Innovators, innovation and increasing returns to scale: Solving New Zealand's productivity paradox

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Using patents as a proxy, we examine New Zealand's performance in innovation from the perspective of the economic geographer. By examining the regional distribution of patents in Australasia, we find that the number of patents per capita in Australasian cities scales superlinearly with city size. In fact, if one empirically corrects for city size, New Zealand cities appear to perform similarly to Australian cities on a per capita basis. We also find evidence for large networks of inventors in the patent literature, supporting the idea that connectivity promotes the generation of knowledge. These findings suggest that New Zealand's poor innovation performance stems from both its small population and its low population density. To overcome these disadvantages, we suggest that New Zealand needs to learn to act like a city of four million people by connecting people and ideas thoughout the country.

Introduction

New Zealand's lack-lustre economic performance over the last twenty years has presented economists with something of a paradox. As the OECD put it in 2003, 'The mystery is why a country that seems close to best practice in most of the policies that are regarded as the key drivers of growth is nevertheless just an average performer' (OECD 2003). While some economists remain focused on New Zealand's policy and institutional settings (2025 Taskforce 2010) despite their closeness to best practice, others suggest that New Zealand's economic geography in the current era of globalisation may be to blame (McCann 2009).

At the same time, New Zealand is poorly ranked with respect to many metrics of innovation (World Economic Forum 2010). On a per capita basis, the OECD countries produce four times as many Patent Cooperation Treaty (PCT) patents as New Zealand (OECD 2008). New Zealand's failure to innovate at rates comparable to other modern economies in recent decades must surely be a contributor to its weak economic growth.

What determines a country's capacity to innovate? In this paper, we will investigate the role of economic geography in innovation through an empirical study of an OECD patent database (Maraut *et al.* 2008) and consider the implications of this study for New Zealand. We will look at the effects of city size in Australasia on patenting rates, finding that, as in the USA (Bettancourt *et al.* 2007), large cities produce more patents per capita than small cities. In fact, if one empirically corrects for city size, New Zealand appears to perform similarly to Australia.

We also identify many large communities of inventors around the world connected via co-patents. In Finland, for instance, we find that a network of more than a thousand inventors formed in the late 1990s, contributing to the rapid development of a €10 billion ICT export sector. The largest network we have found connects approximately 24 000 inventors working with the medical device industry in California. Here we will discuss aspects of the structure of these networks and consider what impact such networks could have on New Zealand's capacity to innovate.

Regionalisation of inventive activity

Regional localisation or agglomeration of economic activity in clusters such as Silicon Valley is a widely discussed phenomenon (e.g. Porter 2000). Agglomeration in the modern economy

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is thought to maximise the efficiency and effectiveness of the knowledge exchanges required for the production processes of high-value-added goods and services (Glaeser 2008). In other words, agglomeration minimises the spatial transaction costs for knowledge-intensive activities. This leads to localisation of such activities, giving knowledge-intensive regions and cities productivity advantages that become 'locked in' as the scale of such activities grows. McCann (2009) has argued that regional agglomeration is the key to understanding the productivity gap between Australia and New Zealand.

Evidence can be found for this point of view by examining patenting activity. For instance, it has been observed that both the number of patents filed and the number of inventors in US cities scale superlinearly with the city's population (Bettancourt *et al.* 2007). Per capita, bigger cities in the USA are home to more inventors and produce more patents.

Here we look this effect in patenting activity in Australasian regions. Figure 1 shows the number of PCT patent applications filed from 1978 to 2008 by applicants in the major Australasian regions, as a function of their 2008 population. The figure shows that agglomeration effects are present in Australasian patenting activity. The dashed line in the plot shows how the data would lie in the absence of agglomeration effects, i.e. if the number of patents per capita were the same in all regions. The fact that the data lie on a line steeper than the dashed line indicates that the number of patents scale superlinearly with city size (or equivalently that the number of patents per capita grows with city size). In economics, quantities that scale superlinearly with size are said to give increasing returns to scale.

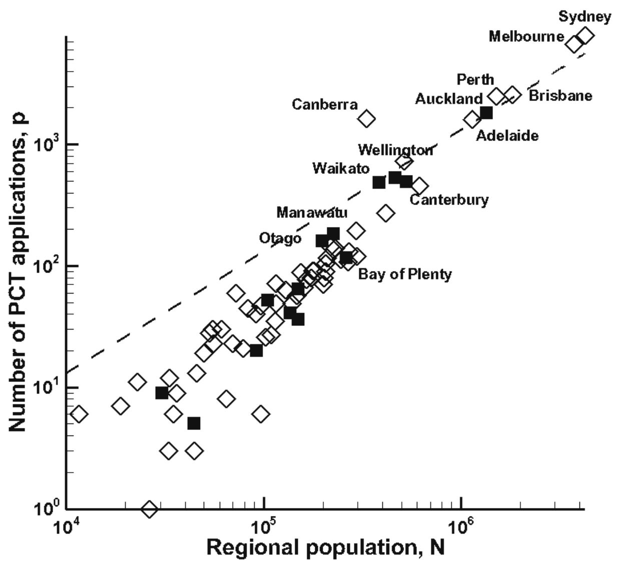

Figure 1. The plot shows the number of PCT patent applications by region (1978–2008) versus regional population size (2008) for Australian (open diamonds) and New Zealand (solid squares) regions. Major metropolitan areas are labelled by name.

As with the USA (Bettancourt *et al.* 2007), we find that the number of inventors in Australasian cities scales superlinearly with city size, with a similar exponent to that exhibited by the number of patents. Thus, on average at least, it does not appear to be the case that inventors in bigger cities are more productive. Rather, bigger cities have proportionally more people engaged in inventing.

Significantly, the New Zealand and Australian data fall approximately on the same line. Thus, one must attribute Australia's advantage in patents per capita to the benefits of agglomeration enjoyed by Sydney and Melbourne. This strongly suggests that agglomeration effects are more important than any differences in innovation policy settings between the two countries.

Why does agglomeration occur? Is higher productivity the result of agglomeration or does agglomeration simply reflect the fact that firms are taking advantage of opportunities for higher productivity in particular locations? In manufacturing-based industries, economic geographers believe that agglomeration favours productivity through a number of effects, including reduction in transport costs, allowance for greater division of labour (allowing opportunities for specialisation), and improvements in labour market pooling and matching (Glaeser 2008).

Not all these advantages remain stable in time: for instance, during the twentieth century, the real cost of moving a tonne of freight one kilometre by rail decreased by 90% (Glaeser 2008), leading some commentators to declare that *the world is flat* (Friedman 2007). Yet despite this, the wage premium associated with living in big cities remains higher than ever (Glaeser 2008), indicating that agglomeration effects are still important in these cities.

In fact, the economies of the world's leading cities have become increasingly reliant on knowledge and services rather than manufacturing and shipping goods. If anything, as the cost of shipping high-value products decreases, the size of the markets available for such products will increase. Hence, as transport costs fall, the value of knowledge will grow.

Cities generate knowledge by connecting people and ideas, creating opportunities for what an economist would call spill-overs (Breschi 2001). Spatial clustering in cities may not only allow more firms to take advantage of knowledge spill-overs but may also maximise the efficiency and effectiveness of knowledge transfers (Glaeser 2008) by minimising the costs for face-to-face contact in knowledge-intensive activities. When it comes to knowledge, the world is rather mountainous.

In the next section, we look at examples of the increased connectivity that cities promote by examining the growth and structure of several networks of inventors that we have extracted from the OECD REGPAT database.

Inventor networks

If cities promote knowledge generation by increasing connectivity, then evidence for this may be available in the patent literature. For this reason, we have mined the OECD patent database for networks of inventors connected by co-patents. If two individuals are named as inventors on the same patent, we consider them to be connected. In this way, we can build up networks of inventors linked by co-patents. In this article, we will focus on two of the more interesting examples of such networks: one that is spatially clustered and another that is geographically dispersed.

In particular, we have looked at patents issued by the European Patent Office (EPO) to applicants from several regions, including Australasia, North America, Scandinavia, and the Netherlands. Generally, we have restricted ourselves to looking at networks within administratively defined regions such as California or the Uusimaa region of Finland (which contains

Helsinki). There is no doubt that such networks extend beyond administrative borders, but the size of the trans-regional datasets that would be need to be handled are significantly larger than the regional sets to which we have restricted ourselves. It would certainly be of interest to look at networks that extend across such boundaries in the future.

One of the most interesting networks consists of 1356 inventors in the Uusimaa region in Finland, whose patents are owned by Nokia. (Appropriately, Nokia's current corporate slogan is 'Connecting People'.) A representation of the network is shown in Figure 2. In this diagram, the nodes are individual inventors, while the edges between nodes indicate that the two inventors share a patent. The number of edges in this network is 3143. The mean path length between nodes (i.e. the mean number of edges needed to connect any two nodes) is 7.32, so the network is not particularly 'small'. [In general, we have found that the mean path length in inventor networks grows faster with network size than it does in the Watts-Strogatz small world networks (Watts & Strogatz 1998).]

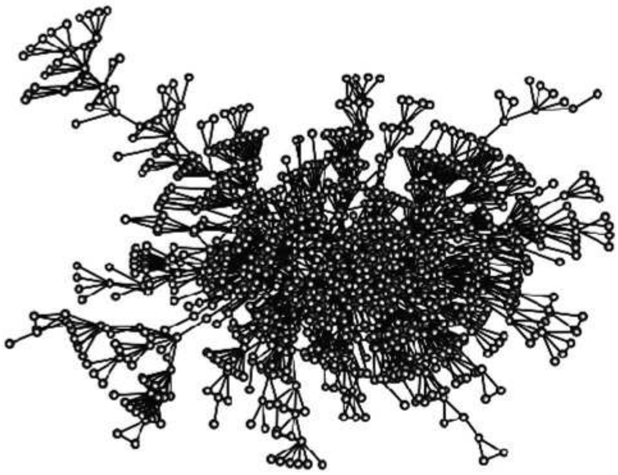

Figure 2. The Uusimaa inventor network constructed using EPO patents at the end of 2006. The network, which began to grow in 1993, contained 1356 inventors by the end of 2006.

This particular network in Uusimaa developed as Nokia transformed itself from a consumer electronics company in the late 1980s (similar in size to Fisher & Paykel Appliances, for instance) to a globally dominant multinational mobile phone manufacturer by the middle of the 2000s. The growth of the network is illustrated in Figure 3 by the number of new inventors that appeared in the network each year. For comparison, the figure also includes the number of PhD graduates in engineering each year over the same period. While not everyone entering the Nokia network will be one of these PhD graduates, this comparison serves to illustrate the magnitude of the demand for human capital that Nokia must have placed on the Finnish economy.

The benefits to the Finnish economy from Nokia's growth are shown in Figure 4. In this figure, the relative increase in electronics exports, patents and journal articles in electrical engineering per year is shown over this period. Between 1985 and 2005, the Finns increased the value of their annual electronics exports by almost 1000% (to approximately NZ$20b), the number of journal articles published per year on electrical engineering by 1500% and the number of PCT patents awarded

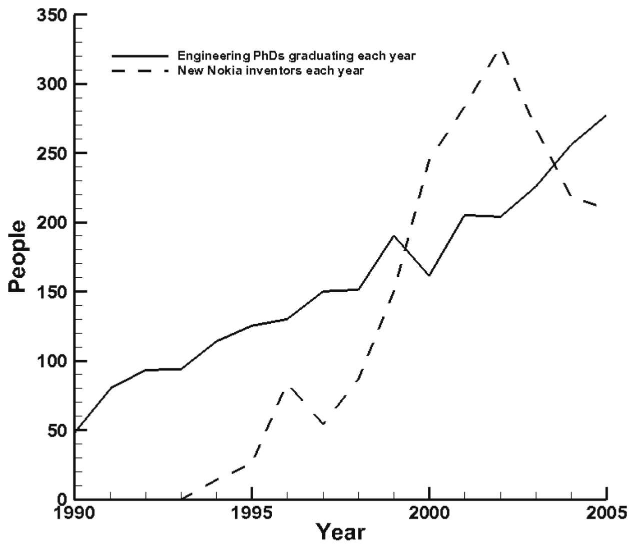

Figure 3. Growth in the Nokia network, i.e. the number of new inventors entering the network each year and for comparison the number of Finnish PhD graduates in electrical engineering per year.

per year by 2000%. In 1990, the Finnish economy looked much like New Zealand's, with a strong primary sector export focus. By 2006, Finland had developed a thriving new, high-tech export sector.

Many of the large networks we have found are similar to the Nokia network in that they are geographically clustered and dominated by large firms. However, the largest network we have found is quite different. It consists of 23 768 inventors and 108 976 edges. Geographically, it extends right across the west coast of California, from San Francisco in the north to San Diego in the south. Unlike the Nokia network, it is not dominated by a single company. Rather, the applicants are dominated by a mix of small to medium health care and medical devices companies.

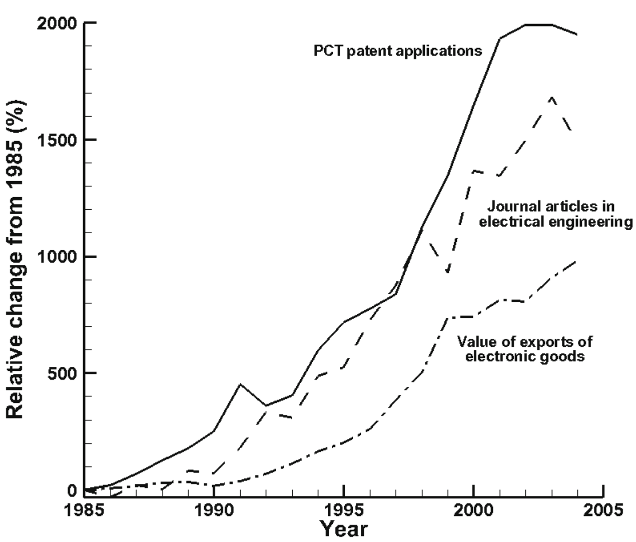

Figure 4. Relative increase in Finnish electronics exports, patents, and journal articles in electrical engineering per year from 1985 to 2005.

Our study of inventor networks supports two key ideas: that connectivity is important for knowledge generation and that cities promote connectivity. What are the implications for a country like New Zealand, which has a small population base and a low population density?

Discussion

In this article, we have attempted to provide evidence for the role of economic geography in New Zealand's ability to innovate. New Zealand's lack of scale (low population and low population density) diminishes its ability to take advantage of the benefits of agglomeration that are evident in Australia and the USA. If patents are used as a proxy for innovation, this lack of agglomeration appears to reduce New Zealand's ability to innovate.

It is not a big leap to suggest that economic geography plays an important role in other aspects of New Zealand's economic performance. Indeed, agglomeration effects are evident on a regional basis in other types of economic data, including measures of productivity (Mare 2008). McCann (2009) makes a strong case that it is economic geography that explains New Zealand's decline in productivity relative to the OECD.

So what can New Zealand do to overcome its economic geography? One approach discussed by McCann is to reduce spatial transaction costs between New Zealand, Australia and the rest of the world. He suggests that we move towards economic union with Australia and look to reduce the monopoly that Auckland's international airport currently enjoys.

Another obvious approach is to increase our own domestic levels of agglomeration. As a colleague of ours put it, New Zealand needs to act like a city of four million people. McCann makes several suggestions as to how we might do this:

- Take full advantage of our existing spatial agglomerations (e.g. Auckland–Hamilton–Tauranga) by ensuring their continued growth, supported by investment in their infrastructure.
- Increase knowledge flows between Auckland and the rest of the country. [McCann argues against concentration of resources in the University of Auckland, suggesting that knowledge transfer primarily occurs through the mobility of people between regions rather than through direct spillovers. This seems to suggest that it may be more effective to mimic the Californian network than the Nokia network.]
- Increase competition on domestic airline routes in order to lower internal airfares. [This would reduce the financial costs of face-to-face contact, yet there is inevitably an opportunity cost incurred by sitting in an airport waiting lounge not to mention the environmental cost of the associated greenhouse gases.]
- Further invest in new technologies for remote collaboration such as desktop video conferencing. [Virtual meetings can more efficient, in terms of time and fuel, but require supporting ICT infrastructure.]
- Reduce the breadth and fragmentation of our RS&T sector. In particular, he suggests a focus on our agricultural sector. [In his public lectures on this topic, McCann has suggested that New Zealand must also look to develop new areas of strength and scale.]

Regarding the last point, we would argue that a narrow focus on agriculture for New Zealand is risky and perhaps even misguided. New Zealand has exceptionally low export diversity, with a heavy reliance on commodity dairy products. Moreover, as McCann himself points out, our labour productivity in agriculture is only 16th in the OECD, despite the strong agricultural focus of our RS& T system historically.

The reality is that to maintain our place in the world we will need both to back our existing strengths and to develop new ones, because other countries are also doing both. New Zealand must develop new sectors of its economy, as small countries such as Denmark, Finland, and Israel have done over recent decades.

As we saw in our study of Nokia's inventor network, this will require substantial investment in human capital over a sustained period. If New Zealand is to take this path, it must build communities of knowledge workers on a scale similar to those networks of inventors found in the OECD patent database. With its low population density and geographic isolation, the challenge for New Zealand will be how to be to build spatially distributed networks around new areas of our economy that take full advantage of our population size. These may well be reminiscent of the network found in California rather than that in Finland.

Is the RS&T sector in a position to contribute to this goal? It appears that the main effect of the science reforms in the early 1990s was to make New Zealand's RS&T sector more financially efficient (Hendy 2010). The reforms paid little heed to the idea of building scale or collaboration. Since those reforms, institutions' financial needs have pre-empted widespread collaboration, compounded by FRST's acknowledged inability to fund large programmes (which has effectively capped the scale of the projects undertaken by the RS&T community).

A more recent policy response to this problem was the establishment of the Centres of Research Excellence (CoREs) in 2002, including the authors' MacDiarmid Institute. The MacDiarmid Institute is a geographically distributed network of more than two hundred physical scientists and graduate students working in advanced materials and nanotechnology. Its experience has been that such a network of researchers, despite its distribution across the country, can be an effective way to build scale and increase research productivity and impact (Davenport & Ullenbach 2010). It may be that this success can be replicated in other parts of the RS&T sector and even in other knowledge-intensive sectors of the New Zealand economy.

Conclusion

Many in the RS&T community would agree that New Zealand must diversify its economy through knowledge-intensive industries to reduce its dependence on low-value commodity exports. The agglomeration effects illustrated in this study suggest that policies that seek to do this without taking into account our economic geography (scale in particular), will probably not succeed. Nonetheless, small countries, such as Denmark, Finland, and Israel, have overcome the disadvantages of size to build successful high-technology industries with scale in areas unrelated to previous strengths. New Zealand must travel down a similar path if it is to ensure that its economic geography is not its destiny. To do this, New Zealand must learn to act as a city of four million people to take advantage of the agglomeration effects that larger population centres enjoy.

Methodology

The OECD database, REGPAT (Maraut *et al.* 2008), contains details of EPO and PCT patent applicants and inventors from most OECD countries over the period 1978-2009. For the EPO patents, both inventors and applicants are labelled by a unique identifier, and each is given an address identifier that localises it in a national regional zone. Co-inventors and corresponding applicant organisations can be matched by a shared patent number. A separate file contains details of the international patent classification subject area and the patent priority year. Unfortunately, inventors on PCT patents do not have a unique inventor identifier, so these could not be used to build inventor networks. The network topologies were analysed using the NetworkX python toolkit (Hagberg 2008). In the current analysis, we have looked at networks that form within relatively large regional units (e.g. States in the USA). We have then considered the properties of the largest connected component with the region-wide network, and analysed the properties of this component.

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