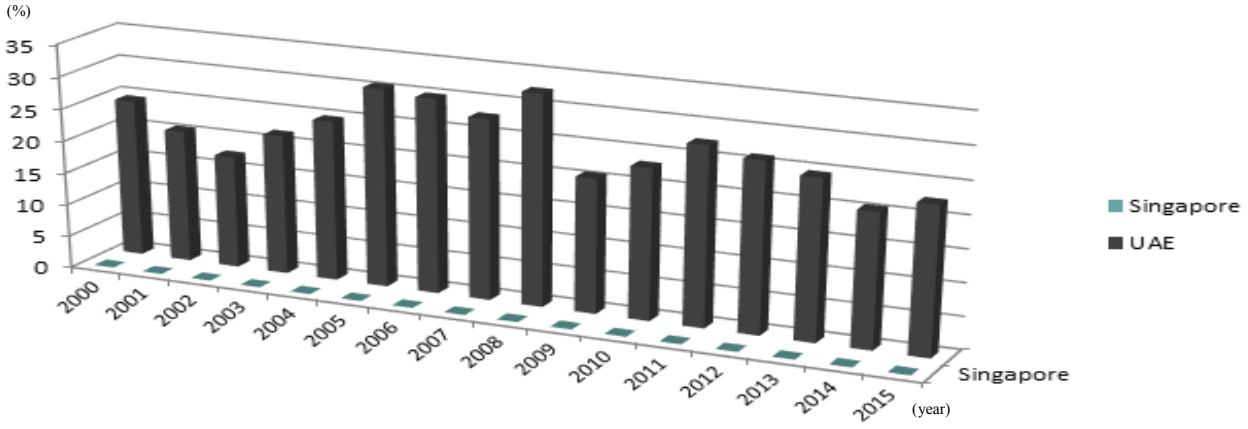


Figure 6. Total natural resources rents (% of GDP)



6.2 Output Variables

6.2.1 High-technology Exports

We determined three output variables to measure innovation in the context of Singapore and UAE.

Figure 7 depicts the condition of high-tech product exports for Singapore and UAE from 2000 to 2015. The trend maintained a rigorous path for UAE from 2002 to 2006; 2007 faced a slight fall in export and it surpassed the previous record since 2008. The trend continued till 2013. But a big leap is very clear since 2014. It peaks the highest in mentioned year. But 2015 faced lower high-tech exports than 2014. On the other hand, Singapore faced constant decrease since 2000. After that, the figure plots a scene of slight rise in high tech export from 2003 to 2006. In 2007, the entire export plummeted sharply. And the downed export trend could not manage to rise due to global financial crisis of 2008 and 2009. The year 2015 is showing an upward style in high tech export as seen in 2008 and 2010.

Figure 7. Total high-technology exports (% of manufactured exports)

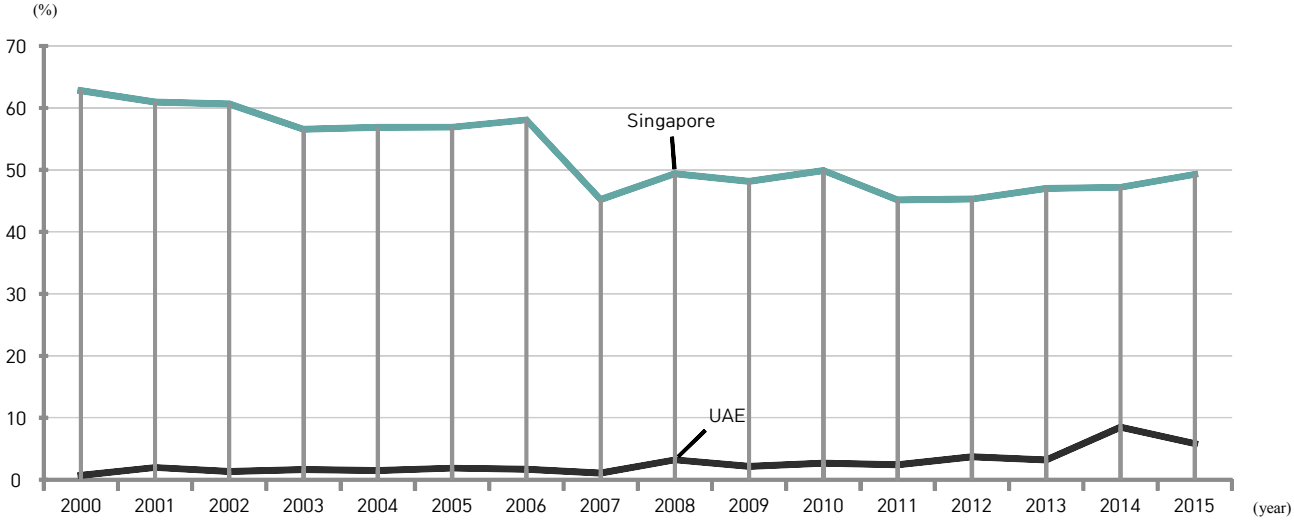
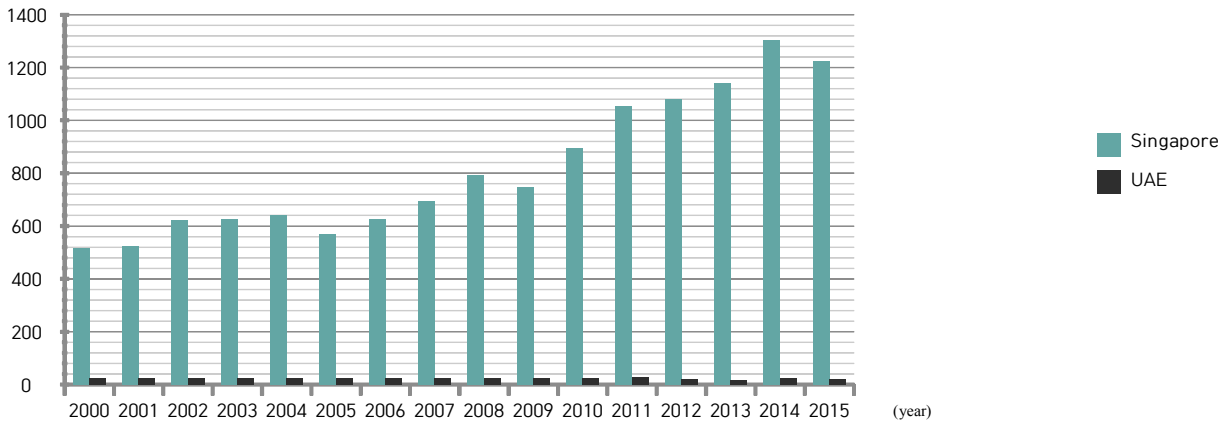


Figure 8. Total patent applications, residents



6.2.2 Patent Applications

Figure 8 is illustrating the patent application claimed by the residents of Singapore and UAE from 2000 to 2015 taking the interval of 2 years. This figure generates huge difference between the amounts of patents for these aforementioned countries. We see the patent claim is highest in 2014 for Singapore. In broad case, the trend is upward increasing. We also figure out an increase in year 2006 to 2008. And the identical boost is seen from 2010 to 2014 although the number of patent claim dipped in 2015. On the other hand, UAE maintained a rigid and constant trend in patent claim since 2000 to 2015. Comparatively, UAE lags highly in knowledge based innovation than Singapore, who kept enriching herself in such area.

6.2.3 Scientific and Technical Journal Articles

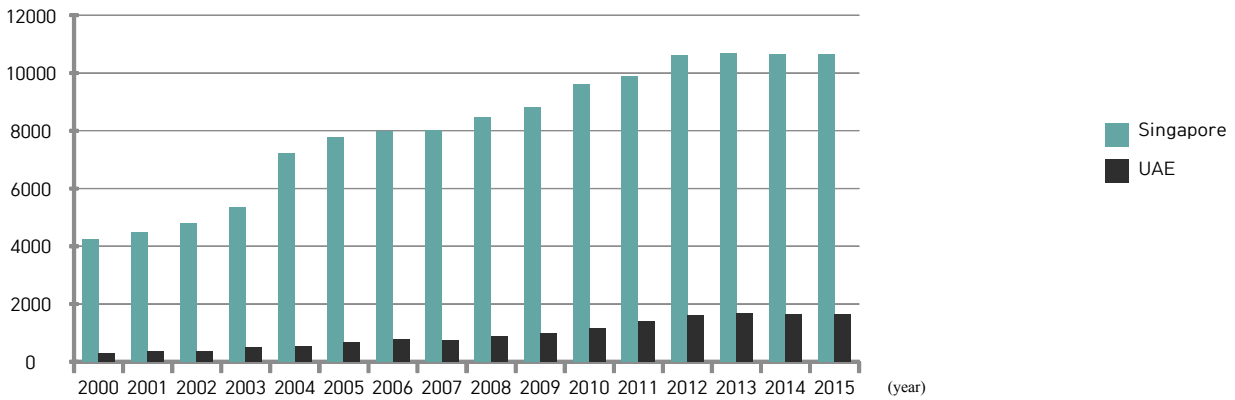
Figure 9 shows the gross scientific and technical journal article published by Singapore and UAE from 2000 to 2015. Singapore continued the upward trend since 2000 to 2015. Except sudden dips in 2002 and in 2007, UAE continued upward trending. A big difference is seen between these countries which depicts the knowledge based innovation is more compact and nourished in Singapore rather UAE.

7. Contribution of this Study

This paper makes four contributions to the literature. First, while most authors have studied the relationship between Singapore and Dubai at the urban planning innovation level or sector level for developed economies there is little known about the relationship for innovation input-output factors in these countries until now. Emerging economies currently adopting mobile phone usage, internet connections and are importing ICT goods much faster than developed economies and the impact that ICT adoption under National Innovation System has on economic growth relationship in emerging economies is an important yet under studied area. Second, this paper presents what is, believed to be the first innovation input-output data study of the concept of knowledge economy and the first from the perspective of the Singapore and UAE, particularly Dubai.

Third, a limitation of homogenous panel data approaches such as the DOLS, PMG technique, this study has used descriptive study for general reader in no-technical way.

Figure 9. Number of scientific and technical journal articles published



Additionally, this study examines the relationship of idea generation to commercialization of knowledge using the proxy variables of scientific and technical journal articles, high-tech exports as percentage of total manufacturing exports.

One limitation of the study may be that the data sample is small due to missing data that required the application of more econometric methods to test the hypothesis. Usually, variable like tertiary education expenditure, skills of the labor force, schooling in tertiary level are important to test our objective of the study. Due to data unavailability for Dubai and Singapore that do not allow us to incorporate these variables in our analysis. In future, the first difference GMM method with short time span, and the panel dynamic ordinary least square technique (DOLS) for testing the VECM model to check the serial correlation problem and the variance decomposition model to investigate the pass-through of external shocks to each variable in the model could be deployed. It is very important to make strong and robust collaboration among input-output factors relationship for the long run sustainable economic growth of these two countries. At the crossroads of globalization and as regional gateways, Singapore and the UAE have great potential to serve as trans-regional hub partners. This was the theme of the inaugural Singapore-UAE Joint Committee meeting hosted by Singapore in November 2014 and co-chaired by the Foreign Ministers of Singapore and the UAE. The East-West Asian nexus of Singapore, Dubai and Abu Dhabi and the UAE may even be dubbed the "Abu Dubai-pore Connect", a model based on robust political leadership, compelling development visions, social harmony, vibrancy and superb connectivity.

8. Conclusion and Policy Implications

In our study we examined the contemporary innovation scenario of Singapore and UAE (2000-2015) which gave us a clear premise on which we can assert that innovation is an accelerating force for a sustainable economy. This study illustrates how a resource based country and a resource scarce country is using knowledge based innovation for their economic development. Amount of high technology exports, number of patent claims of residents and the number of the publication of scientific and technical journal articles indicates economically valuable knowledge creation of two countries. Singapore is positively exceeding UAE in these three cases.

Although having a vast area and higher labor participation in comparison to Singapore UAE is apparently unable to utilize her natural and human resources. The upward trend of domestic credit reveals that private sectors are much appreciated in Singaporean economy where the setting is hostile in UAE. The identical foundation is echoed when we examined the business start-up costs in both countries. The reduction of incubation costs in UAE showed an inverse relationship with the trade openness.

To bring out the best of these economies some well-planned and rigorously managed policies should be undertaken. Firstly, every innovation initiative should be nurtured from the very primary level with the help of public and private sectors. Authority should provide favorable environment and appropriate motivation for all these innovation activities. Secondly, the trade barriers should be recognized and minimized. Trade of high tech products should be encouraged. This might induce positive boost in knowledge sharing beyond the boundary. Thirdly, newer sectors of the economy should be explored and R&D practices should be applied. Also an optimized and priority based R&D expenditure should be planned. Lastly human capital should be nurtured to increase their productivity and should get sufficient motivation for the contribution of scientific, technical and knowledge based sectors.

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Abstract

This paper exhibits the salient properties of innovation and scrutinizes the innovation strategies of Singapore and UAE. The term innovation can be engaged broadly in various economic terms whereas this study specified the generalized form of innovation for a country to achieve the economic and social wellbeing. The study focused on the case study approach by using descriptive statistics. Some significant indications of advanced innovation setting are seen in Singaporean economy in contrast to UAE. Possession of huge in land natural resources in UAE region could not assist the sound development of innovation condition whereas it is visible in Singaporean economy with very low natural resources in proportion of UAE. Singapore's exports of high tech products are 10 to 5 times larger than those of UAE which signal the better innovation and investment condition of the former. The business incubation is appreciated and banks are found broad toward the startups. The South-Eastern country also identified in better situation than the gulf country in knowledge based innovation—in account of patents and scientific articles published by the residents. The study found innovation as a thrust in economic activity for a country. UAE is a better performer in cost of doing business compared to Singapore. Some more effective policies should be in operation in order to prolong the continued development trend of Singapore, whereas UAE needs more engrossment on business incubation, openness of trade and proper utilization of natural resources.

Keywords: UAE, Singapore, innovation, input-output variable

1. Introduction and Literature Review

Singapore and UAE have already assured their position in the world economy. The indicators of economic wellbeing and economic sovereignty vary in the context of these two countries. One of the most influential factors is innovation for sustainable growth strategy of these countries. Innovation has always played a critical role in predicting the long-term survival of organizations. Afzal and Siddiqui (2015) inquired national innovation systems' (NIS) input-output components and formed an efficiency measurement using the partial frontier order-α technique.

In their paper the countries were ranked based on outliers-corrected estimation while this paper uses descriptive analysis to exhibit the current status of Singapore and UAE innovation strategies. In that study, Afzal and Siddiqui (2015) recommended some policies to the efficiency performance of NIS activities in the transformation of knowledge economies.

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Zemplinerová and Hromádková (2012) postulates that innovation input significantly increases innovation output, with increasing firm´s size, *ceteris paribus*. The paper exercised four stage model (CDM) over the period 2004-2007. Pursuant to Wong and Ho (2007) locally produced new knowledge although insignificant and growing is a source for innovation in Singapore.

Wan et al. (2005) investigated the relationship between firm innovation and six of its potential determinants using data from 71 companies in Singapore. The result showed that firm innovation had significant and positive correlations with its determinants. Keivani et al. (2003) described that Dubai has a highly developed ICT infrastructure and suggested to develop its local and community ICT networks as the logical extension of its ICT development program.

According to WCY-2014 data, Singapore and UAE have high HDI index with 0.91 and 0.85 respectively, decent financial mobilization, low poverty rate, port facilities while the overall higher education system is high with indexed 8.20 in Singapore and low with 5.20 in UAE currently. There are common determinants of innovation in these two countries.

Both Dubai and Singapore enjoy great strategic locations and are located in the midst of economically well-off geographies; Dubai in the midst of rich gulf states and Singapore in the midst of South East Asian tigers. A stronger economic environment ensures liquidity for business, ease of establishing and doing business, investments in infrastructure, etc.

Both UAE, especially Dubai, and Singapore are economically well off, enjoying a high GDP growth and per capita income.

According to Shamel Janbek, Chief Technology officer at China's ICT giant Huawei: "By no means is Singapore the leading smart city in the world, but Dubai is determined to take over this role in the coming years." He said: "I think Dubai is very close to surpassing Singapore soon."

A closer look would bring into focus the many similarities shared by these two dynamic and cosmopolitan maritime and aviation hubs of Asia and the Middle East. Taken together, these make Dubai and Singapore fascinating models for studies of comparison, contrast and benchmarking. Historically, both Singapore and Dubai emerged from humble beginnings near internal waterways. Both were originally simple trading settlements, with Dubai rising near its shallow creek, and Singapore founded near the mouth of its main river. Singapore's founding ideas were simple—to protect property, to enforce contracts and to open its doors for the movement of goods and of people.

However, very few studies have done to compare innovation status of UAE and Singapore using a broad range of innovation input-output indicators. Both the countries are heading towards innovation based growth strategy. Therefore, it is immensely important for the researcher and policy makers of both these two countries to get an idea where this two important port based countries stand in recent time in the context of innovation determinants. This paper is an attempt to compare and discuss the innovations features of these two countries with available data and point out the where the gaps lie.

2. Objectives of the Study

a. Detecting the salient features of innovation
b. Entrenching facts of UAE and Singapore innovative strategies

3. Theoretical Background

According to Schumpeter (1942), in each period there is one person (the entrepreneur) who has an opportunity to attempt an innovation. If she succeeds,

the innovation will create a new version of the intermediate product, which is more productive than previous versions. Specifically, the productivity of the intermediate good in use will go from last period's value A_{t-1} up to $A_t = gA_{t-1}$, where $g > 1$. If she fails, then there will be no innovation at t and the intermediate product will be the same one that was used in t - 1, so $A_t = A_{t-1}$. In order to innovate, the entrepreneur must conduct research, a costly activity that uses the final good as its only input. As indicated earlier, research is uncertain, for it may fail to generate any innovation. But the more the entrepreneur spends on research, the more likely she is to innovate. Specifically, the probability μ_t that an innovation occurs in any period t depends positively on the amount R_t of final good spent on research, according to the innovation function $\mu_t = \Omega (R/A^*)$, where $A_t^* = \gamma A_{t-1}$ is the productivity of the new intermediate product that will result if the research succeeds. The reason why the probability of innovation depends inversely on A_t^* is that as technology advances, it becomes more complex and thus harder to improve upon. So, it is not the absolute amount of research expenditure R_t that matters for success but the productivity-adjusted expenditure R_t/A_t^*, which we denote by n_t. n_t consists of factors that improve the productivity of innovation. In this paper, we have classified these as input-output factors of innovation.

3.1 Determinants of Innovation

Innovation process is one of the main drivers for knowledge-based economic growth. It can be influenced by demographic structure (population structure), ICT structure (computer uses etc.), financial structure, education (secondary, tertiary, etc.), research and development, trade openness, business startup costs, incubation costs, education, market circumstances, governance or regulatory quality, natural resource endowments, etc. Locally produced new knowledge even can contribute towards innovation.

Recent studies indicate that patent counts, patent applications, scientific and technical journal articles, high tech exports as a percentage of total manufacturing exports, etc. are innovation output variables to represent economically valuable knowledge creation. That is innovation is measured with these variables.

Observing, analyzing and comparing the input and output variables of innovation might count evaluate innovation activities. According to Schumpeter (1942), one method of assessing innovation is to distinguish between the outputs of innovative activity and the inputs to innovative activity.

4. Singapore and UAE

4.1 Singapore

Singapore is one of the Asian Economic Tigers. This country with an area of 719.1 square kilometers and a population nearly 5.6 million people has very effectively interwoven its development strategy within the global economy ring. A few simple organizing ideas and immediately, money and people and goods and services flowed in and Singapore grew very rapidly. From what has been called an "improbable nation" with little chance of survival at birth, Singapore bloomed into Asia's first global city. Singapore, a small island nation with five million residents in South East Asia, is one of the biggest success stories in Asia. After getting freedom in 1963, the tiny island state took strong initiatives toward industrialization and opening up of economy. In contrast to Dubai where oil played an important role in building up the economy, Singapore's economy is built on technology and labor skills. During the 70's, Singapore's focus on modern industries such as electronics, petrochemicals and

precision machines coupled with foreign investment helped the tiny state to transform itself into an industrial nation. Its liberal economic policies, industrious and highly skilled workforce and other natural advantage such as vast seaports and strategic location helped it attract a huge amount of MNCs to have their base in Singapore along with large amount of foreign investments. From 1963 to present, Singapore has recorded an average GDP growth of 7.9%.

Today Singapore is considered as one of the most liberal states in the world enjoying high per capita income, state of the art infrastructure and a robust economy. It had successfully diversified into services sector and is the financial and export hub of South East Asia. It is also considered as one of the most innovative, liberal and business friendly nations in the world where it takes only three days to start a business in, much lesser than the world average that stands at 34 days.

4.2 UAE

The United Arab Emirates or the UAE in the Middle East is a federation of seven emirates namely Abu Dhabi (serves as the capital), Ajman, Dubai, Fujairah, RAS al-Khaimah, Sharjah, and Umm al-Quwain. It is bordering the Gulf of Oman and the Persian Gulf and borders with Oman to the east and Saudi Arabia to the south. It comprises an area of 83,600 square kilometers. Among all emirates Dubai receives the utmost importance.

Dubai is the second largest emirate in the UAE with an area of 3,885 square kilometers comprising a population of 2.69 million. Dubai has a growth rate of 2.4%. Although being situated in a petroleum resourceful location, Dubai recently imposed immense focus on the other sectors like trade, services and finance. Dubai stands on a geographically lucrative hub area which has given a boost to the economic development through the expansion of its market in Asian and European region. The well-established infrastructure, the finance centers, various industries are all the initiatives of the Al Maktoum family who have ruled Dubai since 1833. The present ruler of Dubai is Sheikh Mohammed Bin Rashid Al Maktoum who is also the vice president and prime minister of the UAE.

An article in the Economist (2006, P1) summarizes this ambition well; “Ruled by a wealthy and ambitious family the Al-Maktoums, it (Dubai) makes no secret of its wish to become the main financial center between Europe and Asia.” HH Sheikh Hamdan Bin Rashid Al Maktoum’s statement to the board of governors in Dubai, during the 2003 Annual Meetings brings light to their present situation. “We realize that as we move forward and try to accelerate growth, we will have to diversify further our economy and export base. As part of this strategy, the government is working to create a suitable investment climate that will enable Dubai to become an international financial center as well as a popular tourist destination in the years to come.” (International Monetary Fund, 2003, p.2)

Sheikh Mohammed bin Rashid Al Maktoum launched a National Innovation Strategy on October 2014 targeting to make UAE one of the most innovative nations in the world within 7 years.

The strategy aimed at energizing innovation in the 7 sectors—renewable energy, transport, education, health, technology, water and space.

5. Methodology

This research applies descriptive analysis to compare the innovation input-output indicators. Non-experimental studies describe and analyze researchable problem without any manipulation or intervention of the situations. Here we attempt to identify the salient features and factors of innovation and describe the current status of Singapore and UAE in this regard.

5.1 Data and Variables

The factors of innovation are demographic structure, financial structure, research and development, market circumstances, openness and natural resource endowments. We express innovation as economically valuable knowledge creation. Moving averages has been used to fill the gaps for missing data. Due to lack of availability of data, we have to cope with existing data to sketch the comparison. The innovation input-output indicators are observed from various literatures (Afzal & Siddiqui, 2015; Afzal, 2015; Hsu, 2011).

The demographic structure affects innovation because young people are thought to have greater potential and be more creative than the older people. Trade openness would stimulate the speed and scope of knowledge dispersion. The credit expansion provides the base and security for innovation process. The cost of business startup procedure helps to setup the business plan with administrative procedures. Overdependence on natural resources may reduce innovation capacity. Singapore and UAE are compared basing on these variables.

Table 2 and Table 3 show the descriptive statistics for Singapore and UAE for the time period 2000-2015.

Table 1. Input output factors of innovation and their proxy indicators

Input factors	Proxy indicators	Abbreviation	Source of Variable
Demographic Structure	Labor force participation rate, total (% of total population aged 15-64)	LFP	World Development Indicators (WDI)-2015
Financial Structure	Domestic credit to private sector by banks (% of GDP)	DCB	World Development Indicators (WDI)-2015
Research and Development	R&D expenditure (% of GDP)	RDE	World Development Indicators (WDI)-2015
Market Circumstance	Cost of business startup procedures (% of GNI per capita)	CBS	World Development Indicators (WDI)-2015
Openness	Trade (% of GDP)	TDO	World Development Indicators (WDI)-2015
Natural Resources Endowment	Total natural resources rents (% of GDP)	TNR	World Development Indicators (WDI)-2015
Output factor	**Proxy indicators**	**Abbreviation**	**Source of Variable**
Economically valuable knowledge creation	High technology exports (% of manufactured exports)	HTE	World Development Indicators (WDI)-2015
	Patent applications (Residents)	PAR	World Development Indicators (WDI)-2015
	Scientific and technical journal articles	STJ	World Development Indicators (WDI)-2015

Table 2. Descriptive statistics of the input output variable (UAE)

Tests / Variable	LFP	DCB	CBS	TDO	TNR	HTE	STJ	PAR
Mean	78.16	54.78	14.2	136.9	24.64	2.71	950.1	23.27
Std. Dev.	1.36	16.98	3.07	32.65	4.16	1.96	506.6	1.9
Min	77	31.27	11	89.86	17.41	0.70	293.8	18
Max	80.8	84.4	18.8	180.47	32.39	8.46	1679.1	26
Obs.	16	16	16	16	16	16	16	16

Table 3. Descriptive statistics of the input-output variable (Singapore)

Tests / Variable	LFP	DCB	CBS	TDO	TNR	HTE	STJ	PAR
Mean	71.8375	104.9	.080	379.67	0.00	52.45	8073.1	816.56
Std. Dev.	1.58	15.05	0.16	31.44	0.00	6.28	2297.4	263.26
Min	69.4	84.7	0.6	326.1	0.01	45.15	4249	516
Max	73.7	132.1	1	439.6	0.0007	62.79	10658.5	1303
Obs.	16	16	16	16	16	16	16	16

6. Result Analysis and Interpretation

6.1 Input Variables

The input variables affect innovation in different ways. We determine the effects of these variables in case of Singapore and UAE.

6.1.1 Labor Force Participation Rate

Figure 1 illustrates the labor force participation rate in Singapore and UAE from 2000 to 2015. It is measured in percentages of total population ages (15-64). It can be seen that the participation rate of labor of UAE remained at a higher rate than Singapore throughout this time.

At the beginning of the period in 2000, the participation rate in Singapore was 71% whereas the participation rate in UAE exceeded this, at just 77%. The participation rate in Singapore dropped slightly over the next two years but from 2003 it started to rise again and 2012 onwards showed to some extent similar results.

Throughout this time the participation rate in UAE ranged between 77% and 81% and a slightly increasing trend can be seen. At the end of this period, the labor force participation rate in UAE was almost 6.8% higher than that of Singapore.

6.1.2 Domestic Credit to Private Sector by Banks

Figure 2 illustrates the domestic credit to private sector by banks as a percentage of GDP in both Singapore and UAE from 2000 to 2015. Much volatility is seen for both countries. Overall it can be seen that domestic credit provided by banks is higher in Singapore than in UAE.

Figure 1. Labor force participation rate, total (% of total population aged 15-64)

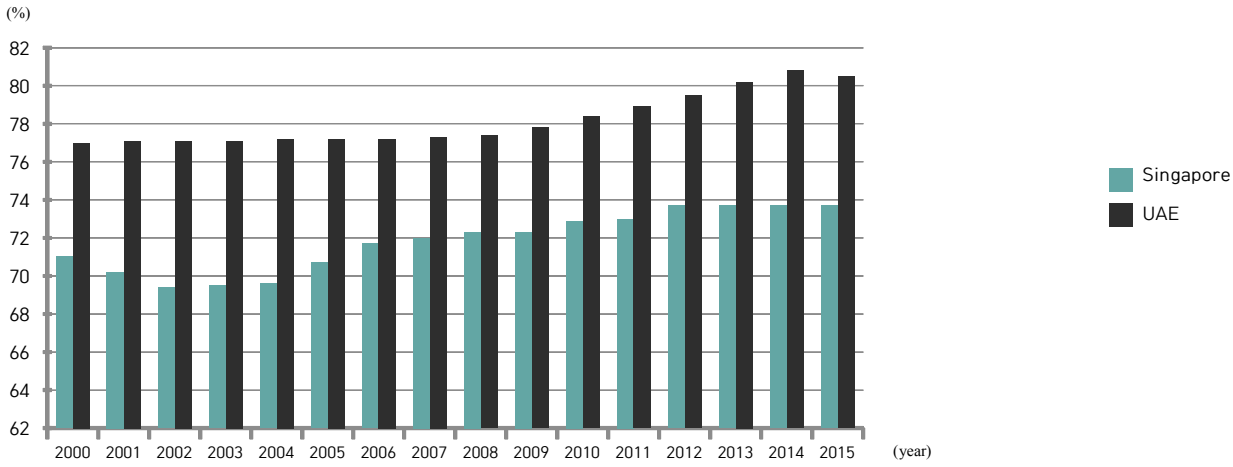
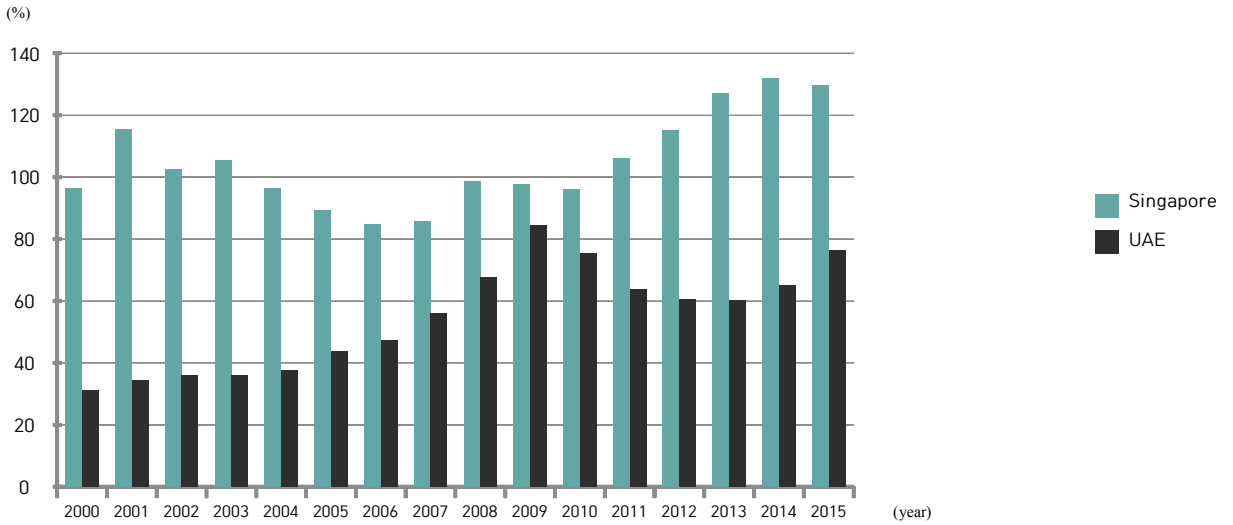


Figure 2. Domestic credit to private sector by banks (% of GDP)



An increasing trend can be seen in case of UAE during the years 2000 to 2009 but in case of Singapore there are fluctuations. A sharp increase in the domestic credit was seen from 2006 to 2009 in UAE and then started to fall until 2013 and rose again. A downward trend could be seen from 2003 to 2006 in Singapore but it remained steady over the next three years and showed an upward trend in the following years. The differences of the percentages are minimized at the year 2009 and maximized in the year 2001. There was a great recession during 2008-2009 which was a reason for the increase of domestic credit in both the countries. Singapore kept injecting capital in the following years as an aid of recovery process to the private sector but a drop was seen in case of UAE till 2013. An increase in domestic credit was seen afterwards.

6.1.3 Research and Development Expenditure

Figure 3 illustrates Research and Development expenditure as a percentage of GDP in Singapore from 2000 to 2015. The data for UAE was only available for 2011 and 2014. In comparison to Singapore, the percentage of R&D expenditure was quite low in UAE in these two years. Data is unavailable for the other years of UAE. The contribution of R&D in GDP for Singapore fluctuated between 1.8 to 2.7 percentages. It contributed highest in the year 2008, 2.62% of GDP.

6.1.4 Cost of Business Start-up Procedures

Figure 4 illustrates the cost of business start-up procedures as a percentage of GNI per capita from the year 2000 to 2015 for Singapore and UAE. Throughout the whole time the cost in UAE is very high compared to that of Singapore. Singapore maintained a very low share of GNI per capita throughout the whole time in business incubation cost ranging from 1 to 0.6 whereas the percentage was around 18% during the first four periods in UAE and then started to decline gradually with a little rise during the year 2007 and maintain trend for the next two successive years. During the last four periods UAE could maintain a cost 11% of GNI per capita. At the end of the period the differences between the results though decreased but still can be considered quite high.

Figure 3. Research and development expenditure (% of GDP)

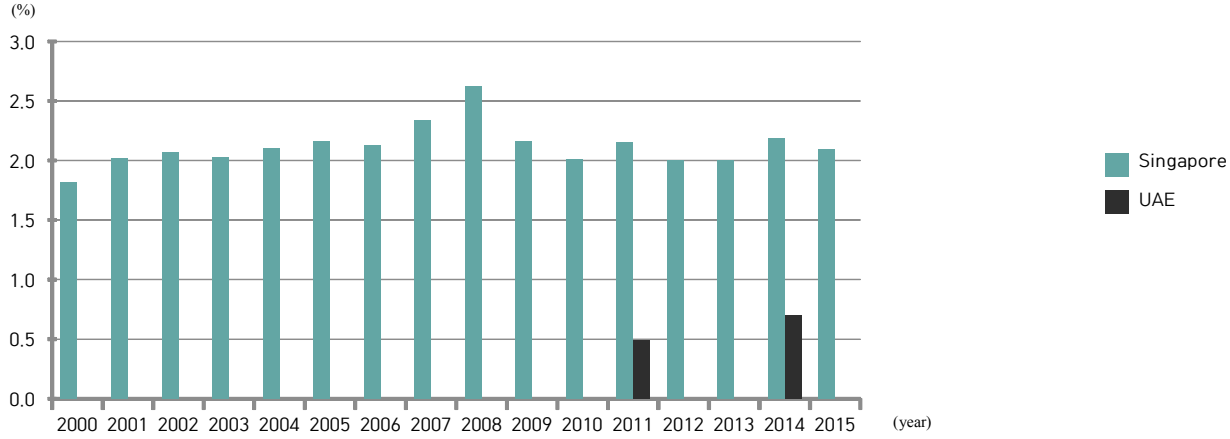
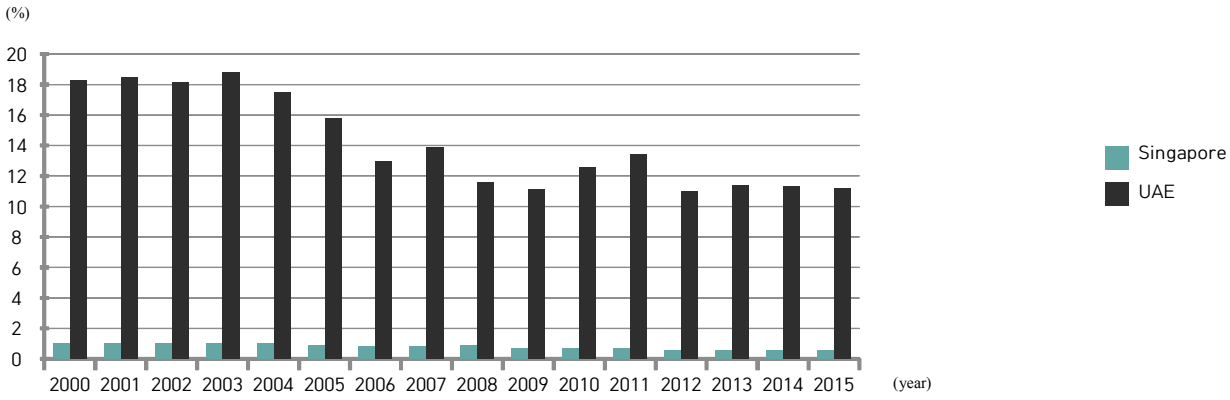


Figure 4. Cost of business start-up procedures (% of GNI per capita)



6.1.5 Trade

Figure 5 illustrates trade of Singapore and UAE as percentage of GDP from 2000 to 2015. Throughout the time, share percentage of Singapore is higher than that of UAE. UAE maintained an upward trend whereas fluctuations are seen in case of Singapore. At the beginning of the period, the trade for Singapore was 366.07 percent of GDP whereas UAE's trade share was 89.86 percent. Over the following years the patterns of the two countries were noticeably different. A sharp fall in trade is seen during 2008 to 2009 during the recession time in Singapore but UAE could maintain the same level. Both the lines converged at the end of the period minimizing gaps but still the trade in Singapore was almost twice that of UAE.

6.1.6 Natural Resources Rents

Figure 6 illustrates the total natural resources rents for Singapore and UAE between the years 2000 to 2015. It is measured in percentages of GDP. From the diagram it is very clear that UAE is a resource based country and Singapore is a resource scarce country. There are fluctuations seen for UAE ranging from 15% to as high as 32.4%. the case for Singapore is negligible in comparison to UAE. Singapore earned the highest natural resource rents during the year 2008 and due to recession, a sudden drop was seen in 2009.

Figure 5. Trade (% of GDP)

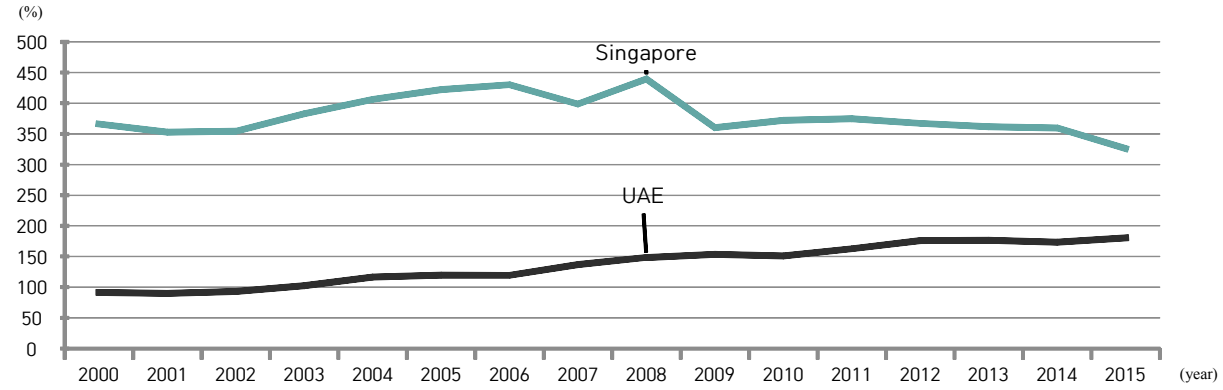
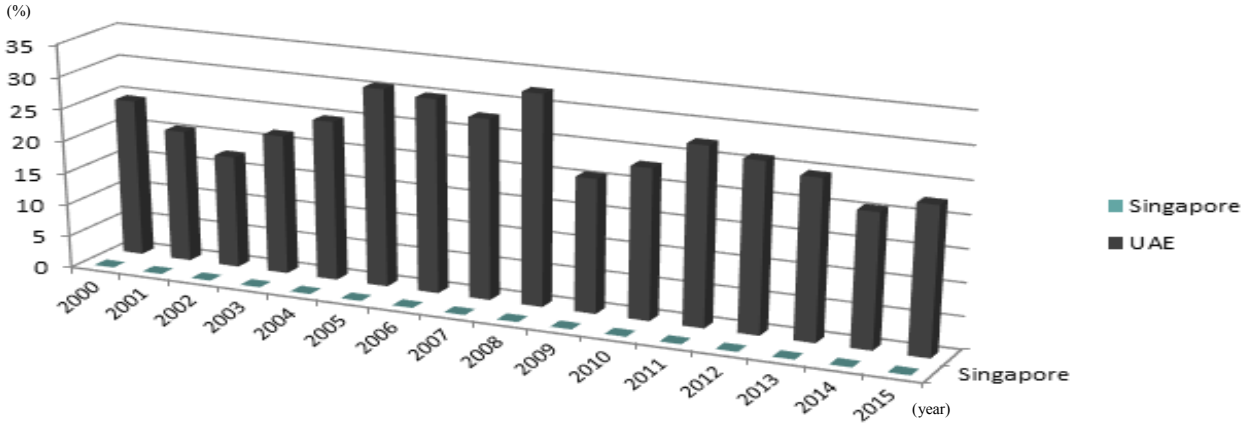


Figure 6. Total natural resources rents (% of GDP)



6.2 Output Variables

6.2.1 High-technology Exports

We determined three output variables to measure innovation in the context of Singapore and UAE.

Figure 7 depicts the condition of high-tech product exports for Singapore and UAE from 2000 to 2015. The trend maintained a rigorous path for UAE from 2002 to 2006; 2007 faced a slight fall in export and it surpassed the previous record since 2008. The trend continued till 2013. But a big leap is very clear since 2014. It peaks the highest in mentioned year. But 2015 faced lower high-tech exports than 2014. On the other hand, Singapore faced constant decrease since 2000. After that, the figure plots a scene of slight rise in high tech export from 2003 to 2006. In 2007, the entire export plummeted sharply. And the downed export trend could not manage to rise due to global financial crisis of 2008 and 2009. The year 2015 is showing an upward style in high tech export as seen in 2008 and 2010.

Figure 7. Total high-technology exports (% of manufactured exports)

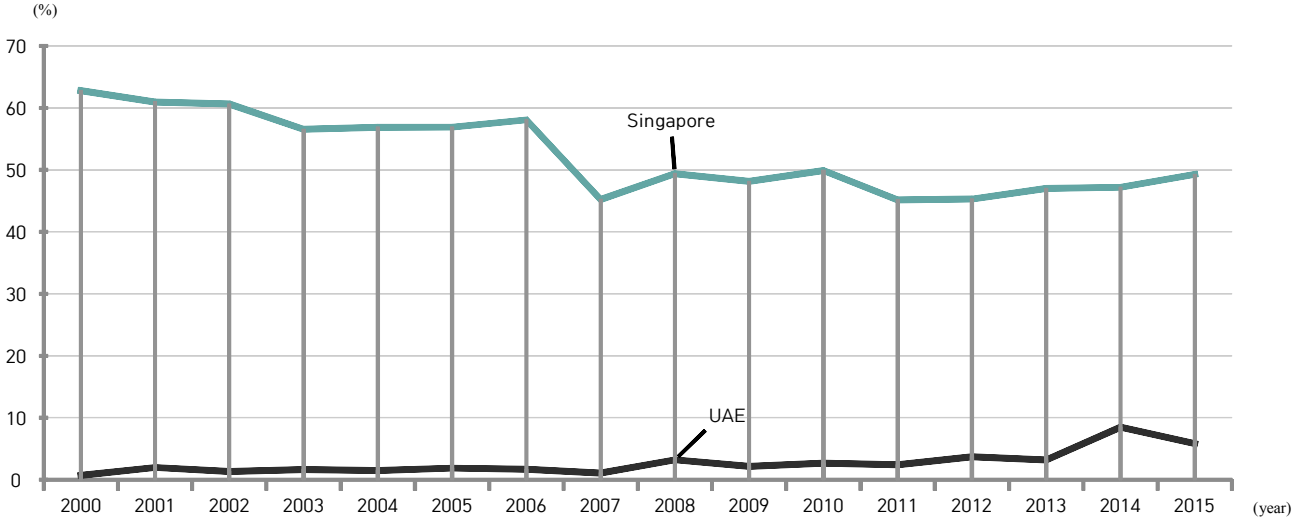
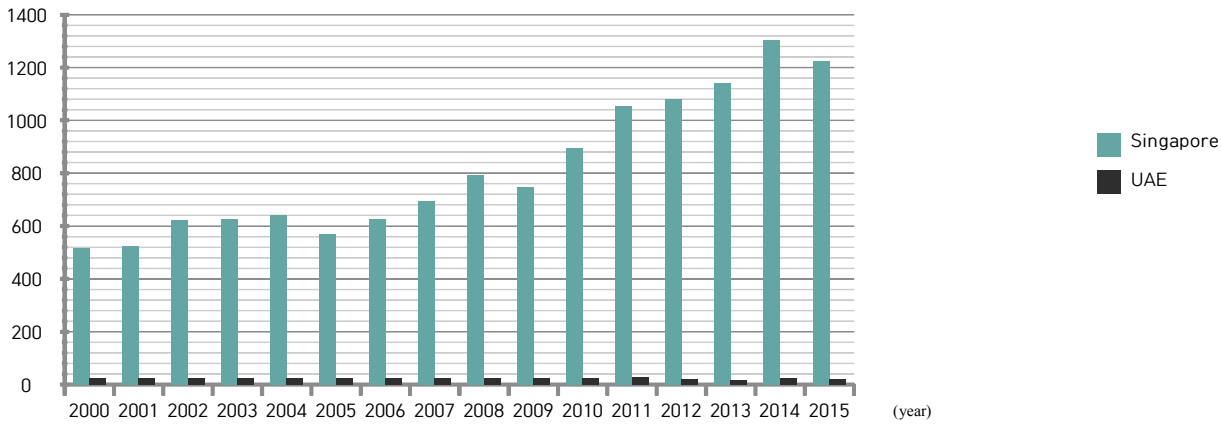


Figure 8. Total patent applications, residents



6.2.2 Patent Applications

Figure 8 is illustrating the patent application claimed by the residents of Singapore and UAE from 2000 to 2015 taking the interval of 2 years. This figure generates huge difference between the amounts of patents for these aforementioned countries. We see the patent claim is highest in 2014 for Singapore. In broad case, the trend is upward increasing. We also figure out an increase in year 2006 to 2008. And the identical boost is seen from 2010 to 2014 although the number of patent claim dipped in 2015. On the other hand, UAE maintained a rigid and constant trend in patent claim since 2000 to 2015. Comparatively, UAE lags highly in knowledge based innovation than Singapore, who kept enriching herself in such area.

6.2.3 Scientific and Technical Journal Articles

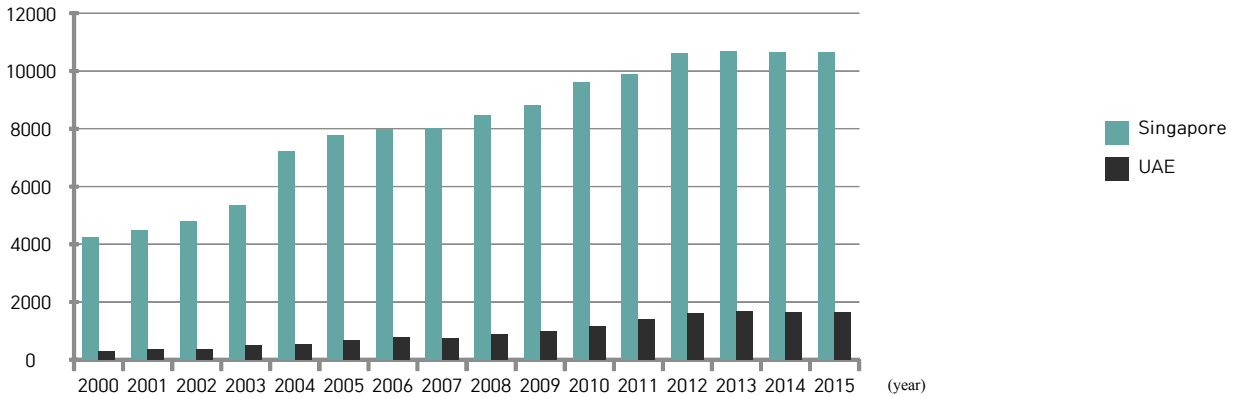
Figure 9 shows the gross scientific and technical journal article published by Singapore and UAE from 2000 to 2015. Singapore continued the upward trend since 2000 to 2015. Except sudden dips in 2002 and in 2007, UAE continued upward trending. A big difference is seen between these countries which depicts the knowledge based innovation is more compact and nourished in Singapore rather UAE.

7. Contribution of this Study

This paper makes four contributions to the literature. First, while most authors have studied the relationship between Singapore and Dubai at the urban planning innovation level or sector level for developed economies there is little known about the relationship for innovation input-output factors in these countries until now. Emerging economies currently adopting mobile phone usage, internet connections and are importing ICT goods much faster than developed economies and the impact that ICT adoption under National Innovation System has on economic growth relationship in emerging economies is an important yet under studied area. Second, this paper presents what is, believed to be the first innovation input-output data study of the concept of knowledge economy and the first from the perspective of the Singapore and UAE, particularly Dubai.

Third, a limitation of homogenous panel data approaches such as the DOLS, PMG technique, this study has used descriptive study for general reader in no-technical way.

Figure 9. Number of scientific and technical journal articles published



Additionally, this study examines the relationship of idea generation to commercialization of knowledge using the proxy variables of scientific and technical journal articles, high-tech exports as percentage of total manufacturing exports.

One limitation of the study may be that the data sample is small due to missing data that required the application of more econometric methods to test the hypothesis. Usually, variable like tertiary education expenditure, skills of the labor force, schooling in tertiary level are important to test our objective of the study. Due to data unavailability for Dubai and Singapore that do not allow us to incorporate these variables in our analysis. In future, the first difference GMM method with short time span, and the panel dynamic ordinary least square technique (DOLS) for testing the VECM model to check the serial correlation problem and the variance decomposition model to investigate the pass-through of external shocks to each variable in the model could be deployed. It is very important to make strong and robust collaboration among input-output factors relationship for the long run sustainable economic growth of these two countries. At the crossroads of globalization and as regional gateways, Singapore and the UAE have great potential to serve as trans-regional hub partners. This was the theme of the inaugural Singapore-UAE Joint Committee meeting hosted by Singapore in November 2014 and co-chaired by the Foreign Ministers of Singapore and the UAE. The East-West Asian nexus of Singapore, Dubai and Abu Dhabi and the UAE may even be dubbed the "Abu Dubai-pore Connect", a model based on robust political leadership, compelling development visions, social harmony, vibrancy and superb connectivity.

8. Conclusion and Policy Implications

In our study we examined the contemporary innovation scenario of Singapore and UAE (2000-2015) which gave us a clear premise on which we can assert that innovation is an accelerating force for a sustainable economy. This study illustrates how a resource based country and a resource scarce country is using knowledge based innovation for their economic development. Amount of high technology exports, number of patent claims of residents and the number of the publication of scientific and technical journal articles indicates economically valuable knowledge creation of two countries. Singapore is positively exceeding UAE in these three cases.

Although having a vast area and higher labor participation in comparison to Singapore UAE is apparently unable to utilize her natural and human resources. The upward trend of domestic credit reveals that private sectors are much appreciated in Singaporean economy where the setting is hostile in UAE. The identical foundation is echoed when we examined the business start-up costs in both countries. The reduction of incubation costs in UAE showed an inverse relationship with the trade openness.

To bring out the best of these economies some well-planned and rigorously managed policies should be undertaken. Firstly, every innovation initiative should be nurtured from the very primary level with the help of public and private sectors. Authority should provide favorable environment and appropriate motivation for all these innovation activities. Secondly, the trade barriers should be recognized and minimized. Trade of high tech products should be encouraged. This might induce positive boost in knowledge sharing beyond the boundary. Thirdly, newer sectors of the economy should be explored and R&D practices should be applied. Also an optimized and priority based R&D expenditure should be planned. Lastly human capital should be nurtured to increase their productivity and should get sufficient motivation for the contribution of scientific, technical and knowledge based sectors.

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Commercialization of Research through Spin-off Enterprises in Vietnam During the 1990s

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Abstract

Science and technology policy in Vietnam has been dominated by a linear model of innovation and the influence of a centralized science management approach transferred from the Soviet Union. However, after the Vietnamese Government embarked on reforms introducing a combination of market driven and State regulated economic mechanisms in the 1980s, scientific organizations were encouraged to commercialize research. In the transition, the leading research organization, known as National Center of Natural Science and Technology (NCNST), pursued technological development in addition to scientific research, and started to establish the first spin-off enterprises to commercialize its innovations. This paper employs institutional analysis to delineate the experience of the spin-off ventures on the basis of government resolutions to support the establishment of spin-off firms, together with the basic institutional requirements such as the autonomy of organizations and the need to mobilize capital for startup funding. Combined with a few case studies, this analysis shows that commercialization of research is difficult in a transition economy without institutional reforms that fully support autonomy, and encourages markets and financial support for spin-off ventures.

Keywords: Vietnam, spin-off enterprises, commercialization of research, science and technology policy

1. Introduction

The Vietnam Center for Scientific Research (NCSR)† was established in the 1970s to further research capacity in the country, and serve the reconstruction of the country after decades of war. Inspired by a combination of French and Soviet elite research organizations, the NCSR initially concentrated on fundamental research in natural sciences such as mathematics and physics. Following

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† The organization has changed its Vietnamese and official English name several times. In this paper, we shall designate the organization as the National Centre for Natural Science and Technology, which was the official name during most of the 1990s. The table below summarizes these changes:

Period	Name in Vietnamese	Official Name in English
1975-1993	Viện Khoa học Việt Nam	Vietnam Center for Scientific Research (literally: Vietnam Institute of Sciences)
1993-2004	Trung tâm Khoa học Tự nhiên và Công nghệ Quốc gia	National Center for Natural Sciences and Technology
2004-2012	Viện Khoa học và Công nghệ Việt Nam	Vietnamese Academy of Science and Technology
2012-present	Viện Hàn lâm Khoa học và Công nghệ Việt Nam	Vietnam Academy of Science and Technology

the government's decision in the mid-1980s to engage in Đổi Mới reforms that introduced policies allowing market-based transaction, the leadership of NCSR recognized the importance of innovation and proposed that scientific activities should be encouraged to link up with production practice and fast commercialization of research results. The Center initiated a pilot project to establish spin-off enterprises, which very soon led to a boom of spin-offs during the decade. The Center was also encouraged through a series of resolutions by the Vietnamese government to create new conditions for entrepreneurial scientists from research units to help them establish technology based start-ups.

In 1993, the National Center for Scientific Research changed its official name to the National Center of Natural Science and Technology (NCNST) and the government approved a new mission, which included being a facility for professional research institutes, but also developing a site for the formation of spin-offs and becoming an incubator of technological start-ups. During the following decade, enterprises that were more successful gradually became completely independent of the Center and several have become well-known innovative firms in Vietnam.

However, the majority of the spin-off firms faced substantial difficulties in commercializing technologies and products, and frequently became lossmaking ventures, even after gaining more autonomy in decision-making. Thus, the experience of commercialization of research through spin-offs during market-based reforms in Vietnam was less successful than those of advanced countries. This paper describes this experience in terms of policy changes and case studies, with the aim to contribute to an institutional analysis of the difficulties of science and innovation policy in developing and socialist transitional economies. The key research questions are: How did Vietnamese government regulations promote the establishment of spin-off for commercialization of research? What role did managerial autonomy play in the success or failure of spin-offs? How does the structure of a transition economy affect the fate of research spin-offs?

2. Theoretical Background: Research Commercialization and Spin-offs from Public Research Institutes

The commercialization of research results has been an important item on the science and technology policy agendas of many countries seeking to make public research institutes (PRIs) or universities more useful for society, and the efforts of NCNST in Vietnam were also motivated by the need to serve national economic development. However, the implicit conceptual model for science and technology that Vietnamese policy makers had used in the 1970s was heavily influenced by traditional ideas of the "automatic" benefits of science (Bush, 1945) and what has become known as the "linear model of innovation" (Godin, 2006).

In addition, it had been formed by the influence that accompanied the extensive economic, scientific and educational cooperation between Vietnam and the Soviet Union, which upheld a strict division of labor between scientific research, technology development and production (Graham, 1993). While the influence of such concepts of the role of science and the contribution of scientific research to technological and economic development remains strong in many developing countries, it has been challenged by innovation models that emphasize the role of market demand and commercialization of research results since the 1980s. For example, a report from OECD (2013, p.11) highlighted "concern among policy makers and practitioners about the effectiveness of commercialization policies and mainstream technology transfer practices at universities and PRIs. This has in turn generated interest in new approaches to turn science into

business as well as in new indicators for measuring the two-ways flows of knowledge and technology between public research and business." Nevertheless, research has indicated the research-based startups generate more patent applications and more radical product innovations, on average, compared to a sample of similar firms (Stephan, 2014).

From a theoretical point of view, the advantages of collaboration between universities and industry are related to the role of scientific and technical human capital in economic growth (Bozeman and Boardman, 2014), especially as societies become knowledge economies. The long-term effects of universities as a knowledge source for industry are widely recognized (Mowery and Sampat, 2005) and the promise of contributions to private firms has become the theoretical rationale behind concepts such as the Triple Helix Model (Etzkowitz, 2008) and legislation such as the Bayh-Dole Act of 1980 that induced US universities to engage more actively in university-industry technology transfer (see Mowery et al., 2004). Nevertheless, the short-term effectiveness and economic impacts have been difficult to assess (Bozeman and Boardman, 2014: 54-55). Thus, there has been growing interest from policy makers and academics relating to the economic, commercial and societal impact of intellectual property generated by research.

The literature on technology transfer from research organizations primarily focus on two modes of output. On the one hand, many studies focus on patents/technology licensing (e.g. Thursby and Kemp, 2002); on the other hand, a number of studies analyze transfer in the form of university spin-offs (e.g. Steffensen et al., 2000). According to OECD (2013, p. 49), there is no standard definition of a public research-based spin-off (or start-up). In the narrow view, it may be defined as any new firm that includes a public sector or university employee as a founder. In the broader view, it may be defined as any new firm including a public sector or university employee or student/alumnus or former public sector employee as a founder, based on a patent and/or other forms of IP (e.g. copyright) and/or non-technical innovations (e.g. business model improvements). Although many elements of technology transfer, licensing of patented knowledge, etc. are also observed in the setting up of research-based spin-off enterprises, there are aspects of entrepreneurial venture, financial resources, and management that are unique for the operation of spin-offs.

The importance of research and development for development of innovative firms and economies has encouraged a search for ways in which public research organizations can contribute through commercialization of results (Walwyn and Scholes, 2006). Although such efforts require consistent and powerful policy frameworks, it has been shown that several newly industrialized countries in East Asia were able to turn previous "Ivory Tower"—type research organizations into that were serving the demand for new technologies for various user communities (Mazzoleni and Nelson, 2007). In France, policies to encourage the commercialization of research output from universities and public research institutes were introduced in the 1980s; these policies have created stronger linkages between publicly funded research and the private enterprise sector, reorienting activities of organizations such as the Centre National de la Recherche Scientifique (Vavakova, 2006). In developing countries and transition economies such as Vietnam, this type of legal environment has only recently been emerging (Sharif and Baark, 2011). Recent research has also demonstrated that support by the parent organization in the early stage of commercialization by spin-offs speeds up the process and helps spin-offs from public research organizations generate first revenues sooner (Slavtchev and Goktepe-Hulten, 2016).

The new policies have often used new legislation, such as the Bayh-Dole Act of 1980 in the United States, to encourage research organizations to engage

in technology transfer. This trend is also stimulated by the "institutional turn" in the economics of innovation, providing a new emphasis on the role of transaction costs, regulation and cultural values in incentivizing actors to pursue economic development and innovation (Evans, 2006; Mahoney and Thelen, 2009). An institutional turn has proved very powerful in understanding essential development problems and policies in low-income countries, and can be considered the "third generation" of development economics (Altman, 2011). Key institutions that have been considered in relation to reform of research organizations have been laws and regulations, economic incentives, and the personal characteristics of entrepreneurial scientists.

3. Reform and Government Policies of Vietnam During the 1980s

After the issuance of Decision No. 175/CP by 1981, the S&T management system passed many revolutionary milestones of conceptual nature. The most particular characteristic point is the gradual process to get out from the exclusive State management and ownership mechanisms and the increasing trends of particularities of self-governed scientific activities. A review of changes through mark stones of conceptual mindset from 1981 to 1992 shows well the reform process of S&T policies starting from efforts to get off from the exclusive State planning frames (as decided by Decision No. 175/CP, 1981) to the large opening of S&T activities to the all of economic components (as decided by Resolution No. 35/HDBT, 1992). The policy mindset also changed gradually in the direction of getting closer to market economy institutions (Dam, 2015)

Before the Đổi Mới reforms adopted in 1986, Vietnam followed a planned economy structure with a centrally controlled mechanism. This economic structure was dominated by State-owned economic units and the collective ownership component remained in a minor position, while the private economic component was being fully rejected. In this economic structure, the State promulgated plans fixed in advance which assigned duties to enterprises to produce certain volumes of products. For the purpose of completing the assigned plans, enterprises did not pay much attention to quality of products or the demand of consumers. The price of products, which was called a "guidance price", was fixed according to orders from the commanding center, without taking commodity-money relations, material costs, or labors' salaries into consideration. Thus, the selling price did not reflect correctly any supply-demand relations and market values. The central control mechanism included an administrative machinery that defined basic operational norms for productive enterprises and economic units that did not carry any liability or face any prospects of bankruptcy. All products from factories were distributed by organizations that were specially assigned to take care of this distribution function, having no competitors. There was little room or incentives for science and technology to play a significant role in this economic structure.

After 1986, the economic management structure changed according to new principles of State economic policies. In this process, the structure of economic components, production structure, social structure and other institutional structures gradually moved towards market relations. From the position of accepting only the existence of state-owned or collective economic components, the Vietnamese government came to acknowledge a multi-component economic structure and started to promote joint business with other countries. These moves offered initial steps that generated a favorable socio-economic environment for science and technology (S&T) activities.

Following the start of the Đổi Mới reforms, numerous State documents were issued to facilitate the implementation of new management mechanisms for S&T activities. Particularly, Resolution No.

35/HDBT, issued by the Council of Ministers on 28 January 1992, offered favorable conditions for scientific organizations to undertake proactive initiatives to mobilize capital resources, to use available capital, and to develop their initial access to markets. Even if it can be argued that they still suffered from the impact of central control mechanisms, they were able to start practical actions that demonstrated the important shift in the managerial mindset, as well as the emergence of more open concepts of management of S&T activities.

Resolution No. 35/HDBT recognized the fact that S&T activities did not need to constitute a State monopoly: on the contrary, the existence and usefulness of private components in S&T activities were recorded, and the roles of individual researchers in S&T activities were respected. Issuing the Resolution by the government thus offered contributions to mobilize S&T resources and allowed the formation of S&T organizations with various economic components. The process of reform was driven forward by the recognition of the market potential of domestic research results, and the need for a new level of autonomy in the management of units that were undertaking production and conducting business activities.

4. The Transition of the National Center of Natural Science and Technology During the 1990s

By end of the 1980 decade, the leaders of the National Center of Natural Science and Technology remained frustrated in their efforts to promote transfer of research results to production. The institute had continued the structural model of Academy of Sciences in the socialist countries where the academic research activities held dominating positions. Facing the new context of economic reform and requirements for more advanced technology, this it became clear that the Soviet model exhibited severe disadvantages, such as: a cumbersome organizational structure; low initiatives to mobilize capital sources; high costs of management; and a high share of non-researching staffs. Therefore, the center needed to restructure its activities to meet new requirements of an economic shift to market driven mechanisms.

In the new context, many research institutes or centers were reduced to the level of 50-100 scientists that cooperated closely in research. This structure would let them be more dynamic in searching for new opportunities to host or to participate in research projects, to develop links to partners, and to develop financial sources for research activities through S&T service contracts, including through international cooperation activities. Moreover, in the new context of decision-making power decentralization, the National Center of Natural Science and Technology created specific research centers to meet demands of development.

The National Center of Natural Science and Technology therefore set up research units to cover all the natural science fields including 24 research institutes, and research centers distributed over all the key cities and provinces of the country. During this period of time the activities of fundamental science and applied science research were implemented in 9 State level scientific and technical programs. An important element of this effort was to upgrade human resources, which led to a fast growth of research staff in terms of both quality and quantity. In 1975, the organization had about 900 scientific researchers including 50 with post-graduate qualifications. By 1985 the number of scientific researchers had increased to 2,400, including 40 doctors of sciences and 230 doctors (equivalent to international PhD degree). Thus, the number of doctors of sciences had increased by 24 times, and the number of researchers with a doctor degree had increased by 5 times (Long, 1996).

In addition to activities to increase human resources during 1990s, the National Center of

Natural Science and Technology initiated first steps to strengthen research infrastructure in terms of laboratories and equipment. The development of infrastructure was made not only for the Nghia Do Research Area in Hanoi, which had been constructed and equipped by the Soviet Union including laboratories in key sectors of biology, earth sciences, chemistry and physics. In addition, numerous researchers and huge volume of machines and equipment were sent to develop the second site of the National Center of Natural Science and Technology in Hochiminh City and to take over the Marine Institute in Nha Trang City.

To achieve an improved management mechanism, the NCNST reduced management size and adopted a decentralization scheme that enhanced liabilities and power of units under its administration. In addition, it separated more clearly management functions and implementation functions, started practicing a more democratic decision-making scheme for S&T activities, proposed measures to encourage young leaders, and stimulated staff to enhance their qualification levels.

In order to improve the economic conditions at research institutes and centers, NCNST gradually reduced the existing subsidy scheme and replaced it with self-financing opportunities, introduced policies for open and diversified international cooperation activities, and conducted pilot schemes of labor contract for recruitment of new staff with graduate degrees. Since Vietnam was still a developing country with a weak infrastructure, the National Center of Natural Science and Technology had to pay great attention to international cooperation ties to develop research activities. Efforts for higher level of international cooperation were important concerns not only of Institute leaders and the Department of International Cooperation, but also became central issues of research institutes and individual scientists. The NCNST leaders thus sought to offer a very favorable environment for researchers to participate in international cooperation activities.

After 15 years of development, the National Center of Natural Science and Technology had gained considerable achievements in development of relevant research by 1990. The most important initiative was to test a new model of linking scientific research and production activities were, allowing research units to sign contracts with industrial production enterprises. For the Center as a whole, the reliance on external business funding continued to increase during the 1980s, as shown in Table 1.

Table 1. Finances from business contracts and finances from State budgets, 1981-1988 period

Year	Finances from State budgets (VND 1,000)			Finances from business contracts (VND 1,000)		B/A (%)
	Salaries & Allowances	Research & Other expenditures	Total (A)	Number of contracts	Total income generated (B)	
1981	3,018	11,635	14,653	9	237	2
1982	3,872	26,150	30,022	46	2,384	8
1983	5,106	43,894	49,000	101	5,125	10
1984	7,155	64,365	71,520	106	13,342	19
1985	8,751	64,818	73,569	141	22,919	28
	4,110	4,760	8,870			
1986	15,501	49604	65,106	154	54,118	83
1987	42,929	123,584	166,513	337	180,072	108
1988	144,144	1,110,455	1,244,599	448	2,393,548	192
Total	234,568	1,499,265	1,733,851	1,324	2,671,421	

Source: Dept. of Planning Services, Vietnam Institute of Sciences

5. Formation of Autonomous Commercial Spin-offs

As a result of the Đổi Mới reforms new spin-off enterprises or units emerged to implement research results in production or S&T services. By 1990 the government introduced Decision No. 268-CT which allowed research institutes to organize business enterprises engaged in industrial production or services, motivated by new requirements to settle redundant staff. Subsequently, the government issued Resolution 24/CP on 22 May 1993 to restructure the National Center for Scientific Research, and to change its name to the National Center of Natural Science and Technology. In the new structure, the NCNST became reorganized from 60 institutes into 17 research institutes and 9 affiliate institutes.

The NCNST had established 60 enterprises and implementation units during the short period from 1988 to 1990. These enterprises and development organizations were established as a result of facing market demands, and the interests of scientists motivated by new State policies that encouraged opening research to society. These units implemented research results, applied S&T advances, and transferred new technologies into production and service activities, on the basis of Decision No. 92-CT by the Council of Ministers on 22 April 1989 and later Decision No. 268-CT on 30 July 1990.

In their practice, the new R&D units relied on potential research results, research equipment, and the knowledge of researchers to develop economic contracts. In the new practice, institutes increasingly operated on the basis of self-governance, self-liability and self-finance without being supported by State budget funding. Operational finances were contributed and mobilized mainly by the scientists of the National Center of Natural Science and Technology themselves, together with external sources including bank loans and overseas sources. The same scheme was applied for mobilization of scientific human resources including researchers of the National Center of Natural Science and Technology and external cooperating researchers.

Incomes coming from external sources at the R&D units sometimes exceeded State budget allowances. These incomes were often used for enhancement of living level of scientists. In addition, contributions were made to capital for scientific research and purchase of research equipment in order to shorten time gaps for application in production activities. After a certain time of operation, such R&D units tended to become separated from research units. Thus, some of the researchers were moved permanently to undertake R&D activities and to organize production and business activities. Their incomes came from realization of economic contracts, S&T services and trading business of products made by their R&D units. In general, they managed without getting salaries from State budget allowances. The management of these enterprises and R&D units was simple and flexible, which then permitted the units to secure development in both advanced research and the application of research results.

A good example of such R&D units was the Applied Physics Center which was separated from Institute of Physics and established on 8 March 1989. The Center was assigned with duties to conduct research and application activities and to implement various achievements of modern physics in production. The Center was equipped with technical infrastructure to secure industrial scale production of high grade products of pieces and equipment. It was also technologically qualified to be the contact point for coordination of research activities with domestic organizations and establishment of joint venture units with foreign organizations. During the 1990s, the Center produced many interesting international publications on renewable energy, electro-optics, TiO_2 nano techniques, catalytic optics and other topics. These publications were reported

in many international workshops on advanced technologies and enabled new cooperation ties with foreign research organizations which led to bigger international financial supports for researches.

The Center subsequently made offers on basis of its research results to large Vietnamese enterprises, including technological products such as SPM microscope, TiO_2 catalytic-optic membrane, and Ferrite based materials. These products were of high quality but low prices because of being produced from local materials. Accordingly, the Ferrite based materials produced by the Center dominated the domestic market with multiple applications such as magnetic pieces of power meters by Hanoi Electro-Mechanical Factory, fabrication of loud speakers, teaching tools, or heat sensors of rice cookers. The Center cooperated with other enterprises to fabricate thousands of tons of alloyed grinding balls of high quality for the Bim Son Cement Factory.

In addition, new enterprises were established on the basis of dissolved ancillary departments at the Center. Typical cases include the Science-Technical Material Company (established in 1988 from Department of Material Supply) and the Enterprise of General Construction (established in 1987 from Department of Construction). The Science-Technical Material Company was renamed the Technical Material Import-Export Company (REXCO) on 20 May 1993, and then to Technical Material Import Export Joint Stock Company on 1 November 2006. The scope of business of the Company is quite broad, including medical equipment, laboratory equipment, scientific research equipment, steel and steel semi-fabricated materials; oil and fuel; installation and maintenance of lifts; gemstone and jewelry exploitation and business, fine arts goods; civil construction (irrigation systems, bridges, roads, transport systems, house and industrial electrical systems); consulting, construction, installation and maintenance of medical gas systems, electro-cooling system, domestic and industrial waste treatment; research and application of new S&T advances in production and business activities (Ha et al., 2015c).

6. The Semi-Autonomous 35-Type Units

On 6 July 1993 The Director of NCNST issued the temporary rules for application of self-governance scheme by R&D units on basis of Resolution 35-HDBT by the Vietnamese government (referred to briefly as 35-type units), allowing these to manage both activities of R&D and business as semi-autonomous units. The 35-type units under management of the NCNST included 1 research institute, 8 research centers, and 11 science-production unions. They are listed in Table 2.

Table 2. NCNST "35-Type" spin-off companies created in 1992

Companies established on Government Decision No. 35/HĐBT on 28/01/1992
Institute of Telecommunication Technology
Center for Energy Research
Science Production Union for New Materials and Equipment
Science Production Union for Chemical Optics and Electronics
Science Production Union for Software Technology
Science Production Union for Glass
Science Production Union for Refractory materials
Center for Chemical-Pharmaceutical and Bio-Chemical Organic Technology
Center for High-Tech Development
Center for S&T research, application and consulting
Science Production Union for Bio-Chemical Industry
Center for Food Technology and Engineering
Science Production Union for Hi-Tech Materials
Center for Marine environmental Monitoring, Research and Consulting
Center for Center for Expertise of Engineering works and Equipment (before: Center for Marine Engineering and Technology Mechanics)
Center for Environmental Technology Research and Application
Science Production Union for Biological and Environmental Technology
Science Production Union for Information and Telecommunication Hi-Tech
Science Production Union for Hi-Tech

Source: Department for Planning and Finance, VAST

The 35-type units under management of the NCNST had full and equal rights to be eligible for participation in State programs and projects of scientific research and technological development. They also had full rights to conclude and to implement economic contracts, civil contracts or to develop partnership links with organizations and individuals, both domestic and overseas. These units were not provided with block finance from State budgets, but were allowed to use research and laboratory equipment provided by parent research institutes. They were required to mobilize the research potential of their staffs according to their own decisions, and to apply results of their research works for production and business activities to make their income resources, using the income for equipment purchase and for personal incomes.

During the establishment of 35-type units, some scientists were transferred to R&D activities, production and business organization works. The total number of staffs working in the 35-type units was 830, where 153 staffs got salaries from State budget sources. Their qualifications were high enough, including 9 doctors of sciences, 27 doctors, 282 bachelors and 312 technicians (Son and Cuong, 2004). At the moment of establishment of these 35-type units, part of scientists of the Center were moved to full-time status of technology implementation activities and production and business activities which provided them with certain additional incomes.

State owned enterprises and 35-type units under management of the Center conducted activities of implementation of scientific advances, technology transfer and scientific-technical services on basis of self-governance and self-liability principles. The operational capitals of the spin-offs were mobilized from their own resources without being supported by State budgets, nor the budget sources of the Center. All the spin-offs from the Center held compact administration services with limited number of tertiary staffs, while the greater part of staff were mobilized for production and business activities. The main practice of spin-offs was to maximize the use of available research equipment, laboratories and capabilities of researchers for immediate implementation of research results of their institutes, scientific-technical services or intensive commercialization of research results. These activities let them produce extra-budget incomes which permitted them to strengthen research infrastructure. Some of the scientists, thanks to spin-offs, were moved permanently to R&D implementation activities, and organization of production and business activities. They stopped getting salaries from State budget sources, and solely relied on the income realized through economic contracts, S&T service contracts, or sales of S&T products.

By the early 2000s, the leading bodies of the National Center of Natural Science and Technology conducted a new reshuffle of equitation of spin-offs to make them joint stock companies (VAST Steering Committee…, 2009). The ownership of these units were assigned to their members, and they thus became completely independent of NCNST. In the end, while there were a few very successful spin-offs such as the DONA-TECHNO Company and FPT, a large number of spin-offs were actually losing money on their business, as shown in Table 3.

Accordingly, the National Center of Natural Science and Technology gradually removed spin-offs and the Vietnam Academy of Science and Technology currently does not have any of them in its organizational structure. Some were turned to private status or equitized, and then became completely independent. Some returned back to the status of research institutes under management of the Vietnam Academy of Science and Technology. Some were simply dissolved.

Table 3. VAST state-owned enterprises suffering losses in 2007

(Accounting in million VNĐ; 1 million VND ~ 50 USD)

No.	Companíes	State capital (in 2005)	Total capital (including state capital)	Debt	Employees (Person)
1	Company for Materials and Technology	2.255	20.120	20.016	11
2	Company for Construction and New Technology Development	1.180	11.571	10.365	55
3	Company for for Biochemistry and New Technology Development	555	14.828	14.530	61
4	Electronic Company ELECO	1.382	1.401	4.518	4
5	Company of New Technology	2.875	38.970	53.941	75
6	Company for S&T Application and New Technology Transfer	1.756	28.752	27.120	30
7	Company for Technology Expertise and Transfer	1.215	56.333	74.891	42
8	Company for S&T Export-Import Service and Production	1.824	68.727	122.679	44

Source: Department for Technology Application and Development, VAST

7. A Few Case Studies of Successful Spin-off Companies

Some of the best examples of models of spin-offs from the National Center for Natural Science and Technology are the Software Technology Science-Production Union (afterward renamed CSE) and the Biological Technology Development Joint Stock Company (DONA-TECHNO). We shall briefly describe the achievements of these two spin-off units.

The Company of Software Engineering (CSE) was originally established by NCNST as the Software Technology Science-Production Union on 14 August 1993. The Union was a self-financed unit that envisioned a target to become a leading software company in Vietnam. Renamed the Company of Software Engineering (CSE) on 14 August 2009, the company undertakes the following activities:

- Research, pilot trial, development and application of new technologies and techniques in information technology and mathematical application areas,
- Development of software solutions oriented to essential application works,
- Consulting, training and education, and enhancement of qualifications and skills in the above noted areas,
- Cooperation for training of international grade experts of software development,
- Import-export service of products in IT sectors.

CSE is strong in analysis, design and building of information systems on diversified technology platforms. Particularly, many typical software systems were developed on UNIX and Oracle environments and were used in many sectors over the whole country for many years. Up to now, CSE developed more than 30 projects for the government agencies, provincial government agencies and international workshops/conferences.

The Biological Technology Development Joint Stock Company (DONA-TECHNO) was established and started operation in 1993. The main scope of activities of the Company include transfer of biological technologies and trading of chemicals and agricultural products. The products of the Company were recognized by State authorities as goods made on the basis of S&T research. Agri-Fos 400 is a chemical specifically to treat phythopthora on plants and has been sold in large amounts in over 35 countries including Australia, USA, Europe, Japan, Brazil, and South Africa. The chemical can be used to treat numerous diseases of various plants including pepper trees, durian trees, rubber trees, rice, blue dragon plants, etc. Agri-Fos 400 is produced in conformity to environment friendly standards and has no hazardous residuals on agricultural products.

During the two years of 1997 and 1998, DONA-TECHNO Company implemented a project related to import and transfer of technology of high grade fruit trees and investments for farmers to develop production, with a total capital of VND 25 billon. With this project the company became a new model for technological investment in both financial investment mode and technological development. The new products served as a solution for poverty reduction and population resettlement in remote areas and for creation of high quality fruit production areas. Up to now, the species of DONA durian and DONA rambutan were developed by the Company have been propagated by farmers in many localities in Western area of South Vietnam. The acreage of cultivation of these trees cover more than 100,000 hectares. The plantations give good harvests of high quality fruits. Farmers are happy to get higher incomes than the income from cultivation of other type of fruit trees.

By November 2015 the DONA-TECHNO Company was qualified by State regulations as S&T based enterprise (Ha et al., 2015c). In addition to technology implementation activities, these units participated actively in scientific research activities of numerous programs and projects. Many research results were applied by these units in various economic fields. They also proved useful for development in national security and defense, or implementation of development programs for remote regions and poverty reduction programs. It is worth noting that S&T activities of spin-offs such as DONA-TECHNO were coupled with their targets to enhance economic efficiency of production and business activities. Success of this combination of research activities and production and business activities depended to a significant degree on the strategic visions of leaders as well as the financial potential of every spin-off. However, during this period, the technology market was not yet formed, with a weakness of institutions for intellectual property rights, which led to a practice of valuation of inventions that was much lower than their actual values.

FPT initially was a State owned enterprise in National Center of Natural Science and Technology with the import-export and processing of food machinery as main scope of activities. The Company developed import-export business of dried banana, sweet potatoes and cassava to the Soviet Union and Eastern European countries. FPT originally was the abbreviation for Food Processing Technology Company; on 27 October 1990 it was renamed to Corporation for Financing and Promoting Technology. After 1993, FPT was transferred to management by the Ministry of Science & Technology. More than a decade later, FPT had turned into a big economic group in Vietnam with IT-related service provision as main scope of activity. Other sources such as the Vietnam Report ranked FPT as the third largest private company in Vietnam by 2012.

8. Analysis of the Vietnamese Experience of Research Spin-offs

The operation and development of spin-offs of

the National Center of Natural Science and Technology during the 1990s demonstrates that the NCNST leadership recognized the need for pursue policies to link scientific research activities to production activities. Given the scope of reform stipulated by the resolutions of the government, the NCNST leadership decentralized decision-making to the leadership of individual research institutes and promoted the commercialization of research results.

However, during the initial steps of formation of spin-offs the National Center of Natural Science and Technology experienced problems with the difficult conditions for these initiatives in a transition economy. In order to evaluate the development of spin-offs of the National Center of Natural Science and Technology, it is necessary to consider the role of how the emergence of the market economy impacted on scientific units, and the capacities of these units for self-adjustment while facing challenges of market economy impacts.

The primary initiative consisted of a series of trial moves which turned research institutes from central duties of fundamental research to emphasize applied research. This led them to search and to open new modes of research activities and application of S&T advances for gradual adaptation to market driven mechanisms. During early years of 1990s, most of the difficulties that the country faced in general, and research institutes in particular, were related to capital mobilization. It is important to recall that the in Đổi Mới reforms of the economy were motivated to a large degree on a severe economic crisis in the 1980s, and the government continued to battle with a considerable budget deficit. One of the motivations for creating spin-offs was to save money on manpower and exploit any opportunity for generating additional income for the institutes. Such additional income of course did not materialize immediately and, in contrast, the initial problems experienced by spin-offs were usually the result of the absence of sufficient capital.

During the process of trying to overcome these difficulties of capital mobilization, spin-off enterprises of the National Center of Natural Science and Technology looked for a way to build links to commercial banks such as Techcombank, Habubank and some others. These banks were able to offer some support for spin-offs through active mobilization of capital, which in some cases helped spin-offs to manage survival during the "valley of death" for startups. It also provided useful experience for searching and mobilizing capitals for R&D activities at a later date. In addition to professional science and technology research activities, spin-offs of entrepreneurial researchers conducted a diversified scope of activities, and finally turned the National Center of Natural Science and Technology into an incubator of start-ups and helped set up one of the earliest science parks of Vietnam. The National Center of Natural Science and Technology also offered favorable environment to attract many entrepreneurial scientists from external research organizations, such as those that belonged to ministries and localities.

The formation and development of spin-offs from the National Center of Natural Science and Technology during 1990s provides important lessons: 1) the development of spin-offs required a complete market institutional environment and suitable legal environment for their operation; 2) success also depended on of the scientific and technological capabilities of R&D institutes, and the actual commercialization potential of products; 3) ultimately, success depended on the strong will of leaders, even before establishment of spin-offs themselves.

The establishment of spin-offs during 1990s was useful for re-arranging the organizational structure, and also for reducing the size of employees at the organizations. It is noteworthy that the government required the Center to cut 600 staff within the short duration of 18 months. The establishment of spin-offs therefore presented a simple solution to three critical

problems: to keep pace with development trends of the world; to adapt to market driven mechanisms; and to solve the difficult problem of staff-cutting as required by the government. The spin-offs diversified the functions and organizational structure of R&D institutes and linked them to production activities, allowing R&D institutes to shift to a new status of self-governance and self-liability, in conformity to Resolution No. 115/2005/ND-CP.

Nevertheless, the reality is that many spin-offs could not overcome the difficulties encountered during the initial development process, particularly their difficulties in capital mobilization. The issues of mobilizing capital in the early phases of entrepreneurship is shared with small entrepreneurial ventures everywhere in the world, but such problems are likely more severe in Vietnam (Tran and Santarelli, 2013). They were also not able to solve the problem of relations with mother research institutes, while remaining dependent on the parent organization for R&D, not having independent technological capabilities. During the 1990 decade Vietnam gradually strengthened market forces in the economy, but this was done without establishing the full institutional status of market economy. For the commercialization of scientific and technological achievements, for example, the absence of a strong intellectual property rights (IPR) protection regime hampered efforts to create a firm position in the market. In fact, the initial steps of shift from multi-economic planned structure to socialist market oriented driven structure did not offer a suitable environment for development of spin-offs. A more recent study of the role of science, technology and innovation in Vietnam also summarizes its findings in the following terms: "Innovation requires conducive and stable framework conditions. Viet Nam has made progress but there remains much scope for improvement, including through continuing regulatory and SOE reforms, stimulating competition, facilitating access to finance etc. Frequent regulatory changes lead to a proliferation of red tape (OECD/TheWorld Bank, 2014)." Even if the government adopted many resolutions to support the ability of research organizations to set up spin-offs, the social and economic policy environment from the macro level to the micro level lacked vital supporting institutions (IPR laws and implementation, financing regulations, etc.), which had negative impacts on the formation and development of spin-offs. The situation for commercialization of research results continues to suffer from similar problems, as summarized by Ca and Hung (2011:140): "Furthermore, to help solve the problem of inadequate linkages between academic organizations and production activities, several issues should be addressed: capabilities of the human resource; financial packages and incentives; organization of R&D system; IPR issues; and assessment of research results. At the same time, a key issue is to increase innovative capability in order to meet the technological innovation needs of enterprises."

A further reason leading to the limitations and failure of many spin-offs during the 1990s was that an organizational model of organic nature applied to spin-offs, while the State administrative structure and management mechanisms continued to follow the organizational model of mechanical nature. In this sense, the problem was that the spin-off model appeared too early during the 1990s, at a time when the administrative structure and management mechanisms of scientific organizations and the economy had merely taken the first steps of change. Once the traditional organizational models failed to accomodate the innovative new model of commercial business, the leaders simply opted for the solution to divest or dissolve the spin-offs.

9. Conclusion

The 1990 decade had experienced a boom of

spin-offs in the National Center of Natural Science and Technology. These enterprises were a reflection of a shift from central control to market driven economic mechanisms, and helped to restructure the National Center of Natural Science and Technology to suit the new economic institutions and trends of international integration. However, a closer analysis reveals that only a few of the entrepreneurial ventures were able to grow and become profitable. We have focused in particular on the institutional context in terms of government regulation, autonomy of management, and conditions for mobilization of capital to identify the intentions behind institutional reform and the actual outcomes of the process of developing spin-offs to undertake production in Vietnam.

Our study shows that the Vietnamese government took some courageous steps to issue regulations that was strongly believed to promote the establishment of spin-off for commercialization of research. The leadership of the National Center of Natural Science and Technology followed up with a decentralization of decision-making and an enthusiastic promotion of the ambitions of scientists to serve the community. This included a fundamental reorientation of the mission of NCNST from an almost exclusive priority on basic science to a mix of basic research, applied research and ultimately technological development. The new emphasis on the development of technologies for society created the space for innovative initiatives and thus the preconditions for entrepreneurship during the 1990s. The leadership of NCNST also used the opportunity to cut down on personnel resources, by spinning off manpower from ancillary units engaged in import-export, logistics, etc.; interestingly, some of these new ventures were among the more successful firms originating in NCNST.

It has also become clear that managerial autonomy was crucial for the spin-offs that became most successful. This provided enterprises such as DONA-TECHNO or FPT the possibilities to explore market opportunities and international cooperation. Partly for this reason, some of the spin-offs were undergoing a transition to business firms and left the administrative purview of NCNST–especially during the early 2000s, when the Center turned them over to private status or equitized their share in the firms. Indeed, the largest and most profitable of spin-offs, namely the FPT Group, became complete independent of NCNST at an early stage, and prospered under the its alternative parent organization the Ministry of Science and Technology until it became privately owned.

Our analysis demonstrates that the structure of a transition economy like the one that Vietnam experienced after Đổi Mới reforms in the late 1980s had a significant effect on research spin-offs. In particular, the economic difficulties of the time made it difficult for the spin-off firms or the NCNST to mobilize sufficient capital to pass unscathed through the "valley of death" for startups, and finance production required for expansion on the market. These difficulties proved too large for the majority of the firms, and therefore the Vietnam Academy of Science and Technology–which is the current name of the organization–only includes a few self-financing units and one state-owned enterprise in its organizational structure (Vietnam Academy of Science and Technology, 2016:9).

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Policy Framework Addressing Legal Impediments to Open Access to Public Funded Research Data in Malaysia

Haswira Nor Mohamad Hashim

Abstract

This study proposed a policy framework addressing legal impediments to open access to public funded in Malaysia. Previous studies have identified legal impediments to open access arising from intellectual property, confidentiality, privacy, national security, patents and tort laws. The legal impediments have not been fully addressed by the existing policies of public research funding agencies and research institutions in Malaysia, hence the need for a policy framework to be proposed. This study analysed and compared various policies on open access to research data currently adopted by civil society, government bodies, research funding agencies and research institutions in Australia, Canada, the EU, the UK and the USA. This comparative analysis identified various measures deemed viable to address the legal impediments to open access to research data. The proposed policy framework is of international standard and can become a benchmark in pursuing the objective of enabling open access to public funded research data among public research funding agencies and research institutions in Malaysia.

Keywords: policy, legal impediments, open access, research data, public funded

1. Introduction

The first decade of the 21st century has seen increasing support for open access to research data, whereby more governments, research funding agencies and research institutions have affirmed open access principles for public funded research (Campbell, 2015). Between 2010 up to now, numerous policies on open access to research data have been developed in various countries such as Australia, Canada, the EU, the UK and the USA. Open access to research data can be seen as part of the broader access to knowledge movement (A2K) which advocates the distribution of educational, intellectual, scientific, creative and innovative works online through permissive licenses by the right holders (Suber, 2012; Fitzgerald & Haswira, 2012; Noronha & Malcolms, 2010; Uhlir, 2010; Uhlir & Schroder, 2008; Esanu & Uhlir, 2004).

Open access to research data principles entail more than just granting access to research data with limited or no restrictions. The core of open access to research data principles aspire to make research data available for any type of reuse by any user (Guibault & Margoni, 2015; Swan, 2010; Bains, 2009; Ebbinghouse, 2005). Under this principle, research data is freely available on the public internet permitting any user to download, copy, analyse, reprocess, pass them to software or use them for any other purpose without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself (Panton Principles, 2010).

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Table 1. Legal impediments to the objective of enabling open access to research data

Legal Impediments	Related Laws in Malaysia	How Does the Legal Impediment Arise?
Intellectual property protection in research data	Copyright Act 1987, ss 7(1)(a), 7(3)(a), 7(3)(b), s 8(1), and s 9(1)	Access to and reuse of the research data protected by intellectual property rights is restricted and subject to permission from data owner.
Ambiguity about first and joint ownership of research data	Copyright Act 1987, ss 26(1) and 26(2)(b)	The ambiguity hinders data sharing/self-archiving practices/open access participations among researchers as the researchers are unsure whether they have the right to deposit the research data in open access repository.
Data owner's exclusive rights in research data provided under	Copyright Act 1987, ss 36(1), 37(1), 37(5), 38(1), 38(2)	A data owner who does not want to lose control over the research data may exercise their exclusive rights by refusing to release the research data in open access environment.
The restrictive scope of the legitimate use of research data	Copyright Act 1987, ss 3(2)(a), 13(2)(n), (o)	Data users are in a state of uncertainty whether their usage is within the permitted acts, preventing them from utilizing the research data deposited in open access repositories.
Complex and lengthy licensing procedures for research data	Copyright Act 1987, ss 27(1), 27(2), 27(3), 27(6), 27A(a) & 27A(b)	Licensing of research data which are protected under copyright law is costly and time consuming, and is not well suited to be used in the digital environment.
Data creator's moral right of integrity/attribution	Copyright Act 1987, ss 25(2)(a), 25(4), 25(2)(b)(i), (ii)	Lack of attribution discouraged data creators from sharing their research, while moral right of integrity enables data creators to prevent data users from making alteration or modification to the research data that tarnishes their honor or reputation.
Non-disclosure duty of confidential research data	Contracts Act 1950, ss 38(1), 38(2)	Disclosure of research data which are subject to promise of confidentiality or under non-disclosure agreement is prohibited unless the research participants can be re-contacted for permission.
The right to informational privacy of subjects of research data	Personal Data Protection Act 2010, s 2 Communications and Multimedia Act 1998, s 211(1)	Disclosure and use of personal information against the will or consent of identified or identifiable data subjects will violate their right to informational privacy.
Protection of national security	Security Offences (Special Measures) Act 2012 Official Secrets Act 1972	Disclosure of research data which is classified as prejudicial to national security is restricted.
Novelty requirements in patent law	Patents Act 1983, s 14(2)(a), 14(3)(a) 27A	Researchers are required by the law to restrict, limit, delay or withhold disclosure of research data until the patent application has been filed.
Lack of a legal duty to ensure data quality	Tegas Baiduri Sdn Bhd v BIMB Trust Ltd & Ors [2011] 8 MLJ 226. The Co-Operative Central Bank Ltd v KGV & Associates Sdn Bhd [2008] 2 MLJ 233 OSK & Partners Sdn Bhd & Anor v Assets Investment Pte Ltd & Anor [2008] 4 MLJ 914 at page 916. The Registrar of Motor Vehicles, Malacca & Ors v KS South Motor Sdn Bhd [2000] 2 MLJ 540.	Since open access data providers have no legal duty to ensure data quality, data users are at risks of accessing and re-using incomplete, unfit, inaccurate or erroneous research data.

Although enabling open access to research data is technically feasible with the internet and ICT, there are social, legal and ethical issues which become barriers to open access (Dehnhard, et al, 2013; Suber, 2012; Peterson; 2010). A recent study made by Lämmerhirt (2016) on open research data identifies legal and ethical issues as primary factors influencing data sharing practices. The intellectual property law, security law, information policies, institutional guidelines and contracts at the national and international levels often impede data access and sharing practices (Pampel & Suenje Dallmeier -Tiessen, 2014; Holdren, 2013; Guibault & Wiebe, 2013; Dana, 2013; Moody, 2012; Arzberger et al, 2004). The existence of various legal impediments is deemed problematic as they restrict, obstruct, hinder and slow down the objective of enabling open access to research data.

This study focuses on the legal impediments to open access to public funded in Malaysia. For the purposes of this study, "publicly funded research" means research projects using funds which are allocated wholly or partly by the government departments or agencies at federal, State or local Government level. Next, "research data" refers to data sets generated through research that are commonly accepted in the research community as necessary to validate research findings (OECD, 2007). These data are typically derived from experiments, measurements, simulations or fieldwork activities such as survey, case study, observations or interviews. Types of research data include: i) raw data ii) processed data in the form of texts (transcript, report), graphics (table, chart, diagrams, animations, simulations, models), numeric (equation, statistics, algorithms), images (whether fixed or moving such as pictures, photos, visual recordings) and sounds (audio recordings); iii) published data used to support scholarly publications and; iv) associated metadata (European Commission, 2016; National Academy of Sciences, 2009).

Legal impediment arises when the existence or absence of legal rights and duties have the effect of restricting, obstructing, hindering or slowing down the objective of enabling open access to public funded. Previous studies have identified 11 legal impediments to open access to research data arising from intellectual property, confidentiality, privacy, national security, patent and tort laws (Mohamad Hashim, 2012; Sane & Edelstein, 2015; RECODE, 2014; Axelsson & Schroeder, 2007). The legal impediments which have been identified are hereby summarized in Table 1.

The intellectual property legal experts and scholars such as Lievesley (2009), Uhlir and Schroder (2008), Moskovkin (2008), Ambruster (2008), Fitzgerald & Fitzgerald (2008) and Arzberger et al (2004) have all argued for the legal impediments to be addressed through a set of policy framework. Therefore, it is submitted that, opening up access to public funded in Malaysia requires these legal impediments to be addressed through proper policy framework (Mohamad Hashim, 2010). While public research funding agencies and public research institutions in many parts of the world have declared their strong support for open access to public funded research data, the trend has not been closely followed in Malaysia. Up to now, research funding agencies and research institutions in Malaysia have yet to adopt open access policy to public funded research data

Due to the above gap, it becomes the aim of this study is to propose a policy framework addressing legal impediments to open access to public funded research data in Malaysia. The research question to be answered in this study is "How should the legal impediments to open access to public funded research data be addressed? Based on the above research question, the objective of this study is to analyse and compare the existing policies addressing legal impediments to open access to public funded research data currently adopted by civil society, government bodies, research funding agencies and research institutions in other countries.

Table 2. Policies selected as data samples

Institutions	Policies
The United States National Health & Medical Research Council (NHMRC)	NHMRC Statement on Data Sharing (2016)
Australian Research Council (ARC)	ARC National Principles of Intellectual Property Management for Publicly Funded Research (2015)
Canadian International Development Research Centre (IDRC)	Open Access Policy for IDRC-Funded Project Outputs 2015
Government of Canada	Policies and Guidelines: Research Data 2011
Directorate-General for Research & Innovation, European Commission (EC)	H2020 Programme Guidelines on Open Access to Scientific Publications and Research Data in Horizon 2020 (2016)
Government of the Republic of Slovenia	National Strategy Of Open Access To Scientific Publications And Research Data In Slovenia 2015－2020 (2015)
European Union (EU)	EU Guidelines on Recommended Standard Licences, Datasets and Charging for the Reuse of Documents (2014/C 240/01)
European Union RECODE FP-7 Project (RECODE)	Policy Guidelines For Open Access And Data Dissemination And Preservation: A Practical Guide For Developing Policies For Research Funders (2014).
Research Council of Norway (RCN)	Open Access to Research Data Policy for The Research Council of Norway 2014
Secretary-General of the Organisation for Economic Co-operation and Development (OECD)	OECD Principles and Guidelines for Access to Research Data from Public Funding 2007
The United Kingdom Natural Environment Research Council (NERC)	NERC Data Policy - Guidance Notes Version 2.1 (May 2016)
The United Kingdom Biotechnology and Biological Sciences Research Council (BBSRC)	BBSRC Data Sharing Policy: Version 1.2 (March 2016 update)
Research Councils of the United Kingdom (RCUK)	RCUK Guidance On Best Practice In The Management Of Research Data 2015
The United Kingdom Economic and Social Research Council (ESRC)	ESRC Research Data Policy 2015
The United Kingdom (UK) Government	UK Cabinet Office, ‘G8 Open Data Charter 2013’
Science and Technology Facilities Council (STFC)	STFC Scientific Data Policy 2011
Cancer Research UK (CRUK)	CRUK Data Sharing Guidelines 2009
The United Kingdom Institute of Education Sciences (IES)	IES Implementation Guide for Public Access to Research Data 2016
The United States Office of Science & Technology (OST)	US Office of Science & Technology Policy: 'Increasing Access to the Results of Federally Funded Scientific Research' (2013)
The United States National Institutes of Health (NIH)	Plan for Increasing Access to Scientific Publications and Digital Scientific Data from NIH Funded Scientific Research 2015
The United States Department of Veterans Affairs (DVA)	Policy and Implementation Plan for Public Access to Scientific Publications and Digital Data from Research Funded by the Department of Veterans Affairs (2015)
University of North Texas (UNT)	Denton Declaration on Open Access to Research Data 2012
The United States (US) Government	US Open Government Data (OGD) Principles 2007
Open Knowledge Foundation (OKF) Working Group on Open Data in Science	Panton Principles for Open Data in Science 2010

2. Methodology

Being a legal study, the research methodology is purely qualitative. Data collection was drawn mostly from secondary sources. Policies addressing the legal impediments to open access to research data were selected as data samples. Those data samples were collected from the official websites of the civil society, government bodies, research funding agencies and research institutions in Australia, Canada, the EU, the UK and the USA which support open access to research data. Altogether 24 data samples have been collected for analysis. The data samples are listed in Table 2.

The data samples were analysed using comparative analysis method. The scope of comparison is pertaining to measures adopted in the policy of the government bodies, research funding agencies and research institutions to address the legal impediments. The criteria in making the comparison are the similarities and differences of various measures adopted in the policies to address the legal impediments (see Gutteridge, 1949; Schmitthoff, 1939). Another criteria of comparison is the special feature or uniqueness of the measures adopted to address the legal impediments (see Reitz, 1998).

3. Results

Analysis of the policies of the civil society, government bodies, research funding agencies and research institutions in Australia, Canada, the EU, the UK and the USA have identified various measures which have been adopted in addressing the legal impediments to open access to research data. Since there are 24 policies being compared with more than one measures identified, the criterion used for distinguishing each measure is their similarities, differences and special or unique features in addressing legal impediments to open access to public funded research data. Common measure that is adopted in two or more policies under comparison will be placed under Measure 1, while a less common measure that is adopted in one or more policies will be placed as Measure 2. On the other hand, Measure 3 is the least adopted measure among the policies. Despite being different, the identified measures are not in conflict but rather they complement each other in addressing legal impediments to open access to public funded research data.

The measures which have been identified are presented in Table 3.

Table 3. Measures adopted to address the legal impediments to open access to research data

Legal Impediments	Measure 1	Measure 2	Measure 3
Intellectual property protection in research data	Research data have to be shared freely on the internet, as open as possible, accessible with as few restrictions as possible through public database or repositories (Government of the Republic of Slovenia; NHMRC).	Non-proprietary research data have to be made available in a format over which no entity has exclusive control (OGD Principles).	The policy should set open access for research data as the default and mandatory requirement (RECODE).
Ambiguity about ownership of research data	Ownership will initially be vested in the employer/research institutions receiving and administering the grants (NERC; ARC).	Research institutions must have policies relating to the ownership IP generated as a result of public funding (NHMRC).	IP generated as a result of collaborative endeavours between research institutions will vest as agreed between those institutions (ARC).

Data owner's exclusive rights in research data	Embargo period to enable researchers to publish findings are between of 30 to 60 days after data collection (NIH), no longer than 12 months from the end of the grant (ESRC), maximum of two years from the end of data collection (NERC), never later than three years after the project has concluded (NERC).	'Published' data should be made available as soon as possible (NIH), never later than at the time of publication (Research Council of Norway), at the time of publication in machine readable format (NIH), within six months of the date of the relevant publication (STFC).	Data owner will be required to grant to the funder a non-exclusive licence to allow the funder to manage and supply the data for reuse (NERC).
The restrictive scope of the legitimate use of research data	Data owner to grant rights to use and reuse the research data, to the widest range of users for the widest range of purposes, permitting any user to download, copy, analyse, re-process, pass them to software or use them for any other purpose (RCUK; Government of the Republic of Slovenia; EU; Research Council of Norway; UK Cabinet Office; Panton Principles; OGD Principles).	The use of licenses which limit commercial reuse or limit the production of derivative works by excluding particular purposes or persons or organizations is strongly discouraged (Panton Principles).	Any restrictions should be outlined in the data sharing plan and applicants should explore ways data sharing requests can be considered by the body that owns the data (CRUK).
Complex and lengthy licensing procedures for research data	The license should be internationally recognized/worldwide, perpetual, royalty-free, irrevocable by using Creative Commons (CC) licenses (version 4.00)/CC Zero Public Domain Dedication and Licence (Research Council of Norway; EU; Panton Principles).	Research data related to publication should be explicitly placed in the public domain/in the form of waiver of license (Panton Principles).	Research data for which no restrictions apply should be in the public domain by using CC0 Public Domain Dedication to make a research data license-free (OGD Principles).
Author's moral right of integrity	Data users must provide citation/give appropriate attribution/credit to the originator/ proprietor of the research data (Denton Declaration; NIH).	Data users should acknowledge the sources of their data (RCUK).	N/A
Non-disclosure duty of confidential research data	Researchers to develop a data management plan that protects the rights of study participants and confidentiality of the data and have in place anonymization/confidentiality procedures that ensure a satisfactory level of confidentiality to preserve as much data utility as possible for researchers (IES;OECD).	Researchers can opt out at any stage (either before or after signing the grant) to free themselves from the obligations of open access (European Commission).	N/A

The right to informational privacy of subjects of research data	Depositing data in data secure access facility/data archives or enclaves/ making personal data protection a contractual obligation/sign data sharing agreement before data release/used of 'Smart Notices' to indicate the original purpose of personal data collection (ESRC; IES; RCUK; EU).	Research data should be de-identified/redacted to strip all identifiers that would permit linkages to individual research participants and variables that could lead to deductive disclosure of the identity of individual participants (Government of Canada); IES). Where data cannot be stripped of identifiers, data may be exempted from the data sharing (Government of Canada).	Researcher to apply for Certificates of Confidentiality to protect identifiable research information from forced disclosure (NIH).
Protection of national security	Specific aspects of the data may need to be kept protected. When open access to the data may threaten personal or national security, the datasets must not be made openly accessible (Government of Canada; Research Council of Norway).	N/A	N/A
Novelty requirements in patent law	There may be a need to delay data release/sharing for a period of time, until the patent applications have been filed by the institutions or researchers. Policies may permit delays in sharing research data for a period of time, in cases whereby institutions or researchers are applying for patents or developing new applications based on that data (CRUK; Government of Canada.	If the outcomes of the research result in inventions, the provisions of the Bayh-Dole Act of 1980 apply (NIH).	N/A
Lack of a legal duty to ensure data quality	The licensor provides the information 'as is' and assumes no responsibility for its correctness or completeness (EU).	N/A	N/A

4. Discussions

This section interprets the findings derived from data analysis with the aim of identifying viable measures to address the legal impediments to open access to research data.

4.1 Intellectual Property Protection in Research Data

Legal analysis found that compilation of data in the form of texts, graphics or audio visual that are collected from various experiments, case studies, interviews or surveys are eligible to be

protected as copyright works under the Malaysian Copyright Act. Based on the policy analysis, it is found that a viable measure to address the legal impediment arising from intellectual property protection in research data is by making open access for research data in digital format as the default (RECODE, D.5.1 Open Access as Default), mandating data owner to facilitate access to public funded for public research or other public-interest purposes (OECD, para E Protection of Intellectual Property), with as few restrictions as possible in a timely and responsible manner (RCUK, Principle 1), on the internet through publicly accessible databases or repositories (NIH), in a format over which no entity has exclusive control (OGD Principles).

4.2 Ambiguity About Ownership of Research Data

Legal analysis found that, there is ambiguity about ownership of research data created by part employees or researchers under research collaborations as most policies only clarify patent ownership. A viable measure to address ambiguity about ownership of research data is by requiring research institutions to have policies relating to the ownership of intellectual property generated as a result of public funding (NHMRC). The policy should clarify ownership of research data by vesting ownership of public funded in the employer of the researcher (NERC, 4(f) Intellectual Property Rights), or the research institutions receiving and administering the grants (ARC, para (c)). The policy should also clarify ownership of public funded IP generated as a result of collaborative research between research institutions (ARC, para (c)).

4.3 Data Owner's Exclusive Rights in Research Data

Legal analysis found that data owners' have the exclusive rights to control reproduction, communication, performance, distribution and adaptation of research data that are protected under the Malaysian Copyright Act.. The legal impediment arising from data owner's exclusive rights in research data was addressed by the NIH and the Research Council of Norway by requiring published data to be made freely available at the time of not later than initial publication (Research Council of Norway, 3.1 The Research Council's guidelines). This position has to be contrasted from the position of the STFC (para xi) which provides that published data should be made available within six months of the date of the relevant publication. However, STFC also provides that where there are accepted norms within a scientific field or for a specific archive they should generally be followed. The legal impediment was also addressed by imposing an embargo for the researchers to publish their research findings as provided by ESRC, NERC, NIH, RCUK and the Research Council of Norway. The embargo periods vary between 30 to 60 days (NIH, Intellectual Property Protection), to a maximum of two years from the end of data collection (NERC, 3(a) Restrictions to Access). By comparison, ESRC (Principle 5) imposed embargo no longer than 12 months calculating from the end of the grant, while the Norwegian Research Council (para 3.2) fixed the embargo at no later than three years after the project has concluded. In contrast, RCUK position is that the length of embargo period varies by research discipline (RCUK, Principle 5). Apart from embargo, NERC requires data owners to grant a non-exclusive license to allow the funder to manage and supply the data for reuse (NERC, 4(f) Intellectual Property Rights). Based on the above finding, the legal impediment arising from data owner's exclusive rights in research data could be addressed by imposing a minimum period of exclusive use for the researchers/data owners to exploit the research data.

4.4 The Restrictive Scope of the Legitimate Use of Research Data

Legal analysis found that the fair dealing exceptions under the Malaysian Copyright Act, are restricted to specific purposes, specific types of uses or specific types of bodies or institutions. Policy analysis found that most research funders require the research data to be accessible free of charge (UK Cabinet Office, Principle 3(19) & (20)), on the internet (Panton Principles), with as few restrictions as possible (RCUK, Principle 1), by anyone on equal terms (Research Council of Norway, para 2.1), for the widest range of purposes (OGD Principles, para 4 Accessible), including for reuse (Government of the Republic of Slovenia, 2.1.2 Open Access to Research Data, re-purposing (Panton Principles, 201), redistribution (Research Council of Norway, 5.0 The Research Council's Guidelines) and commercial gain (NERC, 3(a) Restrictions to Access), as long as there is no legal, ethical or security-related reasons to preclude this (Research Council of Norway, para 2.1). Besides the research funders, the Panton Principles proposed an open data access policy which permits any data user to download, copy, analyze, re-process, pass them to software or use them for any other purpose without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. The Panton Principles also discourage the use of licenses which limit commercial reuse or limit the production of derivative works by excluding use for particular purposes or by specific persons or organizations (Panton Principle, para 3). In addition, CRUK requires any restrictions to data access to be outlined in the data sharing (CRUK, Intellectual Property Rights and Proprietary Data). Therefore, the legal impediment arising from restrictive scope of legitimate use of research data could be addressed by allowing the right to use and reuse research data beyond fair dealing exceptions.

4.5 Complex and Lengthy Licensing Procedures for Research Data

Legal analysis found that, licensing publicly funded research data in Malaysia is a complex and lengthy process, as it is in most countries. In terms of licensing, The Norwegian Research Council requires the license to be internationally recognized (Research Council of Norway, para 5.1 & 5.2), while the EU requires a licensor to grant worldwide, perpetual, royalty-free, irrevocable non-exclusive licensed to use research data (EU, para 2.2 Open Licences). Further the EU recommends Creative Commons (CC) licenses (version 4.0), especially CC0 Creative Commons Zero Waiver (CC0) Public Domain Dedication, as it avoids the need to develop and update custom-made licenses (EU, 2.2 Open Licences) and make a work license-free OGD Principles, para 8). Similar position can be observed in the Panton Principle (para 2-4). As for published research data, the Panton Principles require the research data to be explicitly placed in the public domain with a clear waiver or license (Panton Principles, para 1). Based on the above finding, a viable measure to address the legal impediment arising from complex and lengthy licensing procedures should be for the policy to adopt an open content licensing regime based on advance permission which removes the permission barrier, making it faster, simpler and more flexible.

4.6 Author's Moral Right of Integrity/Attribution

Legal analysis found that authors' moral right of integrity which exists in Malaysia is much broader, less flexible, more rigid and less clear when compared to Australian, the UK and the US laws. Several research funders such as the NIH

requires data users to recognise the proprietary interests of the originator of the research data by giving them appropriate credit for their work (NIH, para 3 & 12). Besides NIH, RCUK also requires data users to acknowledge the sources of their data as a way to recognize the intellectual contributions of researchers who generate, preserve and share key research datasets (RCUK, Principle 6). Further, Denton Declaration on Open Access to Research Data states that the principles of open access should not be in conflict with the intellectual property rights of researchers, whereby a culture of citation and acknowledgement should be cultivated by providing citation (Denton Declaration, para 12). NERC reportedly adopts the citation and DOI-specific metadata laid out in the DataCite metadata schema in ensuring that the researchers responsible for creating the research data receive appropriate recognition for their efforts (Callaghan & Walton, 2012). Based on the above finding, a viable measure to address the legal impediment arising from an author's moral right to integrity/attribution is by introducing data attribution/citation standards that provide a basis for incentives, recognition and rewards for data sharing activities (See Uhlir, 2012).

4.7 Non-Disclosure Duty of Confidential Research Data

Legal analysis found that, a non-disclosure duty of confidential research data in Malaysia may arise from contractual obligations or from the English common law principles adopted in Malaysia. The OECD proposed for data custodians to consider using anonymization or confidentiality procedures that ensure a satisfactory level of confidentiality to preserve as much data utility as possible for researchers (OECD, D. Legal Conformity). The IES, requires its grant holder to develop a data management plan that protects the rights of research participants and confidentiality of the data as required by the laws and regulations (IES, Human Subjects and Privacy Issues). In contrast, the EU allows the researchers to opt out at any stage (either before or after signing the grant), which free themselves from the obligations of open access (EU, 4. Extended Pilot on Open Access to Research Data). Hence, the most viable measure to address the legal impediment arising from non-disclosure duty of confidential research data is through anonymization process, confidentiality procedures and development of a data management plan.

4.8 The Right to Informational Privacy of Subjects of Research Data

Legal analysis found that the right to informational privacy of subjects of research data in Malaysia is protected by statutes as well as common law right to privacy. To address the privacy issue, the research data need to be free of identifiers that would permit linkages to individual research participants and variables that could lead to deductive disclosure of the identity of individual participants (Government of Canada, Policy Environment; IES, Human Subjects and Privacy Issues). This could be done by de-identifying /redacting process which strips all identifiers (Government of Canada, 2.7 Challenges for Policy Implementation). Besides that the ESRC has proposed for sensitive & confidential data or data which pose a disclosure risk after anonymization to be deposited in data provider's secure access facilities (ESRC, Data Security). Where data cannot be free of identifiers or when identifiers are important for linking datasets, apart from qualifying/exempting the data from data sharing requirements (Government of Canada, 2.2 Policy Environment), the researchers should also consider restrictions on data sharing as provided by data archives or enclaves (IES, Human Subjects and Privacy Issues). RCUK requires data sharing

agreement to be signed before data are released prohibiting use of the released data to identify participants or to make unapproved contact with participants (RCUK, Principle 4). On the other hand, the EU introduced "Smart Notices" which is stored in a permanent online location, to indicate the original purpose of personal data collection and processing and serve as a reminder of the obligations with regard to EU rules and national law on personal data protection (EU, 2.4 Personal Data). Where data cannot be stripped of identifiers, the NIH requires the researchers to apply for Certificates of Confidentiality to protect identifiable research information from forced disclosure (NIH, para 2 Protecting Confidentiality and Personal Privacy). To conclude, there are various methods of data redaction and data release that can be adopted as a viable measure to address the legal impediment arising from the right to informational privacy of subjects of research data.

4.9 Protection of National Security

Legal analysis found that there are various statutory laws in Malaysia restricting disclosure of information classified as prejudicial to the national security, that are imposed on any person having in his/her possession or control any document, data or information. While the research funders recognized national security as one of the exceptions to open access, specific measure to address the legal impediment arising from protection of national security has not been included in the policies which have been analysed. In a report "Seeking Security: Pathogens, Open Access and Genome Databases", the US National Research Council's Committee on Genomics Database for Bioterrorism Threat Agents (2004) states that the classification system has traditionally been used to restrict access to information that poses a national security risk. Further, the US National Committee on Ensuring the Utility and Integrity of Research Data in a Digital Age (2009) recommended for the policy makers to draw the line between classified and unclassified data and to balance restrictions on access to sensitive data with the potential costs of such restrictions. Based on the above recommendations, the most viable measure to address the legal impediment arising from protection of national security is by drawing a clear line between classified and unclassified research data.

4.10 Novelty Requirements in Patent Law

Legal analysis found that, the novelty requirement under the Malaysian Patents Act prohibits disclosure of research data about an invention until patent application has been filed. Most research funders addressed the legal impediment arising from novelty requirements in patent law by allowing data release to be delayed until patent applications have been filed (CRUK, Intellectual Property Rights and Proprietary Data). In contrast, the government of Canada permits delay data sharing until the institutions or researchers are applying for patents or developing new applications based on that data (Government of Canada, 2.2 Policy Environment). The NIH requires the provisions of the Bayh-Dole Act of 1980 (equivalent to Intellectual Property Commercialization Policy for Research & Development Projects Funded by the Government of Malaysia 2009) to be applied, if the outcomes of the research result in inventions (NIH. Intellectual Property Protection). Based on the above finding, a viable measure to address the legal impediment arising from novelty requirements in patent law should be for the policy to fix a timeframe for the patent application to be filed to avoid prolonged and unnecessary delay/restriction of data release.

4.11 Lack of a Legal Duty to Ensure Data Quality

The legal analysis found that, there is lack of a legal duty to ensure data quality imposed either by statute or case laws on open access data providers in Malaysia. Even in the presence of such duty of care, the Malaysian court is ready to accept disclaimer as defence provided it is a written disclaimer as opposed to oral disclaimer. The EU Guidelines states that the licensor provides the information 'as is' and assumes no responsibility for its correctness or completeness (EU, 2.3.5 Disclaimer of Liability). The US Committee on Ensuring the Utility and Integrity of Research Data in Digital Age (2009) proposed for a standard of care to be developed as part of the strategy to ensure data quality. Among the standards of care recommended to be imposed on data providers is the responsibility to properly inform, advise and warn data users on the potential risks related to use/reuse of the data (Levesque et al, 2005). There is also a recommendation for data providers to supply the information pertaining to the content and the limitation or defect or potential risk in the data utilisation (Awang et al, 2009). Based on the above recommendations, a viable measure to address the legal impediment arising from lack of legal duty to ensure data quality is by developing a standard of care on the data providers to ensure data quality.

5. Proposals and Recommendations

This section proposed a policy framework to address the legal impediments to open access to public funded research data in Malaysia. The policy framework is developed with reference to the policies analysed in this study as well as based on the recommendations made by the previous studies. The adopted measures are considered as the most viable to address the legal impediments to open access to public funded in Malaysia have been adopted in the policy framework. The proposed policy framework is hereby provided below.

5.1 Addressing Legal Impediment Arising From Intellectual Property Protection in Research Data

Research Data Protected as Intellectual Property
1. Research data may be protected as intellectual property especially where sufficient effort has been expended to make the research data as original works.
2. The intellectual property protection of research data does not relinquish the research data from being a subject of data release under the policy.
3. Data owner is to permit open access to research data in accordance to the requirement of the funding agency.
4. Where data owner is an institution, the researcher who is the creator/originator of the research data must be appointed as data custodian to give effect to data release.

5.2 Addressing Legal Impediment Arising From Ambiguity About Ownership of Research Data

Ownership of Research Data
1. To avoid any ambiguity about ownership and worldwide right, title and interest to or in all public funded in Malaysia which are covered under this Guidelines, it is hereby clarified that:

i. Where a research data is created/originated individually by a researcher who is an employee/registered student of the institution administering the research grant, full ownership and worldwide right, title and interest to or in the research data is vested in the institution regardless whether the research data is originated or created in or outside the course of employment/learning activities.

ii. Where a research data is created/originated jointly under research collaboration, ownership and worldwide right, title and interest to or in the research data is vested in the institution where the researcher is employed/attached/registered, in equal share with the collaborating party.

2. For the purpose of this guidelines:

i. the terms "employee" and "student" are to be interpreted in accordance to the law, constitution or policy of each institution;

ii. a research data is created/originated individually when the research data is the work of a singular nature, is made up of distinguishable contributions (where each contribution can be identified as coming from a particular researcher) and the research data is independently copyrightable;

iii. a research data is created/originated jointly when the research data is the unified/composite/blended work, is made up of indistinguishable contributions (where each contribution cannot be identified as coming from a particular researcher) or the contribution is distinguishable but copyright of the research data is dependent on the work of other researcher.

5.3 Addressing Legal Impediment Arising From Data Owner's Exclusive Rights in Research Data

Data Exclusivity

1. Data owner/creator/originator has a legitimate interest in benefiting from research data but not in prolonged exclusive use of the research data.
2. Data owner/creator/originator is allowed a limited period of data exclusivity, during which a data owner has the exclusive rights in research data.
3. The period of data exclusivity depends on the requirement of the funding agency.
4. Where the period of data exclusivity is not fixed by the funding agency, it is expected that data release is to be given effect:

i. not later than two years from the collection/creation of the research data; or

ii. immediately upon the first publication based on the research data; or

iii. not later than one year from the end (either by expiry or termination) of the award/grant which funds the collection/creation of the research data; or

iv. not later than one year upon completion of the research project for which the research data is collected/created.

5. The earliest data release of the three options shall be the expiry period of data exclusivity.
6. A longer period of data exclusivity shall be allowed only in exceptional circumstances and subject to approval by the funding agency.
7. Upon the expiry of the data exclusivity, the research data must be released in accordance to the policy of the funding agency.
8. Data owner is required to grant to the funding agency a non-exclusive licence to allow the funder to manage and supply the released data for reuse.

5.4 Addressing Legal Impediment the Restrictive Scope of the Legitimate Use of Research Data

The Legitimate Use of Research Data

1. Pursuant to the principles of open access which requires research data to be released with as few restrictions as possible, data owner must expand the scope of the legitimate use of research data which are protected by copyright beyond the fair dealing exceptions.
2. For the purpose of clarity, the expansion of the scope of the legitimate use of research data beyond fair dealing exceptions should include:
   i. for commercial gain;
   ii. permitting data user to download, copy, analyse, re-process, pass them to software or use them for any other purpose;
   iii. to distribute full-copies of the research data to the public;
   iv. to burn copies of the research data on CDs for bandwidth-poor parts of the world;
   v. to distribute semantically-tagged or otherwise enhanced (modified) versions of the research data;
   vi. to migrate the research data to new formats or media to keep them readable as technologies change;
   vii. to create and archive the research data for long term preservation;
   viii. to include the research data in a database or mash-up;
   ix. to make an audio recording of a textual research data;
   x. to translate a text of the research data into another language; and
   xi. to copy a text of the research data for indexing, text mining and other kinds of processing.

5.5 Addressing Legal Impediment Arising From Complex and Lengthy Licensing Procedures for Research Data

Licensing Research Data

1. Research data which are protected as copyright, *sui generis* database rights or other "copyright-like" rights and which are released under the policy must be licensed under Creative Commons License with the most liberal CC License which reserves only the right to be attributed as data owner (CC-BY) to be adopted.
2. While Creative Commons Zero Waiver (CC0) licence and Open Data Commons Public Domain Dedication and Licence (PDDL) are more liberal than CC-BY licences, both CC0 and PDDL licences with no rights reserved are inconsistent with the principles of open access not to harm the intellectual property rights in research data and to balance the interests of all stakeholders.

5.6 Addressing Legal Impediment Arising From Author's Moral Right of Integrity/Attribution

Moral Rights of Data Creator/Originator

1. Data creator/originator is required to permit alteration and modification of the research data which are released under open access policy through a non-assertion pledge of his/her moral right of integrity in the research data.
2. In return, data users are required to recognise the intellectual contributions of researchers who create/originate/generate, preserve and share the research data.
3. Data users are required to acknowledge the sources of their data by giving data creator/originator appropriate attribution/credit for the research data which they exploit.
4. Data users may use the citation and DOI-specific metadata laid out in the DataCite or other appropriate citation and metadata scheme.

5.7 Addressing Legal Impediment Arising From Non-Disclosure Duty of Confidential Research Data

Confidential Research Data
1. Data release must be given effect without violating the non-disclosure duty of confidential research data arising from promise of confidentiality, common law duty (tort or equity) or contractual duty such as confidential agreement or non-disclosure agreement.
2. Confidential research rata must be released using statistical methods such as data suppression, data random perturbations, data coding and recoding which protect the confidentiality of the research data. The statistical methods recommended above must balance the non-disclosure duty against the possibility that the methods applied will also reduce the quality and integrity of the research data.
3. Where statistical methods recommended above are not appropriate/possible, data release must not be given effect. Instead, confidential research data must be deposited in data archive/enclave which is provided by the research institution/funding agency.
4. The data archive/data enclave shall provide a secured, controlled environment where technical mechanisms such as encryption and password are to be used to protect the research data from unauthorized third party's access and reuse.
5. Where the confidential research data is deposited in data archive/enclave, disclosure of the research data may be considered upon ad hoq request made by the third party, either individual or organisation.
6. Where ad hoc request is made by the third party, disclosure of confidential research data can only take effect after full compliance of the Data Security Procedure of the policy.

5.8 Addressing Legal Impediment Arising From the Right to Informational Privacy of Subjects of Research Data

The Informational Privacy of Subjects of Research Data
1. Research data may contain:
i. personal information which directly identifies or which could be used to identify subject of research data such as name, address, passport, identity card number, telephone number, e-mail address, photograph, fingerprint, DNA and social security numbers (hereinafter referred as "direct identifier");
ii. indirect identifier that could lead to "deductive disclosure" of subject of research data. Deductive disclosure of subject of research data become more likely when samples are drawn from small geographic areas, rare populations or linked data sets; or
iii. sensitive personal information such as health information, genetic information, race, religion, culture, ethnicity, national origin, gender, age, marital status, socio economic status, political opinion, educational background, geographic location, sexual orientation or physical or mental health, ability or condition, criminal or prosecution record of identified or identifiable subject of research data.
2. The research data which contains direct/indirect identifier or sensitive personal information of identified/identifiable subject of research data must only be released in a form that protects the right to informational privacy of subject of research data.
3. The research data which contains direct/indirect identifier or sensitive personal information of identified/identifiable subject of research data can only be released with prior-informed consent of subject of research data.
4. In the absence of consent or where consent is not given, the research data can only be released for the purpose that is compatible with the purpose for which the research data was collected.
5. Alternatively, the research data can be released for different purposes and without consent from subject of research data after one of the following data redaction techniques is applied:

i. anonymization/de-identification by stripping or removing personal information which become direct identifier;
ii. pseudonymization by replacing direct identifier such as names with numerical identifiers;
iii. obfuscation by aggregating or reducing the precision of data, information or a variable;
iv. perturbation by introducing random errors into individual records whilst preserving descriptive statistics;
v. generalizing the meaning of detailed text; or
vi. restricting the upper or lower ranges of a variable to hide outliers.

6. Where redaction techniques is not possible, the research data which contains direct/indirect identifier or personal information of identified/identifiable subject of research data must be deposited in data archive/enclave and can only be released in accordance to Data Security Procedure of the policy.

5.9 Addressing Legal Impediment Arising From Protection of National Security

Classified Research Data

1. Release of research data of which disclosure is prejudicial to the national security is strictly prohibited regardless whether or not there is any specific law on this matter.
2. The Data Management and Sharing Plans must clarify whether the research data created/originated by the university researcher may contain information which is prejudicial to national security.
3. Disclosure of research data which contains the following information is classified as prejudicial to national security:
   i. instructions and guidance on bomb-making, biological weapon, illegal drug production or counterfeit products;
   ii. information and statements with regards to possible terrorist attacks;
   iii. information which compromise law enforcement activities, incitement to violence, counsels disobedience to the law or to any lawful order;
   iv. information pertaining to prohibited place, munitions of war, apparatus, equipment, and machinery which are used in the maintenance of the safety and security of Malaysia;
   v. information with regards to the outbreak of a deadly or contagious diseases;
   vi. information which could likely lead to a breach of the peace or to promote feelings of hostility between different races or classes of the population which has a seditious tendency;
   vii. information which could likely lead to outbreak of racial, sectarian or political disturbances in general or a specific part of the country; and
   viii. documents relating the affairs of states such as military secrets, international affairs or Cabinet documents.
4. Research data which contains any of the information classified above, must be deposited in data archive/enclave and its disclosure is subject to Data Security Procedure of the policy.

5.10 Addressing Legal Impediment Arising From Novelty Requirements in Patent Law

Research Data About an Invention

1. Release of research data about an invention need to be delayed until patent application is filed in order not to violate the novelty requirements in patent law.
2. To avoid prolonged and unnecessary restriction/delay, decision to patent the invention must be made by the institution within six (6) months upon formal notification of the invention by the researcher.
3. Prior to the decision by the institution, disclosure of research data about an invention may be given effect in accordance to Data Security Procedure of the policy.
4. Where the institution's decision is not to patent the invention, the research data about an invention must be immediately released in accordance to Data Release Procedure of the policy.

5. Where the decision is to patent the invention, the patent application should be filed within six (6) months from the date the decision was made, unless it is shown that it is not possible due to the complexity of the patent to be filed.
6. Regardless of the above provisions, the research data about an invention may be disclosed without violating the novelty requirements in patent law, provided the patent application is filed within one year after its disclosure to the public.

5.11 Addressing Legal Impediment Arising From Lack of a Legal Duty to Ensure Data Quality

Data Providers' Duty to Ensure Data Quality

1. The duty to ensure the quality of the research data is shared between the researcher as creator/originator/custodian of the research data (hereinafter known as the "Primary Data Provider"), the institution as data owner and the online repository/archive/enclave where the research data is deposited (The institution and data repository/archive/enclave center are collectively known as "Secondary Data Providers").
2. For the purpose of the policy, it adopts the definition of data quality given by the US Office of Management and Budget Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility and Integrity of Information Disseminated by Federal Agencies 2002 (hereinafter referred as the "OMB Guidelines").
3. Under the OMB Guidelines "Quality" is defined as encompassing utility, objectivity and integrity.
4. Being the Primary Data Provider, the responsibility to ensure data quality ultimately falls on the researcher. The researcher must supply the metadata describing the research data which enables data users to assess the quality of the research data. The metadata must be in accordance to the minimum standard required under Data Documentation and Record Keeping Procedure of the Policy.
5. The Data Repository/Archive/Enclave Manager must ensure that the research data is deposited together with the metadata. The Data Repository/Archive/Enclave Manager must require the depositors to declare whether the research data is subject to evaluation, validation and verification by formal, independent, external peer review in-line with accepted best practice to determine its quality.
6. Where the research data is not subject to peer-review prior to data release, the Data Repository/Archive/Enclave Manager must require the university researcher who is the creator/originator of the research data to properly advise and warn the data users about the fact.
7. Regardless whether or not the research data is peer-reviewed prior to data release, the university researcher must advise and warn the non-expert/non-professional data users on the potential risks related to the use/reuse of the research data.
8. The warning should cover information such as data quality, source materials, the date data was last updated, any known limitations of the data, as well as the limitation, defect or potential risk in the data utilization. The warning should also include an advice on the need to obtain independent or professional advice and verification before acting or relying based on the research data which are not subject to peer review.
9. The institution as owner of the research data must treat data quality assurance as integral to data release. The institution should adopt the standard of care to ensure data quality which is provided under the OMB Guidelines and applicable to the institution and the researchers.

6. Conclusion

This study proposed a policy framework addressing the legal impediments to open access to public funded research data based on the key findings from comparative data analysis and the recommendations made by the previous studies. As the policy framework was developed after

analyzing various policies on open access to research data from Australia, Canada, the EU, the UK and the USA it is of international standard and suitable for adoption by research funding agencies or research institutions in Malaysia. Similar to current practices of other countries that already have a policy on open access to public funded research data, the policy is not proposed to be a subsidiary legislation of any law. Neither there is a need for the existing legislations such as intellectual property, confidentiality, privacy and security laws to be amended since the proposed policy can be implemented without violating any of the legal provisions. However, the government bodies, research funding agencies and research institutions adopting the proposed policy is expected to amend their intellectual property, research, publication and research funding policies so as to be consistent with the proposed policy as well as to accommodate the implementation of the proposed policy.

In terms of policy implication, it is anticipated that having a policy to address legal impediments to open access to public funded research data will benefit research institutions in Malaysia as the proposed policy will overcome data

accessibility problem faced by the researchers, while enhancing the visibility of public funded research data produced in Malaysia. The proposed policy could also help to detect data fraud as well as avoiding unnecessary duplication and repetition of data collection among the researchers. As for member of the public, the proposed policy could potentially increase the research's impact on society, as many types of public funded research data can be used beyond the scope of their original production in diverse and unlimited ways. Making public funded research data easily accessible to member of the public in a timely manner could help spur grassroots innovation as research data has been recognized as one of the building blocks and key input of innovation.

In the future, it is suggested that more research to be conducted to fill the gaps left by this study. A gap exists because of the emphasis given by this study to the legal impediments, as opposed to other types of impediments which also become barriers to open access to public funded research data. It is suggested that research on technical, technological or cultural impediments to the objective of enabling open access to public funded be conducted in the future. To complement open access initiative for public funded research data, future research should also focus on public funded research data in non-digital formats which cannot be released online. Since the policy framework is still at an early stage of development, it is also suggested that future research be conducted to determine what other substantive and procedural provisions ought to be introduced to support the implementation of the policy framework. Finally, it is suggested that an econometric analysis to be conducted in the future to evaluate and measure the impact of the policy on open access to public funded research data on data accessibility, data visibility, and grassroots innovation in the respective countries.

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A Study of Business Ventures' Successful R&D Mechanism through Open Innovation

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Abstract

The study focuses on the determinants of business ventures' sales by categorizing intra-enterprise resources in order to properly assess their influence, and classifying firms' competencies into two dimensions to observe the difference between the performance determinants of business ventures in each dimension. Through factor analysis, the firms' competencies including technology, price, quality, design, organization management, and marketing competitiveness were categorized into two dimensions of technological competence and management competence, and the firms were categorized as either technology-driven or management-driven, based on the comparative intensity of the two dimensions. Then, performance determinants were categorized into 6 superordinate categories of enterprise status, entrepreneur resource, human resource, financial resource, technological resource, and external resource, and the influence of the subordinate factors on sales were analyzed using two-year data of "The Survey of Korea Business Ventures." First, the results showed that 22 out of 33 variables used in the model had a significant influence on the sales of business ventures. Second, the analysis on the difference of determinants by group found that of the 33 independent variables, 13 variables at maximum and 8 at minimum were found to significantly influence sales, which verifies the difference between sales determinants in each dimension.

Keywords: business venture, Open Innovation, resource-based theory, performance determinant, technology-driven, management-driven, enterprise competence

1. Introduction

The domestic industrial market environment is rapidly changing, with competition both between domestic and overseas firms becoming more and more fierce due to globalization. It is essential not only for large enterprises but also for small and mid-sized business ventures to secure and develop their core competencies. It is particularly crucial for small and mid-sized business ventures, which are inferior compared to large enterprises in terms of resource procurement including financing and marketing activities, to focus on consistent R&D investment in order to successfully facilitate innovation so that they can seize a competitive advantage and increase their survival rate. If investment brings success to R&D activities, it may enhance the financial performance of a firm, including through sales growth (Branch, 1973; Heunks, 1998). However, it is difficult for small and mid-sized business ventures to actualize groundbreaking innovation through R&D due to their

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small size and lack of basic resources such as human and financial resources. R&D may in fact prove fatal to a firm if a substantial investment of time and money does not lead to appropriate outcomes.

It was through the domestic venture boom, national-level promotion policies and multidirectional aid, that Korea could claim a total of 35,027 business ventures as of September 2017. Despite the long-term economic depression, business ventures are creating jobs and contributing to domestic economic growth through innovative technology and challenging growth strategies. However, while business ventures enjoy high returns, their risk factors include low performance to resource input ratio and slow conversion of performance to revenue. Therefore, business ventures with less internal competence compared to large enterprises must apply their resources effectively, and verify key resources in accordance with the competence of the firm.

Also, technology development through external cooperation, or "Open Innovation", is rising as an alternative to development using internal resources. With less in the way of utilizable internal resources, it is necessary for small and mid-sized business ventures to actively materialize their technology or ideas through external cooperation such as joint development or contracted development with other firms or institutions, rather than focusing on self-led R&D. Previous studies on external cooperation by small and mid-sized business ventures were mainly focused on the following topics: the influence of external resource utilization in small and mid-sized R&D activities on performance; and the determinants of cooperation between small and mid-sized business ventures and large enterprises, and the correlation between such determinants (Belderbos et al., 2004; Lee and Kang, 2006; Kim, 2012). The various methods of technology development promotion, including self-development, and joint or contracted development with universities, national, public and private research institutes, or other enterprises may result in different outcomes in terms of a firm's financial performance. Also, as technology development performance may differ based on various factors, it is important to verify which factors influence sales, a criterion of R&D related financial performance.

Meanwhile, resource-based theory sees internal resources as the main cause of differences between firms' performance, and "resource" here refers to both tangible and intangible assets (Wernerfelt, 1984; Barney, 1991). Therefore, preceding studies from the vantage point of resource-based theory categorize determinants of business ventures' performance into human resources, financial resources, material resources, technological resources, and organizational resources (Hoffer and Schendel, 1979; Grant, 1991; Diericks and Cool, 1998; Lee, 2007). Moreover, core competence theory, which is derived from resource-based theory, refers to "competence" as the source of a competitive advantage and an internal resource that is differentiated from those of other firms, such as technical skills, product quality, and marketing (Hamel and Prahalad, 2006).

As such, the determinants of business ventures' performance include in the broader sense the 'resources' or 'competencies.' Previous studies were focused on case analyses, through which the researchers investigated the determinants of performance from only a single dimension. Therefore, this study aims to verify the determinants of sales by categorizing the internal resources of business ventures, observing the difference in the influences of determinants by classifying firms' competencies into the two dimensions of management competence and technological competence, and ultimately identifying the difference in the effects of Open Innovation on each type of firm. Based on the results of this analysis, we can expect to summarize the success factors of business ventures, and provide an appropriate guideline for the government in formulating supportive policies for the business ventures.

2. Theoretical Background

2.1 Business Ventures and Performance Determinants

While the definition of a business venture has not yet been academically clarified, it is generally considered to be a new firm founded by an individual or a small number of entrepreneurs, with high risk and high return. More specifically, the term "business ventures" has come to refer to technology-intensive businesses that aim to commercialize a new technology or an innovative idea (Lee et al., 2015). According to Article 2 of the Act on Special Measures on the Promotion of Venture Businesses, domestic business ventures should satisfy the requirements of one of the following: venture investment business, research and development business, or businesses that provide guarantee or loan based on technology evaluation.

In terms of the factors influencing a business venture's performance, the resource-based theory sees internal resources as a cause of differences in individual business performance when two business ventures face similar circumstances (Wernerfelt, 1984; Barney, 1991). Thus, according to the resource-based theory, it is the internal factors, rather than the environmental factors, that decide the differences in performance among individual firms. Here, the “resources” of this theory include both tangible and intangible assets, like capital, facilities, equipment, technological know-how, industrial property rights, and organization management. Thus, according to resource-based theory the factors that influence the performance of a business venture can thereby be defined as tangible and intangible assets that the firm owns internally.

This study will categorize business assets into five categories: (1) Firm status, (2) Entrepreneur resources, (3) Human resources, (4) Financial resources, and (5) Technological resources.

2.1.1 Firm Status

The current status of a business is not classified as an internal resource of a firm but falls instead into an independent category, and includes objective indices such as the life span and growth stage of the business. Further, Chung (2015) suggests that subcontract transactions with large enterprises place small and medium venture enterprises in a vertical relationship. This study accordingly includes the difference between the current profit rate and the desired, optimal profit rate of the business venture in the model as a vertical intensity that is quantitatively measurable.

Meanwhile, the analysis performed by Oh et al. (2009) on the influence of governmental support policy on business performance reveals that Venture, Inno-Biz[4] and Main-Biz[5] business support policies have the most significant influence on business performance. Kim et al. (2011) found significantly higher performance in terms of profitability among Inno-Biz certified business ventures. Thus, whether a business venture has received Inno-Biz and Main-Biz certification may have a significant influence on business performance.

2.1.2 Entrepreneur Resources

Study by Lee et al. (2015) on business ventures suggests that the characteristics of the founder should be a core subject of study, and accounts for the majority of research content. The competence of the founder was a main topic in the early stages of the related research, and many studies have been conducted on the age, education level, and experience

4 A firm certified by the Ministry of SMEs and Startups to show competitiveness based on technological innovation. The name is a compound word of innovation and business.

5 A firm certified by the Ministry of SMEs and Startups to show business innovation in non-technological aspects, such as marketing and organizational management. The name is a compound word of management, innovation, and business.

of the founder (Begley and Boyd, 1987; Sexton and Bowman, 1985; Bollinger, et al. 1983; Bowen and Hisrich, 1986). Some studies have found that education level and relevant business experience of the founder have a high influence on business performance (Birely and Norburn, 1987; Roure and Keely, 1990). However, as more firms are driven by modern technology and innovation, and as the founder and the CEO are not the same person in many firms, it is necessary to separate the factors of the firm's CEO and primary founder. Therefore, this study specifically classifies the entrepreneur resources into CEO and founder, taking into consideration the variables studied in preceding research, such as the influence of age, education level, years of work experience, and past entrepreneurship experience.

2.1.3 Human Resources

Human resources are sometimes represented by the number of workers, but this would be taking only the quantitative aspect into account. Workers in a business can be divided into permanent workers and temporary workers—permanent workers will represent the stability of quantitative human resources in a business, and temporary workers will represent the instability of quantitative human resources. Meanwhile, the qualitative human resources can be represented by the education level or job performance of workers, but there is difficulty in measuring this education level objectively. Thus, a way to indirectly measure such variable could be to measure the positive attitude of a business towards training its employees, whether it does engage in training sessions, and whether it conducts its own training sessions, receives commissioned education or utilizes both. On the other hand, motivating workers to enhance their voluntary efforts and creativity is important, and incentive levels actually point to higher business performances. This implies that compensatory motivation to workers can improve performance (Kim and Kim, 2005), and this study examined stock options as a method to compensate for performance and motivate workers to enhance their productivity.

2.1.4 Financial Resources

Business ventures have limitations when it comes to securing financial resources through loans or stocks, and a number of analyses on the survival of business ventures have shown that the financial resources of the firm have a significant influence on the survival of the business (Hong, 2002; Lee, 1998; Lee et al., 2005). There is a divergence of opinion with regard to equity structure, as the interest alignment hypothesis claims it can positively influence business performance, whereas the managerial entrenchment hypothesis claims otherwise (Alchian and Demsetz, 1972; Jensen and Meckling, 1976; Demsetz, 1983; Fama and Jensen, 1983; Rhee and Cho, 1999). According to the empirical analysis performed by Kwon and Lee (2004), it was found that R&D costs do not directly influence business value. This study aims to take the analysis a step further and examine what percentage of the total investment is accounted for by equipment and R&D, respectively, and consider how they influence business performance, taking the financial limitations of business ventures and the difference in size among businesses into account. Meanwhile, the size and source of secured funds for that year may lead to differences in business performance (Lee and Moon, 2002). Consequently, it may be projected that business performance may be influenced by the ratio of liabilities that are from individual investors and general liquidities like banks, and not government organizations or policy support.

2.1.5 Technological Resources

Spanos and Lioukas (2001) analyzed the influence of business resources on business performance based on resource-based theory and industrial organization theory, while the study on business venture performance by Song et al. (2012) concluded that as the level of technological resources of a business improves, business performance would be positively influenced. Here, technological resources can be designated as the main skilled technology or know-how that a business possesses, which may take the form of intangible assets like intellectual property or international patent rights. The study by Kim (2012) on the influence of external cooperation on innovative performance did not analyze the influence of the main product cycle on innovative performance. This study attempts to supplement and expand Kim's findings by including the following in the model: the development stages of main products and services, the position of its technology level in domestic and foreign markets, and the domestic and foreign market share.

However, the assets needed to create business outcomes are not always obtainable internally, as with the rise of the "Open Innovation" concept, resources owned by possible cooperative agents such as government and organizations, other businesses, and universities or research institutions can also become an important source of assets for business outcomes (Van de Ven, 1993; Song and Shin, 1998). Business ventures that are relatively lacking in resources and competence may seek to create business outcomes using the resources of external cooperative agents under the aforementioned "Open Innovation" concept. Studies confirm that cooperation with external agents has significant influence on innovation outcomes of business ventures (Park and Lee, 2006; Kim, 2005; Hong, 2005; Kim, 2012). Thus, it can be expected that the identity of the external cooperative agent, and whether and to what extent cooperation is carried out may influence the business performance of a business venture.

2.2 Open Innovation of Business Ventures

As not only internal competence but external cooperation grows important in the technological innovation of enterprises, the network among firms that is referred to as 'Open Innovation' is becoming crucial. Business ventures that are relatively lacking in R&D resources and technological capacities can set up effective R&D investment strategies by actively utilizing external technical skills and ideas. Businesses can spread risk and cut down on R&D costs by utilizing such external assets, and respond adequately to fast-moving markets and innovation as well (Chesbrough, 2006; Chen et al., 2007; Gann, 2005). Audretsch and Vivarelli (1994) conducted a comparative analysis on patent outcomes in specific regions of Italy, and found that the patent outcomes of businesses were influenced by the research level and R&D level of local universities, and that small and medium-sized venture enterprises in particular benefit more from the infrastructure for innovative activities and research by external agents than large enterprises would.

Hagedoorn and Schakenraad (1994) state that technological cooperation can create economies of scale, and thus the large–scale projects enabled through technological cooperation can lead to a greater number of innovative ideas than individual small-scale projects would. In addition, studies indicating that technological cooperation can shorten product development and expedite market entry (Hagedoorn, 1993; Uzzi, 1997) and studies on the impact of number of partnerships on innovation outcomes (Shan et al., 1994; Kotabe & Swan, 1995) lead to the conclusion that technological cooperation with external organizations can enhance innovation outcomes and improve the competitive power of a company.

Many studies concerning external technological cooperation of domestic business ventures have found that technological cooperation can promote technological innovation in small and medium-sized venture enterprises, and result in higher technological innovation outcomes (Bae and Chung, 1997; Park and Lee, 2006; Kim, 2005). Meanwhile, other studies suggest that technological cooperation with research institutions does not have a significant influence on business ventures in knowledge-based industries. They state that cooperative activities with other businesses have no correlation with financial outcomes, and that there is the risk of exposure of technical information and data due to differences in capital or information asymmetry among businesses, bringing the danger of negative effects related to disadvantageous terms and conditions of business (Small & Medium Business Administration, 2010; Hong, 2005).

Most of the preceding research has been focused on analyzing whether cooperating with large enterprises or institutions will have positive or negative influences on technological development outcomes for small and mid-sized venture enterprises, or on determining the influence it may have on technological innovation outcomes. This study recognizes the need to empirically confirm what determinants influence a company's sales performance according to the level of external cooperation. In addition, this study aims to confirm the relationship with business performance separately according to the agent of external cooperation, which can generally be classified as cooperation with (1) research institutions such as government organizations, university institutions or private institutions, or (2) among firms including large enterprises, companies in the same industry, or others. As research institutions and businesses essentially have different purposes, the motive for cooperation may be different for each, and it can be assumed their level of influence may differ accordingly.

2.3 Competence Dimensions of Business Ventures

Hamel and Prahalad's core competence theory (2006), a concept further developed from resource-based theory, has become a key concept regarding corporate strategy, individual policy and governmental policy. According to Hamel and Prahalad (2006), core competence is the "internal competence of firms that not only differentiates a firm from other competing firms, but also acts as the source of a competitive advantage that takes effect as the core of business success. Furthermore, core competence is based on tangible and intangible assets and organizational abilities, and cannot be consumed and is improved through continuous learning and sharing processes." Also, the ability to create value, the ability to differentiate, expandability and scarcity are suggested as conditions for core competence, among others.

However, previous studies on the core competence of business ventures in Korea were limited to analyzing the influence of each competence on business performance, the influence of each competence on corporate strategy, case studies on the characteristics of core competence and others (Song et al. 2012; Song and Shin, 1998). Song and Shin's research (1998) classified the firm's ability that influences a business venture's performance according to the type of parent organization. It was difficult to generalize this case study, as a small number of samples was targeted for the analysis.

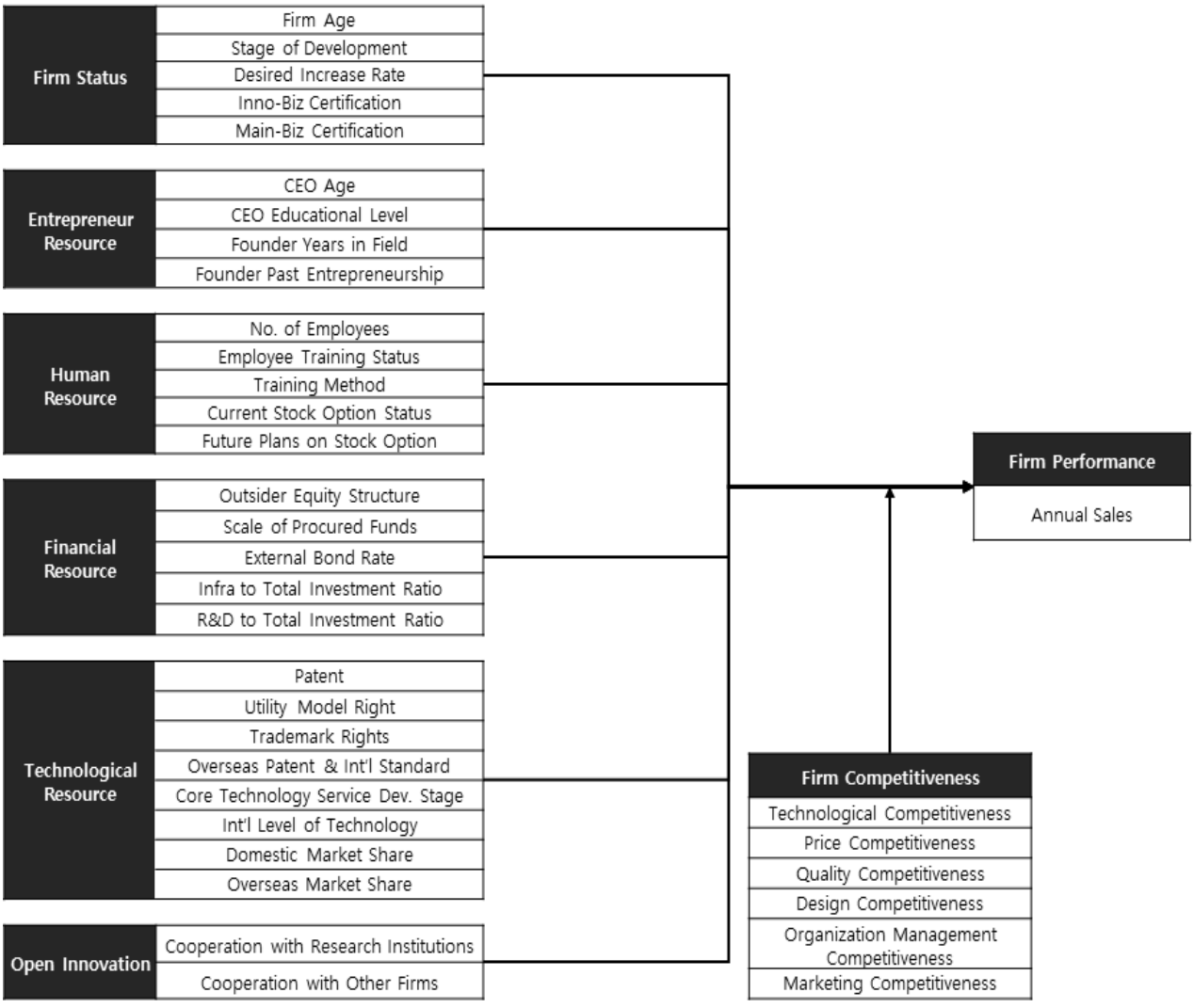
Therefore, this study attempts to classify the core competencies held by a business venture by organizing them according to their realm of competence from the perspective of core competence theory. Here, a firm's core competence is divided into six individual competencies (competitiveness): technology, price, quality, design, organization management and marketing. Through the dimensional reduction using factorial analysis on the six competencies, competence shall be classified

into two competence dimensions. The study aims to verify the difference among each business venture's performance influence factor according to each group after classifying each dimension according to the level of each dimension by forming a two-dimensional surface on X-Y.

2.4 Research Model

Based on earlier studies, the study suggests the following research model, in which annual sales, an index of the financial performance of a firm, is set as a dependent variable. The determinants of business performance were classified into five categories from the perspective of resource-based theory to analyze their influence, and to verify whether the factors in the categories are subject to changes in their level of influence based on competence dimension categorization. Also, the study aims to check whether or not the relationship between these factors has a moderating effect, by considering the category of external cooperation of a firm.

Figure 1. Research model



The five categories of the factors include firm status, entrepreneur resource, human resource, financial resource, and technological resource; detailed factors are as follows. First, the detailed factors within firm status are: firm's age based on the date of incorporation, firm's stage of development, desired increase in rate of return calculated through appropriate rate of return compared with a firm's current rate of return, and Inno-Biz system and Main-Biz system certification. Second, CEO's age and education, founder's past experience in the field and past entrepreneurship experiences are included in entrepreneur resource. Third, quantitative factors including the number of temporary and permanent workers, and qualitative factors including employee attitude toward the method of training are classified as human resources. Fourth, investment of a firm, equity structure of CEO, founder, and outsiders not affiliated with the CEO or founder, scale of geared fund, ratio of external bonds that are not government or national bonds, and ratio of investment in infrastructure and R&D to total amount of investment are classified as financial resource. Fifth, technological competence includes the total number of intellectual properties owned by a firm, the amount of overseas patent and international standards, the stage of development of core technologies and services, and the firm's technology level and market share in the domestic and international market. Finally, regarding external cooperation, cooperation with university, government and national research institutes will be classified as "Cooperation with research institutions," while cooperation with business ventures, large enterprises, and foreign firms will be classified as "cooperation with other firms" with regard to the intensity of the cooperation.

Lastly, the six competencies will each be classified into two competence dimensions, including technology, price, quality, design, organizational management and marketing. Figure 1 illustrates the factors discussed above.

3. Research Design

3.1 Sample and Data Collection

Two-year data of "The Survey of Korea Business Ventures" of 2014 and 2015 were used for the analysis of this study model. The survey, carried out under the Act on Special Measures for the Promotion of Venture Businesses, is based on research and analysis of basic statistics regarding the general status and business performance of 29,067 (in 2014) and 29,844 (in 2015) certified business ventures excluding preliminary business ventures as of December of 2013 and 2014, respectively. The survey was conducted for 2.5 months during the 3rd quarter of each year through a combination of various means including on-line surveys, phone, FAX, and e-mail, and total of 4,325 valid samples (2,098 in 2014 and 2,227 in 2015) were collected through systematic sampling based on type, size, and region of business.

Of the 4,325 samples collected from the two-year data, 348 firms listed on the exchange and KOSDAQ and 468 firms aiming to be listed in the near future were eliminated. This was in order to exclude samples with a substantial amount of capital, sales performance, profitability and financial soundness, as these would be likely to distort the performance of ventures and moderate the "high risk" element, in consideration of the core characteristics of business ventures, which are high risk and high return. After excluding listed firms and missing values, 3509 effective samples were formed for model analysis. The operational definitions of each value used to verify the model used in this study are as follows.

Table 1. Definitions and measurement of variables

Variables			Measurement
Dependent Variable		Annual Sales	Original value as written on the Survey on Sales through R&D
Competence Variable		Technological Competitiveness	5-point scale ranking the competitiveness of the firm compared to the top-level global firms in the same field
		Price Competitiveness	
		Quality Competitiveness	
		Design Competitiveness	
		Organization Management Competitiveness	
		Marketing Competitiveness	
Independent Variable	Firm Status	Firm Age	Firm's age as of the time of the survey
		Stage of Development	Stages of growth: Launch, Growth, Shake-out, Maturity, Decline
		Desired Increase Rate	The difference between the current and desired profit ratio
		Inno-Biz Certification	Acquired Inno-Biz Certificate?
		Main-Biz Certification	Acquired Main-Biz Certificate?
	Entrepreneur Resources	CEO's Age	Age of the CEO as of the time of the survey
		CEO's Education Level	The education level of the CEO, from middle school to doctorate
		Founder's Years in Field	Founder's years in field of business at the time of foundation
		Founder's Past Entrepreneurship	Founder's previous experiences in company foundation
	Human Resources	No. of Employees	Total number of employees, including irregular and temporary
		Training Status	5-point scale on training (Very inactive – Very active)
		Training Method	4 types of training methods (Self, Commissioned, Both, None)
		Current Stock Option Status	Current utilization of stock options
		Future Plans regarding Stock Options	Future plan on stock option utilization
	Financial Resources	Outsider Equity Structure	Percentage of equity held by outsiders, who are not founders, CEO or acquaintances
		Scale of Procured Funds	Scale of newly geared fund (million KRW)
		External Bond Rate	Percentage of external funding excluding government subsidy
		Infra to Total Investment Ratio	Percentage of infrastructure investment to total investment
		R&D to Total Investment Ratio	Percentage of domestic R&D investment to total investment
	Technological Resources	Patent	Number of patents registered and held by the firm
		Utility Model Right	Number of utility model rights registered and held by the firm
		Trademark Rights	Number of trademark rights registered and held by the firm
		Overseas Patent & Int'l Standard	Number of overseas patents and international standards registered and held by the firm
		Core Technology Service Dev. Stage	Stage of development of core products and services (Early development, Commercialization, Early market entry, Market expansion)
		Int'l Level of Technology	The technological level of core products and services, compared with the international level
		Domestic Market Share	Domestic market share of the corresponding year
		Overseas Market Share	Overseas market share of the corresponding year
	External Cooperation	Universities	5-point scale on cooperative activities with universities
		Government and National Institutions	5-point scale on cooperative activities with government and national institutions
		Private Companies	5-point scale on cooperative activities with private companies
		Small and Mid-sized Ventures	5-point scale on cooperative activities with small and mid-sized ventures
		Large Enterprises	5-point scale on cooperative activities with large enterprises
		Foreign Firms	5-point scale on cooperative activities with foreign firms

Table 2. Two dimensions of competence

KMO Value of Sample Relevance			0.830
Bartlett's Sphericity Test		Approx. Chi2	7858.642
		Degree of Freedom	15
		Significant Probability	0.000
Competence Dimension	Indices	Component 1	Component 2
Technology	Technology Competitiveness	0.857	0.170
	Price Competitiveness	0.813	0.254
	Quality Competitiveness	0.675	0.273
Management	Design Competitiveness	0.189	0.876
	Organization Management Competitiveness	0.270	0.836
	Marketing Competitiveness	0.537	0.563
Eigenvalue		2.248	1.951
Variance Explanation (%)		37.461	32.518
Accumulated Explanation (%)		37.461	69.979
Cronbach's Alpha		0.765	0.781

3.2 Classification of Business Ventures' Competencies

3.2.1 Competence Reliability and Factor Analysis

Factor analysis on the level of competitiveness, which is used as a competence variable in the study, was conducted to observe the determinants of business venture sales according to each competence dimension. Factor analysis is a statistical methodology which extracts a small number of potential variables from numerous observable variables, and the study aimed to extract potential competence dimensions from the 6 competitiveness variables of technology, price, quality, design, organization management, and marketing.

The results of factor analysis showed that the Kaiser-Meyer-Olkin (KMO) value, an index which explains the appropriateness of the entire correlation matrix on factor analysis, was 0.83, which falls between 0.8 or more and 0.9 or less, and is meritorious under Kaiser's definition. Bartlett's Sphericity Test also rejects the null hypothesis that the coefficient of variables is 0 with a 99% confidence interval, providing further evidence for the appropriateness of the sample in factor analysis.

Then, it was determined that two components, which was just before the decrease in the eigenvalue, would be selected to be used as the number of factors through Verimax rotation, and it was discovered that two components provided almost 70% of the explanatory power of all variables. Cronbach's Alpha, which indicates the consistency and homogeneity of the variables, was measured as 0.765 and 0.781, respectively, providing an acceptable level of reliability.

3.2.2 Classification of Competitiveness and Competencies

Based on prescribed factor analysis, the 6 competitiveness factors were categorized into two competence dimensions, with technology, price, and quality competitiveness in the technological competence category, and design, organization management, and marketing competitiveness in the management competence category.

Table 3. Difference between the characteristics of technology-driven firms and management-driven firms

Characteristics	Management-driven Mean / SD	Technology-driven Mean / SD	F-Value	p-Value
Dependent_Annual Sales	7402.68	6571.74	2.35	0.13
	16593.97	14653.02		
Firm_Firm Age	10.14	10.11	0.02	0.89
	6.42	6.53		
Firm_Stage of Development	2.78	2.73	2.55	0.11
	0.89	0.89		
Other_Desired Increase Rate	7.77	7.52	1.74	0.19
	5.62	5.57		
Firm_Inno-Biz Certification	0.37	0.36	0.35	0.56
	0.48	0.48		
Firm_Main-Biz Certification	0.06	0.07	0.38	0.54
	0.24	0.25		
CEO_Gender_Male	0.94	0.94	0.01	0.93
	0.24	0.24		
CEO_Age	49.75	50.29	4.02	0.05
	7.64	8.06		
CEO_Education Level	3.03	3.09	2.65	0.10
	1.05	1.14		
CEO_Engineering Major	0.58	0.56	1.35	0.25
	0.49	0.50		
Founder_CEO	0.90	0.89	2.55	0.11
	0.29	0.32		
Founder_Gender_Male	0.95	0.96	2.24	0.13
	0.23	0.20		
Founder_Age Group	37.20	37.53	1.58	0.21
	7.79	7.74		
Founder_Education Level	2.93	3.00	2.64	0.10
	1.05	1.16		
Founder_Engineering Major	0.57	0.56	0.31	0.58
	0.49	0.50		
Founder_Years in Field	10.81	11.14	1.94	0.16
	6.84	7.06		
Founder_Past Entrepreneurship	0.12	0.18	28.99	0.00
	0.32	0.39		
Founder_Successful Past Entrepreneurship	0.12	0.16	6.82	0.01
	0.40	0.42		
Founder_Failed Past Entrepreneurship	0.04	0.09	24.03	0.00
	0.28	0.33		

Founder_Sum of Past Entrepreneurships	0.16	0.25	20.81	0.00
	0.53	0.60		
HR_Corresponding Year_ Regular Employee	26.26	23.29	4.13	0.04
	46.82	35.82		
HR_Corresponding Year_ Total No. of Workers	27.41	24.25	4.13	0.04
	49.50	38.98		
HR_Training	3.26	3.27	0.02	0.89
	0.64	0.64		
HR_Training Method	2.20	2.18	0.14	0.71
	1.03	0.99		
HR_Stock Option_Current and Future	0.04	0.08	43.74	0.00
	0.16	0.22		
HR_Stock Option_Current	0.02	0.03	5.84	0.02
	0.12	0.16		
HR_Stock Option_Future	0.07	0.14	51.98	0.00
	0.25	0.35		
Fund_Equity Structure_Acquaintance	79.90	80.70	0.96	0.33
	23.93	23.46		
Fund_Equity Structure_External	20.10	19.30	0.96	0.33
	23.93	23.46		
Fund_Policy Support_Yes	0.36	0.44	24.96	0.00
	0.48	0.50		
Fund_Procured Fund	299.72	347.76	1.50	0.22
	1031.28	1290.85		
Fund_Gearing Ratio_Government	32.46	38.85	16.56	0.00
	45.50	46.38		
Fund_Gearing Ratio_External Bond	28.36	32.56	7.76	0.01
	43.70	44.40		
Fund_Total Amount Invested	254.79	289.47	1.75	0.19
	782.80	738.54		
Fund_Total Amount Invested_ Infrastructure Ratio	11.45	15.88	18.62	0.00
	28.48	31.96		
Fund_Total Amount Invested_R&D Ratio	41.78	46.74	9.68	0.00
	47.02	45.93		
Technology_Technology Relevance_ Industry	4.17	4.30	2.08	0.15
	2.69	2.63		
Technology_Patent	3.52	4.29	11.38	0.00
	6.08	7.30		
Technology_Utility Model Rights	0.65	0.78	1.81	0.18
	2.83	2.90		
Technology_Design Rights	0.88	1.21	4.14	0.04
	3.55	5.93		

Technology_Trademark Rights	0.99	1.11	0.82	0.36
	4.08	3.18		
Technology_Overseas Industrial Property	0.28	0.37	1.41	0.23
	2.18	2.50		
Technology_IP_Total	6.33	7.76	10.69	0.00
	11.48	14.44		
Technology_Overseas Patent and International Standards	0.42	0.47	8.29	0.00
	0.49	0.50		
Technology_Core Technology Service_Development Stage	4.25	4.35	7.57	0.01
	1.04	0.89		
Technology_Product and Service_Structure	1.97	2.07	20.11	0.00
	0.68	0.68		
Technology_Technology Level_Global	3.31	3.12	37.41	0.00
	0.87	0.95		
Technology_Technology Level_Domestic	2.70	2.45	65.68	0.00
	0.87	0.91		
Technology_Number of Brands	0.81	0.97	4.48	0.03
	2.44	1.79		
Technology_Domestic Market Share	13.14	13.89	1.18	0.28
	19.88	20.13		
Technology_Foreign Market Share	1.50	1.24	1.10	0.30
	7.98	6.32		
Technology_ Raw Material or Component Import	0.23	0.31	34.12	0.00
	0.42	0.46		
Cooperation_University	1.22	1.48	17.24	0.00
	1.84	1.94		
Cooperation_Government	0.63	0.86	19.13	0.00
	1.49	1.71		
Cooperation_Private Company	0.18	0.19	0.12	0.72
	0.83	0.86		
Cooperation_Small and Mid-sized Venture	0.28	0.43	13.85	0.00
	1.04	1.24		
Cooperation_Large Enterprise	0.23	0.37	15.16	0.00
	0.93	1.17		
Cooperation_Foreign Firm	0.10	0.14	3.22	0.07
	0.63	0.75		
Cooperation with Research Institution	0.68	0.85	24.21	0.00
	0.99	1.06		
Cooperation with Other Firms	0.20	0.31	22.45	0.00
	0.62	0.73		

The analysis on the difference in the characteristics of technology-driven and management-driven firms found that 31 out of 60 variables had statistical significance. Specifically, management-driven firms showed a higher mean value than technology-driven firms in the following four variables: 'HR_Corresponding Year_Regular Employee'; 'HR_Corresponding Year_Total No. of Workers'; 'Technology_Technology Level_Global': and 'Technology_Technology Level_Domestic.' In contrast, technology-driven firms showed a higher mean value than management-driven firms in the following 27 variables: 'CEO_Age'; 'Founder_Past Entrepreneurship'; 'Founder_Successful Past Entrepreneurship'; 'Founder_Failed Past Entrepreneurship'; 'Founder_Sum of Past Entrepreneurships'; 'HR_Stock Option_Current and Future'; 'HR_Stock Option_Current and Future'; 'HR_Stock Option_Future'; 'Fund_Policy Support'; 'Fund_Gearing Ratio_Government'; 'Fund_Gearing Ratio_External Bond'; 'Fund_Total Amount Invested_Infrastructure Ratio'; 'Fund_Total Amount Invested_R&D Ratio'; 'Technology_Patent'; Technology_Design Rights'; 'Technology_IP_Total'; 'Technology_Overseas Patent and International Standards'; 'Technology_Core Technology Service_Development Stage'; 'Technology_Product and Service_Structure'; 'Technology_Number of Brands'; and 'Technology_Raw Material or Component Import.'

4. Results

4.1 Determinants of Business Venture's Annual Sales for All Firms

The research was conducted across 3,509 business ventures based on the two-year data of 2014 and 2015, using moderated regression analysis. The results are as shown in Table 4.

Table 4. Determinants of annual Sales of business ventures

n=3509					Collinearity Statistics	
Dependent Variable: Annual Sales		Standardized Beta	t	p	Common difference	VIF
(constant)		-	1.471	.141	-	-
Firm Status	**Firm Age**	**.103**	**5.662**	**.000**	**.487**	**2.052**
	Stage of Development	.006	.379	.705	.583	1.715
	Desired Increase Rate	.001	.081	.935	.971	1.030
	Inno-Biz Certification	.007	.467	.640	.682	1.467
	Main-Biz Certification	**.030**	**2.277**	**.023**	**.934**	**1.071**
Entrepreneur Resources	CEO's Age	-.008	-.520	.603	.610	1.638
	CEO's Education Level	-.019	-1.436	.151	.909	1.100
	Founder's Years in Field	**.032**	**2.153**	**.031**	**.743**	**1.346**
	Founder's Past entrepreneurship	-.012	-.913	.361	.939	1.065
Human Resources	**Number of Employees**	**.605**	**41.963**	**0.000**	**.780**	**1.282**
	Training	-.018	-1.332	.183	.910	1.098
	Training Method	-.003	-.209	.834	.941	1.063
	Current Stock Option Status	-.014	-1.016	.310	.838	1.193
	Future Plans regarding Stock Options	-.003	-.226	.821	.769	1.301

Financial Resources	Outsider Equity Structure	-.009	-.680	.496	.958	1.044
	Scale of Geared funds	-.011	-.807	.419	.888	1.127
	External Bond Ratio	**.026**	**1.797**	**.072**	**.790**	**1.266**
	% Infrastructure to Total Investment	.010	.698	.485	.811	1.232
	% R&D to Total Investment	-.022	-1.486	.137	.719	1.390
Technological Resources	Patent	.021	1.473	.141	.778	1.285
	Utility Model Right	-.012	-.908	.364	.886	1.129
	Trademark Rights	.012	.906	.365	.905	1.104
	Overseas Patent & International Standard	-.004	-.260	.795	.854	1.170
	Core Technology Service Development Stage	-.007	-.545	.586	.891	1.123
	Technology Level in Global Market	**-.028**	**-2.059**	**.040**	**.886**	**1.128**
	Domestic Market Share	.000	.024	.981	.900	1.112
	Overseas Market Share	.008	.584	.559	.934	1.070
External Cooperation	Cooperation with Research Institutions	-.010	-.706	.480	.788	1.269
	Cooperation with Other Firms	-.021	-1.525	.127	.839	1.192

	Adjusted R2	Change in R2	Change in F	p-Value
	0.431	0.436	92.681	0.000

The analysis of 3,509 business ventures revealed that 6 independent variables out of 6 competencies, 27 independent variables and 2 constant variables had a significant influence on the firm's annual sales.

First, of the 5 variables listed under 'Firm Status', CEO's age and Main-Biz Certification were confirmed to exert a significant influence over annual sales, at a 95% confidence interval. In such cases, the positive influence of both factors was contingent on firms' age, which was represented by their date of establishment and the acquisition of Main-biz certification. Second, it was observed that of the 4 variables listed under 'Entrepreneur Resources', the founder's years in the field prior to foundation influenced the company's annual sales up to a 95% confidence interval. In other words, the more experience in the field of business the founder has prior to setting up a company, the more positive influence it has on the firm's annual sales. Third, of the 5 variables listed under 'Human Resources', the number of employees was found to have a significant influence over annual sales, at a 99% confidence interval. In such cases, the total employee number—which includes both temporary and full-time employees—was proven to exert a positive influence over annual sales. In particular, a high standardized β value points to the influence of human resources, which play an important role against a business backdrop characterized by either an individual or a small group of employees. On the other hand, considering that the employee number reflects the size of the company, it is possible to speculate that company

size causes deviations in annual sales performances. Fourth, of the 5 variables listed under 'Financial Resources', the ratio of external bonds was observed to exert a significant influence over annual sales, at a 90% confidence interval. Depending on the rate of positivity afforded by external bonds, deviations in a firm's annual sales can be attributed to differing sources of capital. Lastly, of the 8 variables listed under 'Technological Resources', the level of technology on a global scale was seen to have a significant influence over a firm's annual sales, at a 95% confidence interval. The lower a firm's technology skill compared to international competitors, the more of a negative influence it had on annual sales.

4.2 Determinants of Business Ventures' Sales: Technology-driven vs. Management-driven

A separate regression analysis was conducted for the variables identified in the aforementioned factor analysis to illustrate the differences in sales that result from disparities in corporate ability. Based on competence level, 1,462 firms were classified as technology-driven, while 2,047 were classified as management-driven. The results of the analyses are as shown in Table 5.

The analysis of 1,462 technology-driven firms showed that 7 independent variables among the 27 independent variables and 2 control variables had a significant influence over a firm's annual sales.

The variables listed under the first two categories—'Firm Status' and 'Entrepreneur Resources'—were shown to have no significant influence over sales.

In contrast, of the 5 variables listed under 'Human Resources', the number of employees and training method were each found to have a significant influence over the firm's annual sales, at a 99% and 90% confidence interval, respectively. In this case, the number of employees, in tandem with the overall firm model, was observed to exert a positive influence over annual sales and exhibit a high standardized β value. Conversely, training methods were revealed to have a negative influence over a firm's sales.

Of the 5 variables listed under 'Human Resources', the external bond ratio and percentage of R&D investment to total investment were each observed to have a significant influence over firm's annual sales, at a 90% and 95% confidence interval, respectively. The external bond ratio was shown to have a positive influence over annual sales, just like the overall model. In contrast, the percentage of R&D investment to total investment, which reflects the rate at which investment is allocated toward R&D, was seen to exert a negative influence over a firm's annual sales. This outcome is attributable to the fact that funds channeled towards developing a product are used up as expenses during the development process, failing to generate any form of actual annual sales.

Lastly, of the 8 variables listed under 'Technological Resources', the number of patents and the level of technology in the global market were each observed to have a significant influence over a firm's annual sales, at a 99% and 95% confidence interval, respectively. The more patents a firm possessed, the greater the positive influence it had on annual sales. However, the lower the firm's technology level was in the global market, the more of a negative influence it had on a firm's annual sales, just like the overall model.

The analysis of 2,047 management-driven firms was conducted in the same manner as the analysis for technology-driven firms, and the results are outlined in Table 6.

Table 5. Determinants of annual Sales of technology-driven business ventures

n=1462					Collinearity Statistics	
Dependent Variable: Annual Sales		Standardized Beta	t	p	Common difference	VIF
(Constant)		-	1.615	0.107	-	-
Firm Status	Firm Age	.031	1.132	.258	.471	2.123
	Stage of Development	.014	.583	.560	.573	1.746
	Desired Increase Rate	-.007	-.359	.720	.945	1.058
	Inno-Biz Certification	-.003	-.151	.880	.662	1.511
	Main-Biz Certification	.006	.300	.764	.922	1.085
Entrepreneur Resources	CEO's Age	-.020	-.835	.404	.617	1.620
	CEO's Education Level	.001	.074	.941	.890	1.124
	Founder’s Years in Field	.028	1.309	.191	.754	1.327
	Founder’s Past entrepreneurship	-.006	-.326	.744	.918	1.089
Human Resources	Number of Employees	.681	32.280	.000	.783	1.277
	Training	-.018	-.944	.345	.930	1.075
	Training Method	-.034	-1.748	.081	.949	1.054
	Current Stock Option Status	-.004	-.201	.840	.826	1.211
	Future Plans regarding Stock Options	-.008	-.365	.715	.733	1.364
Financial Resources	Outsider Equity Structure	.004	.198	.843	.935	1.069
	Scale of Geared funds	-.010	-.492	.623	.909	1.100
	External Bond Ratio	.037	1.785	.074	.816	1.226
	% Infrastructure to Total Investment	-.029	-1.356	.175	.787	1.270
	% R&D to Total Investment	-.054	-2.469	.014	.718	1.393
Technological Resources	Patent	.060	2.692	.007	.695	1.439
	Utility Model Right	-.018	-.835	.404	.761	1.314
	Trademark Rights	.006	.328	.743	.892	1.121
	Overseas Patent & International Standard	-.004	-.218	.828	.860	1.162
	Core Technology Service Development Stage	.006	.282	.778	.859	1.164
	Technology Level in Global Market	-.044	-2.225	.026	.877	1.140
	Domestic Market Share	-.018	-.934	.350	.908	1.101
	Overseas Market Share	.028	1.471	.142	.938	1.066
External Cooperation	Cooperation with Research Institutions	.003	.139	.890	.789	1.267
	Cooperation with Other Firms	-.035	-1.724	.085	.859	1.164

Table 6. Determinants of annual sales of management-driven business ventures

n=2047					Collinearity Statistics	
Dependent Variable: Annual Sales		Standardized Beta	t	p	Common difference	VIF
(constant)		-	.756	.450	-	-
Firm Status	Firm Age	.143	5.883	.000	.491	2.036
	Stage of Development	.000	.004	.997	.582	1.720
	Desired Increase Rate	.001	.087	.931	.975	1.026
	Inno-Biz Certification	.012	.557	.578	.675	1.482
	Main-Biz Certification	.048	2.710	.007	.926	1.080
Entrepreneur Resources	CEO's Age	.002	.088	.930	.591	1.691
	CEO's Education Level	-.035	-1.951	.051	.907	1.103
	Founder's Years in Field	.031	1.536	.125	.718	1.393
	Founder's Past entrepreneurship	-.014	-.819	.413	.947	1.056
Human Resources	Number of Employees	.569	29.175	.000	.761	1.315
	Training	-.022	-1.207	.228	.873	1.146
	Training Method	.017	.978	.328	.916	1.092
	Current Stock Option Status	-.021	-1.133	.257	.837	1.194
	Future Plans regarding Stock Options	-.001	-.054	.957	.797	1.254
Financial Resources	Outsider Equity Structure	-.015	-.867	.386	.950	1.053
	Scale of Geared funds	-.011	-.606	.544	.853	1.172
	External Bond Ratio	.014	.706	.480	.759	1.317
	% Infrastructure to Total Investment	.034	1.818	.069	.815	1.227
	% R&D to Total Investment	-.002	-.083	.933	.711	1.406
Technological Resources	Patent	-.007	-.347	.729	.787	1.270
	Utility Model Right	-.016	-.916	.360	.929	1.077
	Trademark Rights	.022	1.232	.218	.887	1.127
	Overseas Patent & International Standard	-.006	-.337	.736	.831	1.204
	Core Technology Service Development Stage	-.015	-.842	.400	.895	1.118
	Technology Level in Global Market	-.018	-.973	.331	.880	1.136
	Domestic Market Share	.011	.632	.528	.875	1.143
	Overseas Market Share	-.004	-.241	.810	.909	1.100
External Cooperation	Cooperation with Research Institutions	-.017	-.872	.384	.773	1.293
	Cooperation with Other Firms	-.011	-.594	.553	.810	1.234

According to the results, of the 6 competencies, 27 independent variables and 2 constant variables, 5 independent variables were observed to exert a significant influence over a firm's annual sales.

First, of the 5 variables listed under 'Firm Status', firm's age and Main-biz certification were each shown to have a significant influence on a firm's annual sales, at a 99% confidence interval. In alignment with the overall model, both variables were observed to have a positive influence over a firm's annual sales.

Second, of the 4 variables listed under 'Entrepreneur Resources', the CEO's academic level was observed to have a significant influence over a firm's annual sales, at a 90% confidence interval. Contrary to expectations, a firm's annual sales enjoyed a higher rate of increase when the CEO's academic level was low.

Third, of the 5 variables listed under 'Human Resources', the number of employees was observed to have a significant influence over a firm's annual sales, at a 99% confidence interval. Here, the number of employees had a positive influence over a firm's annual sales, just like in the overall model, and exhibited a high standardized β value.

Fourth, of the 5 variables listed under 'Financial Resources', the total fund infrastructure rate showed a significant influence over a firm's annual sales, at a 90% confidence interval. An increase in the amount of funds allocated towards infrastructure was reflected by an increase in firm's annual sales. Lastly, the 8 variables included under 'Technological Resources' were observed to lack any significant influence over a firm's annual sales.

5. Conclusion

This study focused on investigating the influence that 6 factors—corporate status, entrepreneur resources, human resources, financial resources, technological resources, and external resources—have on firm performance, from the perspective of resource-based theory. Furthermore, this study divided a firm's competence into two areas, technology and management, so that the varying effects of technology, price, quality, design, organization management and marketing could be discerned more clearly. Moreover, this study categorized cooperation with external organizations into two types—cooperation with research institutes and with other firms—to obtain proof that both variables are correlated with a firm's performance.

To achieve the study's purpose, a close analysis of 3,509 firms using two-year data of 2014 and 2015 was conducted. Selection of factors deemed to have influence over firm performance was grounded in resource-based theory. The 5 identified factors were: firm status, entrepreneur resources, human resources, financial resources, and technological resources. Additionally, firms were classified as technology-driven or management -driven based on the level of technological advancement, price, quality, design, organization management and marketing—the 6 components that comprise a firm's competence. As an extension of this analysis, the 6 competencies were observed to assess whether their influence changed according to the firm's type. The highlights of this study are outlined below.

First, it was confirmed that out of the 29 variables used in the research model, 6 variables exerted a significant influence over a firm's annual sales. Second, upon analyzing the differences of variables for firms classified as technology-driven vs. management-driven, it was found that 7 and 5 variables out of 29, respectively, had a significant influence over a firm's annual sales.

The study has the following implications for theory and policy making. First, theory-wise, the study focused on comprehending the idiosyncratic effects various variables have on a firm's R&D performance. Whereas previous studies have been limited to

analyzing just a few variables due to a lack of data, this study encompasses a full range of variables that stem from a survey conducted by a government organization and data accumulated over the course of 2 years.

Second, the study attempted to verify the success factors of R&D of business ventures by categorizing 6 competencies into two dimensions based on core competence theory, and classifying business ventures as technology-driven or management-driven accordingly. The origin of business ventures can be largely classified into 1) founder with a core technology, and 2) founder with a differentiated idea and a discerning eye for the market. As business ventures tend to reflect the characteristics of their founders, the authors presumed that the business ventures could also be classified into technology-driven and management-driven firms. The results of the analysis suggest that business ventures actually do seem to inherit the personal characteristics of their founders, and that there is a big difference between the performance determinants of technology-driven and management-driven firms.

The political implications of the study are as follows. First, in forming policy on technical development, ventures should understand which factors increase sales in accordance with the characteristics of the firm (technology-driven vs. management-driven). Also, each firm should decide whether it should self-develop or opt for external cooperation, and which partner it should cooperate with, considering the characteristics of target technology, firm's competencies, and level of R&D activity.

Second, national institutions with business venture support programmes should establish adaptive guidelines with different evaluation criteria in accordance with the task and purpose of support, rather than evaluating all firms with identical standards, in order to effectively execute the budget. Also, the government should establish customized support measures for firms subject to Open Innovation-related policies to enhance policy effectiveness.

While the study was carried out carefully, it unavoidably has certain limitations. First, the six variables of firm competence were collected based on surveys of firms, rather than accurate data. Therefore, cautious data design and interpretation are required considering that subjective ideas may have been included in the survey. Second, the study lacks analysis by each industry, and reflection of results over time. Third, using various analytic methods on mass data can act as a strength and weakness of the study at the same time. Due to its exploratory characteristics, diverse variables were taken into account in analysis, resulting in a lack of selection and concentration. The variables found to be significant in the study should be selected for a more concentrated analysis in the future. Also, while the study was based on data collected by the government, a more appropriate dataset acquired through adequate investment will enable a more in-depth analysis. Fifth, the variables shown to have a significant influence, including the age and education level of the CEO, are in fact among those that are the most difficult to utilize in policy-making. However, these variables seem to be widely utilizable indirectly. For example, the fact that business ventures managed by younger and less-educated CEOs show better performance can be seen not as a causal relationship, but as a sign of desperation, which can be indirectly considered in policy-making in terms of motivation. Lastly, a few variables, including financial support and overseas patents, showed results that were contrary to original expectations. A moderating effect showing a direction opposite to what was originally expected should be interpreted as a decrease in the effect of the corresponding variable through external support, rather than seeing it as a negative effect. Additional research is required for a more precise analysis.

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Science and Technology Trends
The Advent of Smart Cities

A Big Data-Based Approach for Understanding Smart City Initiatives of South Korea and its Implications

Choongik Choi

1. Introduction: Why Smart Cities?

Smart city has been regarded as a worldwide phenomenon. The world is getting excited about the potential and attractiveness that smart cities will be able to bring into our daily life. South Korea—a country that takes pride in being an IT powerhouse—has worked on a number of smart city projects, but for various reasons these have not seen significant progress. On the other hand, other east asian countries such as Japan, China and India have been successful in their development of smart cities, and obtained positive outcomes through their policies.

There are several reasons why the smart city has been receiving attention.

Firstly, it is a response to global warming. Since the 1990s, the response to global warming has been a major agenda for the EU, with the EU summit held in December 2008 resulting in an agreement that by 2020 greenhouse gas emissions by EU member countries will be reduced by at least 20% compared to 1990 levels, and the share of renewable energy will be increased by 20%. Currently, efforts to achieve this are underway in various countries around the world.

The second is that it is a response to urban issues. According to the UN (2014), urbanization, or the movement of populations from rural areas to cities, is a global trend. Until 1980 approximately 60% of the world population lived in rural areas, but in 2010 the urban population became about 3.6 billion (approx. 52%) while the rural population was about 3.4 billion (approx. 48%). It is expected that the urban population will reach 6.3 billion, or 67% of the total population, by 2050. This population increase will not just create a shortage of residential spaces in cities, but will also result in other issues, including a lack of sufficient water and sewerage facilities, rail and road traffic congestion, increased demand for daily living-related services such as medical care, education and security, and an aging population.

The third is a response to basic industries in the future. The industries that create smart cities are expected to grow dramatically. In other words, products and services that are currently smaller businesses will develop. If you look at these products and services by item, battery technology accounts for approximately 42%, power transmission facilities about 24%, renewable energy generation facilities

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such as solar or wind power are 12%, and fuels for electric and hybrid vehicles and next generation vehicles such as fuel cell vehicles are 11% (Nekkei BP Clean-tech Institute, 2011).

In other words, all countries expect that smart city-related industries will replace existing, matured industries to become our new key industries, and promote the growth of the related industries to expand to overseas markets by exporting infrastructure of the smart cities as packages.

The smart city has emerged as a solution to various future urban problems, to overcome the urban issues created by global warming, energy problems, and an increased population. As well, there are expectations that smart city-related industries will be considered as the new national key industries, and actively utilized to drive economic growth.

2. Understanding the Concept of Smart City

It is difficult to accurately define the smart city, because domestic and overseas studies and projects view it differently. Also, as pointed out in Sujata et al. (2016), there can be various interpretations without a fixed definition due to the increasing number of concepts about the smart city, and strategies to turn modern cities into “smart” ones.

According to the results of a 2014 survey by International Telecommunication Union (ITU), there are 166 definitions of the smart city used around the world. Among the keywords used in the definitions, ICT, information, and communication, which emphasize “means” form 26%; these are followed by environment and sustainability which are related to the "objectives" of the smart city (17%); then, infrastructure and services (17%) (National Information Society Agency, 2016).

Table 1. Concepts of the smart city in previous studies

Mitchell (2000)	It is the digital city, a technologically-defined city that uses a widespread broadband infrastructure to support e-Governance and a global environment for public transactions.
Komninos (2008)	The notion of the smart city is established from the combination of the knowledge society and digital city. It is defined as a “multi-layer territorial system of innovation” made up of digital networks, individual intellectual capital, and the social capital of the city, which together constitute a collective intelligence.
Washburn et al. (2010)	The use of smart computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient.
ITU (2015)	A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.
South Korea (Act on Smart City Development and Industrial Promotion, Amended in Mar. 2017)	Sustainable city that provides various city services based on an urban infrastructure constructed by combining construction and IT technologies in order to improve its competitiveness and quality of life.

However, it is most appropriate to define the smart city as a city which not just realizes a smart lifestyle but also turns invisible daily living-related services such as education, healthcare, and security into smart services so that people can live more pleasant and convenient lives (Sato, 2013).

Washburn et al. (2010) define the smart city as "the city which utilizes computer technology in order to provide more intelligent, interrelated and efficient infrastructure and services such as utilities (electricity, gas, water), education, healthcare, security, real estate, transportation, and administration." This holds significant value, because this definition includes as part of the infrastructure not only electricity, gas, water, and transportation but also other services that are closely related to people's lives, such as education, healthcare, and security. ITU (2015) suggests that the smart city is an innovative city which considers cultural, economic, social, and environmental aspects of the present and future at the same time, and utilizes ICT and different means to enhance the efficiency and competitiveness of the city along with quality of life.

According to "Act on Smart City Development and Industrial Promotion", South Korea defines a smart city as "a sustainable city that provides various city services based on urban infrastructure constructed by combining construction and IT technologies in order to improve its competitiveness and quality of life" (Table 1).

Table 2. Current trends of smart city projects by country

Country	International Trends
USA	- Announced the Smart Cities Initiative in 2015; plans to invest 160 million USD in related technology R&D and federal government project support - Focusing on resolving regional problems such as alleviating traffic congestion, promoting economic growth, responding to climate changes
EU	- Announced the Strategic Implementation Plan for the European Innovation Partnership on Smart Cities and Communities in 2013 - EC manages the implementation plan for the smart cities with a focus on solving energy and transportation problems
Japan	- Making concentrated investments in the four pilot areas of Yokohama, Kyoto, Toyota, and Kitakyusyu, with a focus on energy efficiency
United Kingdom	- Aims to gain a 10% market share of the global smart city market, implemented the 'Open Data, Future Cities Demonstrator' policy since 2012 - Making concentrated investments in the standardization of technologies such as smart city-related IT
China	- Announced 500 smart city development plans through the new urbanization plan in 2015 - Plans to invest 50 billion CNY in R&D and 1 trillion CNY in infrastructure establishment by 2020
India	- Announced a plan to invest 19 trillion KRW to construct 100 smart cities by 2020
Singapore	- Officially commenced the Smart Nation project in 2014 and established SNPO (Smart Nation Programme Office) - Carries out pilot projects by establishing a collaborative system with domestic and overseas universities and private organizations, multinational corporations like IBM, and the public sector

Source: KB Finance Research Institute (2017)

3. International Trends of Smart City

The smart city concept is being promoted not only in major advanced countries but also in emerging countries such as Middle Eastern and ASEAN countries. Of the 608 global smart city projects Nikkei BP (Japan) estimated as being in progress in 2013, the share of projects in the major five countries/regions (China, the US, Japan, Europe, and South Korea) accounts for more than 84% (Nikkei clean-tech institute, 2013).

The market for smart city-related businesses shows an average annual growth rate of 16.6% from 781.9 billion USD in 2016, and is expected to increase to 1.4 trillion USD by 2020 (Research and Market, 2017).

In terms of the investment scale from 2010 to 2020, it is expected that China will invest USD 7.45 trillion, North America will invest USD 6.85 trillion, Western Europe USD 6.76 trillion, India USD 2.58 trillion, and Japan USD 1.17 trillion (Nikkei clean-tech institute, 2012).

In other words, countries around the world have announced the establishment of smart cities and the development of the related technologies, and are actively promoting related policies. China and India in particular are planning large-scale investments (KB Finance Research Institute, 2017). Smart city projects around the world are currently underway in a range of fields including transportation, energy and environment, safety, medicine, and education. As well, 70% are focused on three major fields: energy, transportation, and safety. While Asian countries such as China and India have expanded investments in urban development and infrastructure in order to enhance their national competitiveness, the advanced countries in the West are concentrating more on fields such as energy and environment and city services in order to resolve major issues in each city and improve quality of life (Lee, 2017).

Table 2 shows the current trends of the smart city projects by country.

4. Understanding Smart Cities Initiatives of South Korea

Since establishing the U-City, an early form of smart cities, in the early 2000s, South Korea has carried out smart city projects involving various related ministries, with the Ministry of Land, Infrastructure and Transport (MOLIT) serving as the central department (Table 3). While policies for the smart city have been developed and established to foster the smart city and expand to overseas markets, recent smart city policies of each ministry focus not only on developing technologies and establishing an integrated platform, but also on finding consumer-oriented services (Hyundai Research institute, 2017).

In 2008, the U-City project was commenced through the enactment of the "Ubiquitous City Construction Act", and the master plan at the national level was suggested through the establishment of the 1st and 2nd Comprehensive Plans on Ubiquitous Cities (2009 to 2013, 2014 to 2018). While the 1st Comprehensive Plans on Ubiquitous Cities suggest a base for U-City's growth and strategies to foster new growth projects, the 2nd Comprehensive Plans on Ubiquitous Cities suggest concrete strategies to spread the U-City domestically and expand to overseas markets.

Moreover, the U-Eco City R&D project was carried out for U-City technology development and application. The U-City advanced R&D project was carried out to find export models. The U-Eco City R&D project has invested approximately KRW 55.9 billion in the development of key smart-city technologies in 16 fields. After that, the U-City upgrading R&D project is being carried out from 2013 to 2019 to upgrade the integrated platform, to create a hands-on test bed, and to explore overseas export models. Also, the U-Eco city R&D project was conducted for the development and application of U-City technologies, and the U-City advancement

project is being carried out to search for export models. Approximately 55.9 billion KRW was invested for the development of core smart city technologies in 16 fields in the U-Eco City R&D project. The U-City advancement R&D project has been underway from 2013 to 2019 to upgrade the integrated platform and look for hands-on test beds and export models.

Table 3. Major policies and plans by Korea government

Ministry	Policy (Year)	Plans and Actions
Ministry of Science and ICT	U-City Construction Activation General Plan (2006)[1]	- Set out detailed tasks for the construction of a futuristic high-tech city which combines an urban space with U-IT infrastructure, technologies and services
	Execution of the Global Smart City Demonstration Complex Establishment Project (2015)[2]	- The Ministry of Science, ICT and Future Planning led a global smart city demonstration complex establishment project around Haeundae district with SKT and Busan Metropolitan City
Ministry of Land, Infrastructure and Transport	Enactment of "Ubiquitous City Construction Act" and Commencement of the U-City Project (2008)	- Master plan on a national level suggested through the establishment of "Comprehensive Plans on Ubiquitous Cities" • 1st (2009-2013): base for U-City's growth and strategies to foster new growth projects • 2nd (2014-2018): strategies were suggested to spread the U-City domestically and expand to overseas markets
	Development of Policies for Execution of Smart City Projects (2016)	- Smart city promotion committee established in 2016 - Smart City Act amended in 2017
	Announcement of "the Overseas Expansion Plan for Korean Smart Cities" (2016)	- Established a plan to construct a specialized demonstration complex in new towns • Construction project for the complex which takes into account the possibility of export to overseas markets and expansion to private markets • To establish functions of each concept for the complex's construction, and to build a demonstration complex specialized for the city
Ministry of the Interior and Safety	Commencement of U-Service Support Project (2008)	- Executed by former Ministry of Security and Public Administration from 2008 to 2012 - Executed jointly by former Ministry of Security and Public Administration and former Ministry of Science, ICT and Future Planning in 2013

Source : Revised from Ministry of Information and Communication (2006), Ministry of Land, Infrastructure and Transport (2009; 2013; 2016), Hyundai Research institute (2017)

1 Established by the former Ministry of Information and Communication
2 Established by the former Ministry of Science, ICT and Future Planning

A smart city promotion committee was established in 2016, and the Smart City Act was amended to develop strategies that will help related industries grow in 2017. The MOLIT announced the "the Overseas Expansion Plan for Korean Smart Cities" in 2016 and established a plan to construct a specialized demonstration complex in new towns.

The first of the main points is to implement a construction project of the complex which takes into account the possibility of export to overseas markets and expansion to private markets. Related complexes will be created with a focus on fields which show potential for expansion to overseas markets, such as energy, culture, safety, and urban total solutions. Starting in July 2016, specialized demonstration complexes have been built by Korea Land&Housing Corporation (LH), Korea District Heating Corporation and SK Telecom, in Sejong, Dongtan District 2, Pangyo and Godeok, Pyeongtaek. The second key point is to establish functions of each concept for the complex construction and to build a demonstration complex that is specialized for the city. The development for Sejong is a total solution type encompassing transportation, stability, urban management, and energy, while the development for Dongtan District 2 is an energy-saving type. Pangyo is a culture and shopping type development, while Godeok, Pyeongtaek is a safety enhancement-oriented type. Completion of the demonstration complexes is planned to take place during the second half of 2020, with the objective of finding services which are interactive with citizens and achieve commercialization (Hyundai Research Institute, 2017).

South Korea's Smart City policies began when the then—Ministry of Information and Communication (now the Ministry of Science and ICT (MSIT)) announced the U-City Construction Activation General Plan in December 2006. In this plan, the detailed tasks were set out for the construction of a futuristic high-tech city which combines an urban space with U-IT infrastructure, technologies and services, with the vision of a "Korea of Hope" through the implementation of the world's best U-City. The main objectives of the plan are 1) to establish a convenient, safe, pleasant, and healthy city through the spread of U-services, and 2) to nurture a new advanced and integrated IT industry.

The Ministry of Science, ICT and Future Planning (now the MSIT) has also been executing a global smart city demonstration complex establishment project around Haeundae district with SKT and Busan Metropolitan City since 2015. The Ministry of Security and Public Administration (now called the Ministry of the Interior and Safety) had performed the U-service support project from 2008 to 2013.

5. An Impasse for the Smart City in an IT Powerhouse, South Korea

In the early 2000s, there were some institutional efforts to construct the U-City. The "Ubiquitous City Act" was established to effectively resolve the transportation, environment and energy-related issues of cities.

The term U-City started to be replaced by the expression "smart city" after Apple introduced the iPhone in 2007. At the heart of this change are IoT (internet of things) and the expansion of a city's intelligent services (Choi, 2015). While the U-City was the establishment of an integrated system for the efficient use of information through the construction of ICT-based infrastructure, the smart city is a more expanded concept which means the creation of a low-cost, high efficiency space to build social capital in terms of the development of services related to urban life (Shin et al., 2015).

The problems that South Korea faces in terms of smart city development can be summarized as follows. First, corporations and the public are not that interested in the smart city due to a recession of the real estate

business and the lack of a profitable, consumer-oriented business model, despite the fact that the U-City has already been established as a concept for the smart city and the construction of smart cities has been in progress nationwide (Han, 2015).

Second, the U-City had limitations, as its focus remained only in the area of general public information and surveillance services. Typical examples of this are Hwaseong and Dongtan new towns, which were completed in 2008, but information on transportation, air pollution, and water/sewage management stayed at the level of integrated control through unmanned cameras. Furthermore, many cities in South Korea have used the name "U-City" and built standardized services and systems. In other words, services specifically based on the characteristics of each city have been insufficient (Hyundai Research institute, 2017).

Third, the smart city, as currently implemented, is not that different from the U-City. The services of the smart city started with the vision of developing from just providing information to intelligent urban services based on integrated control services, and aimed to provide interactive services in which citizens participate. But despite the fact that the City of Busan has been implementing an ambitious plan to tie different regions into smart clusters based on IoT and become one of the world's top 100 cities through the convergence of machinery, textiles and shoes and robot, bio, and digital industries, it is difficult to find any differentiating factors (Choi, 2015).

Finally, the international competitiveness is weak. South Korea started its smart city projects as a pioneer in the global markets; this started with pilot projects in the early 2000s, the enactment of related laws and regulations in the mid-2000s, and progressed to the exporting of intelligent transportation systems to overseas markets. Since then, however, Korea has relied on similar systems and services with no major advancements or developments, and has become weaker and less competitive in fields such as sustainability and governance (Easy Park, 2017; Hyundai Research Institute, 2017).

6. A Big Data-Based Approach to Smart City Initiatives of Korea

According to Google Trends (Figure 1), global interest in the smart city concept has been growing steadily since 2004. This suggests that the smart city has been growing recently in conjunction with the implementation of new technologies from the Fourth Industrial Revolution along with social demands in various areas including transportation, energy, safety, and healthcare. This trend is reflected in South Korea, and the interest in the smart city is on the rise. Notably, the interest in the smart city increased sharply around 2005, but has not showed significant growth until quite recently (Figure 2).

Figure 1. The world trend of smart city (2004-current)

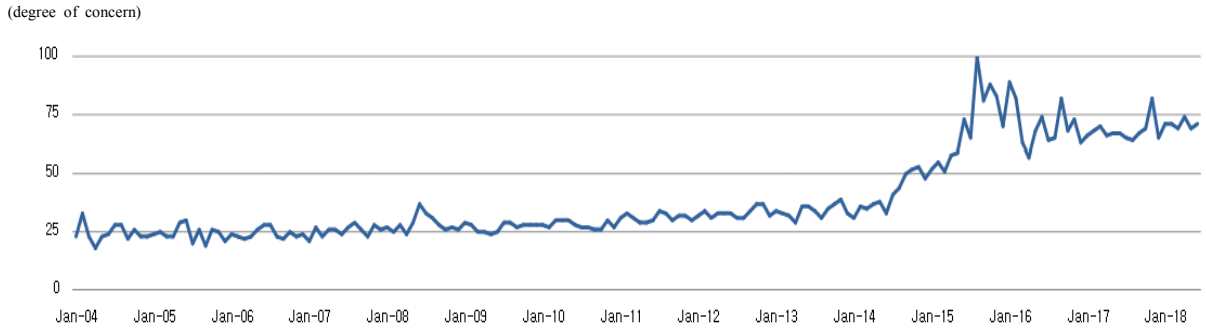
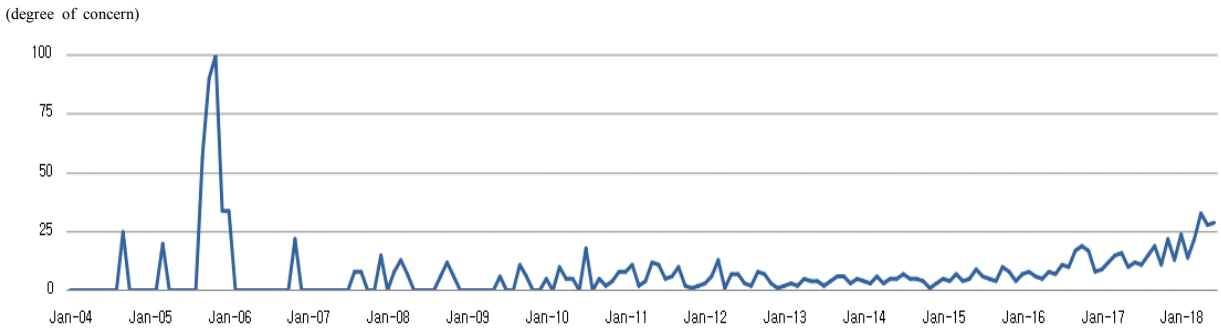


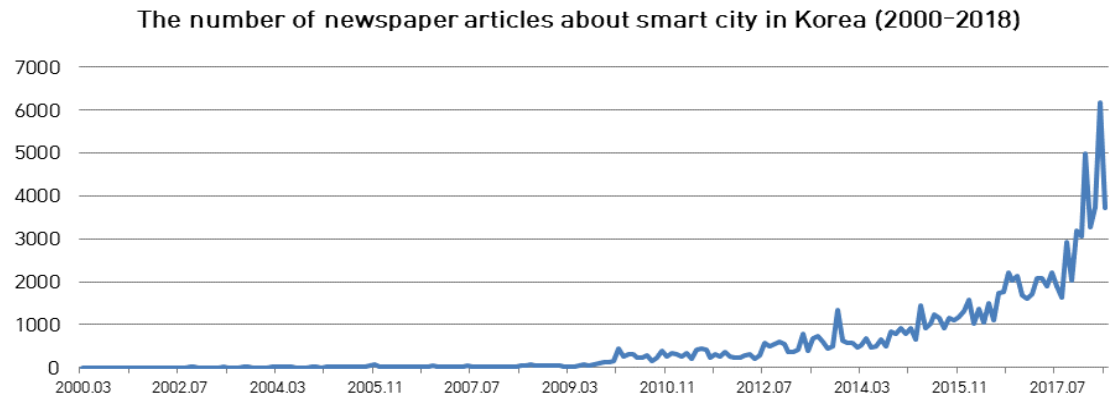
Figure 2. The Korea trend of smart city (2004-current)



Naver News Crawler was used to analyze the meaning of articles on the smart city from 2005 and from 2017. According a big data analysis comparing 2005 and 2017 when the trend index for the smart city was high, Daejeon lay at the center of the smart city issue in 2005 based on a Word Cloud analysis. This reflects the fact that the Korean U-City development project (Ubiquitous City) has been actively implemented since 2005. Also, the development of the high-rise apartment, Daejeon Smart City, which started in 2005 in Daejeon, seems to be the main issue. In addition to Daejeon, Jeollanam-do, the city of Busan and Gyeonggi-do developed U-City master plans and prepared for execution around the same time. However, it is noteworthy that the smart city boom of 2005 did not last that long. There are many reasons for this, but one of them is a lack of consistent government policies. While smart city projects were actively discussed in South Korea from around the 2000s, they were diversified under various names, such as the U-City and the e-city.

Objectives, directions and strategies for the smart city development are inevitably different, because various government departments such as the Ministry of Land, Infrastructure and Transport, Ministry of Science, ICT and Future Planning, and Ministry of the Interior and Safety conducted projects separately. Thus, the government's consistent and intensive policy enforcement on the smart city did not follow, and the driving force was lost for a while. Now, as the government's interest in the Fourth Industrial Revolution is on the rise, the smart city is attracting attention once again. It is thus essential for several ministries to cooperate toward one development goal, and not to repeat the error of dividing their powers.

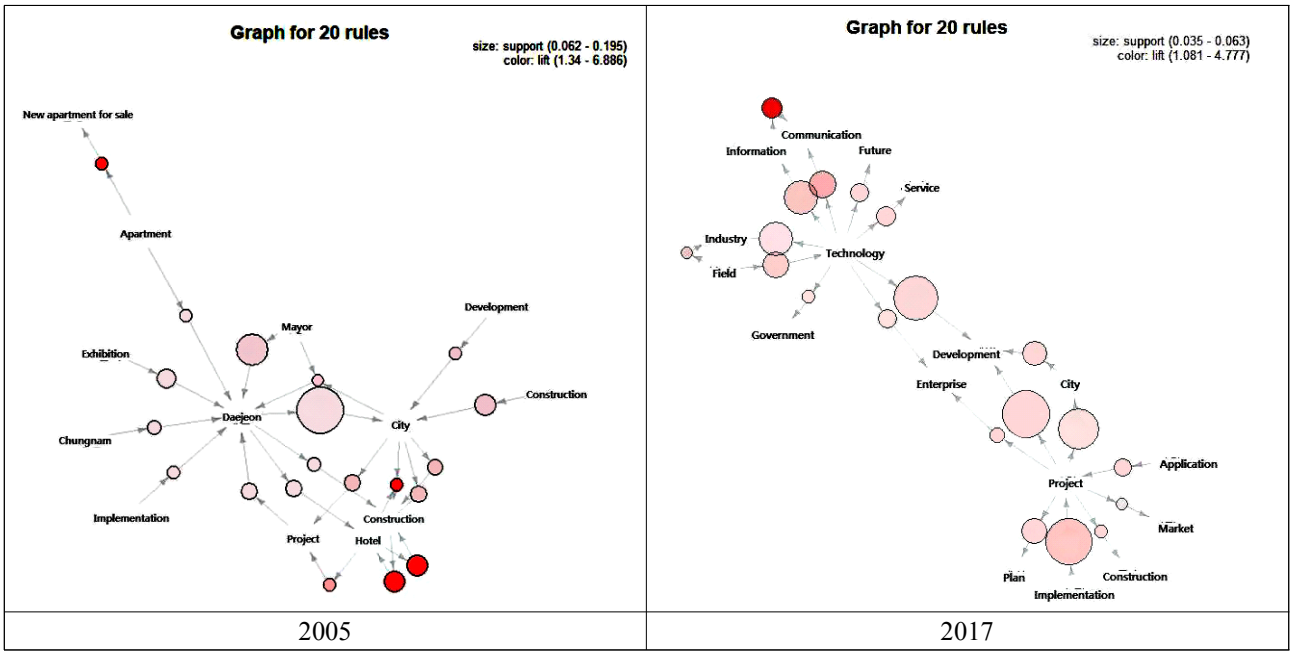
Figure 3. The trend of interest in smart city Korea (2000-2018)



A word cloud analysis shows that Daejeon was at the very center of the Smart City issue in 2005. The reason why Daejeon is represented as the core of the early stage of the smart city–bigger than even Seoul–is due to certain regional characteristics. Daejeon was an area where the science technology research complex was integrated. On the other hand, in 2017, the words that conveyed regional and spatial meanings disappear, and technology and business are located at the center. Furthermore, the smart city issues have shifted from local government policies and election pledges in 2005 to business, technology, and enterprises in 2017. This suggests that the rise of the Fourth Industrial Revolution has not only heightened the interest in the smart city, but has also realized the application of advanced technologies in real life (Figure 4).

Figure 4. Word clouds for smart cities in Korea

Figure 5. Comparison between 2005 and 2017 in terms of big data analysis based on association rule



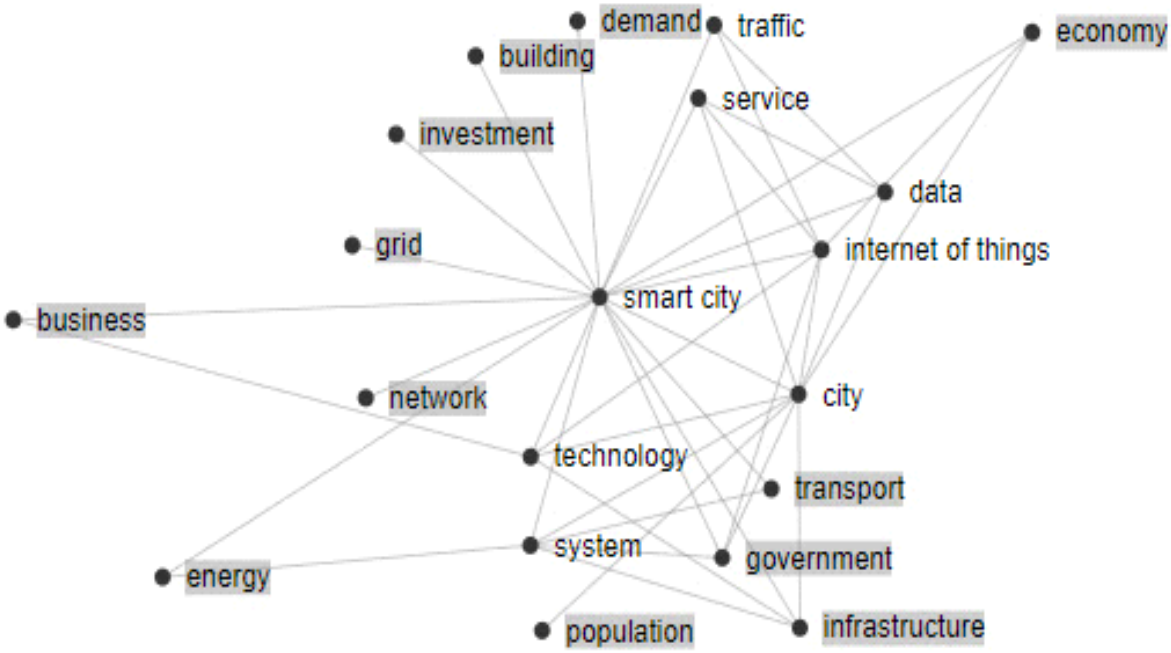
The results of a word cloud analysis are also confirmed through the results from the association rule. In 2005, there is a word connection network formed around the two axes of "Daejeon" and "City." But in 2017, the word network is constructed around the words "Technology" and "Project." What is interesting here is that the medium of both axes is enterprise/development. This suggests that a social consensus was formed that the participation of enterprises that can apply advanced technologies and active development efforts by the government should occur at the same time, as the Fourth Industrial Revolution has become more prominent (Figure 5).

Table 4. Comparison between 2005 and 2017 in terms of big data analysis based on association rule

2005_rules	S	C	L	2017_rules	S	C	L
Daejeon → City	0.195	0.431	1.350	Project → Development	0.063	0.282	1.560
Mayor → Daejeon	0.137	0.767	1.697	Implementation → Project	0.062	0.472	2.113
Hotel → Construction	0.100	0.750	6.455	Technology → Development	0.061	0.268	1.484
Construction → Hotel	0.100	0.857	6.455	Project → City	0.058	0.259	1.436
Construction → City	0.100	0.533	1.669	Technology → Industry	0.053	0.233	1.328
Exhibition → Daejeon	0.091	0.688	1.520	Technology → Information	0.052	0.231	2.066
City → Hotel	0.083	0.260	1.956	Technology → Communication	0.048	0.210	2.658
City → Project	0.083	0.260	1.897	Field → Technology	0.046	0.393	1.732
Deajeon → Hotel	0.083	0.183	1.382	Project → Plan	0.046	0.206	1.620
Project → Daejeon	0.083	0.606	1.340	City → Development	0.045	0.251	1.393
City → Construction	0.079	0.247	2.124	Information → Communication	0.042	0.378	4.777
Chungnam → Daejeon	0.071	0.850	1.879	Technology → Service	0.041	0.183	1.439
Daejeon → Construction	0.071	0.156	1.342	Technology → Enterprise	0.041	0.181	1.261
Hotel → Construction	0.066	0.800	6.886	Technology → Future	0.041	0.179	1.665
Apartment → New apartment for sale	0.066	0.615	6.179	Application → Project	0.040	0.329	1.473
Hotel → Project	0.066	0.500	3.652	Project → Enterprise	0.038	0.170	1.185
Implementation → Daejeon	0.066	0.667	1.474	Project → Construction	0.036	0.163	1.571
Development → City	0.066	0.444	1.391	Technology → Government	0.036	0.159	1.204
Apartment → Daejeon	0.066	0.615	1.361	Field → Industry	0.035	0.299	1.706

It is interesting to compare Korea's smart city development and its characteristics derived from the big data analysis with the smart city topic map from Shaping Tomorrow. Shaping Tomorrow is a future issues analysis system developed for big data based futures forecasting activities. It provides collected results by gathering global issues provided in real time from reports and articles and sorting them into forecast and insight-oriented data. Compared to Google Trends, the data collected through Shaping Tomorrow has the advantage of being more transparent in terms of the data sources. The system is generated by artificial intelligence-based data mining technology, which automatically extracts valid data from search results and provides refined data such as trends and summaries. In fact, global organizations such as OECD and Ford Motor Company also utilize the system to research and analyze futures issues. The topic map shows the importance of collaboration and networking between the private and the public sector for the successful implementation of the smart city. Furthermore, it also suggests that a comprehensive and strategic approach is required, with the integration and application of advanced technologies including the Internet of Things (IoT) led by the Fourth Industrial Revolution in various fields. The topic map shows that huge investments in technology by the private sector and governments alike will be needed to deliver the many social improvements promised by smart cities.

Figure 6. The topic map for the smart city



Source: https://www.shapingtomorrow.com/home/alert/4165100-Smart-City-Futures

7. Conclusion: Smart City and Urban Innovation Challenges

The smart city project is currently in the beginning stage; however, it is expected to create various opportunities from a new socioeconomic perspective based on the technologies and infrastructure accumulated after a certain period of time.

Despite this, it is important to keep in mind that the smart city is a space for living that has a bi-directional relationship between suppliers and consumers through the implementation of advanced technologies in spaces called "cities." In other words, it is not a digital high-tech city that experts create by supplying new technologies, but a civilized community whose members live convenient lives through new advanced technologies.

South Korea started to actively discuss the smart city project in the 2000s, and was a pioneer in the global market thanks to the enactment of related laws and regulations, the establishment of pilot projects, and expansion to overseas markets. However, we have since relied on similar systems and services, with no big advancements or developments. Also, the projects were diversified under various names, such as 'U-City' and 'e-city,' and were executed separately by many different ministries, resulting in different objectives, directions and strategies and a lack of cooperation. As such, the government's consistent and intensive policy enforcement on the smart city did not follow properly, and the driving force was lost for a while.

Today, as the government's interest in the Fourth Industrial Revolution is on the rise, the smart city is attracting attention once again. It is thus necessary for several ministries to cooperate toward one goal and work together for smooth execution of the smart city. The future directions are as follows.

First, the urban construction and services of the smart city in Korea involve private and public corporations in the field of the smart grid related to energy, but there are limitations on corporate participation and voluntary operations given the long-term, non-commercial and public nature of smart city projects. As such, a strategic approach is needed that considers various new models from other countries.

Second, cooperation is required between companies that produce various products and services in order to differentiate smart city products, because the smart city's technologies and services need to be linked not only with the networks of telecommunications companies but also with various contents and platforms. The smart city can benefit from the consilience of the different technologies and services.

Third, long-term investments and attention are needed. It has not been possible to ensure sustainability because Korea's policies have tended to be short-term and visible performance-oriented. Policies focused on short-term achievements can cause conflicts with existing cities as well. Therefore, it is necessary to eliminate discrimination against existing cities through technical and administrative considerations when the smart city policies are enforced.

Fourth, even though it aims for intelligent services, the smart city should provide customized services based on each city's characteristics. If they fail to reflect these traits, it will result in standardized services again. Some studies have suggested that the success or failure of the smart city is correlated with the participation of residents. As well, services that reflect the characteristics of the cities are required in terms of raising the interest of residents. In addition, security and protection measures in the smart city should be improved.

Finally, consistent and intensive policy enforcement for the smart cities is necessary. The reason why the U-City took the leading position in the past but ultimately did not produce results is the lack of cooperation between government

ministries. This is why smart city governance in Korea has been highlighted as a weakness in terms of competitiveness. Therefore, the central government and local governments, as well as companies involved in the construction of various smart cities, should establish a cooperative system and pursue this consistently through governance.

Social and governance networks help cities manage the risks associated with innovation, unexpected events and contextual factors. When imagining smart cities, their cultural and social innovations should thus be as important an element as their technologies.

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Science and Technology Trends
The Advent of Smart Cities

Building a Smart Nation: Singapore's Digital Journey

Siu Loon Hoe

1. Introduction

The journey towards smart city status is a strong global trend as governments around the world strive to harness technology to improve the quality of life for their citizens (United Nations, 2016). The widespread phenomenon of becoming "smart" is a key topic of discussion and research that continues to change as new digital technologies develop (Ishkineeva et al., 2015). The smart cities theme is important because it explores how governments, as providers of public goods, harness digital technologies to improve the lives of citizens around the world in the present and the future.

Singapore's smart nation journey began when the drive was officially announced by the country's Prime Minister Lee Hsien Loong in November 2014 (Lee, 2014). The vision is to improve people's lives and create more opportunities through information and communications technology (ICT). The smart nation drive is an effort by the government to co-create innovative, people-centric solutions with citizens and businesses. The three priority areas, underpinned by cyber security, are elderly, transportation and data. Since then, various digital strategies and policies have been further articulated, and digital programmes and projects implemented in the country.

2. Smart Nation Drive

The drive towards a smart nation is multi-faceted in nature and encompasses a multi-pronged approach to address issues involving a diverse group of stakeholders. Thus, it is natural that there would be overlaps when it comes to the analysis of smart nation trends and factors. To facilitate a better understanding of the key areas affecting smart nation, the section is organised under the various sub-topics: digital infrastructure, mobile apps, transportation, health, cashless economy, data, cyber security, technology start-ups, research and development (R&D), manpower development, administrative capacity, and regional network and global collaboration.

2.1. Digital Infrastructure

At the foundational level, a smart nation enables citizens to use ICT for stress-free and seamless transactions on a daily basis. Therefore, having a robust

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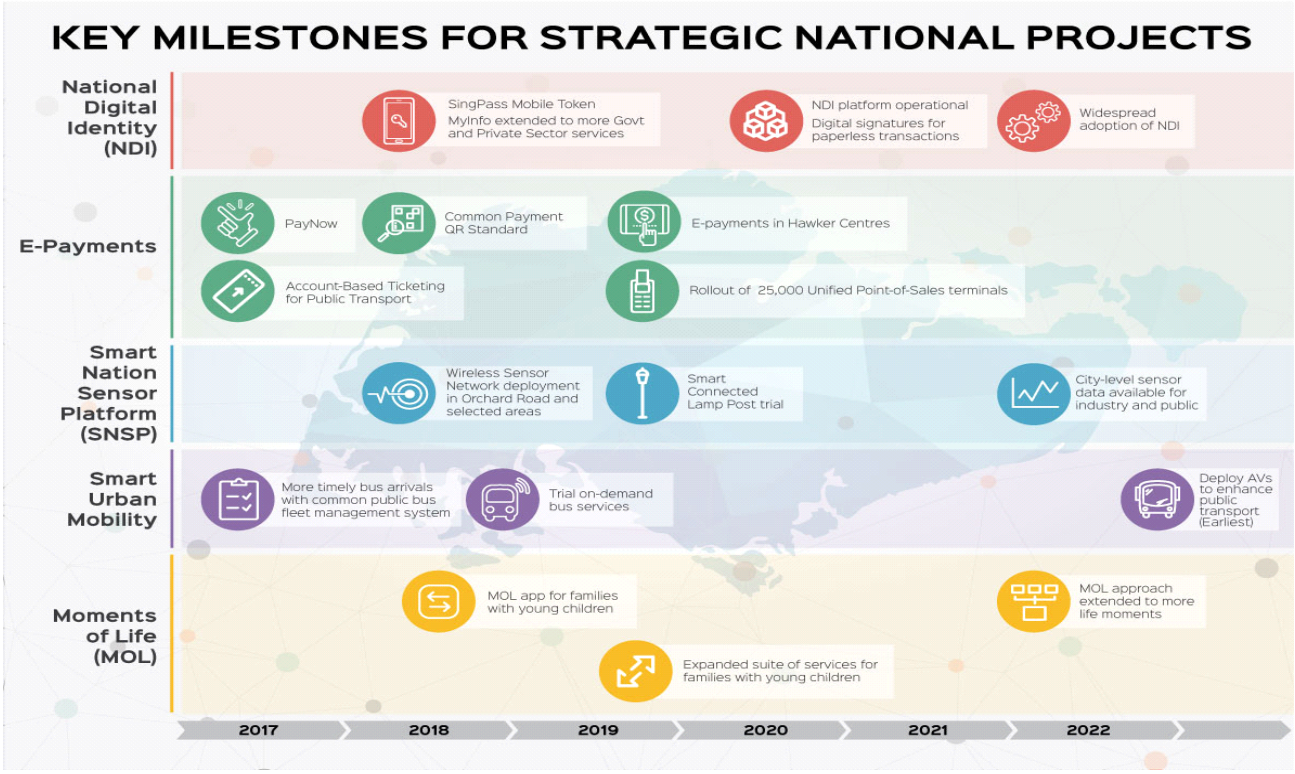
underlying digital infrastructure is key to the proper functioning of public and private services. In 2017, the key milestones for five strategic national projects were announced (Smart Nation and Digital Government Office, 2017). These projects include areas such as national digital identity, e-payments, sensor platform, smart transportation and moments of life. Please refer to Figure 1–Strategic National Projects from 2017 to 2020.

Briefly, the National Digital Identity (NDI) framework allows convenient and secure digital transactions between citizens and businesses with an online identity; E-Payments facilitate a simple, swift, seamless and safe way of payments for citizens; the Smart Nation Sensor Platform (SNSP) enables the pervasive connectivity of a network of physical devices; Smart Urban Mobility enhances public transport commute through data analytics, artificial intelligence and autonomous vehicles; and finally, Moments of Life (MOL) integrates services and information across multiple government agencies for citizens through a single platform.

To further streamline transactions for citizens with businesses, the Singapore government designed the Myinfo portal. MyInfo is a service for SingPass, Singapore's online access account management platform for e-services, which enables users to avoid having to repeatedly fill in personal data for every digital transaction. The service is linked to both government agencies and commercial entities.

In order to manage the technical aspects of such a diverse system of interrelated computing devices, the Minister for Foreign Affairs and Minister-in-Charge of Smart Nation has outlined Singapore's approach to Internet of Things (IoT) development. The approach includes avoiding vendor lock-in, defining open standards, using modular platforms, providing plug-and-play architecture and security by design (Lung, 2018).

Figure 1. Strategic National Projects from 2017 to 2020



Source: Smart Nation and Digital Government Office. (2017, August 20). Strategic national projects to build a smart nation [Press Release].

2.2. Mobile Apps

The population, nowadays, is always on the move and highly connected through mobile devices such as smart phones and tablets. Consequently, mobile apps feature prominently in many of the Singapore government's service delivery projects. Traditionally, apps were designed around the services provided rather than user experience. This approach is giving way to a more human-centred design method in which the solutions developed start with citizens' needs and end with the resolution of these needs.

There are many examples of mobile apps that have been developed with the active engagement of the citizens in mind. For instance, the Municipal Services Office (MSO) deployed the OneService app to give residents a convenient one-stop platform to alert government agencies and town councils about problems faced in their neighbourhoods, without having to know which department is in charge of the issue. Another recently launched app is the parking.sg app which allows motorist to pay for parking digitally instead of using coupons. The motorist simply selects the carpark, keys in the vehicle number and chooses the parking duration. The app would automatically compute the rates and payment could be paid through credit cards.

In many cases, it is very important to involve the citizens so as to achieve socially desired outcomes. Besides designing solutions around citizen needs and perspectives, there is an increase in the use of crowdsourcing for citizen inputs to improve impact. The myRepsonder and SGSecure are apps that demonstrate this principle. In order to quickly attend to emergency cases such as out-of-hospital cardiac arrest and minor fires, the Singapore Civil Defence Force (SCDF) rolled-out the myResponder app. The mobile app functions by notifying members of the public of cardiac arrest and fire cases within 400 metres of their location. The public could then choose to proceed to the location to render assistance, thereby, providing the quick turnaround time that is necessary for heart resuscitation and extinguishment of small fires. Similarly, the SGSecure app allows citizens to receive alerts, report suspicious activities through messages, photos and videos, and seek assistance from the police during major emergencies.

2.3. Transportation

Many major cities face urban traffic management challenges which cause congestion and road traffic accidents. Singapore has embarked on various mobility programmes to tackle these problems on the land scarce island. These projects include the extensive trialing of self-driving vehicles (SDV), researching of standards required prior to the deployment of SDVs on public roads, and exploring mobility-on-demand approaches for real-time booking of taxis and suggestions for best routes to destinations (Smart Nation and Digital Government Office, 2018a). The Land Transport Authority (LTA) has also published and made available the estimated arrival times of buses to help ease waiting time (Chng, 2016). The authority is further tapping on near field communication-enabled mobile devices for contactless payments on the mass rapid transit and public buses.

2.4. Health

With an aging population, the number of elderly persons is projected to rise rapidly in the coming years. The Singapore government has initiated a series of digital programmes and projects that are targeted to help this segment of the population. Some of the examples include HealthHub, a one-stop online health services portal and mobile app. Through this service, citizens are able to access health records and medical appointments, and locate health facilities island-wide (Smart Nation and Digital Government

Office, 2018b). There are also on-going telehealth projects such as elderly monitoring systems for families with elderly persons while they are away from home, and smart health video consultation which offers follow-up services beyond hospitals to the community.

The healthcare sector implemented a National Electronic Health Record (NEHR) system and is currently extending its coverage. The secure system collects patients' health records across different healthcare providers which enables authorised personnel to view a holistic picture of one's healthcare history even if that patient is new to a hospital or clinic. This platform would provide immense opportunities to grow data analytics capabilities for public health management (Bhandari, 2017).

2.5. Cashless Economy

At the 2017 National Day Rally, it was revealed that six in 10 transactions in Singapore are still made in cash or by cheques (Lee, 2017). Also, there are too many different, disparate payment schemes and systems that are not interfaced with one another. In order to speed-up the goal of a cashless economy, a number of initiatives have been launched by the public service and industry. For example, the establishment of a payments council comprising 20 leaders from banks, payment service providers, businesses and trade associations to promote interoperability among e-payments solutions and develop strategies to drive the wide-spread adoption of e-payments (Bhunia, 2017).

Other related initiatives include the launch of a new peer-to-peer funds transfer service called PayNow, development of an Unified Point-of-Sale (UPOS) terminal for merchants and a fully cashless public transport system by 2020.

2.6. Data

A significant part of Singapore's digitalisation journey is related to the use and application of data to solve problems. The Singapore government recognises that data is most valuable when different datasets are connected to form conclusions. It has taken the first step towards data transparency through the online database, data.gov.sg, which is free for public access. The Government Technology Agency (GovTech) is also building an API Exchange (APEX) to facilitate data sharing (Puthucheary, 2017). Other government-related sites such as LTA DataMall, SingStat and OneMap, also offer a variety of datasets and application programming interfaces (APIs) to the public.

In order to increase the efficiency in the delivery of public services, the Ministry of Health (MOH) and Central Provident Fund (CPF) Board collaborated on a consent-based data sharing initiative to extend healthcare financing schemes to Singaporeans based on their Medisave balances, MediShield coverage and subsidy levels. Medisave is a national savings scheme to help citizens set aside part of their income to meet medical needs. MediShield is a low-cost basic medical insurance scheme for hospitalisation bills. The initiative helps to ease administrative work and covers more recipients since their needs are automatically assessed by the system (Ong-Webb & Ang, 2017). The sharing of the Ministry of Social and Family Development's (MSF) data with social service offices, family service centres, divorce support specialist agencies and the Early Childhood Development Agency (EDCA) generated better estimates and informed assessments for government assistance to individuals and families.

On the city and urban management front, smart tools and data analytics to analyse wind flow and solar exposure are used for Punggol town planning (Smart Nation and Digital Government Office,

2018c). New flats are then designed and sited to provide better surroundings and living environment.

2.7. Cyber Security

Cyber security forms the bedrock of the entire technology infrastructure and data architecture in a smart city. In Singapore, a strong cyber security network is a key priority in the smart nation drive and is critical to digital advancement (Ministry of Communications and Information, 2017). Any form of cyber-attacks would have deep economic and societal ramifications (Chik, 2017; Cyber Security Agency of Singapore, 2016).

The country's parliament passed a cyber security bill in early 2018. The legislation covered key areas such as the establishment of a cyber security commissioner, setting out procedures to punish owners of critical information infrastructures, and licensing requirements for companies or individuals providing cyber security services. It includes 11 critical sectors ranging from banking and healthcare, to transport and energy. The comprehensive bill is an enhanced version of bills overseas and addresses many existing gaps in the digital ecosystem (Goh, 2017). Earlier, Singapore topped the global cyber security index 2017 (International Telecommunication Union, 2017).

To better manage cyber threats, the Ministry of Defence (Mindef) has set up a new Defence Cyber Organisation to lead and coordinate cyber-security efforts across the defence cluster, including the Defence Science and Technology Agency (DSTA) and DSO National Laboratories (Cheng, 2017). In line with recent cyber security measures, government computers have been delinked from the internet to prevent work email and document leaks. With the internet separation, public servants would be using Workplace to connect with one another (Tham, 2016). Workplace is a collaboration tool that is specifically designed by Facebook with tight cyber security measures to protect sensitive data.

2.8. Technology Start-ups

Singapore's economic success is in part due to the entrepreneurial culture and the support for small and medium-sized enterprises (SMEs) (Ministry of Communications and Information, 2017). Government-funded centres that offer expert advice, product testing hubs and generous grants play a vital role in this aspect. For example, SGInnovate is a private organisation, wholly owned by the Singapore government, which helps aspiring entrepreneurs to commercialise and scale innovations for the world (SGInnovate, 2018). It focuses on deep technologies such as artificial intelligence, blockchain and robotics that have horizontal applications across industries.

As a result of the government's efforts, the number of start-ups has increased significantly which, in turn, attracted much international attention from businesses looking to expand to Asian nations. Singapore is now considered to be the best Asian location for start-ups (McCauley, 2017). Start-up accelerators such as Jurong Town Corporation (JTC) Launchpad provides support to the ecosystem by connecting technopreneurs with the industry. Block71 houses the largest tech start-up community in Southeast Asia.

In order to maintain Singapore's status as a regional financial hub, there have been various efforts to advance financial technology or "fintech". Facilities such as the FinTech Innovation Lab by Monetary Authority of Singapore (MAS) and FinTech Innovation Village by Lattice80 offer the platforms and communities for experimentation and commercialisation of new products and services.

2.9. R&D

There has been an increase in government funding

for R&D programmes to drive greater adoption of digital technologies, automation and robotics (Ministry of Finance, 2018). The National Research Foundation (NRF) is investing S$19 billion for the Research, Innovation and Enterprise 2020 Plan over 2016 to 2020. The institutes of higher learning have also initiated many programmes and projects to contribute to the smart nation drive. For example, the National University of Singapore (NUS) established a Smart Nation Research Cluster to further develop strategic capabilities in data science and cyber security. The Nanyang Technological University (NTU) opened an autonomous vehicle test centre jointly with LTA and JTC (Land Transport Authority, 2017).

2.10. Manpower Development

Beyond the deployment of ICT, the smart nation drive also serves the objectives of improving the quality of life of citizens and enhancing jobs prospects (Balakrishnan, 2018). Government-funded initiatives such as the national SkillsFuture movement are crucial in helping citizens adapt to digital disruptions across industries and sectors. SkillsFuture is an adult education programme that provides an avenue for citizens to update their skillsets through training grants and help them find employment. Under the movement, a Skills Framework for Infocomm Technology was jointly developed by SkillsFuture Singapore (SSG), Workforce Singapore (WSG), and the Info-communications Media Development Authority (IMDA), together with industry associations, training providers and unions. It provides useful information such as career pathways, emerging skills and training programmes.

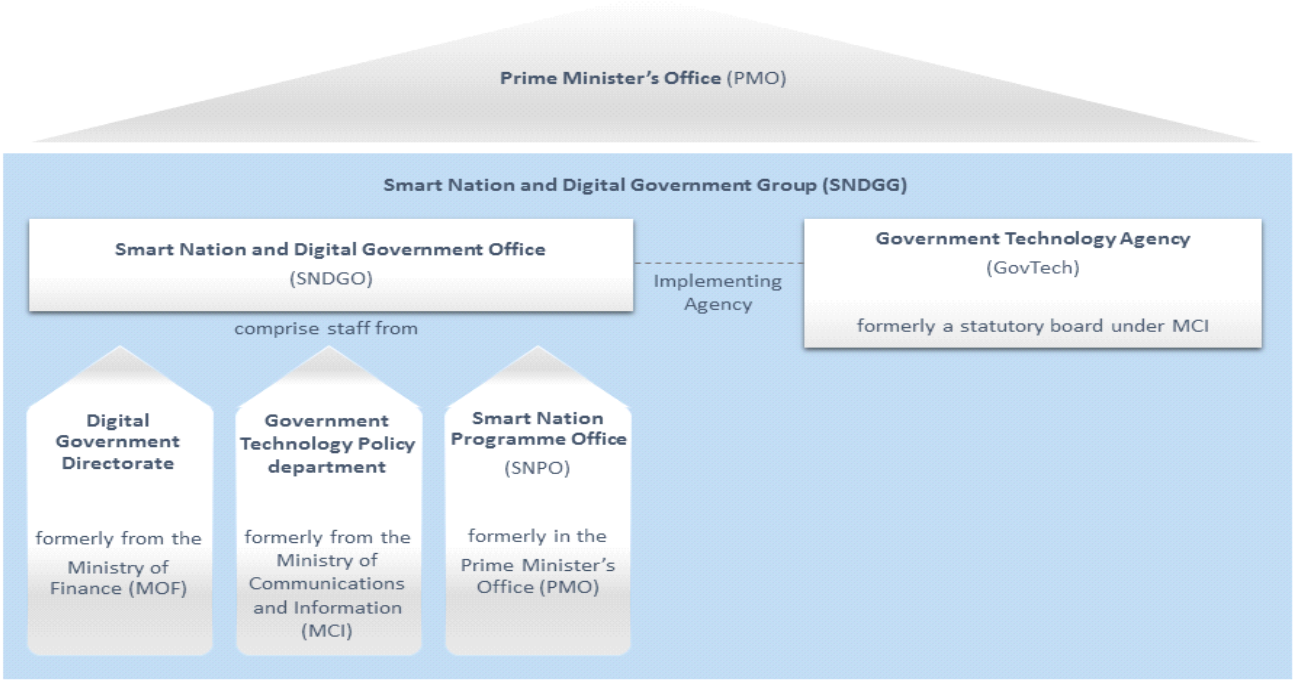
Beginning from the second half of 2018, Mindef would be training 50 to 70 selected full-time national servicemen (NSFs) in a pilot cyber-specialist scheme (Lim, 2018). The personnel would be attending classes at the Singapore Institute of Technology (SIT) once a week and also be deployed in roles such as penetration testing, cyber forensics and malware analysis. They would serve a total of three or four years in uniform, earning regular service pay after first completing a minimum period as NSFs.

The Singapore government has already committed significant resources to grow homegrown ICT talents and broaden the talent pool by attracting professionals from the science, technology, engineering and mathematics (STEM) disciplines (Ministry of Communications and Information, 2016). Furthermore, basic digital skills training would be introduced to the rest of the citizens. Some private and grassroots organisations have already begun to rollout classes on social media and mobile banking for seniors (Aw, 2018).

2.11. Administrative Capacity

The public administration plays a critical role in enabling the implementation of key strategic choices of the government. In order to ensure a more integrated and responsive way to implement the digital programmes, the Singapore government formed the Smart Nation and Digital Government Office (SNDGO) and GovTech, which both made-up the Smart Nation and Digital Government Group (SNDGG) in May 2017 (Prime Minister's Office Singapore, 2017). Please refer to Figure 2– Organisational chart for SNDGG in the Prime Minister's Office. The SNDGG, chaired by the Deputy Prime Minster, collaborates with other government ministries as well as businesses and citizens to develop smart solutions that would improve public service delivery and the quality of life of citizens, and grow economic value. It is hoped that by adopting a whole-of-government approach, in which ministries and statutory boards work jointly across functional boundaries, complex issues could be more readily resolved to hasten the implementation of digital programmes and projects.

Figure 2. Organisational Chart for SNDGG in the Prime Minister's Office



Source: Prime Minister's Office Singapore. (2017, March 20). Formation of the smart nation and digital government group in the prime minister's office [Press Release].

2.12. Regional Network and Global Collaboration

The Singapore government has stressed the importance of connecting with the world, especially in the digital age (Lee, 2017). Therefore, when Singapore took over the chairmanship of the Association of Southeast Asian Nations (ASEAN) in 2018, it proposed a smart cities network to better connect digital infrastructures and services such as e-payments across the region (Baker 2017; Yong, 2018). As many as 26 cities have been put forth by the 10 member countries as part of the ASEAN Smart Cities Network. The cities would be developing specific action plans which may include digital solutions to solve urban issues such as city congestion and air quality (Chia, 2018).

Angelidou (2017) suggested that global collaboration is a necessary component of smart cities because it fosters new and innovative solutions. Singapore is part of the Financial Services Information Sharing and Analysis Centre (FS-IASC), a grouping of nine nations in the Asia-Pacific region that provides security resources, supports cyber security initiatives and warns other countries about imminent threats (Tanoto, 2017). This global collaboration is very timely as nations face increasingly complex and sophisticated cyber-attacks.

3. Moving Forward

With one of the fastest internet speeds and over 100 per cent mobile phone penetration, Singapore is already one of the most digitally connected nations in the world (Bhandari, 2017). The smart nation drive further offers an excellent opportunity to re-look, re-think and re-design how public services could be best provided to the citizens. It is another great

chance to promote public service innovation and active citizen collaboration (Ong, 2017; Pereira et al., 2017). Although collaboration efforts are often very time-consuming and "messy," they help to generate buy-in, and create commitment and trust which are essential conditions for real and lasting social change.

The traditional e-government approach emphasises a supply-based service delivery model using web-based applications. The digital government approach, however, suggests a demand-based citizen-centric model using data and digital technologies such as mobile apps. Nonetheless, it is not just about digital technologies per se but their applications to solve citizen's problems (Chew, 2017). The programmes and projects introduced must solve every day challenges of the citizens (Poon, 2017). Furthermore, there is a need to go beyond efficiency and economic measures that are related to livelihood to innovative and effectiveness outcomes that promote livability or quality of life.

In the digital age, there are no standard frameworks or methodologies to follow, only some simple guidelines for problem solving and innovation. These guidelines include understanding the real problem or "pain point" from a customer's perspective, designing services around outcomes, building an ecosystem to "join the dots" and harnessing digital technology as part of the solution. By applying human-centred research to uncover the real needs of the citizens, there are immense opportunities to create meaningful user experience and systems to bring communities together through digital technologies. All the services provided should be based an end-to-end user-centric approach (Puthucheary, 2018).

4. Conclusion

Singapore has made significant progress in the last few years since the smart nation drive was announced in 2014. Through proactive policymaking and by taking on a whole-of-government approach, Singapore would be increasing the pace for digitalisation in the coming years. A fundamental shift of focus from efficiency and economics to innovation and quality is necessary. There is a need to develop proactive digital strategies and policies that promote public service innovation and active citizen collaboration. With the right approach to change, Singapore could become a more advanced city than what was ever thought to be possible.

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Science and Technology Trends
The Advent of Smart Cities

The Advent of Smart Cities in India

Jagan A. Shah

1. The Context for Smart Cities in India: Urban Governance Reforms and Technology Interventions[1]

India has emerged as one of the fastest growing economies of the world, with urban areas becoming the predominant contributors to the national economy. Cities play a critical role in national growth. An estimated 65 percent of India's GDP comes from urban areas. Rapid urbanisation in Indian cities has led to a dual challenge: increasing densities that have resulted in over-burdening of existing infrastructure like water supply, sanitation, housing, transportation and energy and hence, deteriorating quality of urban life, on one hand; and, expanding city limits resulting in fragmented development and degenerated peripheral growth, on the other, thereby again compromising the quality of life.

The advent of smart cities in India marks the culmination of an extended process of reforms in the urban sector, which refers to the broader national approach to the system of urban settlements in the country as well as the interventions that have been undertaken to develop urban infrastructure, services and urban governance. The reform of urban development and governance was radically affected by the economic liberalization initiated in 1991, marking a dramatic shift away from statist planning towards competitive and free-market driven processes. Two events, one immediately before and one after 1991, give a glimpse of this dramatic shift.

The National Commission on Urbanization, set up in 1986, submitted its final report to the government in 1988. The Commission had conducted an unprecedented and in-depth study of the network of cities in the country and the economic processes that were causing urbanization. It recommended investments in growth corridors and hotspots of economic activity; however, its perspective was national, whereas the urban sector was determined by one single truth: that the Constitution of India gave the responsibility of management of land and municipal governance to the state governments that formed the federal Union of India. Thus, the Commission's brief was rooted in the assumption that the central government could determine the course of urbanization in the country, whereas the imperatives of a liberalised economy required that cities were treated as corporate bodies that could operate as economic entities in the market. This new thinking was initiated by the enactment in 1993–two years after liberalisation of the economy–of the

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1 PEARL programme, Reforms and ICT in Urban Services, New Delhi, NIUA, June 2015

74th Constitutional Amendment that devolved the powers of local self-government to democratically elected 'urban local bodies' (essentially, municipalities of various demographic sizes). This landmark initiative began the modern evolution of the urban sector in India, of which the smart city mission is the latest manifestation.

The Government of India envisaged a broad-based reform of the urban sector. With the support of the United States government, it embarked on an ambitious programme of assessing the reform requirements and capacity-building needs of Indian cities, especially with regard to their financial health and sustainability. The 'Financial Institutions Reform and Expansion Program—Debt and Infrastructure' (FIRE-D) Program commenced in 1994 with funding and technical assistance from US-AID. The program identified deficiencies in financial management, resource mobilization and project development and promoted a comprehensive approach for impactful and sustainable urban reforms and increasing investment in urban infrastructure, with specific focus on the urban poor.[2]

In addition to official initiatives for urban reform, the 1990's also witnessed a number of city-specific and localised initiatives that generated good practices for urban reform through the efforts of capable and enlightened city administrators. These include the transformation of Surat in the aftermath of the plague, the issuance of the first municipal bond in Ahmedabad and PPP projects for sewerage and water supply in Allandur and Tirupur in Tamil Nadu. Pioneering state governments also became champions for reform, resulting in increased transparency and accountability in Hyderabad and Bangalore and streamlining of building plan approvals in Pune and Mysore. Most such reforms were initiated with the support of bilateral agencies like USAID and DFID and multilateral agencies like the World Bank and ADB.

In 1994, the Ministry of Finance set up an Expert Group on Commercialization of Infrastructure Projects.[3] The expert group submitted its report in 1996 and contributed to the 9th Five Year Plan (FYP 1997-2002), which stressed the need to explore market-based forms of financing such as municipal bonds and to achieve the necessary municipal reforms. The 10th FYP (2002-2007) announced comprehensive urban reforms and public private partnerships in urban infrastructure projects, including the introduction of 100 percent Foreign Direct Investment (FDI) in integrated townships and infrastructure projects. The Urban Reforms Incentive Fund (URIF) was announced in the 2002-03 budget, to incentivize reforms in seven key areas, including the repeal of the Urban Land Ceiling and Regulation Act (ULCRA), rent control, computerized registration of property, rationalization of stamp duty and property tax, levy of user charges and introduction of double entry system of accounting in the ULBs.

In 2005, the Government of India (GoI) launched the Jawaharlal Nehru National Urban Renewal Mission (JnNURM) as a logical next step in the urban reforms trajectory. The seven year mission (2005-2012) focused on 65 mission cities and provided stimulus funding for infrastructure projects in water supply and sanitation, transportation, etc. as an incentive for reforms at state and city levels, develop appropriate enabling and regulatory frameworks, enhance the credit worthiness of municipalities and integrate the poor with the service delivery system.

"E-governance" was one of the mandatory reforms to be achieved at the ULB level. Several Indian cities had already begun deploying a few smart technologies to efficiently provide civic services. Cities such as Hyderabad, Surat, Coimbatore, Bengaluru, Mangalore, Jamshedpur, Kanpur, Delhi,

2 See 'India: Pioneer Of Municipal Finance', https://usaid-credit.exposure.co/india-pioneer-of-municipal-finance, referenced 15 June 2018.
3 India Infrastructure Report, IDFC Limited, 1996

Mumbai and Chennai have launched initiatives related to the deployment of advanced communications systems, metro rail systems, traffic management systems, smart meters, GPRS for solid waste management, GIS to manage property tax, online water quality monitoring, and online building plan approval systems.

2. Smart Cities in India: the Formative Years

The enabling policy framework[4] for the technology aspect of smart cities gained momentum with the launch of The National e-Governance Plan (NeGP) by the GoI to institute and enable mechanisms to improve the system of governance and thus provide better services to the citizens by effective use of Information & Communication Technology (ICT). NeGP comprised 27 Mission Mode Projects that included e-Governance in municipalities. A total of 35 JnNURM cities with 1 million population were made pilot cities for NeGP and guidelines were drafted for a new Centrally Sponsored Scheme (CSS) for other cities and towns. The following services were to be covered under this reform at the ULB level:

- Basic citizen services: birth and death registration and health programs
- Revenue earning services: property tax and licenses
- Development services: water supply and other utilities, building plan approval
- Efficiency improvement services: procurement and monitoring of projects
- Back office improvements: accounting and personnel management system
- Monitoring: citizen grievance redressal

In 2011, Government of India approved a scheme for creation of a National Optical Fiber Network (NOFN) for providing Broadband connectivity to rural local bodies or panchayats (village councils).[5] Another significant policy was the National Industrial & Manufacturing Zone policy of 2013, which stipulated the creation of industrial townships to house the workers and other professionals who would be required to operate the new manufacturing industries that are to be established along the Delhi-Mumbai Industrial Corridor, with the Dedicated Freight Corridor as its backbone. Promoted by the Department of Industrial Policy & Promotion of the Ministry of Commerce, seven "smart cities" have been envisaged on the DMIC.

The Delhi Mumbai Industrial Corridor Development Corporation has also committed to developing smart eco-cities with investment from Japanese companies based on their experience of developing Yokohama and Kitakyushu.[6] State governments like Kerala and Gujarat have also independently devised their own plans for developing the Kochi Smart City and the Gujarat International Finance Tec-City (GIFT) respectively.

Reforming the government system through good governance was one of the key agenda points in the Bharatiya Janata Party's (BJP's) election manifesto for India's General Elections in 2014. Open government and accountable administration with administrative reforms as the priority was expected to bring in transparency in the Government's decision-making process. Highlighting the importance and power of the middle class and "neo middle class" (people who have risen from the category of poor and are yet to stabilize in the middle class), the manifesto touched upon the need for proactive handholding to meet the increasing aspirations.

4 PEARL programme, op. cit

5 PIB press release announcing cabinet approval of scheme for creation of a National Optical Fiber Network (NOFN) for providing Broadband connectivity to Panchayats, October 2011

6 ECO CITIES FOR INDIA Jun 20, 2011 by Dhanapal. G. See more at: http://www.sustainabilityoutlook.in/content/eco-cities-india#sthash.oeCw4R2W.dpuf

2.1 Smartness as an Electoral Promise

Under the charismatic leadership of Narendra Modi, the Bharatiya Janata Party (BJP) led the National Democratic Alliance to a historic victory in the elections to India's national parliament in 2014. In its election manifesto, the BJP had stated categorically that part of its approach for delivering its commitments to the electorate was to see urbanisation in India as an opportunity and to plan for urban areas which can reflect efficiency, speed and scale.[7] Cleanliness and sanitation were given high priority along with programmes for integrated waste management, housing & urban poverty alleviation, urban transport, technologically-enabled scientific, strategic and long-term planning. The manifesto also promised integrated habitat management and the development of 100 smart cities. In his first Union Budget Speech, the Finance Minister Arun Jaitley announced a fiscal allocation of INR 7,060 crores (USD 118 million) for creating the blueprint for smart cities.[8]

The Digital India programme was envisaged by the Department (now Ministry) of Electronics and Information Technology, with a vision to transform the country into a digitally empowered society and knowledge economy.[9] With Prime Minister Modi's commitment to digitalisation as a means to achieve transparency and efficiency in governance–inspired by his promise of "more governance, less government"–the Digital India program became the key ingredient for the urban transformation that he would solidify through the smart city mission. Most of the terms of Digital India were deeply connected to cities and urban life and formed a blueprint for the delivery of these features in substantive form. The components of Digital India include "Infrastructure as Utility to Every Citizen", with high speed and cyber-secure internet connectivity and mobile telephony to bridge the digital divide and enable "cradle to grave" digital identity (later to become ADHAAR), financial inclusion through banking services and digital access to government services. The development of 'single windows', improvement of 'Ease of Doing Business' rankings and leveraging of GIS for decision support systems would eventually enable collaborative and participatory governance.

3. Mission Transform-Nation[10]: the Smart Cities Mission as a 'Theory of Change'

India's Smart Cities Mission was launched on 25th June 2015. The Mission treated the lack of a universal definition of "smart cities" as a premise, with the argument that India's needs are very different from the other countries where the global trend toward smart cities was being propelled from locations such as Songdo in South Korea, Masdar in Abu Dhabi and specific projects in Barcelona, Helsinki, Dublin, Berlin and London. Thus, India's Mission guidelines stated quite emphatically that there is no universally accepted definition of a smart city, thus dedicating itself to the holistic development of the urban ecosystem, with cities incrementally adding "layers of 'smartness'" and creating replicable projects, thereby acting like "lighthouses" for other aspiring cities. Significantly, the mission stated its objective in terms of achieving urban 'smartness' in the context of overall urban sector ambitions: "To drive economic growth and improve the quality of life of people by enabling local development and harnessing technology as a means to create smart

7 BJP Election Manifesto, 2014 available at bjp.org

8 Budget 2014-15, Speech of Hon'ble Minister of Finance: Point no 24

9 PIB press release announcing cabinet approval of Digital India – A programme to transform India into digital empowered society and knowledge economy, August 2014

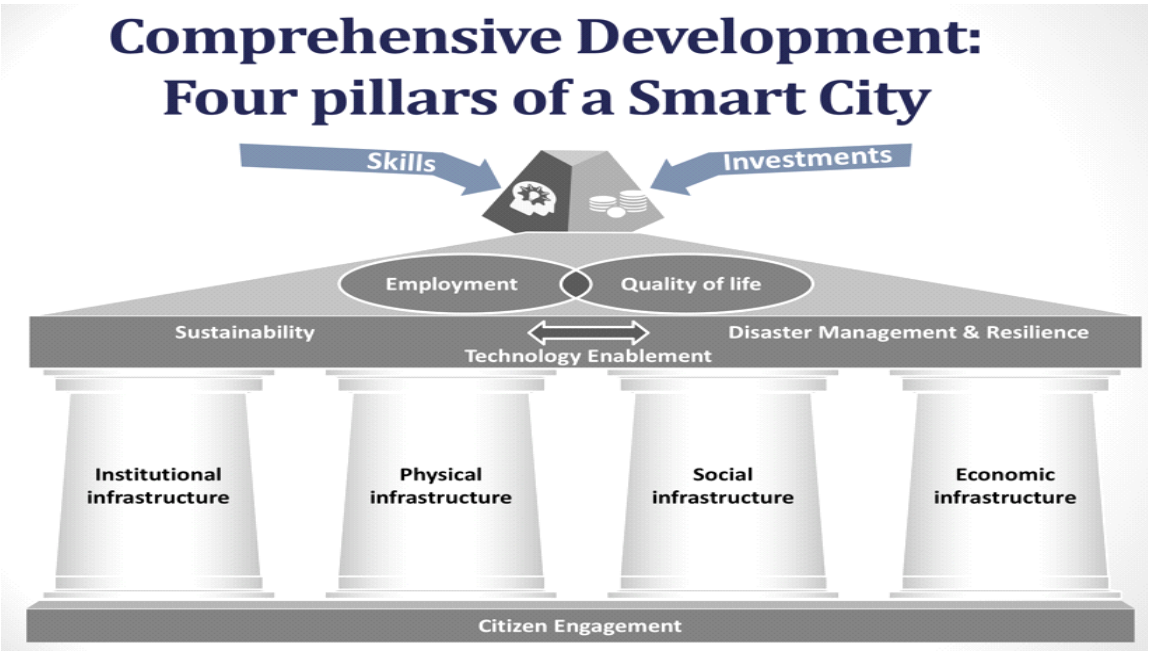
10 Exploratory research on Smart Cities, June 2015

outcomes for citizens." (Smart City Misson Guidelines, 2015) The enabling of local development was seen strategically as a two-pronged approach: to spatially locate the key economic drivers in each city and to pursue retrofitting, redevelopment or greenfield development in such locations in order to fully realize the economic potential. In addition, to identify city-wide priorities with respect to urban management and service delivery needs and to service those needs by introducing at least one or two smart solutions that impact the lives of all citizens.

The smart development strategy for the lighthouse city was evolved through a consultative process wherein large numbers of stakeholders and citizens were engaged in creating baselines and long-term visions as well as identifying the areas for intervention and the specific needs for which 'pan-city' solutions were devised. Thus, a significant thrust was given to result-oriented projects that benefit the local residents in terms of economy, health and well-being and other social and cultural outcomes. Measurable improvements in service delivery and efficiency were given as much importance as qualitative outcomes related to public health and wellbeing, inclusion and access and improved governance. The ambitions of the Mission are pithily captured in the following statement:

"The specific priorities are to have clean air according to norms, move towards zero discharge of solid and liquid waste, make streets litter free, involve citizens in policy-making and execution, generate jobs, expand the identified core economic activity(ies) of the city, make the city prepare for floods and extreme weather, reduce and eliminate poverty, make basic services available to all—especially the poor and disadvantaged, create recreation spaces and parks, realign processes so that citizens get timely municipal services through complete disintermediation, and promote good governance in general and mobile governance in particular."

Figure 1. Four 'pillars' of a smart city, identified in the first draft of the Smart City Guidelines, 2014



Given that the Prime Minister had personally articulated the ambitious byline–"Mission Transform-Nation"–it is not surprising that the Mission became a vehicle for introducing into the urban sector in the country, the good practices and innovations that had been identified through experience and research in the urban sector, especially but not solely during the JnNURM. The dissemination and adoption of good practices was given a fillip through exposure to the global urban sector, which was promoted by the interventions of multilateral and bilateral agencies and bilateral cooperation agreements between India and the developed countries of Europe, North America and the Asia-Pacific region.

It could be argued that the theory of change described by the smart city mission–which guides a mission for urban transformation–has a greater significance than its specific targets: to develop 100 smart cities with at least one in each state and union territory[11] of India from a larger pool of over 4000 cities in an incremental manner over five years. While the numerical targets and their achievement form the tangible promise given by the ruling National Democratic Alliance in its election manifesto, the impact of the Mission must be understood in terms of its longer term goals and its explicit ambition to be a "game-changing" urban initiative. The salient aspects of this larger sectoral goal can be subjected to more detailed examination; however, the broad contours of the theory of change are described in the following sections.

3.1 The Smart City Challenge

The "India Smart City Challenge" is widely recognised to be the first of its kind in India as well as the urban sector globally. It exemplifies the competitive spirit that Prime Minister Narendra Modi has stipulated for all public programs in the country, wanting to thereby push for greater innovation in urban development whereby a development program can address the specificity of local context while following a standardised template and competing for funding on the basis of merit that can be objectively established.

The 'challenge' was conducted in two stages. In stage 1, the state governments were asked to identify 'candidate cities' which would participate in stage 2, the main challenge. The candidate cities were also shortlisted on a competitive basis, taking into account their performance in achieving reforms during JnNURM and their current administrative and financial performance.

A standard template was devised for submission of the proposals, such that all proposals, regardless of the size and type of city, could be judged on a common basis and on their own merit. A unique innovation was introduced through the design of the blank standard template in which the proposals were to be prepared, consisting of a set of 43 questions and providing limited word counts for each response as well as a stipulation of page limits for enclosures.

The competition brief required that each city should propose to develop one area-based development–either a retrofitting of minimum 500 acres, a redevelopment of minimum 50 acres or a Greenfield development of minimum 250 acres–on the principles of place-making and integrated urban planning, and one or two pan-city smart solution which would improve the delivery of municipal services throughout the city. Cities were asked to conceive transformative projects that could result in the highest possible impact in the following aspects: economic growth (measured by the number of new jobs created, new firms attracted, increased productivity and business climate in the formal as well as informal sectors, recognition of and incorporating urban vendors), and improved quality of life, especially for the poor (measured by

11 Union territories in India are under the direct administrative rule of the central Government of India

reduction in commuting time, support of non-motorized transport, improvement in air and water quality, increased coverage of water supply, solid waste management, street lighting, green public spaces, and public safety and security).

3.2 Demand-Driven and Consultative Process

The Challenge process mandated that the projects being identified by the city to achieve the 24 essential features would be identified through the sharing of baseline assessments with the citizens and stakeholders and the conducting of public consultations, focus group discussions and opinion polls. The competing cities employed an array of engagement tools and forums to ensure coverage and deepen the engagement process. More than 1.7 million participants engaged with the mission on the 'My Gov' platform of the Government of India. Overall, "an unprecedented 1.5 crore citizens were consulted while envisioning and preparing smart city proposals (Smart City Mission, Weekly Bulletin)." The local governments used innovative mediums for presenting facts and soliciting inputs from the public, including infographics, creative competitions for essay-writing, poster-making, painting, logo and tagline creation, as well as street plays, sports events, music concerts and discussion groups on social media, television and radio. Specific efforts were taken to engage the poor and vulnerable sections of society.

3.3 Institutional Capacity-Building

A structural weakness in the urban sector in India has been the lack of capacity within the urban local bodies. In order to attain success in the Smart City Mission, it was anticipated that each city would need the capacity to plan, implement, operate and manage the entire life-cycle of the projects funded by the Mission. The need to preserve the orientation toward results and protect the projects from the vagaries of frequent changes in the political economy–an average term for a Mayor in Indian cities is 18 months–forced a strategic decision that continues to be debated.

The Mission requires that in order to avail of funding, each city must establish a 'special purpose vehicle (SPV)', a Limited company incorporated under the Companies Act, 2013, in which the State/UT and the ULB will be the promoters having 50:50 equity shareholding, that would ensure stringent accounting and managerial practices. As per Mission guidelines, the SPV "will plan, appraise, approve, release funds, implement, manage, operate, monitor and evaluate the Smart City development projects (Smart City Mission Guidelines)." This is particularly significant in the context of Indian municipalities, which have historically been weak in such aspects. The Boards of the SPVs would include key stakeholders from government departments and agencies as well as others; however, the Chief Executive was expected to be sourced from the private sector. A key responsibility is to ensure financial sustainability of projects over their entire lifecycle. The SPV is expected to lead the innovation agenda in the city and become an integral part of the reform process, ensuring coordination amongst stakeholders and monitoring results. In addition to the key management personnel, each SPV is also required to hire a team of domain experts in the form of a Project Management Cell.

3.4 Strategic Planning

The Smart City Mission has made a distinct departure from the normal approach to urban planning, which had been dominated by the perpetuation of "master planning." A strategic approach to planning has been adopted rather than the usual physical planning of infrastructure and the determining and regulation of land use. The smart cities were required to adopt such a strategic approach also because the Mission targeted existing cities and

'brownfield' sites[12]. It insists on cities to identify their strengths, weakness, opportunities and threats (SWOT); prepare suitable vision statements, make proposals, and implementation and financial plans for the same. The application framework required a logical framework that related the goals of the project with the outcomes being targeted: the 'means' deployed with the 'ends' being sought by the city. While drawing up the log-frame, the cities also identified the main risks and assumptions as well as the framework for monitoring progress.

Table 1. The logical framework used in the template for submitting proposals in the Smart City Challenge, 2015

Mission Results Hierarchy	Performance Indicators	Assumptions and Risks
Goal at national level:		
Sub-goal of city:	Impact indicators:	
Purpose of area based developments:		
1		
2		
Purpose of each area based activity:	Area based outcome indicators:	Assumptions and risks
1.1		
1.2		
2.1		
2.2		
Purpose of smart solutions:		
1		
2		
Purpose of each smart solution activity:	Smart solution outcome indicators:	Assumptions and risks
1.1		
1.2		
2.1		

3.5 Convergence

The mission encourages cities to leverage their smart city proposals as natural convergence points for other national initiatives, thus enabling an integrated approach to urban planning and a broader engagement with issues ranging from economic development ('Make in India' Mission), adoption of digital technologies ('Digital India') and housing ('Pradhan Mantri Awas Yojana') to urban infrastructure ('Atal Mission for Rejuvenation & Urban Transformation'), heritage conservation ('Heritage Rejuvenation & Infrastructure Development and Augmentation Yojana'), sanitation and waste management ('Swachh Bharat' Mission) and livelihoods ('National Urban Livelihoods Mission'). As a result, a number of cities could converge the funding available from schemes for installation of piped natural gas, solar panels and promotion of e-vehicles. The thrust on convergence between schemes and programs that are being, or can be, executed in the same city was a recognition of a trivial fact: that cities are sites for integrated development and not just incidental locations where different schemes get implemented. Most significantly, convergence rescues the development process from the waste and redundancy caused by overlapping investments and duplicated expenditure.

3.6 Integration

Fundamentally related to the issue of convergence is that of integration. In a dramatic departure from business-as-usual, where each government department or agency would pursue their plans and implement projects in relative isolation from the other, the smart cities are required to integrate their projects across sectors, such that all aspects are

12 A departure from this approach of focusing on existing cities was when the Andhra Pradesh government south approval for the greenfield city of Amaravati, its new capital, in the third round of the Smart City Challenge. However, this selection has been kept in abeyance till such time that Amaravati is formed as an 'urban local body'.

Table 2. Milestones and progress of the Smart City Mission

Round of Selection	Month & Year	Number of Cities Selected	SPV Formed	PMC Setup
Round 1	January 2016	20	20	20
Fast Track	May 2016	13	13	13
Round 2	October 2016	27	27	27
Round 3	June 2017	30		
Round 4	January 2018	9		
Total		99	92	69

addressed in a holistic manner and contribute to the overall quality of life. Thus, each city was required to plan for the provision of 24 "essential features", which included traditionally non-urban services such as power supply, healthcare, education, employment generation and environment. The 'smart city plan/proposal' thus contained a variety of projects that were provided approval and sanctioned funds at the same time.

4. Mission Update: Transformation in Progress

The results of Round 1 of the Smart City Challenge were declared in January 2016, six months after the launch of the Mission. This period included the preparation and submission of proposals in December 2015 and the subsequent evaluation of proposals by a jury of experts. The pace of execution can be described as unprecedented, especially given the unusual scale and nature of ambitions in the Mission. By January 2018, 99 cities have been selected, with the last one awaiting the resolution of an unexpected legal hurdle. The 99 selected cities have proposed a total investment of INR 201979 crores (USD 33.7 billion), with approximately 80.76% of the funds proposed to be invested in the Area-Based Developments and about 19.24% in the Pan City Solutions.

The progress of the Mission and its institutional setup is shown in Table 2.

An appraisal of the Smart City Mission would tend to consider the achievements of the Mission in comparison with the past. However, it is more constructive to consider the ways in which the Mission has become a barometer of the evolution of the urban sector in India. It is worthwhile to recall that the projects being executed in 99 cities are conceived in response to each city's baseline as well as the opinion of local stakeholders about their needs and the articulation of their demands. As such, the Mission indicates changing priorities, needs and wants of the cities.

The projects currently being implemented under the Mission are broadly distributed across 14 categories. These projects include provision of basic infrastructure as well as improved governance and IT-enabled services using cloud-based technology. The new kinds of projects being executed include integrated command-and-control centers, common payment cards across platforms, CCTV surveillance platforms, parking management, signage and Information Management Systems, solar installations, real time monitoring of pollution, waste and transport, and app-based systems for promoting cycling, car-sharing, traffic management, wastewater treatment and reuse, intelligent meters and water ATMs. Innovations like GPS-enabled vehicle tracking and automatic fare collection, SCADA for water management and street lighting, public Wifi, skill development and enterprise incubation, circular economy, and promotion of local Identity and awareness, tele-medicine and digital learning platforms are also proposed by some cities.

Table 3. Sector-wise distribution of the projects in 99 smart cities, with shares of overall costs

	Sector	Number of Projects (% total)	Cost (% total)
1	Area Development	22.0%	11.05%
2	Economic Development	4.2%	1.70%
3	Energy	8.5%	11.02%
4	Environment and Pollution	5.1%	2.48%
5	Housing	2.8%	11.77%
6	IT Connectivity and Digitization	11.2%	11.17%
7	NMT	4.7%	2.30%
8	Safety and Security	1.3%	1.45%
9	Sewerage and Septage	5.2%	6.55%
10	Social Sector-Education and Health	6.6%	3.52%
11	SWM	8.3%	4.67%
12	Storm Water Drainage	1.6%	1.54%
13	Urban Transport	10.4%	8.27%
14	Water Supply	4.7%	14.44%

Since the Mission was launched three years ago, 940 projects are being executed by the 70 cities that have established SPVs and hired the required human resources. The remaining 29 cities are in different stages of institutional development. 313 projects with a total cost of INR 5221.92 crores (approximately USD 870 million) have already been completed. These constitute 16.25% of the total projects. Another 627 projects with a total cost of INR 26910.55 crores (USD 4.5 billion), constituting the remaining 83.75% of projects, are at various stages of implementation. The category-wise distribution of the 940 projects that have been envisaged by 70 cities are described in Table 3.

Within three years of launch, the Smart City Mission has revealed the capacity of the sector for absorbing innovation and reform. While the structural challenges remain in the larger pool of cities in the country that have not been covered by the Smart City Mission, the 'theory of change' and the 'lighthouse' effect has begun to show results, as increasing numbers of cities learn from each other and experiment with 'smart' solutions for their needs and challenges.

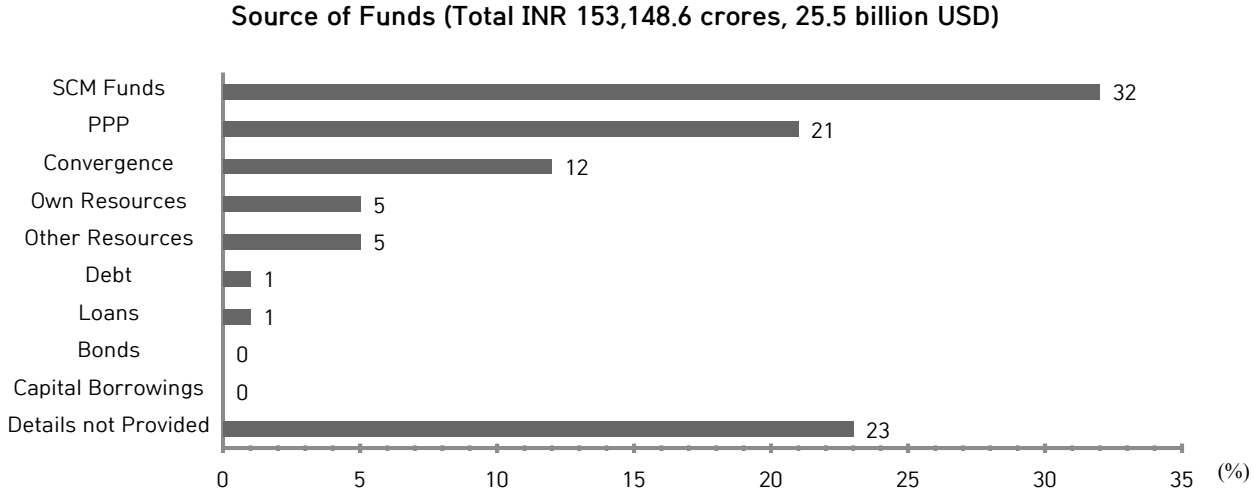
Specific aspects of the Mission that need extensive research and further evolution–based on the evidence that will emerge during 2018-19–include the innovative financial arrangements that cities will need as they progress further along the path to becoming "sustainable, resilient, safe and inclusive", as is envisaged by the Sustainable Development Goal 11, a key part of the New Urban Agenda adopted by India and the international community. Urban transformation cannot be achieved through government funds alone. Smart cities have leveraged government grants to the order of 2.5 times. Popular sources of finance encouraged in the Mission projects are public private partnerships (PPP), municipal bonds, and land value capture. Pune and Hyderabad have issued municipal bonds that provide a 13% return on investment. A policy framework for Value Capture Finance has been prepared by the Ministry of Housing & Urban Affairs and promoted with all state governments (Smart City Mission, Weekly Bulletin). The PPP mode of funding is being used for 98 projects with a total worth of about INR 6000 crores (USD 1 billion). The projects are structured around the leasing of centrally located land parcels or the easing of right-of-way provided by the city. These projects are case-studies in innovative municipal financing, with large PPP components:

- Railway Station Multimodal Hub, Bhubaneswar (INR 600 crores, USD 100 million)
- Janpath Government Housing Redevelopment, Bhubaneswar (INR 1260 crores, USD 210 million)
- Slum Rehabilitation in Junavadaj area, Ahmedabad (INR 462 crores, USD 77 million)
- Sector 43, Chandigarh (INR 2568 crores, USD 428 million)
- Intelligent street poles, Bhopal (INR 690 crores, USD 115 million)
- Mixed Use Development, Faridabad (INR 965 crores, USD 161 million)
- Intermodal Transport Hub, Ahmedabad (INR 609 crores, USD 102 million)
- Market Redevelopment, Raipur (INR 1026 crores, USD 171 million)

It is significant that the PPP mode, which accounts for approximately 20% of the overall financial outlay of the Mission, is predominantly based on the emerging paradigm of land value capture, which promises to become a significant source of self-generated funding for Indian cities in the future.

It has been mentioned earlier that the convergence between departments and agencies and the integration of different domains in the urban sector have been two of the significant aspects introduced by the Smart City Mission. Two examples would clarify further the significance of these aspects. The case of the Command-and-Control Centres provides a clear illustration of the principle, whereby the centers are integrating otherwise standalone services such as E-governance, SCADA, traffic management, solid waste management and GIS-based property tax collection systems. This has required efficient coordination and enterprise resource planning within a large number of departments and agencies such as the Traffic Police, administration, local bus systems, transport licensing and others. Similarly, the common 'smart card' payment system in Bhubaneswar, that provides benefits to users across transportation and other municipal services, involves the transportation as well as IT, finance and other departments. The successful implementation of such a solution will enhance user experience, increase revenues for the service providers and capture valuable data on the use of transit and other services for planning in the future. ICT also enables the city to deliver government subsidies more transparently and efficiently.

Figure 2. Sources of funds for the smart cities



5. Smart Cities and the Future of Urbanization in India

Globally, India is at the forefront of generating massive concentrations of urban population. A widely cited rule of thumb is that as the population of a city doubles, it requires three times the previous built-up area. This results in increased demand for urban services–water, transportation, sewage treatment and affordable housing. A landmark study by the McKinsey Global Institute in 2010 estimated that such demand would increase 5 to 7 times across India's urban centers. At the same time, the Indian government has also made far reaching commitments towards the larger welfare of the planet at the COP 21 Summit, by assuring the world community that it will reduce the emission intensity of its GDP by 33% by 2030. It has also committed to achieving the New Urban Agenda by 2030, which further complicates its ambitions, because the achievement of its environmental commitments must be done while maintaining the equitable, sustainable and resilient growth paradigm.

With the advent of smart cities in India, the country can be more confident of achieving a veritable decoupling of urban development from resource intensity. A description of the desired decoupling resonates with the model of smart city development in India:

> *[Decoupling] will require structural changes in business models, lifestyles and modes of governance and will primarily rely on a combination of changes gained through new alliances of fast-movers working together to demonstrate desirable alternatives to business-as-usual. (ibid)*

The decoupling of a resource-intensive paradigm of urban development will require the wide-scale adoption of smart city principles and the scaling and replication of efforts that have been initiated in 99 cities. While it is predictable that 80% of the costs projected by the cities is devoted to 'area-based development', it is significant that in more than 80 of the 99 cities, 60% of the ABD expenditure will be on retrofitting the existing urban spaces.

The retrofitting of existing urban areas may not be as fast and as convenient as the development of greenfield areas, however, the fact that most cities have chosen to invest further in existing areas is a reflection of their confidence that the contemporary city must build further on the economic value created by numerous generations of local residents over the city's history. This is inherently a reflection of faith that older areas of the city can be made more sustainable through adaptation and improvement. Smart cities can benefit from the replication of some key aspects across the entire city.

In pursuit of compactness and the disavowal of urban sprawl, the smart cities can adopt mixed land use by planning for a range of compatible activities and land uses in juxtaposition in order to make land use more efficient. The creation of safe and walkable localities will reduce congestion and air pollution and boost the local economy by promoting localised interaction between diverse economic agents. The area-based development is also a manageable scale at which smart cities can pursue the integrated planning of infrastructure, services and public open spaces. It can easily be mapped onto the spatial structure of municipal wards or development zones. It also perpetuates the consultative spirit of the smart city, whereby local stakeholders and citizens become the generators of consensus about local needs and demands. The scaling and replication of the area-based development model can embed the 'bottom-up' approach to urban development in all cities of the country—which perhaps explains why the Vice-President of India, in a speech on 25th April 2018, chose to highlight this particular aspect of the smart cities mission.

The area-based developments in the smart cities have a concomitant in the 'pan city solutions' that are an equally significant component of the smart city plans. As solutions that leverage ICT and digitalisation, and given their 'pan-city' footprints, these solutions can proliferate across each city, deepening the impact and relevance of the smart city mission. While most cities have currently focused their attention on monitoring of municipal services, traffic management and security through surveillance, there are numerous solutions that can be introduced into each city. The proliferation of pan city solutions will allow the smart cities to intersect their development trajectories with other smart cities across the globe, thereby accessing ready-to-use technologies. However, it is more significant that as the cities replicate and scale their 'smartness', they will also attract the talent and human resource that can produce the innovative solutions required for the solution of local and peculiar problems. Thus, the Mission's ambition of promoting frugal innovation through development of locally customised solutions can become a reality as each city evolves further.

A significant role in identifying innovative solutions will be played by the evidence and data that is gathered during the Mission and made available to researchers, entrepreneurs and civil society organisations who can subject the evidence to the cold light of scientific inquiry. This purpose will be greatly served by the City Liveability Standards that have been developed by the Ministry of Housing & Urban Affairs in 2017, which shall form the basis for the preparation of the Liveability Index for smart cities in India. Although the ISO 37120 and the SDGs do offer criteria for measuring progress, there is a felt need for an Indian adaptation of these standards, which could either be too elaborate or simply indeterminable in the Indian context. While the smart cities are adopting different pathways for achieving their goals, a 'common minimum framework' was needed. The first annual assessment across 116 Indian cities on 79 indicators in 15 categories will soon be completed, with results scheduled to be announced on 25 June 2018, the third anniversary of the Mission.

The existence of objective criteria for measurement of impact will also allow for the larger partnerships that the country is eager to establish with countries and organisations that can bring innovations and sustainability to the Mission.[13]

Besides the access to good practices and global recognition, India will benefit from partnerships, investments and technical assistance from around the globe. These already include the Indo-French cooperation in the field of Sustainable Urban Development, through which the French development bank, AFD will extend a Loan of EUR 100 million to fund innovative projects in the smart cities, as well as the European Commission's funding of a Euro 6 million 'Technical Assistance' grant to handhold the cities to create world-class projects. The German, British, Dutch and other countries are offering their support to the Mission. The World Bank and Asian Development Bank are also devising programs to support, with the ADB already identifying 10 cities to support through Technical Assistance.[14]

Even internally, new programs of the Government of India are seeking collaboration with the Mission, such as the sanctioning of INR 2,920 crore by the Ministry of Home Affairs under the Nirbhaya Fund, to make the smart cities safer for women.[15] Further innovation is being sparked by the Mission in other countries: in 2015, Infrastructure Canada launched the Canadian Smart Cities Challenge on a similar

13 Extracted from 17 issues of the mission's 'Weekly Bulletin', SmartNet

14 Jalandhar, Raipur, Bhagalpur, Aurangabad, Rajkot, Lucknow, Kakinada, Allahabad, Guwahati, and Coimbatore

15 The program has commenced with support to Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Lucknow.

pattern as India's mission. The Global Smart City Performance Index devised by the British market research agency Juniper Research, ranks the top 20 global smart cities in terms of the integration of Internet of Things (IoT) technologies and connected services across four key areas: mobility, healthcare, public safety and productivity. It has listed Bhubaneswar among the top 20 best performing smart cities in the world, along with London, San Francisco, Barcelona, Melbourne, Seoul, Rio de Janeiro, Tokyo and Singapore, which tops the list.

The evolutionary vision of the Smart Cities Mission makes it the most likely pathway for achieving the Sustainable Development Goals, especially Goal 11 that calls for the development of safe, inclusive, sustainable and resilient cities.

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