Inventing the New North:
Patents & Knowledge Economy in Alaska

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In the last few years, Alaska's economy suffered as world oil prices plunged to very low levels and production declined. Modern economic development theories would suggest searching for alternative ways to manage northern regions. Investment in the knowledge-based economy seems to be one of the possible options. In Alaska, there have been very few studies of its knowledge economy. The key feature of a knowledge economy is a greater reliance on human capital than on natural resources, combined with efforts to integrate innovations in every stage of the production process. Patents are considered a good representation of innovative activity. We provide evidence drawn from patent data to document geography and dynamics in Alaska's knowledge production over thirty-five years (1976-2010). The results show that Alaska has considerable patent activity, especially in certain oil-sector-related industries, and strong clustering of innovation in major urban regions (Anchorage, Fairbanks, and Matanuska-Susitna boroughs). Alaska inventors, however, tend to be independent individuals ("lone eagles"), even though corporate innovation activity has been growing. In addition, small Alaska communities sometime demonstrate high levels of knowledge production in a few niche industries, articulating the importance of individual-driven and niche-based innovation in remote regions. Overall, between 1976 and 2010 Alaska's regional innovation system evolved from a small isolated system dominated by individual inventors focused on innovation in old, low-technology sectors to a relatively diversified (although still over-reliant on the oil sector) intra- and internationally connected system with a considerable presence of company-driven innovation, but with a strong position of individual inventors, including those from smaller communities.

Introduction

Exploring the role of innovation and creative activity in economic development recently became a critical area of inquiry among economists around the world (Feldman, 2000). Over the past few decades, the knowledge economy has risen to occupy a key status in economic development and has played an essential role in advancing the global economy (Bell, 1973; Clark, Feldman, & Gertler, 2000). Many studies demonstrated that regions that experienced economic growth have concentrations of creative activities and patent production (Sonn, 2008; Florida, 2002). They also

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revealed the importance of using patents as an indicator of innovation and economic development (Breschi 1999; Hall et al., 2001). However, with the advent of the internet, it is possible for cooperation to occur between distant places thus creating new economic and intellectual connections between cores and peripheries (Sonn, 2008).

This study examines the role of the knowledge economy in Alaska focusing on local innovation represented by *patents*. Patents is the main instrument for protecting intellectual property rights for individuals and groups (Merges, 1997). Patents give an inventor an exclusive right to economically exploit the innovation for a certain period. A patent should be a piece of novel work. In addition, a patent must have an invention and should solve a problem in a field and lead to the possibility of a valuable application. An invention within a patent must be explained in enough details to enable others to take advantage from this patent. (Merges, 1997). Patents are usually considered as a good indicator of knowledge production (Feldman, 2000; Jaffe & Trajtenberg, 2002).

Alaska is a part of the national (U.S.) and global periphery. It is an Arctic region and a resource-dependent economy currently suffering from low oil prices and falling production. At the same time, as the Alaskan economy evolves, a variety of economic sectors outside the traditional "pillars" of the Arctic economy (resources, public sector, and subsistence), such as professional and financial services, specialized manufacturing, and information technology, have contributed to the Arctic's growth (Petrov, 2016). Thus, examining the role of innovative activities in Alaska could help us to better understand the emergence of new economies in peripheral areas as they become affected by globalization, urbanization and knowledge-driven development. The goal of this study is to analyze the geography and dynamics of the patent production in Alaska between 1976 and 2010. This study addresses the following research questions: (1) what are the geographies and typologies of patent production in Alaska? And (2) what are the internal and external components and connectivities within the Alaska Regional Innovation System?

Literature Review: The Knowledge Economy and its Role in Economic Development

The knowledge economy is defined as an economy that depends on knowledge and technology as main factors of production and wealth making, since technology and knowledge convert wealth-creation activities from physically-based functions to knowledge-based activities (Lagendijk, & Lorentzen, 2007; Kogler, 2014; Sonn, 2008). Innovation can be defined as the implementation of a new product or development process (Feldman, 2000).

In the literature there is an overall consensus that innovation, knowledge, and education are important for building a strong and healthy economy (Bell, 1973; Clark, Feldman & Gertler, 2000), including the Arctic (Larsen & Fondahl, 2014). Innovation is at the core of economic development connecting previous knowledge and new knowledge. Innovation ensures the continuation of economic progress and affects all components of regional development (Kogler et al, 2011; Feldman, 2000). In addition, a number of previous studies suggest that there is a significant connection between creative and artistic capital and scientific technology production (Florida 2002; Cavin & Petrov, 2012).

Regional Innovation Systems

The Regional Innovation Systems (RIS) is a well-accepted approach to understanding the geographic encapsulation of the knowledge economy (Asheim & Isaksen, 2002; Lundvall, 1992).

It recognizes that innovation takes place within a particular regional context. The concept has two main lines of inquiry: the first is innovation process and its characteristics, and the second is regional analysis, since it is interested in explaining the local distribution of regional tech industry and innovation industry networks (Cooke, 1997). The RIS strategy promotes the interactive innovation and systematic learning and focuses on supporting institutions, agencies that feed those regional knowledge exchanges.

In respect to the Arctic and adjacent northern areas, there have been a number of RIS studies in northern Fennoscandia (e.g., Jauhilinen & Suorsa, 2008; Suorsa, 2009). Alaska is one of the regions still in need of exploring the structure of local RIS and the factors that play a role in regional innovation and stimulate vibrant knowledge economy. Alaska RIS (AKRIS) is yet to be described and mapped, a significant gap and potential impediment for economic development efforts in the state.

Geographical Analysis of Patents

Simply put, a patent is the award of an intellectual property right for an invention to the inventor. Patents are an indicator of innovation and R&D process (Jaffe et al., 1993; Jaffe & Trajtenberg, 2002; Khan & Dernis, 2006). In the United States patents must be granted by the U.S. Patent and Trademark Office (USPTO) upon the examination of an invention (Kogler, 2014). USPTO also holds the patents statistics for various locations. However, not all patents are useful and not all of inventions are patented. In addition, the degree of novelty of patents may vary. The importance of a patent depends on its type since technological patents are more directly valuable in a knowledge economy than other types of patents. The number of patents in a certain area reflects the knowledge economy outcomes or, in other words, indicates the output of knowledge production.

The Knowledge Economy in the Arctic

The knowledge economy is shaped by the location of the study region. The Arctic is known for its peripheral and dependent status with respect to the southern regions (Agranat, 1992; Bone, 2009; Petrov, 2012). With unstable resource economy, finding new economic opportunities is needed to improve economic development prospects in Arctic (Petrov, 2016). However, these opportunities in the Arctic are not plentiful since there is a shortage human capital among other economic, geographic and political impediments (Huskey, 2006; Larsen & Fondahl, 2014). By analyzing spatial patterns, temporal dynamics and sectoral characteristics of patents production in Alaska, and examining inventor networks this study fills a substantial research gap in respect to evolving Alaska Regional Innovation System. In addition, the results help advance our understanding of the role of knowledge economy in remote regions, including resource peripheries.

Data and Methods

The study area for this research is the U.S. State of Alaska and, specifically, its eight boroughs where patents were issued over the 35-year period from 1976 to 2010 (Figure 1). Alaska has the largest area, but is the fourth smallest population among U.S. states with 710,231 residents in 2010 (United States Census, 2010). Anchorage is the largest city in the state. The second largest city is Fairbanks, followed by Juneau, the capital of Alaska.

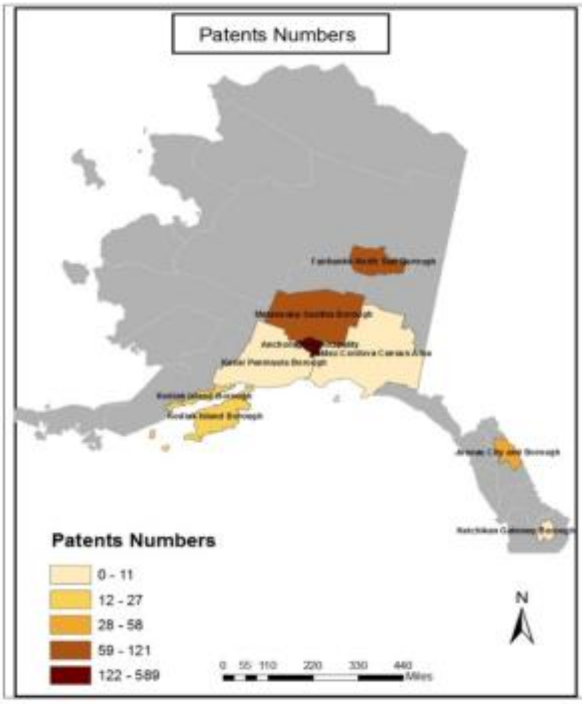

Figure 1: Study Area: Alaska (Patents in Alaska Boroughs. Source: USPTO)

USPTO Data

USPTO data serve as a foundation for this analysis. In the U.S. patents, or awards of an intellectual property right, are allowed for new, beneficial and intelligent inventions for a term of 20 years from the filing date of a patent application, and give the right to prevent others from taking advantage of the invention over that period (Foray, 2002). U.S. patents are published via the USPTO.

USPTO provides multiple attributes for granted patents, including names and geographical locations of inventor(s) and applicant(s), industrial/technology category of the invention, any cited or citing patents, description of the innovation and other characteristics. These attributes allow researchers to follow the trends of patent activities in time and space. This study investigates USPTO dataset to determine the spatial and sectoral characteristics of Alaskan patents between 1976 and 2010. Using USPTO patent database ensures strong confidence in the results because the Patent Office itself issues patents and records all related information. Furthermore, this database provides a large dataset of relevant information for U.S. inventors and co-inventors, regardless of their place of residence at the time they worked on a specific invention.

In this study we used USPTO data files that included any patent that had at least one inventor who resided in Alaska listed from 1976 to 2010, for which the data were compiled by Dr. Dieter F. Kogler. The beginning and the ending date of analysis were chosen to alleviate issues caused by a possible delayed publication of the most recent patents (past 2010) and by an incomplete record of patents prior to 1976. The data consist of the patent number and the sequence of inventors with a unique inventor ID for each. Also, there are spatial indicators based on inventor residence, e.g. state, city, and country name. The database contains the organization a patent is invented for (listed as the patent's 'applicant'), and if it is blank, the patent is most likely not assigned to a company, but to the inventor directly. Patent technology classification codes are also listed in the patent document according to the USPTO classification (USPTO, 2017). This study uses only the first

USPTO code which yields good results if one wants to know the 'spread' of technology within a state in a certain industry sector.

We grouped USPTO patents awarded between 1976 and 2010 in 5-year periods to eliminate annual fluctuations and make it easier to analyze and compare the results. Analyzing patents data starts with examining the temporal dynamic of patents and identifying the historical trends of patents over the time. Then, the study investigates the spatial distribution of patents in Alaska and the clustering of patents. Industry sectors that have the largest number of patents are also analyzed to have a deeper understanding of the nature and diversity of innovations activities. We also map inventors and co-inventors of these patents to gain a full image of the inventors' spatial networks to understand the spatial distribution of local and external inventors.

Inventor networks are very important in understanding innovative flows and knowledge spillovers that could be investigated by mapping the networks to show the locations of the inventors and respective knowledge exchanges (Ejermo & Karlsson, 2006). Networks are often considered as a main underlying factor for innovation activities (Borgatti & Cross, 2003; Kogler et al, 2013). Inventor networks build joint knowledge production and cooperation systems. Through time this synergy enhances knowledge production and establishes strong knowledge circulation. Since the networks develop over time and space, the evolution of networks is closely related to the evolution of the knowledge economy (Boschma & Ter Wal, 2008).

In this research, inventors' networks analysis relies on the first inventor of the patent since it is usually considered as the main inventor. As mentioned earlier, the analysis covers all patents that have at least one Alaskan inventor (a resident of Alaska when a patent was awarded). Inventors' network analysis determines the geographical location for each patent according to the first inventor residency, and builds a network between Alaskan inventors and the external co-inventors to elucidate both the clustering and inter- and interregional connections of inventors. We examine both individual inventors and company inventors (working for corporate applicants) to explain the co-authorship between inventors in relation to the patents' spatial and sectoral characteristics.

Measuring Innovation Activity in Alaska Using Patents

Patent-based indicators are frequently used for measuring knowledge production (Pavitt, 1985; Grupp & Schmoch, 1999; Jaffe & Trajtenberg, 2002; Kogler, 2010). This study uses standard measures of innovative activity, such as the number of patents per capita and patent/inventor ratio. Albeit there are various ways to measure the spatial distribution of patents, the Location Quotient (LQ) remains a powerful tool that allows comparing the share of patenting in a particular industry sector at the regional (e.g., borough) vs. the U.S. national levels. LQs are ratios that indicate an area's relative distribution of patents by industry sector, i.e. reveals the region's specialization in certain innovative activities (Burt et al., 2009).

Using the equation below, one can calculate the LQ of a specific industry/technology classification group by dividing share of total patent output in the region (*j*) devoted to the sector (*i*) on the total national share of the sector (*i*).

$$LQ_{i}^{j} = \underline{A_{i}^{j}/\sum_{i=1}^{n}\left(A_{i}^{j}\right)} \qquad (1)$$

$$B_{i}^{j}\sum_{/\,i=1}^{n}\left(B_{\ i}\right)$$

If LQ =1 industry has the same share of activity as it does in the reference area.

If LQ>1 reflects the relative concentration of specific activity in the region compared to the nation.

If LQ<1 reflects that the sector is underrepresented of the region of interest compared to national share.

To examine co-inventor collaborative networks we identify multi-authored patents and then determine the spatial locations for the listed inventors by geocoding the places of inventor's residency, and then connecting nodes in the networks between these locations by applying a custom Python script. We analyze team size, internal, out-of-state and international co-authorships and differentiate between individual and corporate inventors.

Results and Discussion

Patent Production in Alaska: Historical Trends and Evolution

Over the period of 1976-2010 the total number of Alaskan patents was 1,077 created by 1,873 inventors. The number was very low until the early 1990s when it rapidly increased only to decline again in the 2000s (Figure 2). The total count of inventors from Alaska (first inventors and co-inventors) was 1,340 (71.5% of all inventors), while the non-Alaskan-inventors count was 532 (28.5%). Alaskans were lead inventors on 86.2% of all recorded patents.

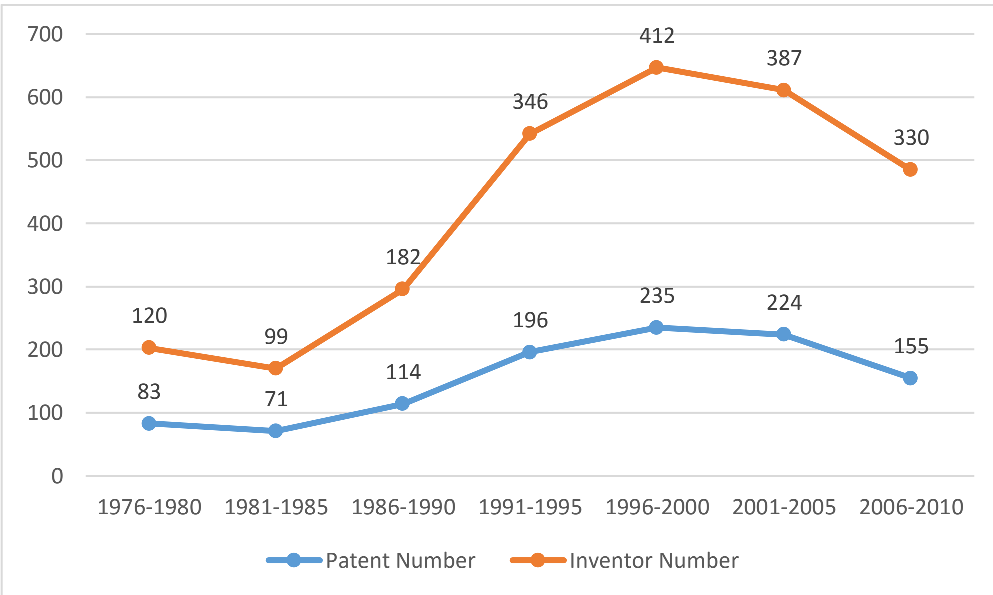

Figure 2: Patents and Inventors Numbers Trends.

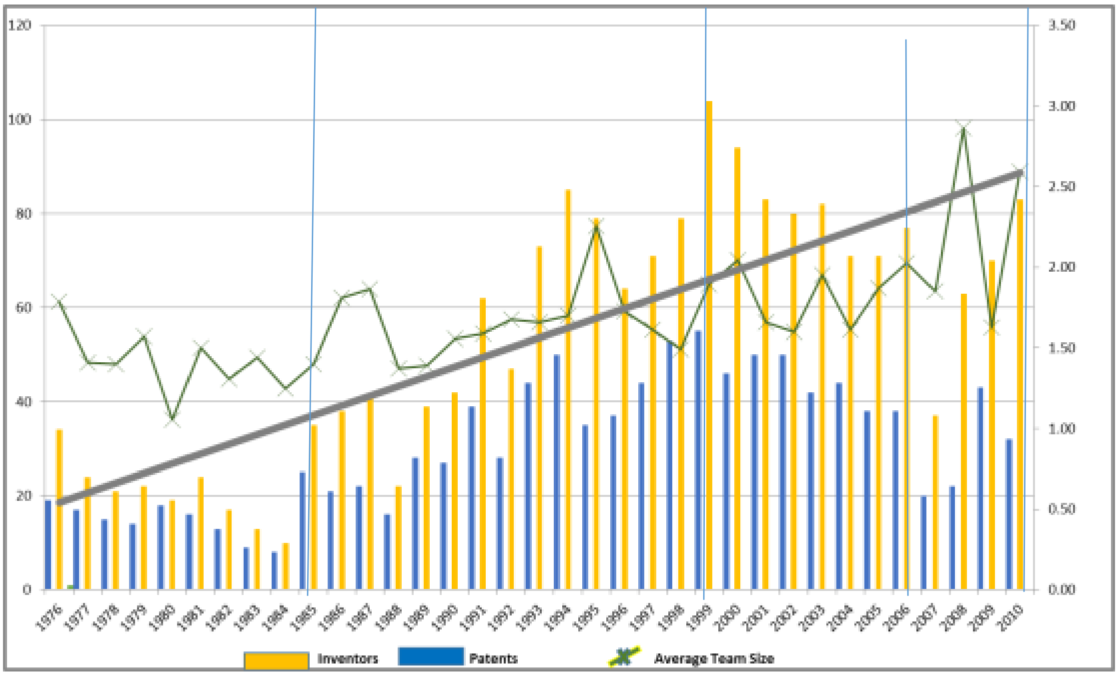

Figure 3: Annual Number of Patents and Inventors, and Average Team Size per Patent

Figure 3 shows the annual dynamics of patents and inventors and respective team size per patent in 1976-2010 in Alaska. Based on the nature of these dynamics, we can identify four periods: before 1985; 1986-1999, 2000-2006 and after 2007. In 1976-1985 the number of patents and inventors were low, with 219 inventors and 154 patents and the team size less than 2 inventors. That means most of the patents were created by individuals. The largest industry sectors were wells, hydraulic-earth engineering (both are related to oil extraction) and fishing/trapping/hunting. During the Alaska oil boom in 1986-2000 we notice a significant growth in the numbers of patents and inventors: 940 inventors produced 545 patents, and the team size increased, with many more inventors from other states. The largest industry sectors were wells technology, followed by surgery and hydraulic-earth engineering. In 2000-2005, the numbers of patents and inventors declined, although oil-related sectors still dominated: wells, liquid purification or separation and hydraulic-earth engineering. In the last time period, coinciding with the Great Recession, since 2007 the quantity of patents dropped and then slowly increased while the number of inventors quickly recovered. This means more inventors were involved in producing one patent, building larger, geographically diverse teams. The industrial mix remained similar with some new technology sectors emerging (measuring and testing equipment, etc.) Overall, since 1976 we observe the pattern of increased knowledge production, team size and industrial diversification of the patent activity in Alaska with continuing dominance of innovations associated with the oil sector.

Between 1976 and 2010, most patents in Alaska were granted in wells, hydraulic and earth engineering, surgery, liquid purification and land vehicles sectors. These five industries accounted for about 60 % of all patents granted in this period. Oil dependent sectors produced almost a half of patents from three leading boroughs (Anchorage, Fairbanks, and Matanuska-Susitna). Top patent-producing industries changed over time, but generally remained similar: hydraulic and earth engineering, wells, land-vehicles, and liquid purification (all oil-related). Road structure and fishing and trapping (corresponding to pre-oil specialization and pipeline construction) appeared in the top five in the 1976-1985. Surgery emerged as a key innovation industry since the late 1980s and data processing and measuring in the 2000s, indicating the diversification of innovative activity and a shift to new technologies.

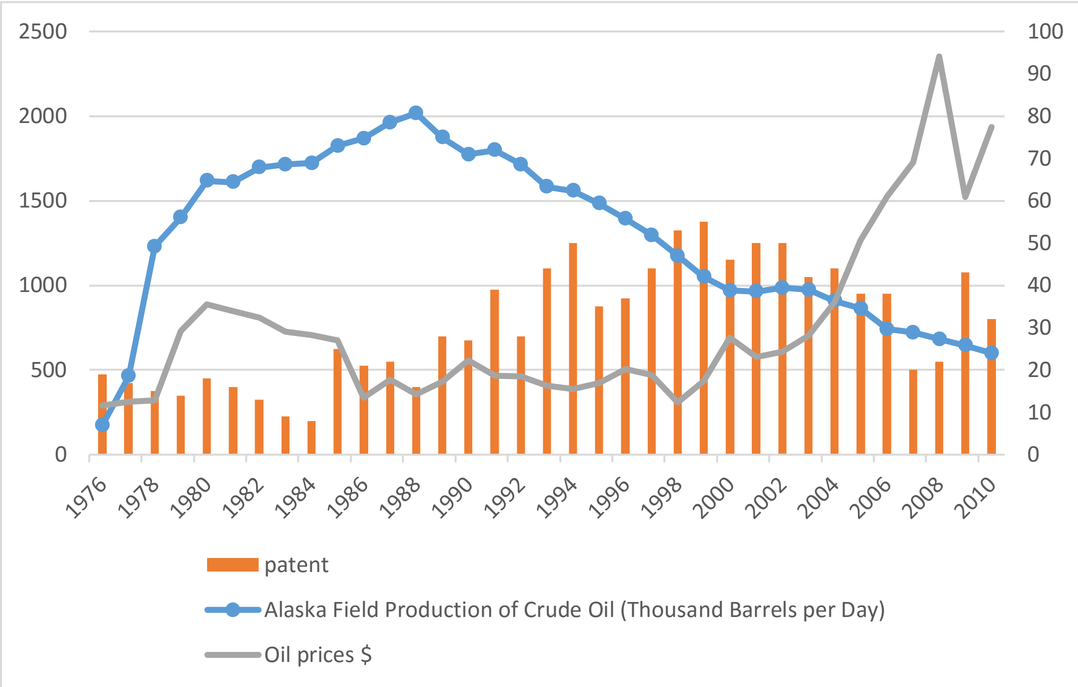

Figure 4: Oil prices, production and patent activity in Alaska

Figure 4 compares the oil price, oil production and the count of patents in 1976-2010. Although the chart does not show a clear relationship, it appears that the periods of lower oil prices coincided with higher innovation activity in Alaska. For example, from 1986 to 2002 there was a steady growth in patent production, while oil prices remained low. A spike in oil prices in the mid-2000s corresponded with diminishing innovation activity. It is too early to conclude whether these observations reveal a potential pattern. One possible hypothesis to test might be that the oil industry, which dominates Alaska innovation, tends to innovate more under lower profit margins (and in Alaska's case, declining production) say, to develop new technologies for cost saving and production increase. Alternatively, a resurgence of individual innovators and a relative decline of corporate, i.e. oil sector, patenting during the crisis of the mid-2000s may point to different resource cycle responses among agents of innovation in the Alaska RIS. These patterns should be tackled by future studies that will incorporate the analysis of company's activities, business operations, investment data, etc.

The Geographical Distribution of Patents and Inventors

Patents production in Alaska is highly concentrated in space. The majority of them, more than 90% in each of the five years' periods from 1976- 2010, located in eight boroughs (Figure 4). At the borough level, the Anchorage Municipality has had the highest number of patents, larger than the rest of boroughs combined. Fairbanks North Star Borough and Matanuska-Susitna Borough (suburbs of Anchorage) are distant seconds in terms of the number of patents. This could be explained by the city's size and role in the Alaska economy, since Anchorage is the largest city in Alaska and houses technology, communication and engineering firms. At the same time, it is worth pointing out that many smaller communities had relatively high per capita patent production levels (Figure 5).

In Anchorage, the number of patents was the largest in 1996-2000, when it reached 255 patents and 133 inventors. Fairbanks North Star Borough followed by Matanuska-Susitna Borough demonstrated a considerable gap compared with Anchorage Municipality, although the peak was recorded in the same time period. Juneau City and Borough was a distant fourth. The rest of boroughs, including Kodiak Island Borough, Ketchikan Gateway Borough, Kenai Peninsula and Valdez-Cordova Census Area had a few patents and inventors. Noticeably, the periods of 1991-1995, 1995-2000, and 2001-2005 showed higher production of patents compared with the periods before and after.

Inventor distribution was similar to the patents distribution with the highest number of inventors living in Anchorage Municipality, Fairbanks North Star Borough, and Matanuska-Susitna Borough. However, when measuring inventors per 1,000 residents we found that some low population density boroughs had a high share of inventors, e.g., Ketchikan Gateway Borough had 3.1 inventors per 1,000, and Valdez-Cordova Census Area had 1.9 inventors per 1,000. These unlikely innovation 'hubs' deserve further investigation. This is an interesting phenomenon that most likely constitutes a special property of innovation in remote regions embedded in individual-driven and niche-based innovation in these places.

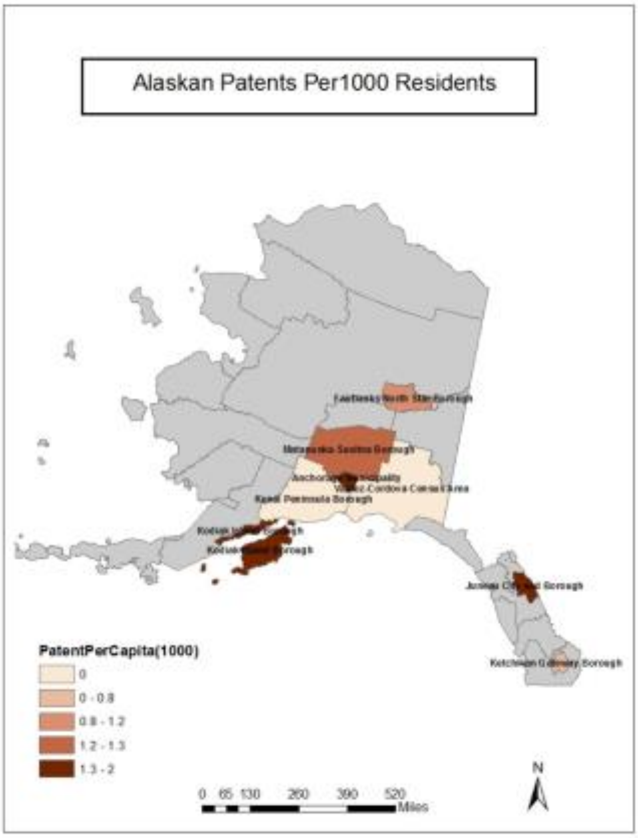

Figure 5: Patents per 1,000 Residents

Specialization and Sectoral Concentration of Patents

This section aims to describe knowledge formation as specified by the technological specifications of patents. To measure and compare patenting activity in a particular technology sector (or industry, to which it was associated) at different geographic locations we used the Location Quotient (Burt et al., 2009). In this study we focused on 25 industries (based on the USPTO technology classification) with the highest amount of patents awarded to Alaskan inventors. The six boroughs with the largest patent counts between 1976 and 2010 were analyzed and LQs for the top 25 industry sectors were computed for them using USPTO data.

Table 1 represents patent counts in each of the 25 top technology/industry sectors. LQs with a value greater than 2.0 (black), and values below 0.5 (red) are shown to indicate respectively higher or lower relative patent activity compared to the U.S. as a whole. High LQ means specialization of a borough in creating patents in a certain sector. The gray boxes indicate sectors, in which no patents have been recorded to the residents of a particular borough, and the white boxes include the rest of the values, which are LQs with results between the values 0.5 and 2.0 exclusively (i.e., near the U.S. national level). The last column in Table 1 shows the overall count of patents granted in a particular industry over the 35-year time period.

Each of the six boroughs showed specialization in at least three industry sectors. Matanuska-Susitna Borough specialized in developing new technologies in 14 industry sectors (black boxes), Fairbanks North Star Borough in 13 sectors, Anchorage Municipality in 11 and Kodiak Island Borough in 10. Anchorage Municipality was the most productive borough by the total number of patents, and Anchorage-based inventors created new products in each of the 25 industry sectors. Similarly, Matanuska-Susitna Borough and Fairbanks North Star Borough had high counts of patents in almost all sectors with a few exceptions. However, it is worth mentioning that despite the overwhelming dominance of Anchorage in patent production, it was not the most diversified region in terms of specialization (only in 10 sectors). This most likely reflects the overrepresentation of the oil-sector-related innovation in Anchorage and a resultant "innovation monoculture" entrenched in a few powerful, but undiversified knowledge industries. This observation should be further investigated especially since it could be a technology-sector manifestation of the resource curse.

Boroughs with much smaller patent output, such as Ketchikan Gateway Borough and Juneau City and Borough, have had patents in relatively few industry sectors, i.e. were narrowly specialized occupying a constricted technological niche. On the other hand, some technological sectors were only present in a few boroughs, for example, liquid purification or separation, land vehicles, data processing-measuring-calibrating or testing, multiplex communications, internal- composition engines and fluid handling. These tended to be sectors with a low count of recorded patents (Table 1).

Among the technology/industry sectors, fishing was the most frequently overrepresented technology among Alaska patents in six boroughs, followed by animal husbandry with five cases. These 'old' industries represented the areas of Alaska's consistent and long-established technology excellence. The most radical specialization, with LQs exceeding 20, was observed in smaller regions (Kodiak, Ketchikan) in some of these niche industries (fishing, marine propulsion) indicating a narrow stream of knowledge production in these remote areas. On the other hand, new technologies have also found their spots on the top 25 list (Table 1). They included, among others, amusement devices/games, measurement instruments, surgery and communication technologies.

Table 1: Calculated LQ Values of Recorded Patents from 1976-2010

IndustrySector	Anchorage Municipality	Faribanks North Star Borough	Ketchikan Gateway Borough	Juneau City and Borough	Matanuska _Susitna Borough	Kodiak Island Borough	Total# of patents(1976-2010
Wells	17.9	0	0	0	12.1	4.9	117
Hydraulic	12.8	17.2	0	0	2.2	9.6	43
Surgery	3.5	0	7.2	0	0	0	30
Liquid purification or seperation	1.9	2.6	0	1.4	0.7	0	24
Land Vehicles	1.9	0.8	0	1.7	9.1	0	24
Boring or penetrating the earth	7.4	2.4	0	0	2.4	0	21
Fishing	5.1	6.3	34.4	26.1	6.3	56.0	21
Data- processing- measuring ,Calibrating or testing	1.2	1.9	0	0	2.9	0	17
Drug, bio-affecting and body treating compositions	1.2	0.4	0	1.6	0.4	0	16
Measuring and testing	0.7	1.0	0	1.0	0	0	15
Ships	4.4	0	0	9.8	2.4	10.6	14
Animal husbandry	2.8	2.3	0	23.9	2.3	10.3	14
Supports	1.3	2.3	0	0	1.5	0	14
Static Structure	1.0	0.8	0	0	2.5	3.7	13
Geometrical Instruments	2.9	6.0	0	8.3	2	0	13
Exercise devices	2.5	0	0	0	15.4	27.4	12
package and article carriers	2.9	5.6	0	5.9	8.5	0	11
MultiplexCommunications	0.3	0	0	0	2.3	0	11
Communications: Electrical	0.8	0.5	0	0	0.5	0	11
Marine Propulsion	5.2	12.7	69.9	0	0	28.5	10
Internal - composition engines	1.2	0	0	0	4.9	0	10
Amusement Devices: games	1.9	3.8	0	3.9	1.9	8.4	10
Material or article handling	1.7	1.2	0	0	1.2	0	9
Fluid handling	0.8	3.7	0	0	0	0	9
Refrigeration	0.7	2.3	0	0	2.4	5.3	9

The Regional Innovation System in Alaska

To apply the RIS concept to the Alaska innovation system (AKRIS), one needs to quantity different sources of patent production (Figure 6). We used information about patent applicants (entities that filed a patent application) to define main RIS structural elements. These elements or 'agents of knowledge production' in Alaska were classified as internal (located in Alaska) and external (led by extraterritorial actors with Alaskan co-inventors), and each component was assigned a share in the innovation process based on patents it produced. This share gives an insight into the importance of each element in the overall innovation process. Both levels, internal and external, had different roles in the innovation system. They are also interacted. In Alaska, the major structural elements of RIS (and agents of knowledge production) were individual inventors, government, private or non-government organizations, and universities. Within Alaska individuals had the highest percent of patented innovations (57%), followed by private organizations (9%), universities (1.7%), and, lastly, by the state and local government (0.2%) (Figure 5). External innovation activities in AKRIS exhibited a different pattern. The private organizations' share of patents was the highest (27%), individuals and government were at par (1.7 % each), and universities had the smallest share of innovations (0.8%). This structure is not accidental, but reflects the key properties of remote RIS: an elevated role of individual inventors locally coupled with the predominance of extraterritorial private companies in the external flows of knowledge and innovation.

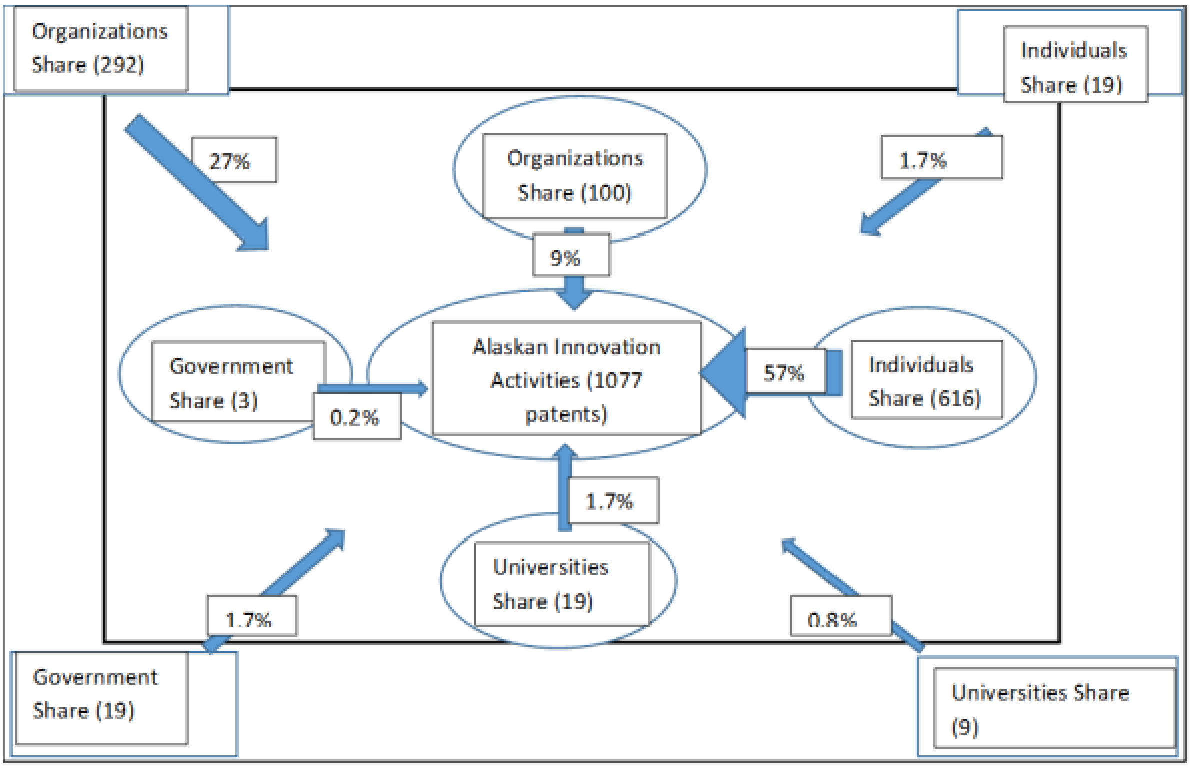

Figure 6: Alaskan Regional Innovation System Components.

Co-Inventor Networks Analysis and Trends

This section aims to determine the spatial distribution of co-inventors of Alaska-based patents and identify the external and internal networks within Alaska and between Alaska and other regions. All co-inventors for each patent were linked and their networks were built and mapped using GIS (geovisualized). We then compared dynamics and various characteristics of inventors 1976 and 2010 dividing it into 5-yar study periods (1976-1980, 1981-1985, 1986-1990, and so forth) to elucidate the progress of inventors' networks over time and observe the changes of inventors' clustering.

In order to highlight the spatial evolution of inventor networks, we compared the earliest and the latest five-year periods (1976-1980 and 2006-2010). First, Figure 7 presents the co-inventors network in 1976-1980. The total number of inventors is 120, most (74) of them were individual inventors, i.e. either a single inventor or a group of independent co-inventors with no recorded relationship to any organization or company. On the other hand, there were 46 inventors involved with organizations. All co-inventors were located inside the USA, with most inventors residing in Alaska (Alaska had 95 inventors, about two thirds of them were individuals and one-third belonged to an organization). Most non- Alaskan inventors (60%) were company inventors, while 40 % were individuals. Anchorage Municipality recorded the largest number of inventors (53 inventors). Among external locations Texas had the largest number of inventors (11 inventors), 64% of them were company-based.

This analysis suggests that the AKRIS in its early days was relatively inward oriented, dominated by individuals and small, localized inventor teams. It had rather limited connectivity within the USA and was isolated from the rest of the world. The time period between 1976 and 1980 reflects the "pre-oil" situation, when the role of large corporations was still modest. It is interesting to point out that the number of patented innovations was small, with a large share fishery, trapping and other "old" sectors. This is the only time when road construction patents made to the top five sectors, a situation reflective of intensive construction phases of oil development.

Figure 7: 1976-1980 Alaskan Inventors Network

In the most recent time period, 2006-2010 (Figure 8), there were 330 inventors, slightly fewer than in the previous five-years, but many more than 35 years earlier. Among them, 69% were involved with an organization, while 31% were individual inventors. The share of company inventors became the largest in the early 2000s, and it slowly declined in 2006-2010, perhaps, reflecting the diversifying nature of knowledge production away from oil sector dominance and towards individually produced innovations. Alaskan inventors outnumbered non-Alaskan inventors (188 to 142). The percentage of company-based inventors grew to 52% among Alaskans and 91% among outside collaborators. Anchorage still had the largest number of inventors, 54% whom were company inventors. Among other states Texas again had the largest share of inventors (94% of them were company inventors). On the other hand, Alaska innovators were globally connected having co-inventors in Australia, India, United Kingdom, and South Korea.

Figure 8: 2006-2010 Alaskan Inventors Network

Conclusions

This study explored the dynamics of innovation activity in Alaska expressed through USPTO-registered patents in order to improve the understanding of knowledge creation and other creative activities in remote areas. It constitutes a first look into the Alaska knowledge economy that can potentially play an essential role in diversifying Alaska's economic system. Patents is an important indicator of knowledge economy and their typological, geographical and historical patterns provide a key insight into the Alaska's regional innovation system.

Patent development in Alaska grew over time, so did the number of Alaska-based inventors. Since 1976 we observed the pattern of growing knowledge production, team size and industrial diversification of the patent activity with a continuing dominance of innovations associated with the oil sector. Based on the nature of patent dynamics in 1976-2010, we identified four periods: before 1985; 1986-1999, 2000-2006 and after 2007. In 1976-1985 the number of patents and inventors was low, and most of the patents were created and claimed by individuals. The largest industry sectors were wells technology, hydraulic-earth engineering and fishing/trapping/hunting. During the Alaska oil boom we noticed a significant increase in patents and inventors with the most prolific patenting in wells technology, followed by surgery and hydraulic-earth engineering.

Since 2007 the quantity of patents dropped and then slowly increased, although co-inventor teams became considerably larger and geographically dispersed reflecting an increasingly globalized nature of Alaska knowledge production.

There has been heavy clustering of patents in some of Alaska's boroughs, specifically, in Anchorage Municipality, Fairbanks-North Star Borough, and Matanuska Borough. These Alaska regions with intensive patent activity have become highly specialized in multiple industrial technologies related to the oil sector (wells, hydraulic, drilling, etc.), "old" industries (such as fisheries or animal husbandry) and "new" technologies (telecommunications, surgery, etc.). Smaller boroughs tended to occupy narrow knowledge production niches in a few industries, such as fishing and marine propulsion.

In respect to the structure of the Alaska RIS this study mapped its main elements and identified their contribution in knowledge generation within the system. We considered both internal and external elements (knowledge-producing agents), such as individuals, companies/organizations, government and universities. It is important to highlight that independent individuals developed more than one half of all patents over the observed period, and most of them were Alaskan inventors. Private organizations (companies) were the second largest owner of the intellectual property, and non-Alaska biased firms were the dominant external force of innovation. The government and universities played modest roles in the AKRIS. These findings reflect a key property of remote RIS: an elevated role of individual inventors locally alongside with the predominance of non-local private companies that control external flows of knowledge and innovation.

Collaborative networks of Alaskan inventors underwent substantial changes during the 35 years we examined. In the early days a single inventor or a group of independent co-inventors was a leading force of innovation working primarily within Alaska or with a few co-authors from other U.S. states. This constitutes a sharp contrast to the most recent years when patents tended to be created by company-based inventors working with large groups of co-authors scattered around the U.S. and the world.

Overall, between 1976 and 2010 AKRIS evolved from a small isolated system dominated by individual ("lone-eagle") inventors focused on the innovation in old, low-technology sectors to a relatively diversified (although still over-reliant on the oil sector) intra- and internationally connected system with a considerable presence of company-driven innovation, but a strong position of individual inventors, including those from smaller communities.

This study constitutes a first-cut analysis of patent activity in Alaska and is limited in scope to address only general patterns and trends. Perhaps it raises more questions than provides answers. More in-depth analysis should focus on patent citation networks, evolution of industrial and technology mix, connections of innovation with economic development, and resource economy in particular, relationships with creative capital, to name a few research directions. One aspect that seems very intriguing is the relationship of innovation activity and the price of oil: it appears that the periods of lower oil prices coincided with higher patent production in Alaska. Further research will find out whether this is a coincidence or a pattern, a potentially impactful finding that may shape our understanding of innovation in the periphery. It is also important to investigate innovation in smaller communities and elucidate their linkages with community capacities and capitals, as well as potential implications of community development paths.

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