Analysing National Innovation Capacity and its Importance for Competitiveness and Growth

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Abstract

This paper uses data from the OECD's Scientific and Technological data base and the Global Competitiveness Report (GCR) to analyse the national innovation capacity of nineteen OECD countries over the time period 2001 to 2007. A total of three sub-indexes are constructed which rank the strength of the common innovation infrastructure, cluster specific environment and quality of linkages which exist within each of the countries. These sub-indexes form the basis of an overall index measuring countries' national innovation capacity.

The results indicate that each of the three components considered are important in explaining the innovation output of the countries studied. Further to this, national innovation capacity is found to have a positive effect on GDP per capita and on a country's GCR ranking. However, national innovation capacity in 2001 is found to be negatively associated with the subsequent growth rate of GDP per capita. This counterintuitive result may arise due to determinants of growth other than innovation such as capital and labour accumulation.

Key words: National Innovation Capacity, Competitiveness, Economic Growth, Economic Geography

JEL Classifications: O3; O57

1. Introduction

The ability of a nation to compete at the technological frontier of knowledge is regarded as essential for a country to maintain an increased level of economic growth in the long term (Romer 1996). Key drivers of a nation's ability to accomplish this are the frameworks which are in place which stimulate innovation within the economy. A successful innovation system requires the coordination and cooperation of firms, public and private research institutes and government (OECD 1999). Furman, Porter and Stern (2002) capture the interaction of these three components in their national innovation capacity framework.

National innovation capacity is comprised of three components: common innovation infrastructure, the cluster specific environment and the quality of linkages which exist within a nation. Each of these components has its origin in different aspects of the innovation literature. Lundvall (1986) describes the innovation system of countries, emphasizing the important influence national cultures, institutions and legal frameworks can have on a country's ability to generate a series of commercially viable innovations. At a micro level, Porter (1998) notes that ultimately it is firms which innovate, and that in modern economies the most innovative firms are found in clusters, which support and provide for their innovative needs. Finally, Furman, Porter and Stern (2002) postulate that, while both of the above elements are important for innovation, individually neither is sufficient to ensure the generation of new technologies. They highlight the importance of establishing strong linkages between both components so that knowledge and information can be transferred from one to the other, ensuring that both segments are conducive to innovative activity.

This paper uses data from the Organisation for Economic Co-operation and Development's (OECD) Scientific and Technological data base to analyse the national innovation capacity of nineteen OECD countries for the time period 2001-2007. This paper follows a similar approach to that utilised by Porter and Stern (2002) who analyse the national innovative capacity of a group of 75 countries in 2001. While Porter and Stern's (2002) analysis provides an insight into the effects of innovation capacity in one particular period of time this paper adds to the literature by examining innovation capacity over a seven year time period using alternative measures and data sources. By considering the temporal evolution of innovation capacity, the effects of variation in the different components of a nation's innovation system can be analysed.

Initially, to analyse national innovation capacity, this paper generates a number of sub-indexes based on a nation's common innovation infrastructure, cluster specific environment and the quality of linkages which exist in the economy. This is accomplished through the use of data obtained from the Global Competitiveness Report (GCR). These sub-indexes are then used to construct an overall index of nations' innovation capacity. Following this, an analysis is conducted to assess whether a country's national innovation capacity impacts on that country's economic prosperity, economic growth and competitiveness. This will allow for conclusions to be drawn as to the importance of innovation capacity for long term economic competitiveness and growth.

The structure of the paper is as follows. Section 2 introduces the underlying concepts of the national innovation capacity theory and explains its importance for economic growth and competitiveness. This is followed in Section 3 by a description of the data utilised by this paper. Section 4 outlines the construction of the national innovation capacity index. Section 5 presents the empirical results derived and analyses the importance of national innovation capacity for economic growth and competitiveness. The final section concludes.

2. Literature Review

A nation's national innovation capacity describes its ability to generate and capture new innovations. It is comprised of three components: common innovation infrastructure, cluster specific environment and the quality of linkages between the two (Porter and Stern 2002). This self reinforcing triad is represented in Figure 1.

[insert figure 1 about here]

2.1 Common Innovation Infrastructure

Each of the three components contributes differently to a country's national innovation capacity and are grounded in different economic theories of innovation. A country's common innovation infrastructure is comprised of a range of far reaching and overlapping factors which support innovation in the economy as a whole. These factors are not specific to any particular industry, but have an overarching effect on the innovation capacity of every firm in the economy (Furman, Porter and Stern 2002).

Among the important elements of a nation's common innovation infrastructure is the quality of the nation's institutions. Hodgson (2006: 2) defines institutions as "systems of established and prevalent social rules that structure social interaction". Olson (1996) shows, by the use of natural experiments, how different institutions between countries can have dramatic impacts on their economic performance. Using examples such as the difference in the performance of East and West Germany, where institutional divides were extreme, he highlights the importance of institutional frameworks.

One of the key elements of institutions pertaining to innovation is the presence of strong and enforceable property rights. The presence (absence) of institutions in a nation exerts a strong incentive (disincentive) for firms, across all sectors of the economy, to innovate. Apart from property rights examples of other important institutions are laws, regulations, contracts, market exchange rules and rules of conduct (Balzat 2006).

2.2 Cluster Specific Environment

A country's cluster specific environment is the second component of national innovation capacity. Clusters can influence innovation, and competitiveness within regions and countries (Alberti et al., 2016). This component does not have an overarching effect on all sectors of the economy, as common innovation infrastructure does, but rather relates to a specific industry segment (Porter and Stern 2002). While common innovation infrastructure forms the basis of innovation activity in a country, it is ultimately the firms which innovate. It has been suggested that innovation takes place disproportionately in clusters – geographic concentrations of firms based on specific criteria (Porter 1998). Furman, Porter and Stern (2002) suggest that this cluster specific environment can be captured in the diamond framework developed by Porter (1990). This is illustrated in Figure 2.

[insert figure 2 about here]

This diamond contains four distinct sub-groupings: factor conditions, firm strategy structure and rivalry, demand conditions, and related and supporting industries. Each of these components contributes to the development, and innovation capacity, of the cluster environment in the nation (Furman, Porter and Stern 2002). When considering factor conditions, these relate to the factors of production which are important for the production of new knowledge and innovations. In this context, the factors which are important are those described by Porter (1990) as being both advanced and specialised. These factors are not inherently inherited by a nation, as basic factors such as geographical location are, but require development and continual investment and upgrading. Factors which could be envisaged as being critical for innovation performance could be the human capital available in the cluster, high quality specialised infrastructure and an ample amount of risk capital.

The presence of related and support industries in a cluster provide opportunities for innovative firms. The genesis of new ideas can be accommodated through cooperation with related industries or through interaction with suppliers. Firm level analysis by Roper, Du and Love (2008) and Freel (2003) has indicated that backwards and horizontal linkages play an important role in aiding firms to innovate.

Porter (1990) notes that demanding local customers, who are sophisticated and technologically aware, can act as a catalyst for innovation. This occurs as a result of firms responding to the demands of their customers and, as postulated by Porter (1998), the more sophisticated the consumers are the more innovative a firm is required to be in order to satisfy their wants. If these consumers' demands can be used to anticipate the demands of other consumers, then this provides the firm with a window into future demand in other markets, thus stimulating innovation.

Finally, the local environment can shape a firm's strategy and also rivalry (Porter 1990). Porter (1998) suggests that firms operating in clusters experience increased levels of domestic rivalry when compared to firms operating outside of clusters. This occurs due to the ease at which it is possible to make comparisons across companies in a cluster by firm management and also by investors. This ease of comparison is facilitated by proximity and the fact that the operating environment and costs of firms in a cluster are comparable. This increases domestic rivalry and as a result stimulates firms to continually innovate.

A number of these cluster specific environment factors are similar in nature to the concept of Marshall's triad (Marshall 1892) which suggests that the secrets of industry are in the air in clusters of industry. The benefits accruing to firms from locating in a cluster are also hypothesized by Parr (2002) in his consideration of localisation economies. Firms established in a cluster have the potential to benefit from externalities relating to a range of factors such as access to specialised input providers, a skilled labour pool, and knowledge spillovers.

2.3 The Quality of Linkages

The quality of linkages between both of the above factors is also of crucial importance for national innovation capacity. As the creation and dissemination of knowledge and innovation is a vital part of a nation's national innovative capacity, linkages contribute to the system as a whole (Balzat 2006). A strong common innovation infrastructure can help the growth and evolution of clusters through the provision of the necessary laws and support required for high technology business to develop. However, clusters can also influence a nation's common innovation infrastructure. As firms operating in clusters often operate at the technological frontier of knowledge, they can help guide policy so as to position a nation's innovation infrastructure in the best possible way to capitalise on technological advances (Furman, Porter and Stern 2002; Porter and Stern 2002).

Balzat (2006) notes that there are many possible formal and informal ways in which a nation's common innovation infrastructure and cluster specific environment can be linked. Further, the orientation of the linkages may also vary, with Balzat (2006) emphasizing the importance of horizontal and vertical linkages. Horizontal linkages may refer to instances where agents belonging to the same organisational category cooperate on research and development activities while vertical linkages are those in which agents that belong to different types of organisations innovate collaboratively.

To provide a measurable way in which common innovation infrastructure and the cluster specific environment are linked, Balzat (2006) gives the example of putting in place a series of innovation enhancing incentive structures by policy makers and the resulting effects these incentives have on firms' organisational structure and their operation. Therefore, for example, the establishment of a strong common innovation infrastructure may incentivise firms operating in the local environment to increase their innovative activity by increasing expenditure on research and development.

2.4 The Importance of National Innovation Capacity for Competitiveness and Growth

Porter (1990) highlights the importance of innovation for a country's competitiveness. He notes that, in modern economies, the drivers of competitiveness are moving away from basic conditions, such as geographical location and a pool of low cost labour, to more advanced factors such as innovation. Balzat (2006) notes that innovation can drive competitiveness through efficiency gains in production, lower product prices, new investment and an increased scope of products. This suggests that a country's capacity to innovate is essential to its competitiveness. This is emphasized in past Global Competitiveness Reports, which place an increasing emphasis on the role innovation plays in sustaining a country's competitiveness (World Economic Forum 2008).

Endogenous growth models, as described by Romer (1990), also highlight the importance of technological advancement for a country's long term economic growth. Romer (1996: 101) notes that "it is plausible that technical progress is the reason that more output can be produced today for a given quantity of capital and labour than could be produced a century or two ago". Krugman (1994) argues that, in the long term, technological advancement is the only sustainable method of economic growth. Young (1994) notes that, in the short term, increases in capital and labour inputs can raise a country's growth rate; in the long term, growth derived from these sources is un-sustainable. Again this points to the importance of a country's ability to consistently expand its technological frontier in order to ensure increasing living standards in the long term.

3. Data

This paper utilises data from the OECD Countries Profile and Science and Technology datasets as well as information from the Global Competitiveness Report (GCR) to analyse the national innovation capacity of nineteen countries.

The total number of patent applications to the European Patent Office is utilised by this paper to proxy for countries' innovation output. In order to account for the varying size of countries considered patents per capita are calculated. While patents per capita are not an ideal proxy for innovation output, it is one of the few variables that is consistent and available over the time period studied. Reported problems relating to the use of patents as a measure of innovation output include the fact that not all innovation is patentable, not all patents generate an equal profit and some patents are never developed into viable products (OECD 1995). Despite these issues patents are used extensively in the innovation literature for cross country comparisons of innovation levels (see for example Porter and Stern 2002).

In order to assess whether the use of patents per capita in this paper accurately reflects the innovation output of a country, the patents per capita registered by a country are plotted against data taken from the European Innovation Scorecard. The European Innovation Scorecard is a measure of the innovativeness of a country and is calculated using a variety of different innovation inputs and outputs. The data from the Scorecard is only available for European countries and, therefore, it is not applicable for all the countries considered by this paper. Figure 3 presents a scatter plot of 14 nations' European Innovation Scorecard ranking against the number of patents per capita for 2007.

[insert Figure 3 about here]

The graph shows a strong positive relationship exists; countries with a lower ranking have a lower rate of patent applications per capita. This suggests that patents per capita, while not ideal, can be used in this instance to proxy for innovation.

When using patents as a proxy for innovation output, it is important to note the differences in the propensity to patent across the nineteen countries studied. Figure 4 displays the variation in patent applications per capita for a subset of the countries analysed. It can be observed that there is substantial variation in the level of patenting across nations. This suggests that national heterogeneity in innovation capacity may explain some of the difference in patent applications per capita.

[insert Figure 4 about here]

Measures from the Global Competitiveness Report are used in the construction of the sub-indexes required to calculate a country's national innovation capacity. The use of data from the Global Competitiveness Report to measure the various elements of national innovation capacity is consistent with Porter and Stern (2002). Similar to this, Valliere and Peterson (2009) suggest that the use of data from the Global Competitiveness Report can proxy for the strength of a country's national innovation systems. A summary of the variables utilised are presented in Table 1.

Each variable utilised from the Global Competitiveness Report is presented as a country's rank out of the nineteen countries considered. As such the variable is an ordinal measure of the various factors and care must be taken when interpreting the results as a difference of one ranking may not be consistent across the distribution of the variable.

[insert Table 1 about here]

The institution variable is one such ordinal measure derived from the Global Competitiveness Report. This variable is utilised as part of a proxy for a country's common innovation infrastructure. As noted in Section 2, countries which possess stronger institutions are expected to exhibit a higher level of national innovation capacity. The Global Competitiveness Report uses survey data from the Executive Opinion Survey to compile this variable. Two specific areas are covered by this variable: a measure of contract and law enforcement, and corruption. The first is measured by firms' responses to questions concerning neutrality in government procurement, judicial independence, clear delineation and respect for property rights, and costs related to organized crime. The second is comprised from answers relating to the abuse of public service positions for personal financial gain.

A second variable, macroeconomic environment, is also used to measure common innovation infrastructure. This variable is compiled by the Global Competitiveness Report from hard data as well as responses from the Executive Opinion Survey. Hard data is used to measure the overall stability of a country's macro economy while survey data assesses the short-term outlook of firms in the economy. Finally, a measure of the share of government expenditures as a percentage of GDP is included. This variable pertains to the overall stability of the common innovation infrastructure in an economy. If firms perceive that an economy is unstable and in decline this will impact on their confidence in the nation's ability to provide the necessary infrastructure vital for innovation.

To proxy for the cluster specific environment a variable from the Global Competitiveness Report is used which assesses the quality of the local business environment. The quality of the national business environment is comprised from survey data. Questions relating to four broad areas - factor conditions, demand conditions, related and supporting industries, and firm strategy structure and rivalry - are included in the survey. In terms of factor conditions, respondents are asked about the quality and availability of physical infrastructure, venture capital, and human capital available in their local environment. For demand conditions issues such as buyer sophistication, consumer adoption of latest products, and government procurement of advanced technologies are assessed. Factors such as the local supplier quality, extent of product and process collaboration, and state of cluster development are addressed under related and supporting industries. Finally, firm strategy, structure and rivalry is analysed using questions on the favoritism of government decisions, extent of irregular payments, and intensity of local competition (for a fuller description of the composition of the variables discussed consult the Global Competitiveness Reports 2001 through 2008). These cover all of the important aspects of a firm's cluster specific environment as discussed in Section 2.

The final element considered is a proxy for the quality of linkages. In order to proxy for this factor a country's ranking on the proportion of research and development performed by private firms within a nation is used. Unlike the above mentioned proxies this variable is derived from data from the OECD Scientific and Technological Indicators dataset as opposed to the Global Competitiveness Report. This variable is used as it complies with the theoretical aspects for the quality of linkages as discussed in Section 2. Should a strong common innovation infrastructure and cluster specific environment prevail in a country, and the quality of linkages amongst them be strong, it can be expected that firms will have the confidence to invest heavily in research and development. Should poor linkages exist, the expectation is that research and development will not be performed to the same extent by private enterprises.

Two control factors are also considered which may affect a country's patent applications per capita output. These are the proportion of the population involved in research and development and also the previous patenting performance of the country. Data for these variables are again obtained from the OECD (2009). To calculate the previous patenting performance of a country, a seven year moving average is utilised. For example, when considering the patenting rate of countries in 2001, a seven year moving average of patent applications for 1994 to 2000 is included. This allows for different historical trends in patenting activity to be controlled for.

4. Calculating Weightings for National Innovation Capacity Sub-Indexes

The methodology employed by this paper follows that utilised by Porter and Stern (2002) closely. The climax of the analysis is to generate an index of the national innovation capacity of the countries considered. In order to do this three sub-indexes are created: the common innovation infrastructure index, the cluster specific environment index, and the quality of linkages index. Prior to generating these sub-indexes it is essential to develop weights for each one which reflect their effect on the patent applications per capita of a country. In order to accomplish this a series of regression equations are estimated. These are outlined below with the corresponding estimations displayed in Table 2.

4.1 Baseline Estimation

Initially, as a baseline estimate, the effects of the proportion of the population engaged in research and development and the average patent stock produced by the country is regressed on patent applications per capita. This relationship is expressed in equation (1):

$$PPC_{it} = \alpha_0 + \alpha_1 R\&D_{it} + \alpha_2 PS_{it} + \varepsilon_{it} \qquad (1)$$

Where PPC_{it} is the patent applications per capita of country i in time period t, $R\&D_{it}$ is the proportion of the population of country i in time period t engaged in research and development and PS_{it} is the moving average of the patent applications made by country i for the seven years preceding period t. All these variables are expressed in natural logarithms. Porter and Stern (2002) postulate that these basic conditions, a country's stock of research and development personnel and also the previous propensity to register patents, exert an important influence on a country's current national innovation capacity.

4.2 Common Innovation Infrastructure Sub-Index

Following from this baseline estimation a series of three equations build on this in order to derive the weights for the common innovation infrastructure, cluster specific environment and quality of linkages. Initially the common innovation infrastructure weight is derived as:

$$PPC_{it} = \alpha_0 + \alpha_1 R\&D_{it} + \alpha_2 PS_{it} + \beta_1 INS_{it} + \beta_2 MACRO_{it} + \varepsilon_{it} \qquad (2)$$

Where INS_{it} is an ordinal measure indicating the ranking of country i out of 19 countries for the strength of the country's institutions in time period t and $MACRO_{it}$ is an ordinal measure indicating the ranking of country i out of 19 for the stability of its macroeconomic environment. These measures are derived from the Global Competitiveness Report. All other variables are defined as above.

4.3 Cluster Specific Environment Sub-Index

The equation for the cluster specific environment is defined as:

$$PPC_{it} = \alpha_0 + \alpha_1 R\&D_{it} + \alpha_2 PS_{it} + \lambda_1 QNBE_{it} + \varepsilon_{it} \qquad (3)$$

Where $QNBE_{it}$ is an ordinal measure indicating the ranking of country i out of 19 countries for the quality of the local business environment in time period t. All other variables are defined as above.

4.4 Quality of Linkages Sub-Index

Finally, the weight for the quality of linkages sub-index is derived by:

$$PPC_{it} = \alpha_0 + \alpha_1 R\&D_{it} + \alpha_2 PS_{it} + \chi_1 GERDIND_{it} + \varepsilon_{it} \qquad (4)$$

Where $GERDIND_{it}$ is an ordinal measure indicating the ranking of country i out of 19 countries for the gross expenditure by industry on R&D in time period t. All other variables are defined as above.

4.5 National Innovation Capacity Index

The results for the OLS estimation of the four equations above are presented in Table 2. Each of the variables chosen to proxy for the three components of a country's national innovation capacity are statistically significant. The results observed are consistent with Porter and Stern's (2002) estimates. The weights derived from these regression estimations are applied to generate the three sub-indexes considered by this paper. The summation of these three sub-indexes results in the overall index for a nation's national innovative capacity.

[insert Table 2 about here]

5. Empirical Results

5.1 The National Innovation Capacity Index

Using the weightings derived in the previous section the three components of national innovation capacity are combined and presented in Table 3. Before discussing these results it is important to assess their robustness. In order to accomplish this the results for 2001 derived by this paper are compared to the results from Porter and Stern's (2002) analysis. This comparison is displayed in Figure 5. It can be observed that there is a strong positive relationship between the two rankings, with an R^2 of 0.92. This suggests that the index presented in Table 3 is robust and that the results can be confidently interpreted.

[insert figure 5 about here]

From Table 3 it can be seen that there is only minor variation in country rankings over the time period analysed. Finland is consistently the top ranked country in terms of their capacity to innovate, suggesting that Finland's common innovation infrastructure, cluster specific environment and quality of linkages is ideally suited to the generation of new innovations. For three of the seven years, from 2001 to 2003, the United States is ranked second, with a deterioration of this ranking in subsequent years to fifth in 2007. While the United States over this time period does produce more patent applications per capita than Finland, it is important to remember that national innovation capacity does not simply refer to the amount of patent applications produced but also the potential to innovate (Porter and Stern 2002). This suggests that the United States may be generating innovations at a higher rate than national innovative capacity can sustain or that Finland may be underperforming relative to its potential. The differences may also be driven by the higher proportion of R&D personnel in the US or its larger stock of past patents.

[insert Table 3 about here]

Apart from these leading countries the performance of other countries has varied. Austria, for example, has seen its innovative capacity increase dramatically since 2001. The reasons for this will be discussed below when analysing the sub-indexes calculated. Ireland, on the other hand, has maintained its ranking with relatively little variation over the time period while Canada and the United Kingdom have seen a decrease in their innovative potential.

To fully understand why the countries discussed above experienced the corresponding increase or decrease in their innovative capacity it is important to consider the sub-indexes of common innovation infrastructure, cluster specific environment and the quality of linkages. Using Finland as an example it can be observed that, apart for 2005, it has continually topped the rankings for the effectiveness of its common innovation infrastructure (see Table 4). This is due to the high quality of its laws and institutions and its relatively stable macro-economic environment. Finland also performs relatively well when analysing its cluster specific environment; however, in three of the seven years studied it is surpassed by the United States (see Table 5). Finally, when considering the quality of linkages, Finland's ranking varies from third to fourth, exceeded by Japan and Korea (see Table 6).

[insert Tables 4, 5 and 6 about here]

From the discussion surrounding Finland, it can be seen how it surpasses the United States in two of the three sub-indexes. This explains its superior ranking in the overall national innovative capacity index. Austria, which has seen a dramatic increase in its rankings, owes most of this increase to improvements in common innovation infrastructure and the quality of its linkages, while also observing minor increases in its cluster specific environment. The United Kingdom's poor performance can be traced back to a relatively underperforming quality of linkages compared to their overall common innovation infrastructure and cluster specific environment. These findings emphasize the importance of developing policies suited to sustaining all facets of the innovation system.

5.2 The Importance of National innovation Capacity for GDP per Capita

Figure 6 displays a plot of national innovation capacity against GDP per capita for 2001 and 2007 respectively. As would be expected *a priori*, there is a strong positive relationship between a country's national innovation capacity ranking and GDP per capita. This suggests that countries with a more developed national innovation capacity have higher levels of GDP per capita. Interestingly, the importance of national innovation capacity is not consistent across years. Throughout the time period studied, national innovation capacity has exerted an ever greater impact on a country's GDP per capita. For example, in 2001, a one unit fall in the national innovation capacity ranking was associated with a decrease in GDP per capita of approximately $1,226. A similar drop of one position in the rankings in 2007 had a corresponding fall in GDP per capita of approximately $2,208. While only two years are displayed in Figure 6 this result holds across each year with national innovation capacity becoming incrementally more important in explaining countries' GDP per capita. This is consistent with Porter and Stern's (2002) findings that national innovation capacity is positively associated with a country's GDP per capita.

[insert Figure 6 about here]

It can also be observed in the scatter diagram that some countries have a higher GDP per capita than their national innovation capacity should allow while others are not exploiting their national innovation capacity to its fullest potential. This may be explained as short term deviations from the country's sustainable growth rate. Young (1994) highlights the impact rapid capital and labour accumulation can have on short term economic growth. He suggests that while countries can experience periods of rapid economic development through the accumulation of these factors, this growth is only sustainable in the short term and that in the long term, if a country does not experience corresponding increases in productivity, this growth will be unsustainable. In 2001, for example, Ireland is ranked 6^{th} in terms of national innovation capacity and has a GDP per capita of $30,611 (PPP). The predicted level of GDP per capita given its national innovation capacity ranking is $27,951 (PPP). This difference may be attributed to factors such as an increase in capital accumulation, through foreign direct investment, and the employment-population ratio which occurred in the years preceding 2001 (Kennedy 2001).

5.3 The Importance of National Innovation Capacity for Economic Growth

While it is interesting to observe that countries with higher national innovation capacities have higher levels of GDP per capita another important point of investigation is whether national innovation capacity impacts on a country's economic growth rate. It would be expected that countries with a higher capacity to innovate would be able to generate and sustain higher levels of economic growth. However, this is not what is observed in Figure 7. Figure 7 clearly indicates that countries with a lower level of national innovation capacity actually grow faster than countries with a high level of national innovation capacity. However, it must be noted that the R^2 associated with this result is quite low.

[insert figure 7 about here]

While this result may appear counter intuitive, the results may be explained by differences in the accumulation of capital and labour (Solow 1956). In the short term deviations in economic growth can be caused by differences in the rate of capital and labour accumulation (Young 1992). This may explain the pattern observed in Figure 7. Countries may have experienced faster growth rates, due to factors such as capital accumulation, regardless of their lower national innovation capacity ranking. However, Romer (1990) suggests that in the long run this is not sustainable.

5.4 The Importance of National Innovation Capacity for Competitiveness

Figure 8 provides a scatter plot of national innovation capacity against a country's ranking on the global competitiveness report. As observed a strong positive relationship exists between a country's ranking on the Global Competitiveness Report and the country's national innovation capacity ranking. This suggests that countries with a strong national innovation capacity are more competitive nations. This finding is unsurprising given that most modern economies are shifting the basis of competition away from basic factors of production to technologically advanced sectors. In these sectors the key driver of competitiveness is not an abundant supply of unskilled workers, but the ability for firms in these areas to continually upgrade the products and processes offered and to push the boundaries of the technological frontier (Porter and Stern 2002).

[insert figure 8 about here]

6. Conclusions

This paper ranks the innovation capacity of a sample of nineteen countries using data from the OECD Scientific and Technological dataset and the Global Competitiveness Report. To accomplish this, three sub-indexes were generated measuring the strength of nations' common innovation infrastructure, cluster specific environment, and quality of linkages. Each of these factors form an integral part of a country's ability to generate commercially relevant innovations. These sub-indexes are then combined to create an overall measure of national innovation capacity.

Over the time period analysed countries were found to follow three distinct patterns. Some countries remained relatively stable in their ranking, not progressing up or down the rankings. Others were found to either increase or decrease in ranking, depending on their relative performance in the composite sub-indexes. Finland was found to be the country with the highest level of national innovation capacity; however, this advantage was not translated into this country being the leading patent applicant, perhaps suggesting that Finland is not exploiting its innovative capacity to its full potential. The US, while falling in the rankings over time, is found to have the highest patent applications per capita for any country studied.

When considering the importance of national innovation capacity for economic prosperity, a positive relationship was observed. Countries with a higher national innovation capacity ranking possessed higher levels of GDP per capita, suggesting that the innovation potential of a country has important implications for the living standards of that country. However, a surprising relationship is observed when analysing the relationship between national innovation capacity and the growth rate of GDP. It is observed that, in general, countries with a lower innovation capacity ranking experience higher levels of subsequent growth. This result is counter intuitive but can perhaps be explained by the impact of other factors, besides innovation, on economic growth such as capital and labour accumulation. As this analysis only covers seven years, it is possible that short run variation in these factors of production may distort the levels of economic growth experienced by countries.

In conclusion this paper finds that national innovation capacity has an important role in explaining the economic prosperity and competitiveness of nations. A number of important policy implications can be drawn from this summation. The OECD (1999) notes that for countries to take full advantage of innovations and the potential for knowledge generation governments must adapt in order to ensure that the benefits from these innovations are captured by the country.

First, it raises the importance of developing a strong common innovation infrastructure within a country. Traditionally, the role of government in innovation processes has been to address market failures, for example, when firms under-invest in research and development in socially desirable areas (OECD 1999). The above results point to the importance of a wider approach to innovation policy than rectifying market failures. Policy must ensure that systematic failures, which could impede the incentives or ability of firms to innovate, are corrected. The development and improvement of basic factors such as property rights and independent, transparent legal systems provide the foundation for this. However, the development of a stable macroeconomic environment also plays an important role in stimulating innovation. Controlling the level of public debt to GDP ratio may entice innovative firms to that country.

Second, incentives and support of an environment conducive to the development of cluster formations should play a crucial part in policy formation. While the majority of innovative activity is relatively centered in a small number of countries, even within these countries a disproportionate amount of innovation occurs in clusters (Porter 1998). Hertog, Bergman and Charles (2001) suggest that clusters reflect the character of modern innovation, which depends on both market and non-market interaction. They suggest that the nature of clusters is diverse with each country and region possessing clusters with different characteristics and orientations. This points to the conclusion that, when considering policy implications for supporting clusters, a certain degree of flexibility and adoptability is required. As the needs of clusters vary depending on the sector they operate in policy makers may need to take an *ad hoc* approach to policy formation and adopt a case by case basis for policy formation in order to ensure clusters are provided with adequate support.

Third, from a policy perspective, it is important to consider the type of support clusters may require throughout their life (Porter 1998). Pender (2001) suggests that cluster development progresses over various stages through its life cycle. Hertog, Bergman and Charles (2001) postulate that in a newly forming cluster government support may be best orientated towards investment in the generation of new knowledge and the formation of linkages between the various actors. At the mature stage of a cluster's life, the codification of knowledge becomes increasingly important along with the expansion of downstream linkages. This implies that policies need to be tailored to satisfy the unique conditions and maturity of clusters in order to ensure a thriving local environment which can contribute to the overall quality of a nation's innovation capacity.

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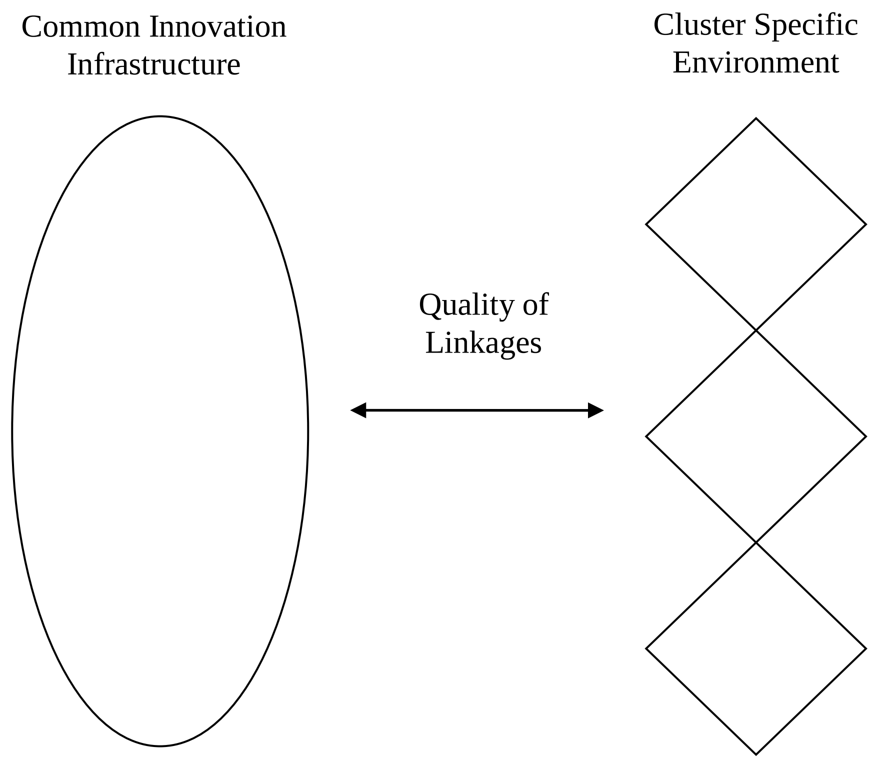
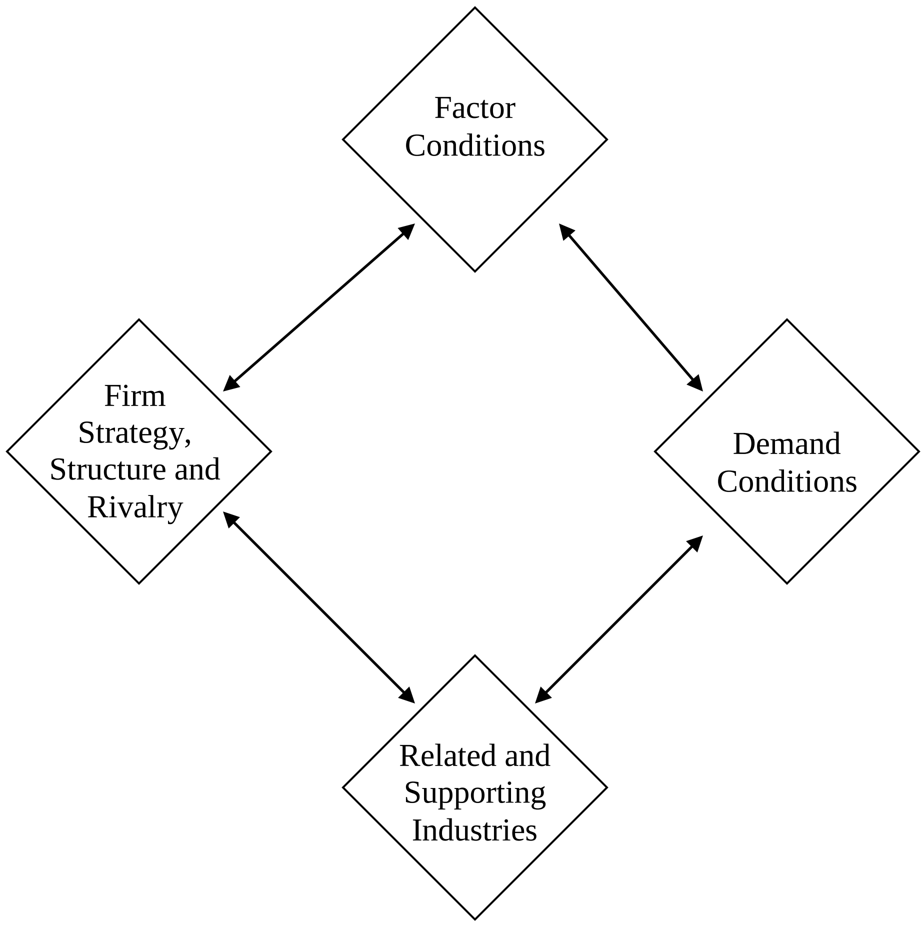
Figure 1: The Determinants of National Innovation Capacity

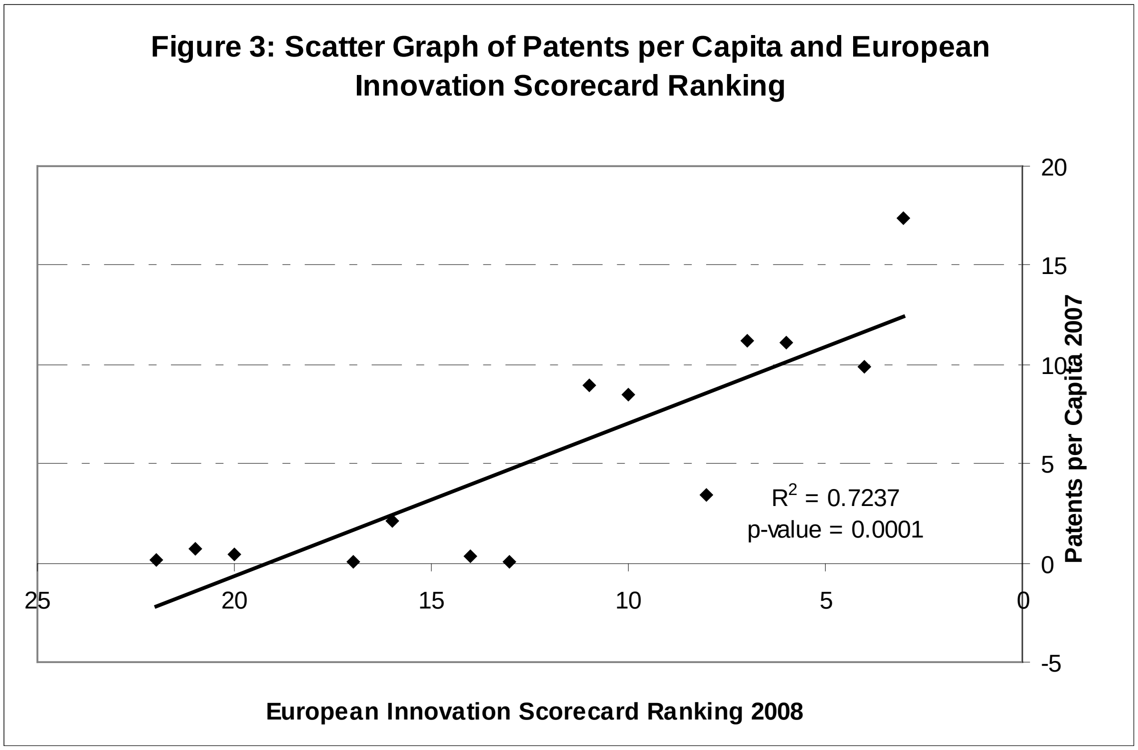


Source: Derived from Porter and Stern (2002)

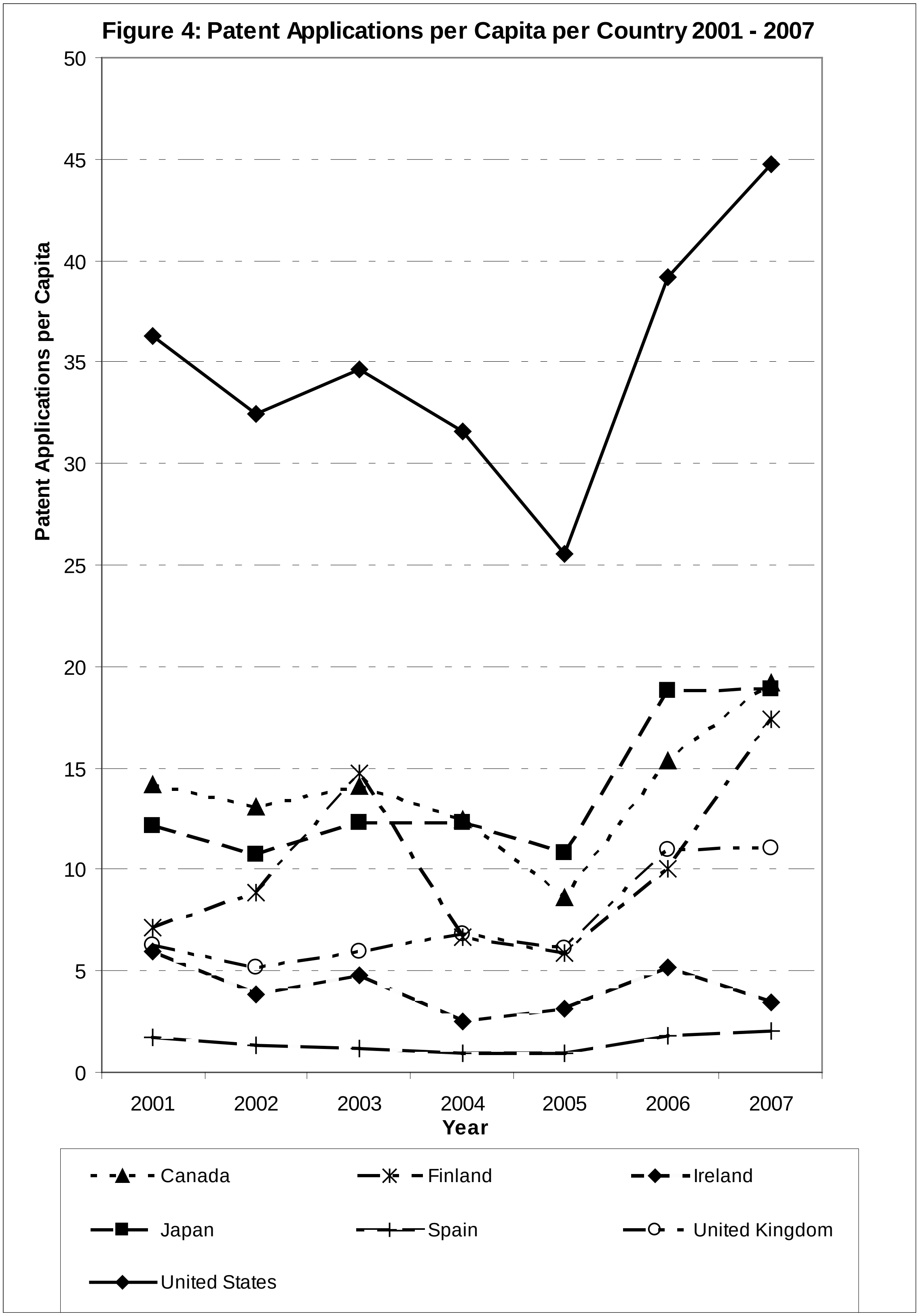
Figure 2: Cluster Specific Environment



Source: Derived from Porter (1990)



Source: OECD (2009) and Pro Inno Europe (2008).



Source: OECD (2009)

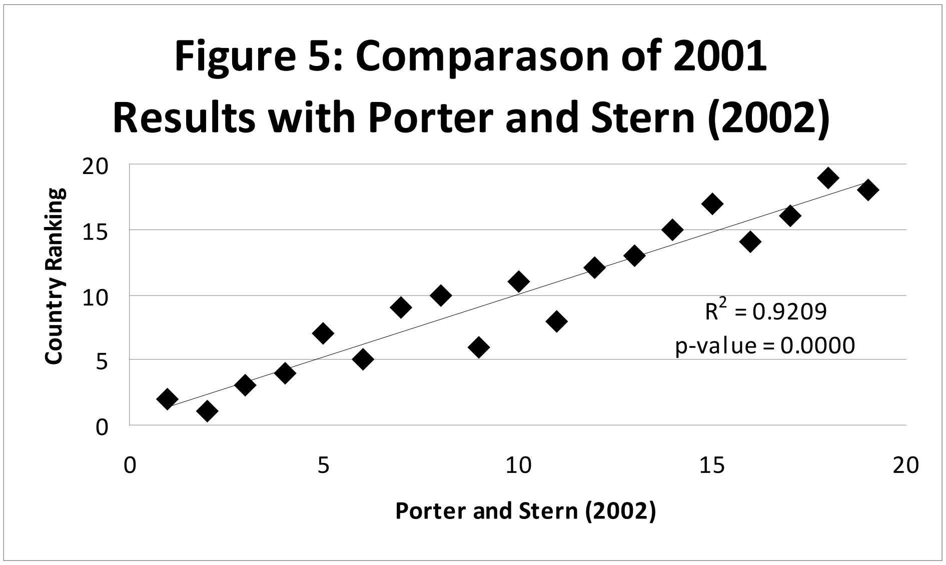


Figure 5: Comparason of 2001
Results with Porter and Stern (2002)
Country Ranking
Porter and Stern (2002)
R2 = 0.9209
p-value = 0.0000
0
5
10
15
20

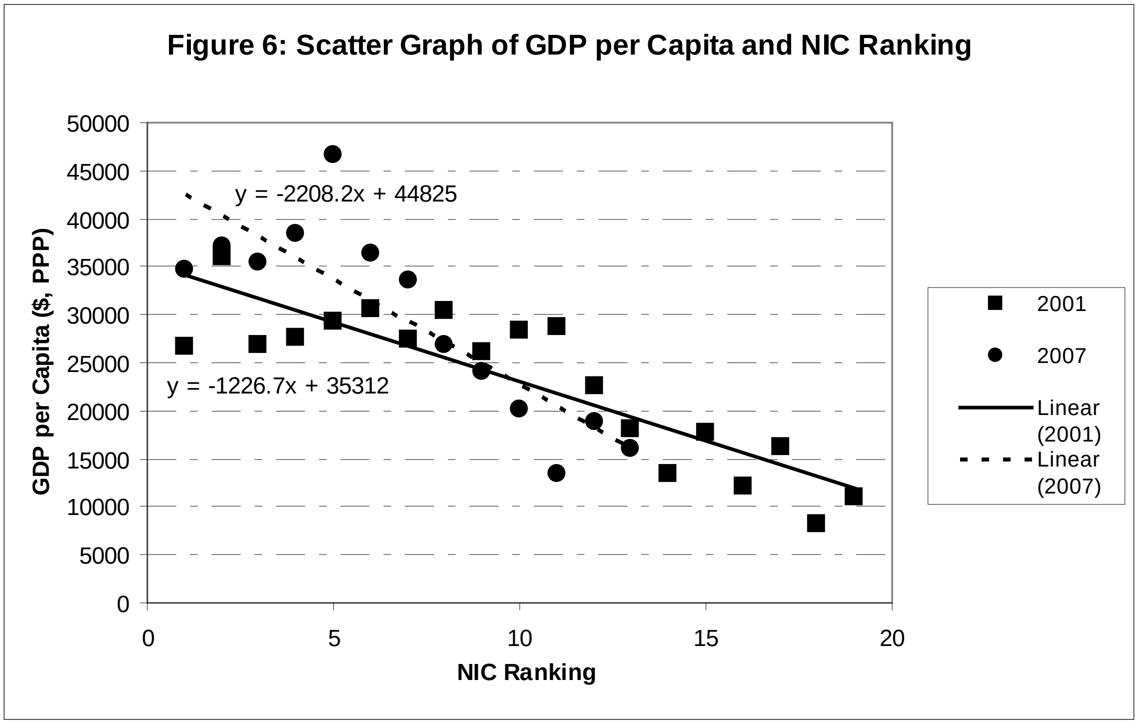


Figure 6: Scatter Graph of GDP per Capita and NIC Ranking
y = -2208.2x + 44825
y = -1226.7x + 35312
GDP per Capita ($, PPP)
NIC Ranking
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
2001
2007
Linear (2001)
Linear (2007)

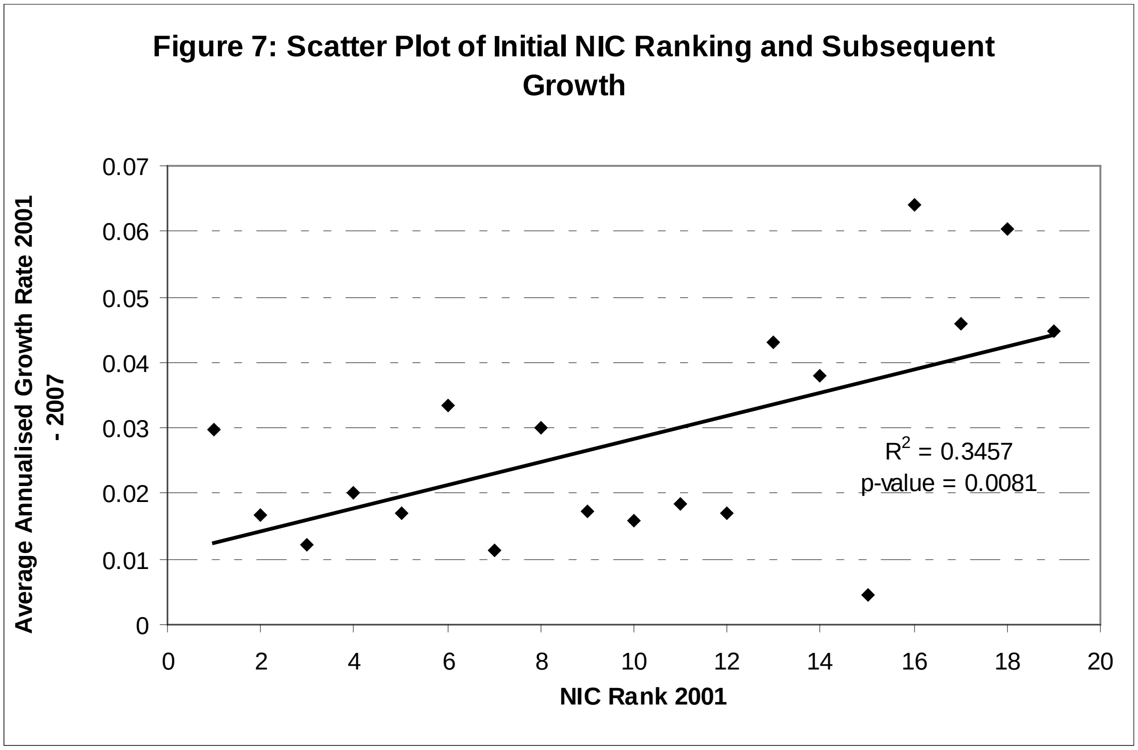


Figure 7: Scatter Plot of Initial NIC Ranking and Subsequent Growth
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
12
14
16
18
20
Average Annualised Growth Rate 2001 - 2007
NIC Rank 2001
R2 = 0.3457
p-value = 0.0081

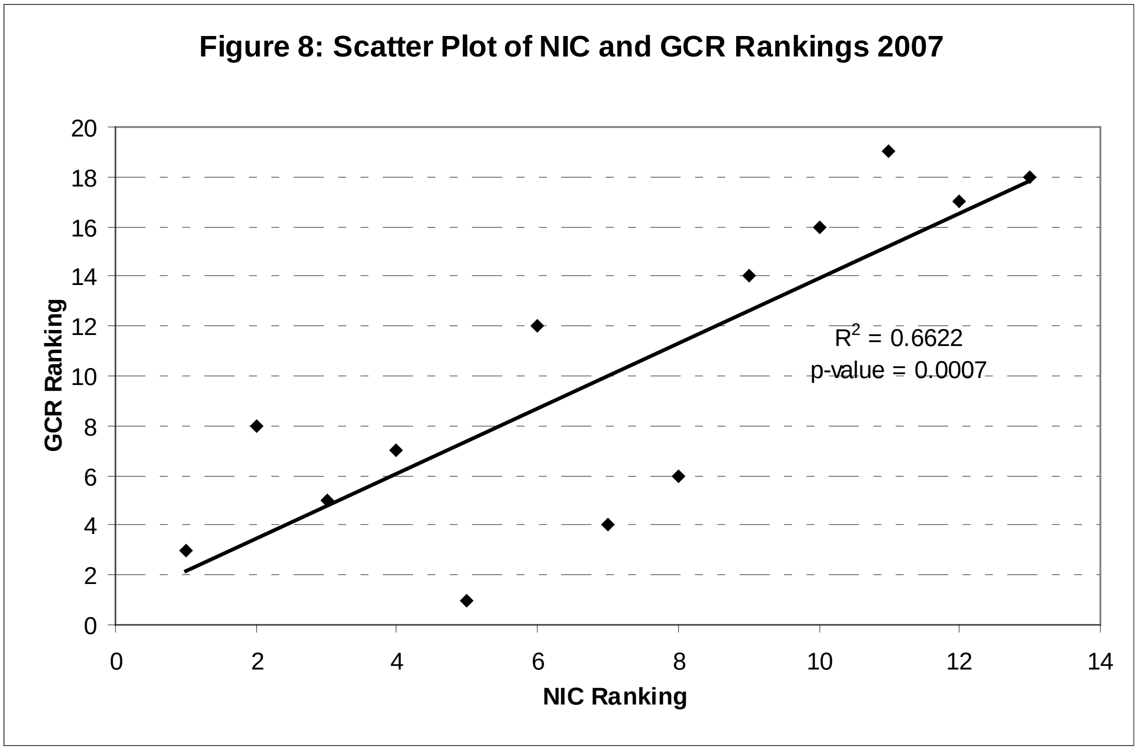


Figure 8: Scatter Plot of NIC and GCR Rankings 2007
GCR Ranking
NIC Ranking
R2 = 0.6622
p-value = 0.0007
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14

Table 1: Description of Variables

Variable Name	Variable Description	Variable Type	Source
Patents per Capita	This variable is a proxy for the innovation output of a country. It is the total patent applications made by residents of the country to the EU patent office over population.	Continuous	OECD
Institution	This variable is a measure of the strength of the institutions present in a nation. It is used to proxy for the quality of common innovation infrastructure.	Ordinal	GCR
Macroeconomic Environment	This variable is a measure of the strength of the macroeconomic environment of a nation. It is used to proxy for the quality of common innovation infrastructure.	Ordinal	GCR
National Business Environment	This variable is used to proxy for the quality of the cluster specific environment.	Ordinal	GCR
Percentage of BERD	This variable measures the proportion of business expenditure on R&D out of total R&D within the nation. It is used to proxy for the quality of linkages within the nation.	Ordinal	OECD
Previous Patent Stock	This is a variable included to control for the effect of previous patenting propensity on current patenting potential.	Continuous	OECD
Research Personnel per capita	This is a variable included to control for the effect of research personnel on patent output.	Continuous	OECD

Table 2: Estimations of Regression Equations

Bench Mark Regression

Variable	Coefficient	Stand. Err.
Intercept	-1.312	(0.7761)
lnPatent Stock	0.3947***	(0.0246)
lnResearch Staff	1.9004***	(0.1133)
Adjusted R2		0.9156
Obs		124
F(2, 121)		668.37
Prob>F		0.0000

***, **, and * indicate significance at the 99, 95 and 90 percent confidence level.

Cluster Specific Environment

Variable	Coefficient	Stand. Err.
Intercept	-1.6705	(0.7552)
lnPatent Stock	0.3292***	(0.0311)
lnResearch Staff	1.6609***	(0.1316)
Local Business Environment	-0.0627***	(0.0193)
Adjusted R2		0.9218
Obs		124
F(3, 120)		484.31
Prob>F		0.0000

***, **, and * indicate significance at the 99, 95 and 90 percent confidence level.

Common Innovation Infrastructure

Variable	Coefficient	Stand. Err.
Intercept	-2.8599	(0.7884)
lnPatent Stock	0.3763***	(0.0233)
lnResearch Staff	1.4831***	(0.1362)
Institutions	-0.0533***	(0.0141)
Macro-environment	-0.0244**	(0.0126)
Adjusted R2		0.9281
Obs		124
F(4, 119)		397.66
Prob>F		0.0000

***, **, and * indicate significance at the 99, 95 and 90 percent confidence level.

Quality of Linkages

Variable	Coefficient	Stand. Err.
Intercept	-1.217	(0.7677)
lnPatent Stock	0.3579***	(0.0277)
lnResearch Staff	1.8200***	(0.1192)
GERD Financed by Industry	-0.0344**	(0.0152)
Adjusted R2		0.9205
Obs		118
F(3, 114)		452.28
Prob>F		0.0000

***, **, and * indicate significance at the 99, 95 and 90 percent confidence level.

Table 3: National Innovative Capacity Index from 2001 - 2007

Country	2001	2002	2003	2004	2005	2006	2007
Austria	11	6	7	6	4	4	2
Belgium	10	9	9	9	11	n.a.	n.a.
Canada	5	5	6	7	10	9	4
Czech Republic	17	14	15	14	15	13	9
Finland	1	1	1	1	1	1	1
France	7	11	8	10	9	10	n.a.
Germany	3	3	3	3	2	2	n.a.
Hungary	14	15	16	15	16	14	12
Iceland	8	n.a.	5	n.a.	6	8	6
Ireland	6	7	11	8	8	6	n.a.
Japan	9	8	10	5	5	3	7
Korea	13	10	12	12	12	11	8
Poland	19	17	18	18	19	17	13
Portugal	15	13	14	13	14	n.a.	n.a.
Slovak Republic	16	16	17	16	17	16	10
Spain	12	12	13	11	13	12	n.a.
Turkey	18	18	18	17	18	15	11
United Kingdom	4	4	4	2	7	7	3
United States	2	2	2	4	3	5	5

Note 1: n.a. represents not available. This is due to data for this year not being available.

Table 4: National Innovative Capacity
Common Innovation Infrastructure sub-Index from 2001 - 2007

Country	2001	2002	2003	2004	2005	2006	2007
Austria	8	6	4	3	3	2	2
Belgium	12	9	10	9	12	n.a.	n.a.
Canada	4	2	7	6	8	7	4
Czech Republic	18	15	16	16	17	13	9
Finland	1	1	1	1	2	1	1
France	9	13	8	11	11	8	n.a.
Germany	7	7	5	4	6	5	n.a.
Hungary	15	14	15	14	15	14	13
Iceland	5	n.a.	2	n.a.	1	3	5
Ireland	6	5	11	5	4	4	n.a.
Japan	11	12	13	8	9	10	7
Korea	13	11	14	13	14	11	6
Poland	17	17	18	17	19	16	11
Portugal	14	10	9	12	10	n.a.	n.a.
Slovak Republic	16	16	17	15	16	15	10
Spain	10	8	12	10	13	9	n.a.
Turkey	19	18	19	18	18	16	12
United Kingdom	2	3	3	2	5	6	3
United States	3	4	6	7	7	12	8

Note 1: n.a. represents not available. This is due to data for this year not being available.

Table 5: National Innovative Capacity
Cluster Specific Environment sub-Index from 2001 - 2007

Country	2001	2002	2003	2004	2005	2006	2007
Austria	7	6	9	8	5	6	3
Belgium	8	7	8	9	9	n.a.	n.a.
Canada	5	5	5	6	8	9	6
Czech Republic	17	15	16	14	14	12	9
Finland	1	2	1	1	1	4	2
France	6	9	7	7	7	7	n.a.
Germany	3	4	4	4	3	2	n.a.
Hungary	13	13	15	15	16	15	11
Iceland	9	n.a.	6	n.a.	10	10	7
Ireland	11	10	11	10	11	8	n.a.
Japan	10	8	10	5	6	3	5
Korea	15	11	12	12	12	11	8
Poland	19	17	18	18	18	17	13
Portugal	14	14	14	13	15	n.a.	n.a.
Slovak Republic	18	16	17	16	17	16	10
Spain	12	12	13	11	13	13	n.a.
Turkey	16	18	19	17	19	14	12
United Kingdom	4	3	3	3	4	5	4
United States	2	1	2	2	2	1	1

Note 1: n.a. represents not available. This is due to data for this year not being available.

Table 6: National Innovative Capacity
Quality of Linkages sub-Index from 2001 - 2007

Country	2001	2002	2003	2004	2005	2006	2007
Austria	16	13	12	12	13	11	9
Belgium	7	7	6	6	6	n.a.	n.a.
Canada	11	11	10	10	10	9	7
Czech Republic	10	8	8	8	8	7	5
Finland	3	3	3	3	4	4	3
France	9	10	9	9	9	8	n.a.
Germany	6	4	4	4	3	3	n.a.
Hungary	17	18	18	16	16	15	11
Iceland	13	n.a.	14	n.a.	11	10	6
Ireland	5	6	7	7	7	6	n.a.
Japan	1	1	1	2	1	1	1
Korea	2	2	2	1	2	2	2
Poland	19	17	19	18	19	17	13
Portugal	18	16	17	17	18	n.a.	n.a.
Slovak Republic	8	9	13	14	17	16	12
Spain	12	12	11	11	12	12	n.a.
Turkey	15	15	16	15	14	13	8
United Kingdom	14	14	15	13	15	14	10
United States	4	5	5	5	5	5	4

Note 1: n.a. represents not available. This is due to data for this year not being available.