Patenting in nineteenth century New Zealand:

An economic and historical analysis

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Matthew Gibbons

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Abstract

This thesis has studied the relationship between patenting and economic development in nineteenth century New Zealand, and the extent to which different population groups patented. These topics are studied using all patents applied for in New Zealand between 1860 and 1899, with the data being weighted by fees and other required expenditure on each patent.

Patent application costs were substantially reduced in the 1880s when the government sought to broaden access to patenting. This thesis has confirmed that the lower cost of patent applications was associated with increased patent applications by New Zealanders. In addition, the proportion of patenting by some skilled trades workers increased after application fees were reduced. However, despite reduced application costs, patenting by low income earners, such as labourers, remained low. New Zealand farmers made a higher proportion of patent applications than farmers in comparable patenting systems, but the rate at which they patented was below average for male workers. Engineers, who had trained through apprenticeships, were the occupational group that applied for the most patents. Patenting by women increased from the mid-1880s, but even in 1899 women applied for only 2.5% of total patent applications. Maori made little use of the patenting system. No New Zealand region had the highest patenting rates for very long.

The highest spending New Zealand patentees were typically engineers who patented products, such as agricultural or mining equipment, they had invented. Furthermore, they usually owned a business that produced goods and services they had patented. Some of the highest spending patentees became prosperous, although those who developed mining technology were relatively economically unsuccessful. For individual output series there were more cointegrating relationships with Granger causality between patent expenditure and economic output than between patent applications and economic output. Output series usually led patenting, particularly using patent expenditure data, which indicates patentees were concentrating on economic needs. In some of the results, however, such as the important area of agricultural output, output followed expenditure on patents. Similarly, output sometimes followed patent applications. These results suggest that patent applications and expenditure sometimes directly helped increase living standards in New Zealand over the period studied.

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A regional population dataset developed by Rebecca Craigie for a Canterbury University economics dissertation has been used and extended. In addition, Rachel Cotter's descriptions of patenting topics, which was also developed for a Canterbury university economics dissertation, was used. Research by both these economists has considerably enhanced this thesis.

Library staff arranged for the efficient interlibrary loan of key items, including rare documents. In addition, Kathryn Parsons provided valuable advice on New Zealand biographical sources. The School of Management's computer staff provided help and advice, and tolerated me storing documents in the computer lab overnight when I was making corrections to the dataset. Staff at Archives New Zealand in Wellington provided valuable guidance and timely supply of the original patent ledgers books. Contributors on the rootschat.com forum provided useful advice and links to primary sources containing information about patentees.

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Chapter 1: Introduction

1.1 Introduction

This thesis examines the related questions of the extent to which patenting promoted economic development in New Zealand during the nineteenth century, and the degree to which different economic and demographic groups made use of the patenting system. These two topics are of considerable interest to economic historians both in New Zealand and overseas. Whether patents promote or hinder economic growth, and for how long new inventions should be protected, has been fiercely debated (Moser, 2005, p. 1214) (Dutton, 1984, pp. 3-5). During recent decades economists have been able to empirically study the relationship between patenting and economic development, and whether output leads or lags patenting (Greasley & Oxley, 2007; Schmookler, 1966). Furthermore, in some countries there has been considerable research into the extent to which different economic groups patented during the nineteenth century, and into the background characteristics of the most prolific patentees (Khan, 2005; Magee, 2000). Because by the 1880s patenting application rates in New Zealand were high, and there was considerable pride in the level of patenting (Evening Star reporter, 1889, p. 1), patenting in nineteenth century New Zealand deservers further attention.

This thesis analyses New Zealand patent applications between 1860 and 1899. The research is primarily based on unit record data on 12,283 patents, where the topic of each patent has been coded using a scheme previously applied in Australia and in New Zealand. Furthermore, the individual applicants for each patent have now been identified, their location coded, and their contribution weighted both by their share of patent applications and total expenditure on patents. This makes it possible to identify the individuals who made the most applications and spent the most on patents, and the relationship between expenditure on patents and economic activity. In addition, comparisons are made with patent applications in other places during the nineteenth century, such as the self-governing colony of Victoria, which in 1901 became part of Australia.

Section two of this chapter briefly discusses what patents are and why they are important. Section three then details the two main research questions. The final section outlines the contents of the next seven chapters.

1.2 Why patents are and why they are important

Patents are documents that give people legal protection over intellectual property for a fixed period in exchange for publishing specifications that, on the expiry of the patent, make the knowledge available to others. Patents are therefore of interest to researchers because they provide unique insights into innovation and investment in research, particularly for periods before official data on private and public investment in research and development is available (Auger, 1992, pp. 1-2, 166). However, since some inventors do not patent, and some firms rely on secrecy to protect their intellectual property, these insights are imperfect.

Some economists argue that well designed patent systems can promote economic development by providing incentives for innovation. This is because inventions are protected by a temporary monopoly that allows the inventors to sell products based on their invention, or to recoup their investment by licensing their invention to others. Furthermore, patents encourage the diffusion of knowledge by ensuring that inventions are written down, and are therefore available to others when the patent expires (Auger, 1992, p. 10; Dutton, 1984, pp. 17-22). Low patent fees can democratise invention by ensuring that people from all social and economic groups can protect their inventions and receive a just reward for their hard work (Khan, 2005, p. 7).

Other economists have argued that patenting encourages rent-seeking and opportunistic behaviour by those seeking to benefit from general scientific progress. Critics of patent protection argue that patents encourage monopoly and prevent the diffusion of knowledge. These critics argue that patents reduce, rather than increase, productivity (Boldrin & Levine, 2008; 2013, pp. 4-7). During the 1850s Britain's *Economist* magazine argued that abolishing patent systems would produce similar types of economic benefits to freer international trade in goods and services (Economist, 2015a, p. 50). However, during the second half of the nineteenth century inventors in Britain were popularised by writers and by newspapers, and patent protection became viewed as a just reward for hard work and original thinking (MacLeod, 2007, pp. 1-3, 265).

1.3 Research questions

The key research questions addressed in this thesis are about the relationship between patenting and economic growth, and about the extent to which different groups patented. These two research questions, which are closely related, will now be considered.

1.3.1 The relationship between patent applications, patent expenditure and economic output

The first main research question of this thesis is about *the relationship between patent applications, expenditure on patent fees and other costs, and economic output*. Previous New Zealand researchers have used total patent applications based on published summary data. Greasley and Oxley found that "on balance patenting led output, but in many cases output led patenting". This finding was the reverse of the situation in some other countries (Greasley & Oxley, 2010b, p. 452). However, the cost of a New Zealand patent application changed considerably between 1860 and 1899, and a decrease in application fees was associated with increased numbers of applications from the 1880s (Greenshields, 1884, p. 2). Since many patent applications subsequently lapsed, the international literature indicates that the total number of applications may be a relatively poor measure of innovation. Indeed, there has been growing academic interest in how the value of knowledge from patents dissipates over time, and how the value of patents can be calculated using data on the patent renewals (Lanjouw, Pakes, & Putnam, 1998, p. 412; Schankerman & Pakes, 1986, pp. 1054, 1056, 1059, 1067).

However, since some applicants probably faced a liquidity constraint, and this may have prevented them from renewing protection on worthwhile inventions, applications may sometimes be a better indicator of innovation than expenditure (MacLeod, Tann, Andrew, & Stein, 2003, pp. 542-543, 560). This thesis therefore investigates whether there is a closer relationship between expenditure on patents and economic activity than between just patent applications and economic activity.

Furthermore, some types of patents, such as foreign patents or patents renewed for a full 14 year term, may have a different relationship with output than all patent applications or expenditure. For instance, overseas inventors would probably only have incurred the expense of patenting in New Zealand if they were confident in the value of their inventions. These foreign patents might have a bigger effect on economic output than

New Zealand patents. However, New Zealand inventors may have been more aware of economic opportunities than inventors living overseas. They may therefore have been particularly active patentees in some parts of the economy, and have boosted economic output more than overseas patentees. Indeed, using total applications, Cotter found that New Zealand patents Granger caused real GDP for 1870-1938, but that for foreign patents the reverse was true (Cotter, 2006, pp. 19, 20). In addition, this thesis will test whether the relationship between patent applications or expenditure on patents is stronger for some types of output than for other types of output. In particular, investment in some sectors may have followed economic output, and in other sectors the relationship may be the reverse.

1.3.2 The extent of patenting by different economic, social and geographic population groups

The second main research question covered in this thesis is about *the extent to which different economic and social groups found patenting affordable, and in which geographic places patenting was concentrated*. Low application fees meant that patenting in the nineteenth century United States occurred at a higher per capita level than in Britain, and that patent applications were also more common among lower income groups (Khan, 2005, p. 7). However, there has been no systematic research on this topic for New Zealand, despite it being asserted that the democratisation of invention in the United States boosted economic development (Khan, 2005, p. 13)

This thesis therefore examines which occupational groups patented in New Zealand, and whether and how this changed over time. In particular, lower initial application fees may have made patenting more accessible to a wider range of occupational groups, or may have simply resulted in more patenting by higher income groups. The extent to which women, New Zealand's indigenous Maori population, and Chinese migrants patented is also of interest since it provides an indicator of the extent of economic equality in New Zealand. Furthermore, changes in the geographic location of patenting may provide insights into changes in the regional distribution of economic activity.

In addition, the identities and characteristics of the most prolific and highest spending patentees are of considerable interest (Khan & Sokoloff, 1998). For instance, the extent to which people from different family and educational backgrounds invested heavily in

commercialising inventions indicates whether a wide range of people in colonial New Zealand could succeed economically through technological innovation. Furthermore, newspaper reports will reveal how the most prolific inventors were viewed during their life-time, while probate data and other sources will indicate the level of economic success they enjoyed.

1.4 Chapter outline

Chapter two of this thesis reviews the literature on patenting in more depth than has been possible in this chapter. Books on nineteenth century patent data have been published on the United States, Britain and the self-governing colonies that later became Australia (Bottomley, 2014a; Khan, 2005; Magee, 2000). There has also been research into the economic effects of patenting in New Zealand. However, studies of New Zealand patents have either used a sample of the unit record data (Craigie, 2009) or summary data (Cotter, 2006; Greasley & Oxley, 2010b) from statistical reports that provide less information than the complete 1860-1899 unit record data collected for this study. Furthermore, there has been no systematic research into the demographic characteristics of New Zealand patentees, and the extent to which different economic and social groups patented.

Chapter three considers the legislative framework and nineteenth century guides on patenting. Changes in official costs and in other required payments, such as advertising costs, are considered. Renewal periods are also systematically tabulated for the first time.

Chapter four discusses the sources for the dataset and outlines the coding scheme for patents. In addition to initial patent applications, data was collected on whether applicants paid to have patents advertised, and whether they paid renewal fees. Other datasets discussed include regional and national population data, and a new dataset on urban populations.

In chapter five the focus switches to using unit record data to consider growth in the number of patent applications and in expenditure on patent fees and other required costs, the proportion of patent applications and expenditure by New Zealanders, and the countries in which foreign patentees lived. How the geographic location of patenting activity changed over time is considered. In addition, New Zealand's revealed technological advantage is calculated using patent applications and expenditure on patents.

Chapter six then focusses on the individuals who applied for patents and invested in renewal fees. The most prolific occupational group is shown to be engineers, although New Zealand farmers applied for a higher proportion of patents than farmers in Victoria. Furthermore the most prolific patent applicants and the biggest spenders on patent fees are systematically identified and researched. The biggest spenders on patent fees are shown to have disproportionately been successful makers of farming equipment, such as ploughs. However, there was also a generally less economically successful group of high spending patentees who were involved in developing mining technology. The gradual increase in patenting by women, the almost non-existence of patenting by New Zealand's indigenous Maori population, and the low level of patenting by Chinese migrants are discussed. The recent creation of the *Papers Past* collection, which contains digitalized and searchable text from historical New Zealand newspapers and periodicals, means that considerable information on the most prolific patentees can now be found.

Chapter seven examines the key question of the relationship between patenting, patent costs, and economic activity. Patenting applications per capita by New Zealanders are shown to be strongly correlated with changes in initial application costs. Contrary to Greasley and Oxley (2010b), who use more disaggregated output data over a longer time period, the results presented here suggest that output led patent applications more frequently than vice versa. The same pattern occurs when patents are weighted by expenditure on these patents. However, using this unique patent expenditure data the relationship between output and patenting is much stronger than simply using applications. This higher predictive validity suggests that weighting the applications data by expenditure on patent fees and other required costs usually results in a more accurate representation of investment in patents.

Chapter eight concludes this thesis and answers the two research questions. In addition, the desirability of expanding the unit record patent dataset to include the twentieth century is discussed.

Chapter two: Review of the literature on patents

2.1 Introduction

Patents are legal documents that give the owners of the patent a temporary monopoly over an invention in exchange for recording their invention so that others can use it in the future. Economists have frequently used patents as a measure of inventive activity, particularly for historical periods when research and development expenditure data is not available (Griliches, 1998, p. 301; Jaffe & Trajtenberg, 2002, p. 3). Furthermore, patent records have often been used to advertise products and gain credibility (Berg, 1998, p. 144), and provide one of the few sources of information available about inventors, their occupation, and where they lived (MacLeod, 1988, p. 2). The extension of an existing patent to another country is also an indicator of its attractiveness as a market (Bottomley, 2014b, p. 48).

Academic researchers have frequently studied patents since the 1960s, and in recent decades research methods have become increasingly sophisticated. As well as detailed studies of patenting in the United States, there has been an expanding literature on patenting in Great Britain and on Australia. One of the most relevant studies to this thesis is by Magee, who examined patent applications in Victoria, which in 1901 became part of the Commonwealth of Australia, between 1857 and 1903 (Magee, 2000). In the United States, Khan has written a book on patenting in the United States between 1790 and 1920 (Khan, 2005). Detailed studies of patenting in Britain during the industrial revolution, have been conducted (Bottomley, 2014a; MacLeod, 1988), and there has also been research into patenting in Britain during the second half of the nineteenth century (MacLeod, 2007; MacLeod et al., 2003).

This literature review summarises overseas and New Zealand studies of patents that are relevant to the research questions. Section two briefly discusses the origin of patents and their justification. Then section three outlines the debate over the importance of patents for economic development. Section four is about the origins of patentees in different countries, the inclusiveness of patenting systems, and the characteristics of the most prolific patentees. Section five is more methods based, and discusses how patent renewals and citations can identify which patents are most important for economic development.

2.2 Origin of patents and their justification

The word “patent” is based on the Latin term “patere”, which means to lie open. In patent law an invention is an improvement (Schmookler, 1966, p. 13). Patents are frequently justified on the basis that they ensure innovation and inventiveness is justly rewarded. In addition, patents provide incentives for inventors by ensuring temporary monopoly profits for inventions. Furthermore, patents stimulate economic growth by ensuring that in exchange for a temporary monopoly, knowledge and inventions are written down and over time become available to others (Auger, 1992, p. 10; Dutton, 1984, pp. 17-22). The length of patent protection reflects a tradeoff between static and dynamic economic efficiency. This is because patent protection reduces static efficiency by reducing the diffusion of knowledge, while encouraging dynamic efficiency by rewarding innovation (Guellec & Van Pottlesberghe de la Potterie, 2007, pp. 8, 50). Although patents can be difficult to read, they are nevertheless a potentially valuable source of information to other firms and researchers.

Venice introduced the first recorded patent law in 1474. Patents were awarded from the 1600s in Britain, with the 14 year term patents were in force being twice the conventional length of a trade apprenticeship (Guellec & Van Pottlesberghe de la Potterie, 2007, p. 18). The Paris Convention of 1883 then established rules for gaining worldwide patent protection, and the principle of equal treatment of foreign and domestic residents.

2.3 The debate over the importance of patents for economic development and empirical results

Some economists and historians have downplayed the importance of patents. They have argued that patents are often ineffective at stimulating inventiveness, and that many inventors rely upon secrecy (Anderson, 2011, p. 920), while patents can also result in inventive activity being concentrated on patentable activities. Patents have also been criticised for rewarding opportunistic rent-seeking individuals seeking monopoly profits from inventions stemming from general scientific progress. Since innovation tends to build on previous discoveries, patents can slow technological advancement and uptake of new technology (Bessen & Maskin, 2009, p. 611; Nuvolari, 2004, p. 353). As a result, sometimes practices of open collective invention have occurred, in which innovators have shared knowledge, avoided patents, and sought reward by concentrating on the quality

of goods and services they provide (MacLeod, 2009, p. 48; O'Donoghue, 2004, p. 96). The usefulness of patent specifications for diffusing knowledge has been queried, with some patentees making deliberate errors in specifications to avoid imitation. Some countries (such as the Netherlands between 1850 and 1888 and Switzerland between 1869 and 1912) abandoned patents (Dutton, 1984, pp. 3-6, 24, 76).

It has been argued that patent rights in Britain during the industrial revolution were weak, and that the patent system was slow, expensive and sometimes undermined by the government (MacLeod, 1988, pp. 37, 41). Sometimes considerable productivity growth occurred in sectors, such as agriculture, with low rates of patenting. MacLeod has implied patenting in Britain during this period often reflected the rise of capitalism, rather than necessarily being a key driving force. Even in countries where patent protection exists not all important inventions are patented.

Some economists continue to argue that there is no empirical evidence that patents increase innovation and productivity. This is because the surge in patenting in recent decades has not been associated with higher research and development or total factor productivity. Instead, they argue, greater competition, not patents, drives innovation and productivity, and patents reduce competition by encouraging monopolies and increasing the price of products such as pharmaceuticals (Boldrin & Levine, 2008; 2013, pp. 4-7). Critics of patents argue that patent "trolls" buy patents and then sue others for using patented knowledge (Economist, 2015a). Indeed, patents have been likened to "Rembrandts in the attic" for corporations, and enforcing overlooked patent rights through litigation has become a potential "gold mine" (Rivette & Kline, 2000, p. xi).

Indeed, poor scrutinizing of patents in the United States has encouraged patent litigation and opportunistic filing of patents that block innovation (Jaffe & Lerner, 2007, pp. 2, 46). Critics of patents argue they should be more difficult to obtain, and that prizes for innovation should be considered as an alternative (Boldrin & Levine, 2013, p. 13). Parallels with freer trade in goods and services are often made, and since the 1850s the *Economist* business magazine has consistently campaigned for weaker patent laws (Economist, 2015b, 2015c).

Other economists acknowledge the weaknesses of patent systems, and that they sometimes need reforming, but argue that on balance patents foster economic growth. They argue that the rewards from patents reflect hard work and ensure a just reward for personal industry, inspiration, and genius. Furthermore, patent rights continue to make it

easier for companies to raise money and to license their innovations to others, rather than relying on secrecy and limited access to knowledge to protect their intellectual property (Kaufer, 1989, pp. 20-22). Reforms have been suggested in the United States that would ensure greater scrutiny of patents to protect the public interest, reduce patent terms for rapidly changing industries, and curtail patenting in some areas (Alderucci & Baumol, 2013, pp. 224-226; Gilbert, 2011, pp. 425-430).

Many economic historians have sought to empirically show that patents play a key role in economic development, although they have often found that applications lag behind economic development. For instance, in a pioneering study Schmookler noted that there was a strong relationship over time between patent applications and the number of technological workers in the United States, and a strong correlation by industry between corporate research and development expenditure and patents in 1953 (Schmookler, 1966, pp. 43, 44). Over half of patents were in commercial use. Assignments, renewal rates and survey data in a number of countries also suggested that patents were valuable (Schmookler, 1966, pp. 50,51, 53). The pace of technological innovation in industries, such as railways, slowed as technological advancement became less commercially valuable (Schmookler, 1966, p. 96). When a stimuli to the invention could be discovered it was almost always a technical problem or opportunity conceived by the inventor largely in economic terms, rather than a scientific discovery.

Schmookler's most important results showed that there was a strong correlation between gross investment and patenting relating to such capital goods. Invention relating to railways often seemed to follow investment and stock prices at cyclical troughs and peak periods, with cause effectively preceding hypothesized effect. Schmookler argued that inventors looked at what products were in demand, and planned their research accordingly, with fluctuations in invention being caused by fluctuations in the number of inventive problems recognized (Schmookler, 1966, pp. 106-107, 111, 119). As a result, inventions were "creative responses to felt needs" (Schmookler, 1966, p. 136). Supporting evidence came from the petroleum and building industries. In addition, cross-sectional data showed that increases in patent applications tended to follow increases in investment in physical capital (Schmookler, 1966, pp. 138, 147).

Economic development in Britain during the industrial revolution also led patenting (Greasley & Oxley, 2007, p. 345). Indeed, profit was the main stimulus to invention in Britain during the industrial revolution (Dutton, 1984, p. 142). Similarly, in colonial Victoria

Magee found that usually the direction of causality ran from technological and economic need to scientific knowledge, rather than the reverse (Magee, 2000, p. 111). The increase in patenting in Britain after 1790 occurred across a number of industries, making it unlikely there was a leading technological sector (Sullivan, 1990, p. 349).

Research by Moser has shown the importance of patenting laws, with Moser finding that nineteenth century inventors in countries with weak or non-existent patent laws concentrated on a smaller set of industries than in countries with stronger patent laws. In particular, innovation in countries without patent laws focused on scientific instruments, food processing and textiles, which were areas where innovation could be protected by secrecy. Counties without patents also had smaller shares of innovation in machinery, particularly for manufacturing, and in agriculture (Moser, 2005, pp. 1216, 1222). Research using more recent data has shown that stronger patent laws are associated with higher research and development expenditure (Kanwar & Evenson, 2003, p. 258). Policy changes that increase intellectual property rights have a larger effect in countries with weak initial patent laws (Lerner, 2002, p. 31). High patent fees can also restrict the number and type of inventions patented.

In a recent book Sean Bottomley has shown that, despite high patenting costs and imperfect enforcement, between 1760 and 1830 the British patent system increasingly encouraged trading in patent rights, the formation of companies to work new inventions, and economic development. He argued that few important inventions completely bypassed the patent system (Bottomley, 2014a, pp. 171, 217, 284). Indeed, patents were important for companies seeking to raise capital (MacLeod, 2009, p. 52). Similarly, Khan has argued that the United States patent system was key to the development of technology and the United States economy (Khan, 2005, p. 13). Khan argued that in the United States people believed that intellectual property rights were key to economic development much earlier than this realization occurred in Europe (Khan, 2005, pp. 1-5).

Magee has examined the determinants of total inventive activity in Victoria between 1854 and 1903, and its relationship with economic growth. Magee's models explained most variation in Victorian patenting. Of the variables Magee considered, the natural log of GDP was the single most important variable (Magee, 2000, pp. 95-96). For foreign patenting in Victoria, the natural log of population was the single most important variable, followed by the number of locally trained engineers (Magee, 2000, p. 103).

Magee also studied the effects of foreign patents on demand for imports. He found that initially an increase in foreign patents increased imports, but that after the first year imports fell. This suggested that foreign patents fostered import substitution in Victoria (Magee, 2000, p. 144). A revealed technological advantage index revealed that between 1858 and 1902 there was a marked heightening of specialization in Australian and Victorian patenting activity (Magee, 2000, pp. 144-145).[1] Victoria had a comparative technological advantage in building materials, furniture, and a variety of food products including alcoholic beverages and preserved meats. Foreign patenting was largely in manufacturing and the tertiary sector, whereas Australian patenting was largely in the primary and household sectors (Magee, 2000, p. 51). The results supported a technology as a resource model, rather than exploitation or technological capability models (Magee, 2000, pp. 152, 154, 156).

2.3.1 The relationship between patenting and economic growth in New Zealand

There is also a growing literature on the relationship between patenting and economic growth in New Zealand, although there are still important gaps in the literature. Two studies have used summary data on patent applications that were published in official statistical reports. Cotter examined whether there was a relationship between patents and macro-economic variables between 1870 and 1938. Real Gross Domestic Product, exports per capita, real wages, and the money supply had correlations of 0.75 to 0.95 with patents, but real government expenditure (for which she used the Consolidated Account component) was poorly correlated with patent activity (Cotter, 2006, p. 18). The number of patents in force Granger caused real GDP per (Cotter, 2006, p. 22). As in Victoria, patenting by foreigners increased as New Zealand's population increased (Cotter, 2006, p. 20).

A 2010 article by Greasley and Oxley examined the relationship between patenting and economic output in New Zealand in more depth using similar summary data. Greasley and Oxley noted that patenting in New Zealand typically led output between 1861 and 1939, with this occurring for five out of eight industry groups and for overall commodity output. However, for the key meat sector production led patenting, suggesting that pioneering

[1] RTA is the number of national applicants' patents in a technological field divided by the total number of patents in that country in a specific technology field, all divided by the total number of national patent applications divided by the total number of patents applied for from all countries. An equation for RTA is included in section 5.6.

industries were less likely to be led by patenting (Greasley & Oxley, 2010b, pp. 444, 452, 454).

In addition, Craigie developed a unique, but selective, unit record dataset on a sample of New Zealand primary sector patents between 1880 and 1895. Craigie found an increase in the geographic concentration of flax patents was associated with an increase in output in the agricultural sector. Total patent density in agriculture also boosted sector output consistent with agglomeration effects. Furthermore, the geographic concentration of dairying patents boosted sector output (Craigie, 2009, p. 19). The results suggested that agglomeration of innovation was only important for output in the dairy and flax industries (Craigie, 2009, p. 25).

Craigie found few intra-industry knowledge spillovers in dairying or sheep farming. However, there was some evidence of them occurring. For instance, the density of pastoral patents in Otago was positively correlated with the subsequent density of pastoral patents in Canterbury (Craigie, 2009, p. 28). There was also some evidence of inter-industry regional knowledge spillovers between related industries. The small sample size often made it difficult to reach firm conclusions, suggesting that a longer time period would produce firmer results (Craigie, 2009, p. 34).

2.4 The inclusiveness of patenting systems and the geographic location of patenting

The inclusiveness of patenting systems, and the consequences of this for economic development, has been an important research topic. Whereas in Britain high fees discouraged the working class from patenting (MacLeod, 2009, p. 42), low patent fees in the United States democratized invention during the nineteenth century. As a result, United States patentees came from a much wider range of occupational backgrounds than patentees in Britain. Nevertheless, in both countries the dominance of patenting by those in commerce and in the professions declined over time. Patentees in the United States patented less capital intensive inventions than in Britain because it was profitable to patent lower cost inventions (Khan, 2005, p. 7). Consistently over 40% of United States patents were traded by way of assignment, whereas in Britain it was harder to assign a patent and the proportion assigned was therefore never that high (Khan, 2005, p. 16).

In the United States and Britain usually over half of patents were by inventors who only filed one patent (Khan, 2005, p. 16). Few United States patentees specialized in particular

types of inventions (Khan, 2005, pp. 114, 118). Explanatory variables for the number of patents per patentee in the United States showed career patenting was higher in urban areas, in higher income areas, and in the most economically developed areas (Khan, 2005, p. 123). Machinists and metal workers were highly involved in patenting in the United States (Khan, 2005, p. 124).

In contrast, blacks and women were underrepresented in patenting in the United States. Indeed, even in the 1890s, women accounted for just over 1% of patents. Compared to other women, middle class women seemed to be overrepresented in patenting. So were women in frontier and rural regions, whereas male patentees tended to be in urban regions. This geographic bias was partly because property rights for women were stronger in the western states: once legal reforms protected the rights of women elsewhere patenting rates by women, particularly in urban areas, soared. Inventions by women were largely to do with home and family, and concentrated on minor improvements to existing goods (Khan, 2005, pp. 129, 135, 137, 142-143, 145, 181). Similarly few women patented during the 1800s in Australia (Magee, 2000, pp. 64-65).

Inventors during the nineteenth century in the United States tended to be clustered in places with better transport links, such as navigable waterways (Sokoloff, 1988, p. 813). In the modern-day United States higher density metropolitan areas still have the highest patenting rates (Carlino, Chatterjee, & Hunt, 2007, p. 389). Patenting in nineteenth Britain and in the colony of Victoria was largely an urban phenomenon, but there was gradual geographic dispersion (Magee, 2000, p. 42). An in-depth study of Norwegian patentees has found that although individuals accounted for most nineteenth century patents, they had strong connections with industry, making the distinction between professionals and amateurs not very useful (Basberg, 2014, p. 15). In nineteenth century Victoria, patenting was almost exclusively the preserve of individuals (Magee, 2000, pp. 64-65). A gradual shift from independent to corporate invention has been noted in the United States (Schmookler, 1966, p. 55).

Khan and Sokoloff looked at the patenting activities and background of important United States inventors, and noted their low education levels until the birth cohort of 1846-1865 (Khan & Sokoloff, 2004, p. 397). Concentrating on 160 great inventors who filed their first patent by 1846, Khan found half the sample had little or no formal education, but instead usually had practical training from apprenticeships, and that the proportion with technical education changed only gradually over time. Similarly, in Britain scientists, engineers, and

technicians were poorly represented among the most important British inventors until the 1870s. Instead, innovation was largely by artisans with apprenticeships (Khan, 2015, pp. 5, 12).

The middle aged and older were predominant in inventive activity in the United States, Britain, and Victoria during the nineteenth century. Sixty percent of great inventors in the United States patented for twenty or more years. Seventy percent migrated to two or more states. One fifth were involved in litigation involving their patents. United States patentees were disproportionately of immigrant origin (Khan, 2005, pp. 189, 191, 197, 201, 206, 214). About half of great inventors in the United States inventors obtained income by selling or licensing rights (Khan & Sokoloff, 2004, pp. 396, 398). Biographical data shows prolific patentees in Victoria were largely middle aged men from the British Isles, and the proportion of Catholics and Jews was lower than the proportion of these groups in Victoria's population (Magee, 2000, p. 76).

In the United States and Britain, agriculture received little attention from patentees. By contrast, in Australia many inventors focused on improving farming methods (Moyal, 2015). Patenting in Australia by United States inventors was similar to the level of British patenting in Australia by 1900 (Inkster, 1990, p. 47).

In Britain many inventors and patentees acquired heroic status during the Victorian era. Their achievements were recognized from the 1850s by the 1851 Great Exhibition, by writers of biography and popular self-help books, in obituaries in the *Times*, and by monuments (MacLeod, 1996, p. 141). Similarly, in the United States inventors such as Edison became revered (Khan, 2005, p. 185). However, inventors lost status during the twentieth century, at least in Britain. This was because attention switched to new heroes such as explorers and entertainers, invention became professionalized by scientists, and the short-comings of the industrial revolution were recognized (MacLeod, 2007, pp. 1, 3, 91, 177, 378, 380).

2.4.1 Invention and famous inventors in New Zealand

Limited research has been conducted into the inclusiveness of New Zealand's patenting system during the nineteenth century. However, in 1900 patenting per capita in New Zealand was 20 percent higher than in Australia, and more than twice the rate of most West European countries and the United States (Greasley & Oxley, 2010b, p. 450). During

the 1890s foreign patenting in New Zealand approximated that of Australia (Inkster, 1990, p. 60). Craigie used her unit record data, which included all patents for 1880-1886 (1400 cases), and primary sector, food and refrigeration patents for 1887-1895 (1591 cases), to show that most patentees patented just once or twice (Craigie, 2009, pp. 11-12). However, she did not calculate demographic characteristics for patentees, or identify the most prolific patentees.

Two books aimed at a general audience have also discussed innovation in New Zealand and important inventors, although their coverage has been very selective. Patented inventions by New Zealanders have also been discussed in other books, and recently on websites and in the media. For instance, Bob Riley has discussed Richard Pearse's development of the aileron for controlling the wings of aircraft in 1906. However, Pearse's failure to renew the patent before the First World War meant that he did not profit from the aircraft industry's adoption of his invention (Riley, 1995, p. 18). Similarly, Jon Bridges and David Downs have discussed how John Eustace failed to patent his airtight tin lid outside New Zealand during the 1890s, and therefore received no overseas revenue from his invention (Bridges & Downs, 2014a, p. 101).

In contrast, in the 1880s John Reid patented his successful Titan Wire Stretcher (Bridges & Downs, 2014a). Furthermore, in the early twentieth century Robert Dickie's innovative stamp vending machine was patented in New Zealand and overseas, and widely installed in many countries (Howard, 1964, pp. 178-179; Reid, 2007). Similarly, in the 1910s and 1920s Ernest Godward patented domestic appliances, including a spiral hairpin he sold for 20,000 pounds in the United States that would be worth $3.5 million now. Godward also patented a profitable fuel vapouriser in the 1910s and 1920s (Bridges & Downs, 2014b, pp. 101, 197, 203, 239). The high number of patents relating to milking machines during the early twentieth century has also been discussed (Riley, 1995, pp. 37, 41). Although the existing New Zealand literature has included some material on historical inventions and patents, the focus has often been on twentieth century innovation. Furthermore, previous researchers have not had access to data that would identify which inventors were the most prolific patentees, or which inventors spent most protecting their inventions.

2.5 The number of patents, patent renewal and patent quality

The number of patent applications has increased in most countries over time. Reductions in government fees, whether by inflation or by lower nominal charges, and reduced travel costs and fewer administrative obstacles for applicants were strongly associated with increases in patenting in Britain and the United States between 1790 and 1850 (Khan & Sokoloff, 1998). Researchers have frequently used patent counts as an indicator of inventiveness, but these counts are imperfect measures of innovation. This is partly because the rates at which initial patent applications have been allowed to lapse has often increased (MacLeod et al., 2003, pp. 555-558). In addition, important inventions in a particular area of research are also sometimes poorly correlated with the level of patenting in that area (Schmookler, 1966, pp. 66-67).

Renewal data is a valuable source of information on the value of patents because renewal indicates that its expected future earnings exceed the renewal cost. The high non-renewal rates found by researchers indicate many twentieth century patents have little economic value (Schankerman & Pakes, 1986, pp. 1054, 1056, 1059, 1067). For instance, Pakes and Schankerman used data on the percentage of patents renewed by payment of an annual fee in five European countries between 1930 and 1939. Their point estimate for the decay rate of knowledge was 0.25 (Pakes & Schankerman, 1984, pp. 75, 80). Using data on three European countries since the mid-1950s, Schankermann and Pakes found that the private returns from holding patents declined at a higher rate than the returns from most capital goods. Indeed, sometimes patent counts were negatively correlated with the mean values of patents from particular years (Lanjouw et al., 1998, p. 412; Schankerman & Pakes, 1986, pp. 1065, 1069-1070, 1075). However, strategic responses may result in the value of patents being underestimated. In particular, the mere possibility of being able to take out a patent might deter entry into an industry, and mean that established companies did not need to patent all their products (Pakes, Simpson, Judd, & Mansfield, 1989, p. 403).

In contrast to later periods, when Sullivan estimated the value of patent rights in Britain and in Ireland for 1852-1876 he found that there was no tradeoff between the quality and quantity of patents. One reason for this was low variation in the cost of a patent during this period (Sullivan, 1994, pp. 37, 49-50). In common with all studies located, Sullivan restricted his calculation of patent values to renewed patents and ignored the cost of the initial application.

MacLeod has argued that during the nineteenth century, when patent fees in Britain were relatively high, many British patents were not renewed because inventors were credit constrained, while some technically flawed patents (e.g. for perpetual motion) were renewed. Furthermore, some applicants for provisional protection were primarily interested in the prestige associated with patenting. As a result, renewals expenditure is an imperfect measure of the value of intellectual property (MacLeod et al., 2003, pp. 542-543, 560).

Patent citations and litigation over inventions are also increasingly used to value patents (Guellec, Van Pottlesberghe de la Potterie, & Zeebroek, 2007, p. 85). For instance, in the United States a three million case dataset on all patents between 1963 and 1999 now includes all 16 million patent citations. Trajtenberg has used this data to show how the citation weighted patent count received by computed tomography (CT) scanners was highly correlated with the social surplus generated by these inventions (Jaffe & Trajtenberg, 2002, pp. 1, 9, 12). Researchers have also valued patents by counting the number of countries in which patent protection for an invention is sought (Lanjouw et al., 1998, p. 405).

2.6 Conclusion

This chapter has considered the existing literature on patenting relevant to the research questions about the relationship between patenting and economic growth, and about the inclusiveness of the patenting system in New Zealand during the nineteenth century. It has focused on the literature on nineteenth century patenting in modern day Australia, the United States, and in Britain, although results from other countries and time periods and methodological advances, such as considering patent renewals, have also been considered.

Although the relationship between patenting and economic growth remains controversial, there is considerable evidence that patenting boosts economic development. Often patenting lags economic output, but the reverse was true for most New Zealand output areas between 1870 and 1938 (Greasley & Oxley, 2010b, p. 452). However, there is a need for further New Zealand research that considers the relationship between expenditure on patents and output rather than just the relationship between applications and output.

In the United States, Australia, and Britain there has been considerable research into the backgrounds of patentees, and the inclusiveness of the patenting system during the nineteenth century. However, there has been little research on this topic for nineteenth century New Zealand. There are therefore substantial gaps in the New Zealand literature on patents that this thesis seeks to remedy.

Chapter Three: Nineteenth century New Zealand patents legislation, debates about patents, and the advice patentees received

3.1 Introduction

This chapter outlines changes in legislation relating to patents in New Zealand, public and political commentary and debate about patenting and patent fees, and advice to patentees both in official guides and in guides published by patent agents. In addition, it quantifies changes in the cost of patenting, with official fees, required advertising and other costs, and recommended patent agent fees being considered. Key aims are to document changes in patenting costs, to understand the financial and other obstacles patentees faced, and the advice and help available to them.

Section two of this chapter discusses the patents legislation that was in force from 1860, and regularly revised, and changes in the requirements for receiving a patent. In section three New Zealand's pride in its level of patenting is outlined and the advice patentees received is summarised. Section four graphs changes in the real cost of patenting, while section five discusses how these costs are attributed in later chapters.

3.2 The 1860 Patents Act

Britain used the Treaty of Waitangi (1840) to assert its sovereignty over New Zealand, and self-government was achieved when New Zealand's first Parliament met in 1854. Initially inventors sought patent protection by petitioning Parliament, and two such applications were made in 1860. The Patents Act of 1860, which was based on similar 1854 legislation in the colony of Victoria in Australia, reflected a desire for more general rules for systematically managing patents in New Zealand (Parliamentary Reporter, 1860a, p. 3; 1860b, p. 3). Newspapers commented on the Act and also printed large sections (New Zealander reporter, 1861).

The Patents Act of 1860 stated that letters patent could be applied for by "Any person being the originator or discoverer of any new invention or improvement for which no patent or instrument in the nature of letters patent has been issued or granted in New Zealand or in any other country" (New Zealand Government, 1860, p. 96). Applicants were

to pay ten pounds, provide a clear written description of their "invention or improvement", and include drawings where necessary. Applications were to be advertised in the Government *Gazette* and in a newspaper in the main town of each Province, and objections could be lodged within four months on the payment of ten pounds. If the objection was sustained the patent applicant would be refunded the balance of their ten pounds after deductions for the cost of the investigation. From 1869 Hokitika was added to the list of places in which a patent notice had to be advertised (Bennett, 1869, p. 13).

Records of patents were to be kept (New Zealand Government, 1860, p. 97). When letters patent were granted the holder "shall have within the Colony for a term of fourteen years … after the granting of such letters patent the exclusive enjoyment and advantage in the Colony of such invention or improvement and the same protection and … the same remedies at law … as any person to whom letters patent have been granted under the Great Seal of England". Patents were to be assignable, which involved transferring ownership to another party, upon payment by the assignee or grantee to the Colonial Treasurer of ten shillings (New Zealand Government, 1860, p. 98). As in the other British Australasian colonies, this and subsequent New Zealand patent legislation broadly followed English law. However, there were some changes to meet local circumstances (Finn, 2000, p. 113).

Although "No person shall receive a patent under this Act for an invention or discovery which has been previously patented in Great Britain or any other country", holders or assignees of overseas patents could, upon payment of ten pounds, receive letters of registration. Letters of registration legally had the "same force and effect as letters patent" (New Zealand Government, 1860, p. 100). Their duration was for the length of patent protection in the patentee's home country.

3.2.1 The 1870 Patents Act

The much more detailed Patents Act 1870 replaced the 1860 Act. It stated that "It shall be lawful to make and issue … letters patent and grants of privilege, for any term not exceeding 14 years from the date thereof, of the sole working or making of any manner of new manufactures within New Zealand, to the true and first inventor of such manufactures". However, this was contingent on them being "not contrary to the law nor

mischievous to the State, by rising prices of commodities or hurt of trade, or generally inconvenient" (New Zealand Government, 1870a, p. 391). Inventions were now protected for six months after an application, whereas previously they had not, but people gained access to the specifications to make it easier to oppose the granting of letters patent. During this period applicants could make alterations to the application, while the Patent Officer could also require alterations. Applications had to be published by the applicant or their agent in the *Gazette,* and at their expense also printed twice in a newspaper in each province. At least sixty days later a patent hearing would take place, and if no objections were upheld the Patent Officer could grant a patent. The applicant then had three months to pay for the patent to be sealed. Letters patent were to have the date of deposit of the initial specification. Patent protection expired after three years unless an extension fee was paid. Inventions had to be brought into use within two years from the date of letters patent or patent protection would expire (New Zealand Government, 1870a, pp. 390-391, 393-394, 396).

As in 1860, letters of registration were granted to patent holders in other countries and colonies for patent protection in New Zealand at a cost of ten pounds. Rules and Regulations issued in 1871 under the Patents Act provided for a Patent Office within the Colonial Secretary's Office and for further details about record keeping and fees, including the writing of applications upon "skin or skins of parchments" (Governor, 1871, pp. 525-526). The Patent Office was to keep a book called the Register of Patents containing unit record data on each patent. There was also be a book called the Register of Proprietors (New Zealand Government, 1870a, pp. 394, 397).

A fee of two pounds 10 shillings was due on depositing the specification, and a further two pounds 10 shillings charged for obtaining letters patent. In addition, advertising costs were incurred when a patentee decided to proceed with an application by placing an advertisement in the *Gazette* and in newspapers. Under the 1870 Act, 15 pounds was due for seeking an extension at or before the expiry of the third year (New Zealand Government, 1870a, p. 402). As a result, fees were lower for the initial application, but higher for a 14 year term, to allow inventors to test whether they could get a return on their invention (Gisborne, 1870, p. 31).

Whereas the 1860 Act had passed after only very brief discussion in Parliament (Stafford, 1860), there was much fuller discussion of the 1870 legislation. Drawing on arguments that remained popular in Britain, and citing stories in the London *Times*, it was argued

that patents allowed individuals to benefit from general scientific progress, encouraged litigation, and were injurious to economic progress (Waterhouse, 1870). However, patents were defended as "securing the just reward to the inventor to stimulate invention, and thus allow science to be utilized as a substitute … for manual labour" (Gisborne, 1870, p. 67). During the Parliamentary debate the term of patents was extended from the proposed seven years to 14 years to encourage invention and to ensure an appropriate reward for inventors (O'Neill, 1870, p. 55). A government booklet summarised the patent act in straightforward terms for inventors (New Zealand Government, 1870b).

3.2.2 The 1879 Patents Amendment Act

During the 1870s there was pressure to reduce application fees, with it being argued that application fees dissuaded "intelligent artisans" from applying (Hutchison, 1879, p. 66), and to reduce use of patent fees as a government revenue stream (Reynolds, 1879, p. 66). The Patents Act Amendment Act of 1879 slightly reduced the fee for obtaining a patent from 1880 onwards, and halved advertising costs by only requiring one insertion in the *Gazette* and in a newspaper in each province. The 1879 amendment also considerably reduced the renewal fee from 15 to 10 pounds. (New Zealand Government, 1879).

Then, in response to strong political pressure (Barron, 1881, p. 607), an 1881 amendment reduced the cost from 1 January 1882 (if there was no opposition) from 14 to ten pounds of getting and renewing a patent to full term from 1882, with the application fee being halved. Only seven pounds was now due for seeking an extension at or before the expiry of the fifth year, compared to 10 pounds previously (New Zealand Government, 1881). One justification was that Patent Office costs were only about 100 pounds a year, which was less than a quarter of the Office's estimated revenue (Barron, 1881, p. 607).

Patent applications also immediately no longer needed to be advertised in newspapers, and the advertisement in the *Gazette* was now paid for by the Patent Office (Barron, 1881; New Zealand Government, 1881, p. 183). An editorial in a Dunedin newspaper argued that these changes were likely to have a "favourable effect on the local development of inventions". Furthermore, the editorial argued that much of the "inventive genius" of the United States was attributable to low patent fees and laws that protected inventors (Evening Star editor, 1881, p. 1).

3.2.3 The 1883 Patents Acts

The Patents Act was amended in September 1882 to reduce the cost of depositing an application to ten shillings, which was half of its previous level (Haselden, 1883, p. 7). The Patents Act 1883 then consolidated laws relating to patents, although many of its provisions were similar to the 1870 legislation. A fee of 10 shillings was due on depositing the specification and a further 10 shillings was charged for amending the patent (New Zealand Government, 1883, p. 123).[2] Applications could now be on either parchment or paper, and a standard form was on sale at Post Offices. The need for an agent of the applicant to be present for unopposed applications was also abolished. The *Evening Post* commented that the "the procedure of obtaining patents in New Zealand is believed now to be simpler and the fees less than in any other place in the world" (Evening Post editor, 1883, p. 2). An increase in patenting was attributed to the low application fee (Greenshields, 1884, p. 2).

Nevertheless, the forty shilling cost of depositing a specification, revising the specification, and getting the patent sealed would have been roughly equal to a general labourer's weekly wage. Even a skilled tradesperson would have had to work for three days to afford the cost (Registrar General's Office, 1884, pp. 186-187).

[2] There were 20 shillings in a pound and 12 pence in a shilling, and therefore 240 pence in a pound.

Table 3.1: Nominal cost of applying for and renewing a patent

Act	1860	1870	1879	1881	1882	1883	1889
Into force	1861	1871	1880	1882	Sept 1882	1884	1890
On depositing specification	£10.0	£2/10	£2.00	£1.00	£0/10	£0/10	£0/10
On depositing revised specification						£0/10	£0/10*
On obtaining letters patent		£2/10	£2.00	£2.00	£2.00	£2.00	£2.00
Extending patent before 3rd year		£15.0	£10.0				
Extending patent before 4th year							£5.00
Extending patent before 5th year				£7.00	£7.00	£7.00	
Extending patent before 7th year							£10.00
Cost of taking to 14 years nominal	£10.0	£20.0	£14.0	£10.0	£9.5	£9.5 or £10.0	£17.5 or £18
Cost of taking to 14 years 1861 values (as decimal)	£10.0	£24.1	£20.25	£14.2		£14.3 or £15.0	£20.9 or £30.2
Deposit for challenging	£10.0	£2/10	£2	£2	£2	£2	10s
Cost of revising	£10.0	£2/10	£2/10	£2/10	£2/10	£2/10	£1
Letters of registration	£10.0	£10.0	£10.0	£10.0	£10.0	£10.0	-

*Providing lodged provisional specification in first instance. If filed complete specification initially the cost of amending the specification was £1.00.

Table 3.2: The duration of a patent

Act	**1860**	**1870**	**1883**	**1889**
On application	4 months	6 months	12 months	12 months
Initial term	14 years	3 years	5 years	4 years
2nd term				3 years
Maximum duration after sealing	14 years	14 years	14 years	14 years, but could ask for further 7 years or 14 in "exceptional cases"

3.2.4 The 1889 Patents Act

The Patents, Designs and Trade-marks Act 1889 was "practically the same as the Imperial Patents, Designs and Trade-marks Act of 1883", with slight modifications to accommodate "different conditions" (Registrar Patents Office, 1890, p. 1). The 1889 Patents Act, which came into force from January 1890, stated that any person, "whether a British subject or

not, may make an application for a patent" (New Zealand Government, 1889, p. 23). A patent could "be granted to several persons jointly, some or one of whom is the true and first inventors or inventor". Patent agents now had to be registered. Britain applied section 103 of the Imperial Patents, Designs, and Trade-marks Act to New Zealand, giving New Zealand applications for letters patent priority in Great Britain (Registrar Patents Office, 1890, p. 2). The new act contained no provision for letters of registration for patents filed elsewhere in the world in order to ensure uniformity with other countries (Registrar Patents Office, 1890, p. 2).

The 1889 Act noted that each application "must be accompanied by either a provisional or complete specification" (New Zealand Government, 1889, p. 23). The Registrar was to examine each patent to ascertain whether the "invention has been clearly described, and the application, specification, and drawings (if any) have been prepared in the prescribed manner, and the title sufficiently indicates the subject-matter of the invention". The Registrar could refuse the application, require amendments, or accept the application. Unless a complete specification was submitted within nine months from the date of the acceptance of an application it would be deemed to be abandoned (New Zealand Government, 1889, p. 24). By filing the complete specification immediately the 10 shilling provisional specification filing fee was avoided and only 10 shillings was payable. However, if a complete specification had been initially lodged instead of a provisional specification the cost of filing a revised specification doubled from 10 shillings to a pound (New Zealand Government, 1889, p. 59).

Complete specifications that were accepted continued to be advertised in the *Gazette*, in part to allow for objections to the patent. After the expiry of the two month period in which objections were allowed, but before the expiry of provisional protection, applicants could pay a fee to have a patent prepared and for the patent to be sealed. After sealing a patent existed for 14 years from the date from which the patent took effect, contingent on prescribed payments. An additional term of seven "or in exceptional cases, 14 years" could be granted. Existing laws on payments for patents continued to apply to patents previously granted (New Zealand Government, 1889, pp. 24-26, 29, 33). Although there was little debate of the changes in Parliament, the increase in renewal fees was criticised in a newspaper editorial for ending the low fees that had prevailed since the early 1880s (New Zealand Herald editor, 1889).

A patent agency advised inventors that patents could not be gained for a "natural product, game of skill, method of calculation, or an abstract principle" unless connected with an apparatus with which they can be made useful. The nominee, or assignee, or the legal representative of an inventor could apply for a patent. In addition, women and minors could apply for patents (Hughes, 1895, p. 5).

There were now four stages in the life of a patent: firstly the application; secondly the granting of the patent; thirdly the payment of the first renewal fee; and fourthly the payment of the second renewal fee. A rare fifth stage was petitioning for a further patent extension on the basis that the inventors had received inadequate remuneration for their invention. The first such application to the Supreme Court was made in 1898, by the Christchurch agricultural engineers William Andrews and Arthur Beaven, and was successful (Registrar Patents Office, 1899, p. 1).

During the early 1890s it was also argued that support for patentees should be increased, by employing more staff and making library resources easier to access (Murdoch, 1892). Increasingly detailed information on patent applications from 2 April 1891 was in a supplement to the New Zealand Government *Gazette* (Agricola, 1891, p. 5). The Registrar of Patents expressed concern that few people subscribed to this supplement, although he thought business people would derive considerable benefit from it, especially since newspapers no longer printed descriptions of patent applications (Registrar Patents Office, 1892). Patent specifications became easier to access in mid-1899 when the patents supplement to the *Gazette* began printing descriptions of completed patents.

The Registrar thought New Zealand manufacturers needed to make more use of the patent system to protect their intellectual property (Registrar Patents Office, 1892, p. 2). He noted that the Patent Office lacked the resources to conduct research into the novelty of inventions, and judgements were therefore based on the Registrar's prior knowledge (Registrar Patents Office, 1890, p. 2).

The *Gazette* of 11 May 1899 contained new and additional patent regulations. Applicants now had to provide a New Zealand address. New rules for foreign applicants were laid down (Prendergast, 1899). There were minor changes to fees, which halved the cost of gaining an extension of time on an application, and also halved the cost of obtaining complete patent specifications (Murdoch, 1899).

3.2.5 International Convention for the Protection of Industrial Property (1891)

From 1891 New Zealand was part of the International Convention for the Protection of Industrial Property, which had been signed by some European and American countries, including Great Britain, in 1883. This provided for the citizens of contracting states to register patents in member countries, and to have the same legal protection as the citizens of these states (New Zealand Government, 1891, pp. 1349-1352). A person who had secured protection in a contracting state now had 12 months to apply for letters patent for their invention in any other member state without losing their rights through piracy or publication by another party. Effectively this meant that patentees now had a year to decide whether their invention was worth patenting overseas (Registrar Patents Office, 1893, p. 1)

3.3 Pride in the level of patenting and patent guides

There was considerable pride in the fact that by the late 1880s New Zealanders patented at a higher level per capita than people in the United States (Evening Star reporter, 1889, p. 1). However, one newspaper argued that most patents were for "old and valueless inventions" and that the number of patents in no way reflected the level of industrial progress (Hawke's Bay Herald editor, 1889, p. 2). Nevertheless, after the Patent Office began an annual report in 1890 this usually merited at least a paragraph in metropolitan newspapers (Auckland Star Reporter, 1896, p. 4; Otago Daily Times reporter, 1896, p. 4; Otago Daily Times Wellington correspondent, p. 2; Press reporter, 1893, p. 4). The volume of New Zealand patenting in New South Wales was high. Furthermore, the number of applications in London from New Zealand exceeded those from any other British colony and possession except Victoria, Canada, and India, and also most foreign states (Registrar Patents Office, 1890, p. 3).

Several patent guides were produced by agents from the 1880s, and an 1890 guide by the Hastings patent agent H.H. Murdoch was serialised in a newspaper as well as printed as a brochure (Murdoch, 1890b). Murdoch's 1890 guide noted that most inventors would need to develop inventions that had low capital requirements and provided a chance of making an immediate profit through producing a slight improvement. He noted that labour-saving inventions, and better agricultural and household goods paid well. Firearms and munitions inventions, by contrast, had low market potential and risked appropriation,

without payment, by governments. Inventors were advised to concentrate on their own branch of trade (Murdoch, 1890d, p. 6). Patenting was described as a lottery, but also as being no more speculative than other commercial enterprises (Murdoch, 1890f, p. 2). A 1901 guide by Henry Hughes, which had become the dominant patent agency firm with six New Zealand offices, printed a list of inventions required. It was observed that "Anything that will perform a well-known work quicker or better than heretofore, or make a well-known machine more efficient, is patentable" (Henry Hughes Limited, 1901, p. 27).

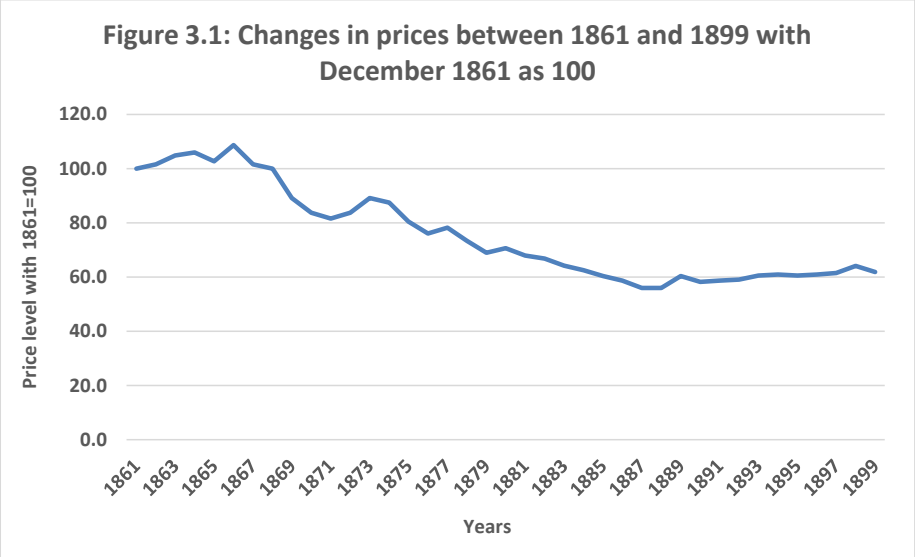
Murdoch's 1890 guide discussed the need for secrecy and to protect intellectual property from claims by workmen. The importance of protecting inventions in England and in the United States was emphasised. In contrast, patents in Europe were often contingent on producing an invention there within a fixed period of time. Patenting in Germany was not seen as worthwhile due to anti-British feeling resulting in German courts not upholding British patents (Murdoch, 1890e, p. 5). Since provisional specifications provided protection for nine months, there was time to gain international protection. However, the provisional specification had to be close to the complete specification or it could be refused or challenged legally (Henry Hughes Limited, 1901, p. 12). The desirability of selling or licensing patent rights was discussed, and of having a good working model, and of high quality promotional work (Henry Hughes Limited, 1901, pp. 15-16, 20). Indeed, marketing was seen as crucial to the returns generated by an invention (Murdoch, 1890f). Advice on raising capital from friends was given (Henry Hughes Limited, 1901, p. 27).

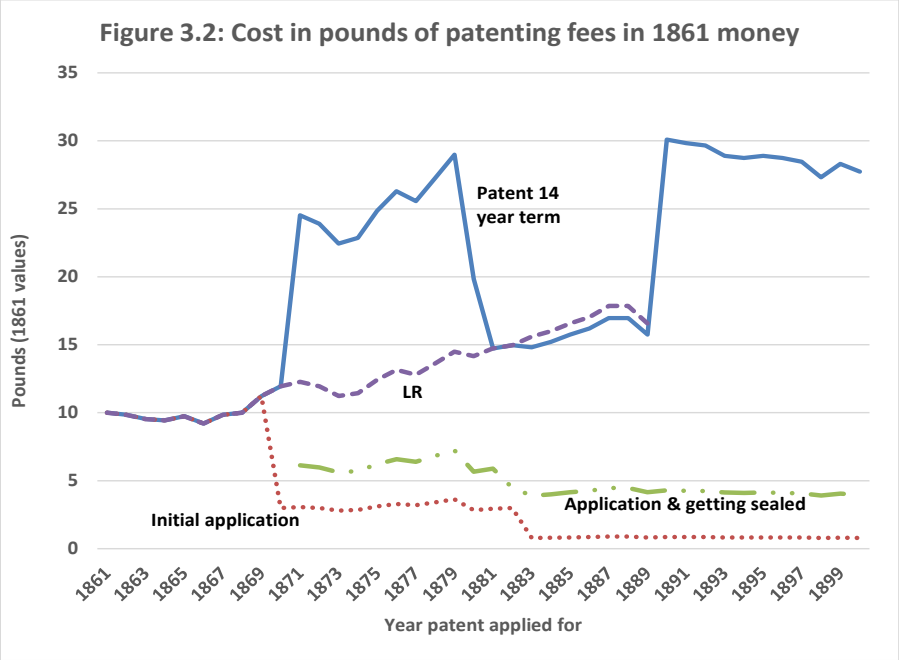
3.4 The inflation adjusted cost of patenting fees

Although New Zealand's historic inflation statistics have limitations, the best available data, which is shown in Figure 3.1, suggests that consumer prices in New Zealand fell by 40% between the late 1860s and the early 1870s (Briggs, 2003), before slightly increasing over time. Figure 3.2 shows that the total cost in government fees of patenting an invention for 14 years fluctuated only slightly in the 1860s, before increasing sharply in 1871 and becoming considerably greater than the cost of a letter of registration. However, Table 3.1 shows that the initial cost in patent fees of taking out a patent fell from 1871, even though the cost of a 14 year term increased substantially. The real total cost of taking a patent to 14 years trended upwards, before sharply falling as a result of lower fees from 1880, and fell for the same reason again in 1881. However, the real cost of a 14 year term was above 14 pounds during most of the 1880s, and trended upwards as prices fell. From

1890 there was a sharp increase in fees for a 14 year term. Although for the next ten years inflation slightly reduced real patent fees, the real cost of a 14 year term remained over 25 pounds.

From 1871 the combined legislated cost of an initial application and of getting a patent sealed, which is plotted in Figure 3.2, was much lower than for patenting for a 14 year term. However, under the 1860 Act there was provision for unsuccessful applicants to be refunded fees paid, less administration expenses (New Zealand Government, 1860, p. 97). Unsuccessful patent applications in the 1860s were therefore attributed two and a half pounds in fees in later chapters. The cost of an initial application fell from almost two pounds in 1860 values in 1871 to half a pound (10 shillings) for complete specifications for a patent filed in the 1890s. The cost of getting a patent sealed remained stable in nominal terms from 1882 at two pounds. In 1893 general labourers earned on average just over two pounds per week (Greasley & Oxley, 2004, p. 31), which would have made getting a patent sealed a significant cost.





The cost of advertising for a patent application had long been contentious, and was seen as adding unnecessarily to the cost of a patent (Editor, 1870, p. 2). In 1879 the estimated cost of required advertising when making a patent application was 11 to 12 pounds. It was stated by one patentee that "the costs of obtaining a patent seldom exceeds twenty five or thirty pounds" (Quest, 1879, p. 2). However, another patentee stated that in 1880 the cost for obtaining a patent, once advertising and patent agent fees were taken into account, had amounted to 42 pounds for 14 years protection (McColl, 1882a, p. 3; 1882b, p. 3). The Christchurch coach builder Abiel Howland put the cost of his 1868 and 1875 patents as being between 30 and 40 pounds each (Press reporter, 1880, p. 3). In 1881, when advertising requirements had been reduced, it was estimated by one newspaper that the cost of fees, advertisements, and agents for a patent was about 30 pounds (North Otago Times editor, 1881). One prominent patentee argued in 1882 that advertising costs had often exceeded patent fees, and that drawing costs were at least two pounds (Greenshields, 1882a, p. 3; 1882b, p. 6).

A letter in the *Otago Daily Times* put the 1881 cost of gaining a patent in Dunedin, excluding renewal fees, as being over 16 pounds, even though the patentee had prepared their own drawings at a saving of almost two pounds, with the costs shown in Table 3.3. The author of the letter, who was probably the 1881 Dunedin patentee Robert Scott, argued that was scope for preparation costs to be reduced (R.S., 1882, p. 3). The need for patent applications to be on parchment ceased at the end of 1883, and instead applications could be made on a standard form that cost sixpence. A rough estimate from

Auckland from 1882 put costs for applying for a patent at about 17 pounds (Citizen, 1882, p. 3; Hesketh & Richmond, 1882, p. 2). To place these costs in context, at this time a cow cost three to seven pounds, a saddle horse about 12 pounds, and a draught horse about 20 to 30 pounds (Registrar General's Office, 1884, p. 188).

Table 3.3: Estimated total costs of taking out a patent in 1881 before the elimination of advertising requirements

Expenses	Cost in pounds, shillings and pence
Dunedin agent	5/0/0
Wellington agent	1/1/0
Telegrams and postage	0/4/2
Advertising once in 10 newspapers	5/4/0
Cost of application and sealing patent	4/0/0
Miscellaneous expenses	0/3/0
Preparing specification and parchment	0/10/0
Total	16/8/8

Subsequently the *Otago Daily Times* stated that the imminent opening of local patent offices would save those in the regions five pounds per application on agency fees (Otago Daily Times reporter, 1882, p. 6). However, the only active patent agent in Wellington argued that the savings were illusionary since inventors would still need specialist help with checking the specifications and drawings, in addition to attendance at the Patent Office. He stated two pounds five shillings would be a standard charge for these services (Carroll, 1882, p. 4). In 1886 a patent agent noted that properly applying for provisional registration would cost two pounds, with three-quarters of this for checking the preparation and drawings met legal requirements. A further payment of one pound to the patent agent would cover the agent's costs related to getting the patent sealed, making total payments to the agent for their services two and a half pounds. Patent agency costs for letters of registration were five pounds. However, the author of the guide commented that some patentees were seeking cheap publicity for their products by filing provisional patents that would not survive legal scrutiny (Galbraith, 1886, p. 4).

H.H. Murdoch's 1890 patenting guide implied that four pounds ten shillings should be budgeted for agent fees for getting a patent to complete status. Having drawings prepared could add another four pounds to the cost (Murdoch, 1890a, p. 2; 1890c, p. 2).

In 1899 the head of the leading patent agency firm stated that it paid on behalf of its clients two-thirds of patent fees (Rayward, 1899, p. 5), indicating that most patentees were paying for the services of an agency. Indeed, its surviving publicity material includes glowing testimonials from New Zealand's leading patentees (Henry Hughes Limited, 1901).

3.5 Attribution of these expenses

Attribution of advertising, agency, and other costs is therefore difficult. Furthermore, between 1874 and 1891 there is no information available on which patent applications included drawings. Nevertheless, newspaper advertising cost estimates seem to be about 11 pounds in the late 1870s when two insertions were required, and about half that amount from 1880 until newspaper advertising requirements ended in September 1881. These amounts were attributed to all applications advertised in newspapers and adjusted for inflation. Only one insertion was required for advertisements up to 1871, which halved the real cost for this period. Patents advertised in newspapers were identified using *Papers Past*.

Parchment costs were attributed until this requirement was dropped in 1884, and adjusted for inflation. Subsequently patent applications were on a standard form, and the sixpence cost of this was attributed. These costs were attributed both to letters patent and to letters of registration.

Agency cost estimates are more variable, with patent agent estimates by Carroll and Galbraith being considerably lower than either O.S.'s 1881 recorded costs or H.H. Murdoch's 1890 quote. Furthermore, no details are available on fees charged by Henry Hughes, which became the biggest patent agency in the 1890s. Although New Zealand's National Library holds some of Henry Hughes' archives, none of the files held are for the nineteenth century (Henry Hughes Limited, 1874-1979). Agent fees and drawing costs have therefore been treated as a constant and not attributed.

Figure 3.3 shows the main non-government fee cost of patenting in 1861 money, excluding the costs of an agent and of preparing drawings. Since prices of different goods and services have been assumed to change in response to the consumer price index, the only driver of real costs has been changes in government requirements.

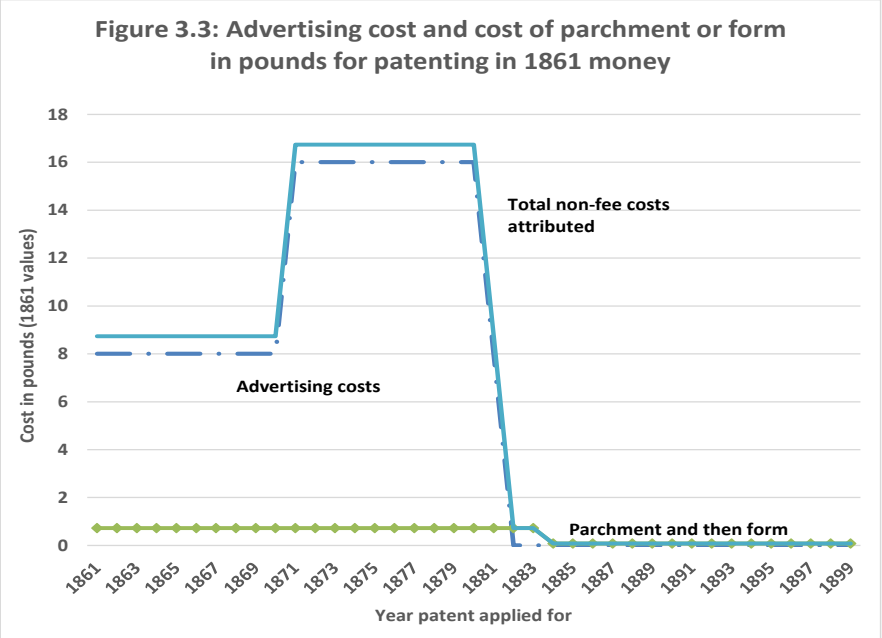
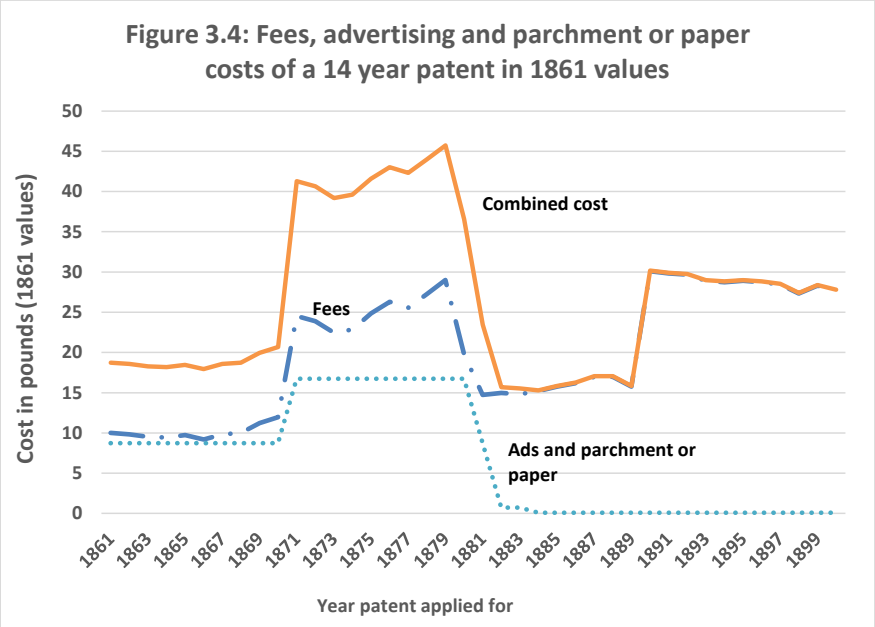


Figure 3.4 shows the calculated fees and advertising cost of taking out a 14 year patent in 1861 values. Compulsory newspaper advertising and parchment costs were almost as expensive as government fees until the early 1880s. The total cost of a 14 year patent increased sharply after 1870, before declining in the early 1880s. Increased government fees from 1890 then increased the total cost of a 14 year patent to about 30 pounds, which was about 10 pounds higher than in the 1860s.



3.6 Conclusion

This chapter has outlined the legislation and parliamentary debate relating to patents in New Zealand from the first Patents Act in 1860 to legislative and fee changes in the 1890s. Changes in the real and nominal cost of patent fees have been discussed, while the cost of required newspaper advertising and of other costs of applying for a patent have also been considered.

The results showed that fees and required advertising costs meant that the cost of applying for a patent was considered high until initial fees were reduced and advertising requirements abandoned in the early 1880s. Indeed, in the 1870s compulsory advertising costs for patent applications were considerably higher than the combined application fee and subsequent cost of sealing a patent. However, even after application and sealing fees were reduced in the early 1880s to make patent protection more affordable for tradespeople, the fee for getting a patent sealed would have approximately equalled a labourer's weekly wage. The real cost of a 14 year patent was higher in the 1890s than in the 1860s, but lower than in the 1870s.

Chapter 4: The patents dataset and other datasets

4.1 Introduction

This chapter outlines how patent data between 1860 and 1899 has collected and coded, and provides information on other datasets used in this thesis. The focus is on the data used, with chapter five being the first results chapter.

Section two details the varied sources of the first 440 patents located, while section three covers how digitalised records since 1880 were copied into Excel. Section four outlines the collection of information on when patents lapsed or were renewed. The patents data was coded using a methodology developed by Magee for Victoria (Magee, 2000, pp. 29-32), and this is described in section five. Section six discusses how the country and region of patentees were coded, and also includes regional and urban population statistics. New urban population series have been developed to quantify the number of New Zealanders living in the four main centres. In section seven the occupation codes used in chapter seven are discussed. Section eight briefly outlines the sources used to research prolific and high spending patentees. Finally, section nine concludes this chapter.

4.2 The 1860-1879 data

Record keeping for New Zealand patents until the 1870s was poor, and even in 1871 the new Patent Office was being reminded to improve its record keeping (Bowen, 1871, pp. 172-174). Details of 206 patents in New Zealand between 1860 and 1873 were retrospectively published in an 1874 publication called *Specifications of Inventions*, although due to imperfect record keeping it was noted that five early specifications were missing (Patent Office, 1874, p. iv). Patents up to 1870 were also subsequently numbered and recorded in a ledgers book, now held at Archives New Zealand in Wellington. Subsequent patent applications were also recorded in this book, which is held at archive number AEGA 18986, and in subsequent ledger books now also held by Archives New Zealand (Patent Office, 1861-).

Between 1874 and 1879 patent specifications numbers 208-418 were published annually by the Patent Office in a similar format, and a distinction was made between letters patent and letters of registration (Patent Office, 1875-1879). The date when patents applied for

before mid-1875 lapsed is not available from the *Specifications*, so this information was collected from the ledger. In addition, information on the original inventor is not always available for overseas letters of registration for 1861-1873 (Patent Office, 1874, p. iv), although some original inventors were identified by searching electronic United States patent records from this period. From the end of 1874, details were given for letters of registration when the person was an assignee or acting in accordance with a communication from abroad. In these cases the original inventor's details were used, with the assignees' names, addresses and occupations recorded in separate columns. Sometimes there were up to nine patentees, although for applications by New Zealanders there were a maximum of three authors.

Data in the *Specifications of Inventions* was checked against the New Zealand Government *Gazette*. The University of Waikato has unique software, which is only available on its campus, for searching the *Gazette*, but there are still limitations to the type of searches than can be made. Newspapers in *Papers Past*, which contains scanned text from many New Zealand newspapers, were therefore also searched. However, letters of registration were not advertised in newspapers. It was discovered that the *Specifications* and Ledger in Wellington omitted unsuccessful patent applications up to the end of 1870. In addition, a successful patent application and a successful letter of registration application from the early 1860s were located. As a result, an additional 22 cases (20 unsuccessful applications and 2 successful) were added to the dataset.

Furthermore, up to the middle of 1871 the *Specifications* published the date a patent was issued. From July 1871, however, application dates for patents were published. The date the patent was applied for, or when this was missing the date the patent was advertised in the *Gazette*, was added to the dataset. Until the end of the newspaper advertising requirement in late 1881, a check was made of which patents were advertised in the *Gazette* and in newspapers.

4.3 The 1880-1899 data

Between 1880 and 1893 unit record data on patents was published, more or less in numeric order, in the Patents Office *Annual Report* in the *Appendices of the Journals of the House of Representatives*, and this includes patents 419-6598. The 1894 *Annual Report* was the last to print detailed information on each application for letters patent,

which it does for 1893 (Registrar Patents Office, 1894, pp. 16-37). However, from 1895 the *Annual Report* printed alphabetical lists of applicants and the titles of inventions (Registrar Patents Office, 1895).

Increasingly detailed information on patent applications from 2 April 1891 is in in a supplement to the New Zealand Government *Gazette* (Agricola, 1891, p. 5). There patent records were split into "Notice of Acceptance of Complete Specification" and "Provisional Specifications", whereas in the *Annual Report* there had simply been a single "List of Applications for Letters Patent". Both provisional and complete specifications were brought into Excel for 1894-1899, and these patents were numbered 6599 to 12282. Some 1899 patent applications were not published until 1900, but these have still been included in the dataset. The final dataset included 12,283 patent applications.

Whereas the 1860-1879 data was copied from primary sources into Excel, the data from 1880 was copied from pdf documents into Word, checked against paper copies, and rearranged for Excel. Tabs were used to put text into columns (Hood, 2005, p. 222), using common symbols and words in the text. However, variations in how patent applications were arranged made this a time consuming process.

4.4 Status of the patents and accuracy of the data

Considerable information was available on when patent applications lapsed or were refused, when provisional applications became complete, and when patents were renewed or lapsed. This information was collected from checking the *Gazette*'s patents supplement up to 1907, the Patent Office's *Annual Report*, and the *Specification of Inventions*. During the 1890s the *Gazette* progressively published more information on the status of patents.

For 1890 and 1891 sealed dates from the Ledger were copied into *Excel*, and from 1893 the year a patent was sealed was available from the *Gazette*. For patent applications before 1890 the sealed date was estimated by adding 120 days onto the application date to get the estimated year a patent was sealed. Renewed patents were attributed the fee paid in the year the renewal was made, which was sometimes considerably earlier than when the renewal fee was due.

The *Gazette* search engine at Waikato University was able to search for particular patents by number and by author. Nevertheless there are gaps in the information originally

recorded in the *Gazette* and in other published sources. Some information was therefore collected by checking the hand-written patent ledgers in Wellington. Although Archives New Zealand holds most of the early patent applications, these detailed hand-written documents were not consulted. Due to time constraints data on the assignment of successful patents, which is recorded in a variety of sources, was not collected.

There are a few inconsistencies in the data, and limitations to the records. The ledgers were hand-written and during the nineteenth century people did not always spell their names consistently. When people have varied the spelling of their name *Papers Past* was consulted along with overseas patent records and history books to establish the most usual spelling they used. The records were then amended, and noted in a comment in Excel. Although all the records were carefully read through, additional checks would undoubtedly result in some further changes. Nevertheless, the data is clean enough for occupations and location to be able to be coded in Stata using a computer program to recognise the names of occupations and places.

4.5 Patents coded by industry of use

The coding scheme for patents in this thesis is based on the methodology used by Gary Magee, who categorised patents into three sectors and 33 categories "according to their primary intended use (rather than origin): that is, the industry where the principle and ideas embodied in the patent were expected by the patentee to be employed". Magee used this method rather than categorising inventions according to either their technological properties or by the industry that produces the invention (Magee, 2000, p. 29).

Three studies have applied Magee's methodology to New Zealand. Cotter applied this methodology to New Zealand patents for 1871-1894 using totals for patent applications for different activities published in statistics books, although multiple uses were recorded in these sources (Cotter, 2006, pp. 9,12). Furthermore, Greasley and Oxley used Magee's categories to code total patents in statistical reports from 1871-1939, but also merged categories for some of their analysis. For instance, food preserving and refrigeration were included in a pastoral patents group. Craigie applied Magee's framework to a sample of individual patent records, but included subcategories for some primary sector patents.

For instance, for the pastoral and dairying categories she included subcategories for patents on sheep, fencing, and on pest removal (Craigie, 2009, pp. 16-19).

Some of the main patenting categories and brief descriptions are included in Table 4.1. Further details are in Appendix A.

Table 4.1: Selected examples of industry categories for patents

Primary sector	
1. Agriculture	Agricultural machinery, processes in agriculture, ways to protect and encourage agricultural growth and profits.
2. Pastoral	Techniques and equipment relating to sheep farming and particularly shearing. Includes fencing and exterminating rabbits.
3. Dairying	Dairy farming and storage of cream, milk and butter.
Mining sector	
4. General mining	Boring through rock, excavating machines, dredging.
5. Mechanical and chemical mining	Amalgamating, pulverising and crushing of ores, extraction of chemicals, metal etc.
Secondary sector	
6. Construction and infrastructure	Earthworks, building construction, large man-made objects such as iron bridges and any new designs of building objects. Sewage.
10. Furniture	Billiard tables, household furniture, furniture making, beds, bedding and mattresses, picture frames, window and veranda blinds.
15. Clothing and textiles	Clothing, boots, shoes, repairs of and accessories, cleaning and preparing for use, flax and treatment and preparation of flax.
18. Refrigeration	Ice making, refrigerating and cooling.
23. Heat, light and power	Generating electric light, power and heat. Includes heating equipment, lighting equipment such as lamps and gas works.
Tertiary sector	
28. Railway	Increasing the efficiency of railways, railway goods and rail services.
30. Communications	Telegraphs, telegraphic wires and cables, telephone. Letters, fire-alarms, clocks, post boxes.
Household sector	
31. Household consumer goods	Parlour games, ornaments, water and earth closets, tea strainers, bread boxes, bathtubs.
32. Household producer goods	Goods which are used in the running of a household. Washing machines, stoves, ovens, clothes pegs, garden instruments, fire-extinguishers.

4.6 Data on geographic location

The modern-day country of patentees was coded using self-reported country or colony. For instance, references to the German Empire or to Prussia were coded as Germany. Patents from the self-governing colonies of New South Wales and Victoria were coded as Australia, even though Australia came into existence as a nation state only in 1901.

Region was coded for patentees living in New Zealand. Between 1852 and 1876 New Zealand was divided into provinces, with nine existing in 1876. Although the provinces were abolished in 1876, the legislation that abolished them renamed the geographic entities covered by each province as Provincial Districts with the same name as previously (New Zealand Government, 1875, pp. 56, 58). Statistical publications regularly reported economic statistics on a provincial basis (McLintock, 1966).

Historic regions in New Zealand sometimes differ from current regions (Dictionary of New Zealand Biography, 1973, pp. 66-67). In particular, the Auckland area covered the upper half of the North Island and encompassed the current Northland, Auckland, Waikato, Bay of Plenty, and Gisborne regions. The Wellington region also included part of the modern Taranaki region, most notably Waverley. In the South Island the Nelson region extended south to include large parts of the current West Coast region, with the latter region only splitting from Canterbury in 1873. Southland was only separate from Otago for 1861-1870. Although some statistics were reported at a more finely grained level (Bloomfield, 1984, pp. 11-14; Kelly & Marshall, 1996, pp. 18-19), reworking them to apply to modern boundaries was not possible within the time available. In any case, the new upper North Island regions were sparsely populated during the period covered.

The New Zealand data was therefore sometimes analysed using the nine provincial districts the Statistics Department used for reporting purposes. However, because four fields were used for address information, more detailed analysis of people's location is also possible.

A dataset developed by Rebecca Craigie from the annual *Statistics of the Colony of New Zealand* (Craigie, 2009) has been extended for national and regional population statistics that unfortunately exclude New Zealand's indigenous Maori population. During the period covered New Zealand's Maori population, which largely lived in remote parts of the North Island, was counted less regularly and systematically than the non-Maori

population (Pool, 1991, pp. 64-67). Figure 4.1 shows New Zealand's non-Maori population grew sharply between 1860 and 1899, with the main causes being high migration from Britain and increasingly natural increase. Whereas in 1860 New Zealand's population (excluding Maori) was 83,919, by 1899 it was 756,243.

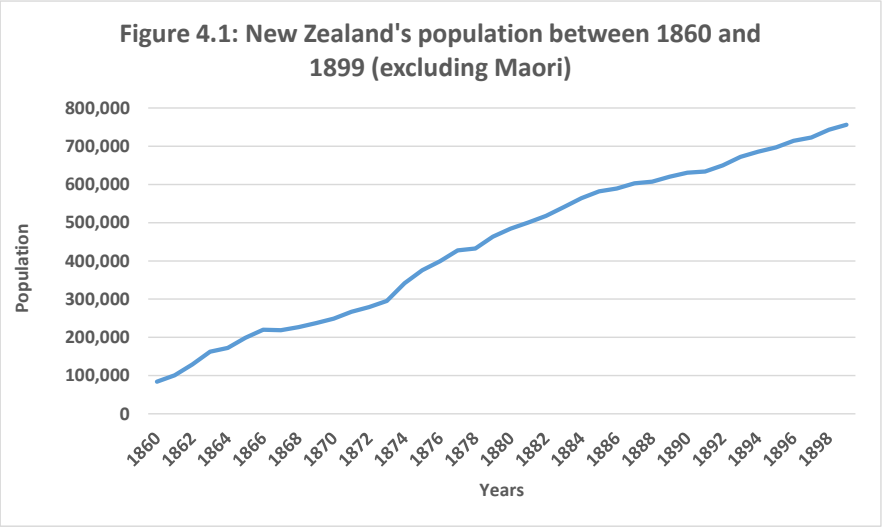
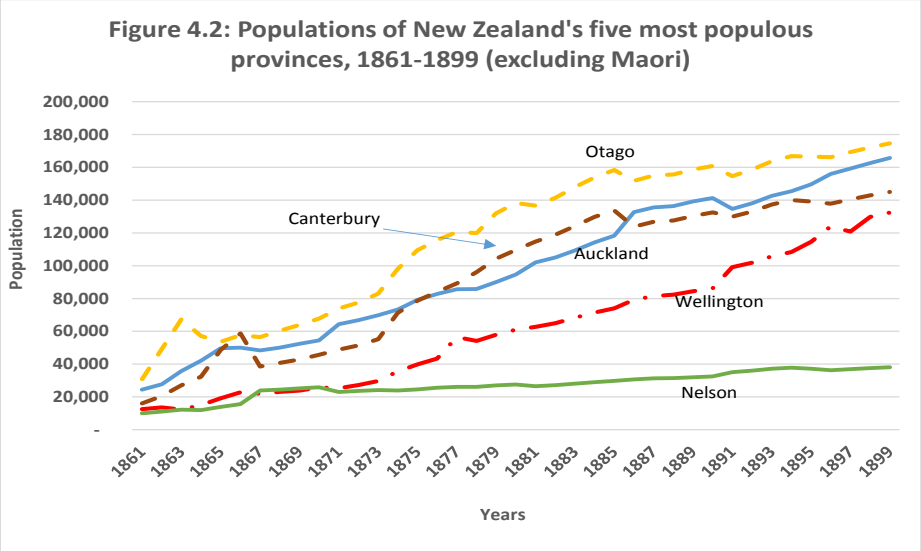
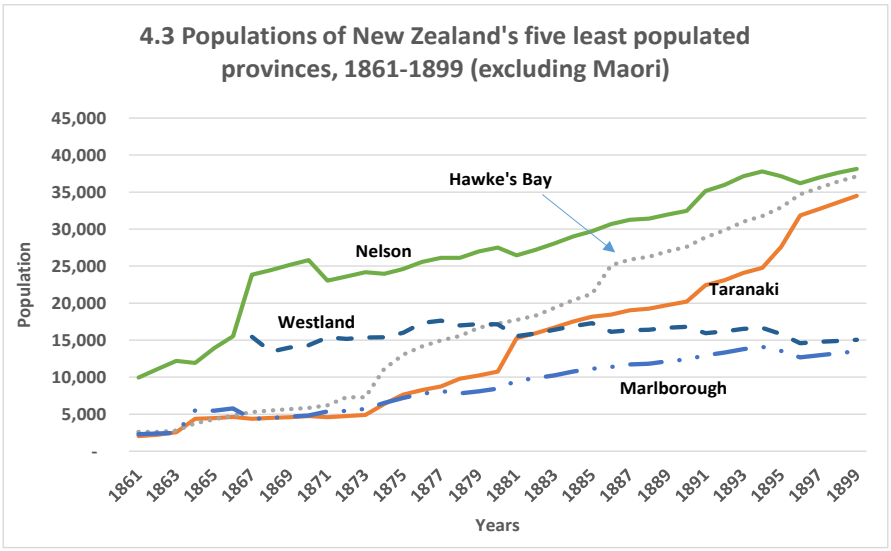
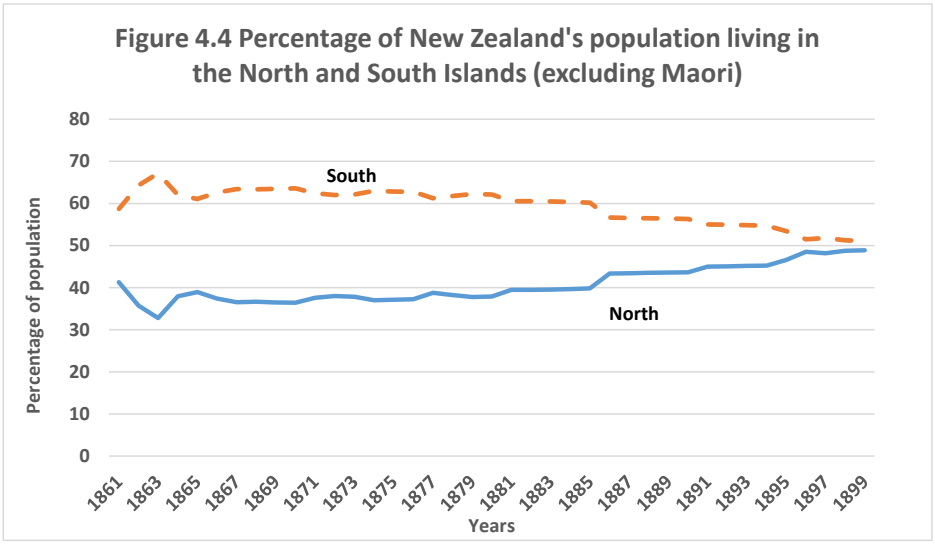


Figure 4.2 shows population statistics, which also exclude Maori, for the five most populous regions between 1861 and 1899. Otago, which here includes Southland, had the biggest population during the period covered, but from the mid-1880s experienced low population growth. Auckland and Canterbury both had periods when they had the second biggest population, while in the early 1870s Wellington overtook Nelson. Figure 4.2 shows Nelson consistently had a bigger population than the four other provinces with low populations. Marlborough enjoyed population growth, but Westland's population stayed stable.





The proportion of New Zealand's population living in the North Island gradually increased, while the proportion living in the South Island gradually decreased. In 1899, however, the South Island still had a slightly larger non-Maori population than the North Island.

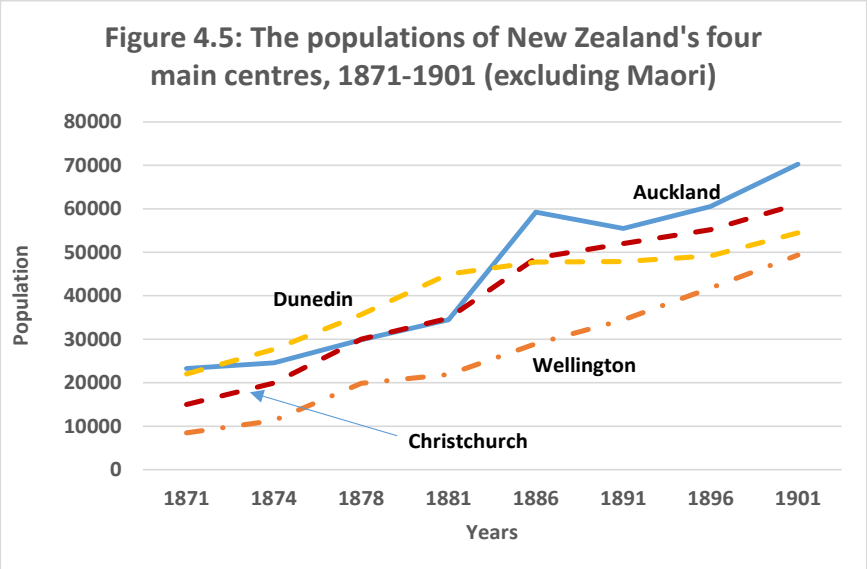


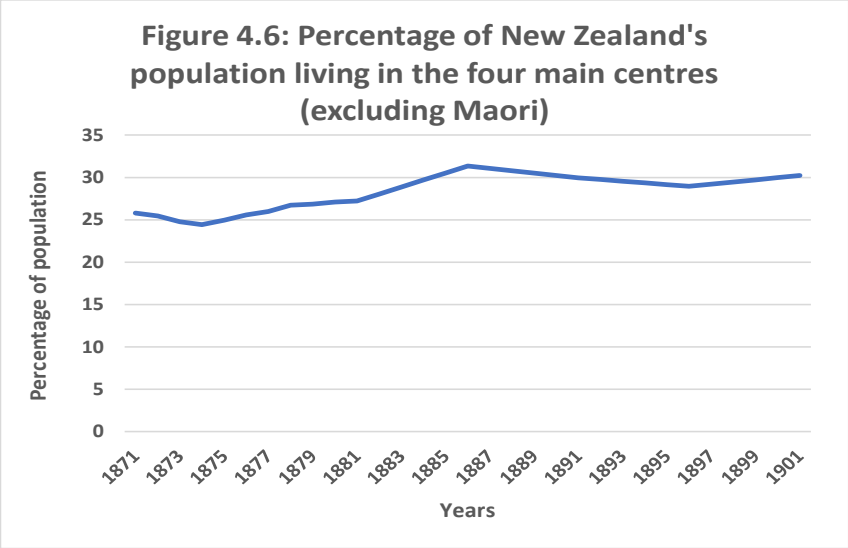
Allocating people to urban centres is potentially difficult because patentees sometimes just gave the name of a street or suburb that was geographically close to a main centre. Furthermore, even in the 1870s some people in suburbs crossed local government boundaries each day to work in urban centres. However, the census sought to overcome this problem from the 1870s by stating that it considered the four main centres to include a particular city and adjacent boroughs and road districts (Pollen, 1874, pp. 5-6). As a

result both population statistics and a definition of metropolitan boundaries are available for the four main centres. The urban boundaries were further clarified in 1917 (Fraser, 1917, p. 1297). A map of the 1876 counties was also located (Dictionary of New Zealand Biography, 1973, pp. 10-11).

For this thesis, the populations of the four main urban centres included adjacent suburbs and ports for the entire period. For instance, Auckland included Devenport and Onehunga, Christchurch included Lyttelton, and Dunedin included Port Chalmers. The population statistics for the main centres exclude the small number of Maori living in these centres.

Figure 4.5 shows that from 1886 Auckland had the biggest metropolitan population in New Zealand, with just over 70,000 people. Previously Dunedin had the largest urban population. Figure 4.6 shows that the percentage of New Zealanders living in the four main centres increased only slightly over the period covered.





4.7 Data on occupation

The OCCHISCO classification of occupations was used, which is a simplified version of HISCO (Roberts, Woollard, Ronnander, Dillon, & Thorvaldsen, 2003). Occupations are divided into groups for (0,1) professional, technical and related workers, (2) administrative and managerial workers, (3) clerical workers, (4) sales workers, (5) service workers, (6) agricultural, farming and forestry workers, and (7,8,9) production workers, transport equipment workers and labourers (Minnesota Population Center, 2011; van Leeuwen, Maas, & Miles, 2002). When multiple occupations were given the first was used unless the second clarified a potentially ambiguous first occupational code (van Leeuwen et al., 2002, p. 34).

OCCHISCO was applied to both the patent applications dataset, and also to the "alphabetical arrangement" occupation listings in the 1886 Census (Office of the Registrar General, 1887, pp. 301-304). The 1886 Census was the first to include such listings, and after eliminating duplicate entries the total matched with totals in earlier tables. Population groups such as school children and farmers' children aged under 20 were then removed to create an employment dataset that more closely approximated patentees. Time constraints unfortunately precluded rearranging the much more detailed occupation listings from the 1891 and 1896 censuses. Although there are clear limitations to relying on employment data from just one census, the results are nevertheless insightful. Data on farm and mining employment from other censuses are also available (Bloomfield, 1984, pp. 126-133) and were consulted to check the 1886 Census results.

Unfortunately only brief details of occupation were given in the source documents, when occupation is best derived by asking people to describe their duties and whether they have people reporting to them at work (Galbraith, Jenkin, Davis, & Coope, 2003, pp. 14-15). In the coding framework, those whose job title included the term "manufacturer" were usually coded into group two. However, there were some exceptions such as farm managers (group 6), and hotel managers (group 5) in the coding system.

Coding those who state they are manufacturers as such is an obvious limitation since some manufacturers could be self-employed and have little in common with proprietors of major businesses. As a result, an agricultural implement maker is in group eight, while an agricultural engineer is in group one. Furthermore, sometimes the same person listed both these occupations at different times. Nevertheless, the results are potentially illuminating.

New codes were added for occupational status descriptions that were absent or HISCO considers to be effectively about social status (van Leeuwen et al., 2002, p. 315). These included gentlemen/women (50), married woman (53), spinster (54), and widow or wife (55). The extra codes for occupations were for Inventor (60), patentee (61), rentier (62). Those who called themselves a gentleman or gentlewoman were included in the professionals HISCO group since these occupations often denoted those of independent means or investors.

4.8 Researching prolific and high spending patentees

The prolific and high spending patentees discussed in chapter seven were researched using published texts, such as the *Cyclopedia of New Zealand* (1897-1908), the *Dictionary of New Zealand biography*, and company histories. Considerable use was also made of the National Library's *Papers Past* collection of scanned newspapers, and of National Library of Australia's equivalent *Trove* collection. In addition, births, deaths and marriages certificates were collected. New Zealand death certificates stated the Minister of Religion officiating, the number of children a person had, and their father's occupation. Information on births was also available from searching by surname in New Zealand and Australian births records. British death certificates unfortunately contained less information than New Zealand death certificates. However, British census data on individuals was frequently available from websites such as *FamilySearch.org* and the

library version of *Ancestry.com*, whereas this data has not been preserved for New Zealand. Probate information on wills was collected, when available.

All these sources have limitations. The *Cyclopedia* required payment for business entries and information on business people was therefore "invariably flattering" (New Zealand Electronic Text Collection, 2015). Because some errors occurred during scanning, *Papers Past* and *Trove* do not always find all the articles on a person. For instance, the optical character recognition version of the death notice for Christchurch inventor John Greenslade has scanned all three occurrences of his surname inaccurately (Greenslade, 1931, p. 1). As a result, Greenslade's death notice was only located after his death certificate had been obtained. Nevertheless, *Papers Past* provided valuable information on topics such as when individuals were living in New Zealand. Some of the sources used, such as obituaries, have relied on people's recollections, which are not always accurate. Probate was only required for estates valued above a particular value, which changed over time, and there were strong incentives for people to understate the value of their assets (Galt, 1985, pp. 2,7).

4.9 Conclusion

This chapter has outlined the collection of data on patents, including when patents lapsed or were renewed, for all New Zealand patents applied for between 1860 and 1899. In addition, the use of Magee's (2000) framework for coding the content of patents has been discussed. Magee used this framework for Victoria between 1854 and 1903, enabling interesting comparisons with the New Zealand results, and his method for coding patents has previously been applied to New Zealand. Furthermore, information on how countries and other geographic places and occupations were coded has been covered, and the populations of New Zealand's regions and main centres briefly discussed. The challenges involved in collecting data on occupational status and people's background have been outlined.

Chapter Five: Changes in the level and source of patents

5.1 Introduction

This chapter examines the level and origin of patenting in more detail than has previously been possible, including examining the number of patents that were renewed and that ran to full term, expenditure on patents in New Zealand, and which countries and regions patentees were living in. Although the Patent Office *Annual Report* included data on some of these topics, this chapter uses unit record data to make a more detailed examination, and over a longer time period. Furthermore, additional topics, such as required expenditure and technological strengths of domestic and foreign patenting are quantified. The aim is to gain insights into the level of patenting, the extent to which people from different places used the patenting system, and the level of New Zealand's reliance on overseas intellectual property.

The chapter first considers the number of patent applications and the countries where patentees lived. Previously only summary data from 1892 on the countries in which patentees lived has been available (Registrar Patents Office, 1896, p. 5). This chapter then looks at the fate of patents in more detail than has previously been possible. Expenditure on patents, both in terms of official fees and required advertising and production costs is quantified in section three. In section four a regional breakdown of patenting applications and expenditure in New Zealand investigates whether any regions dominated patenting. Section five examines the distribution of patenting by industry using both applications and expenditure data. Section six then quantifies technological strengths by calculating the revealed technological advantage of New Zealand and the main countries supplying technology to New Zealand.

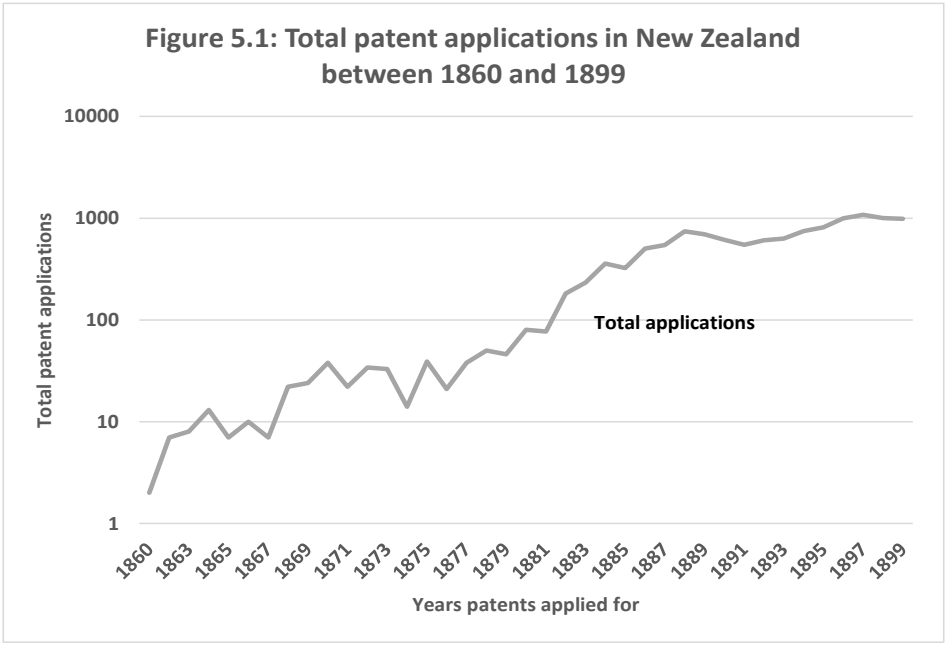
5.2 Total number of patent applications

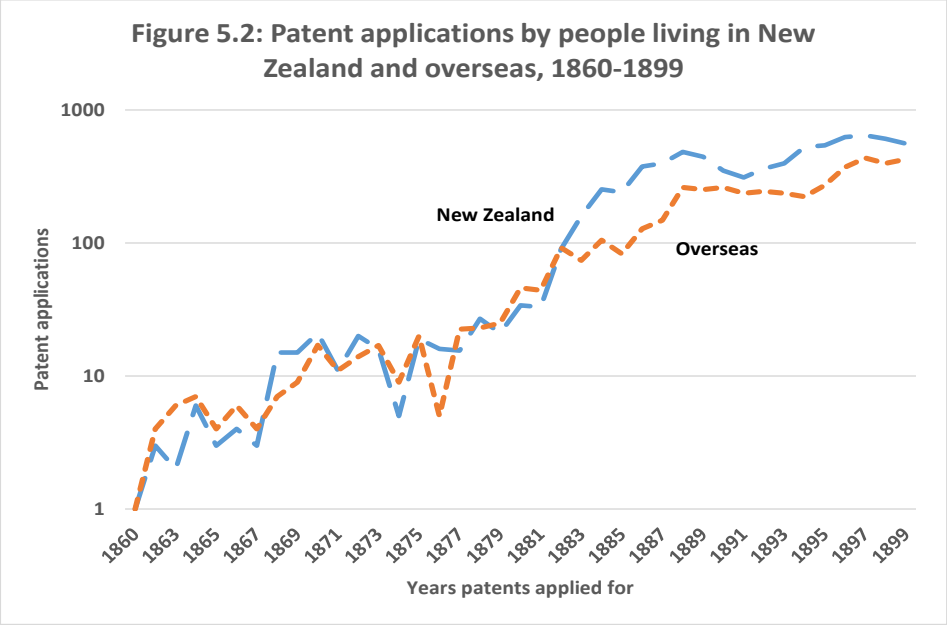
Figure 5.1 shows, using a log scale, total patent applications in New Zealand between 1860 and 1899. The results reveal considerable growth in total patent applications until the late 1880s. Both New Zealand and overseas patent applications then dipped from a peak in 1888 (Figure 5.2), but after a low point in 1891 total patent applications grew to 1,061 in 1897 before falling to 891 in 1899. Until the 1880s the number of patents filed by those

in New Zealand and those living overseas were similar, with no consistent pattern for one group to file more patents. From 1883, however, patent applications by New Zealanders always exceeded applications by those living overseas.

Figure 5.3 shows patent applications per 10,000 people living in New Zealand, although as chapter four noted the population statistics exclude New Zealand's indigenous Maori population. Per person patent applications in New Zealand increased considerably between the late 1870s and late 1880s, with fast growth in patent applications by people living in New Zealand occurring from the early 1880s. For people living overseas the increase in per capita New Zealand patent applications seems to slightly precede the 1880 reduction in application fees.

It has been argued that strong population growth and the development of infrastructure during the 1870s, together with continued public investment, technological innovation and the expansion of the secondary sector encouraged economic development and entrepreneurial activity in New Zealand during the 1880s (Hunter, 2007, pp. 47, 54, 67). Real wages also grew during the 1880s in New Zealand (Greasley & Oxley, 2004, pp. 35-36). The patent application results support the belief that the 1880s were a period of economic expansion in New Zealand.





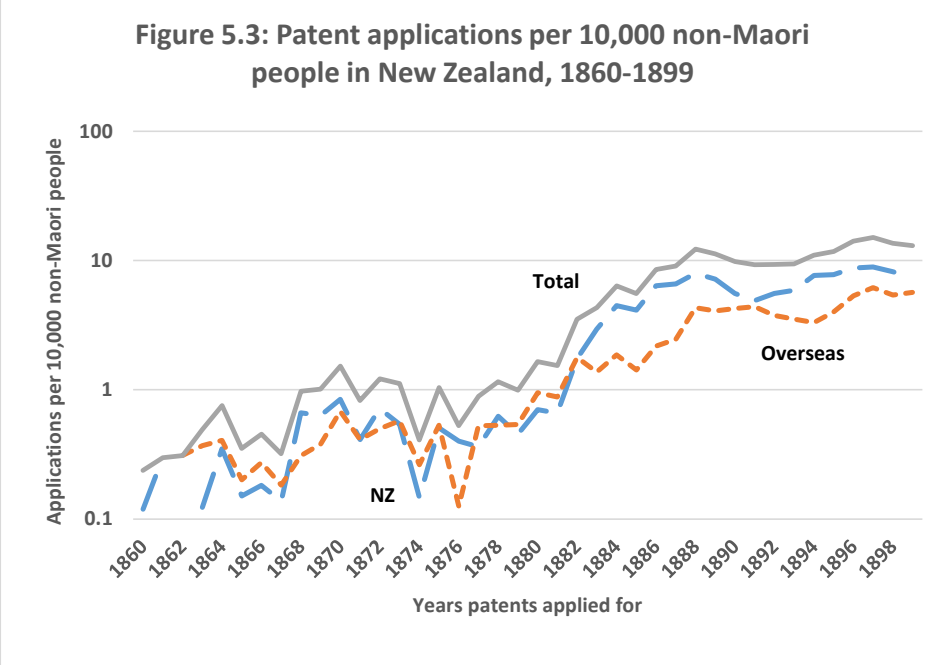


Table 5.1 shows that 62.3% of patent applications between 1860 and 1899 were for inventions by people living in New Zealand, which is slightly below the 66.3% in Victoria for inventions by people living in Australia over the 1859-1903 period. Inventions by Australians constituted 16.4% of patents applications in New Zealand, whereas New Zealanders made only 5.1% of patent applications in Victoria (Magee, 2000, pp. 133-134). However, over the time covered the Australian continent always had at least four and a half times New Zealand's population, and Victoria always had at least one and a half time New Zealand's population. Inventors from Victoria alone made 8.4% of patent applications in New Zealand.

People living in Britain made 11.1% of total applications in New Zealand, while people living in the United States made 6.0%. The next highest countries were Germany (just 1.0% of applications) and France (0.8%). Although applications were traced back to the original inventor whenever possible, due to unreported patent assignments there may still be under-counting of patents originating from Europe, and over-counting of patents from Great Britain. United States patent records for the period covered are usually on the internet and provide information on the original inventor. Similarly, assignments made through Australia usually provide details of the original inventor in Australia or in another country. Any under-counting of European patents is therefore likely to be small, and the results show that most foreign intellectual property utilised in New Zealand came from the English speaking countries of Britain, Australia, and the United States.

Figure 5.4 shows the proportion of patent applications by New Zealanders trended slightly upwards over time. However, there was considerable variation in the percentage of patents from the three main overseas sources. The percentage of patents applied for by people living in Australia trended downwards until increasing in the late 1880s. In contrast, the percentage of patent applications from people living in Britain trended upwards in New Zealand until the early 1870s, while the percentage of applications from people living in the United States peaked in the early 1880s. A moving average is used in Figure 5.4, and in many subsequent graphs, to reduce the effect of short term fluctuations on the results.

Figure 5.4: Four main countries where patent applicants lived (three year moving average)

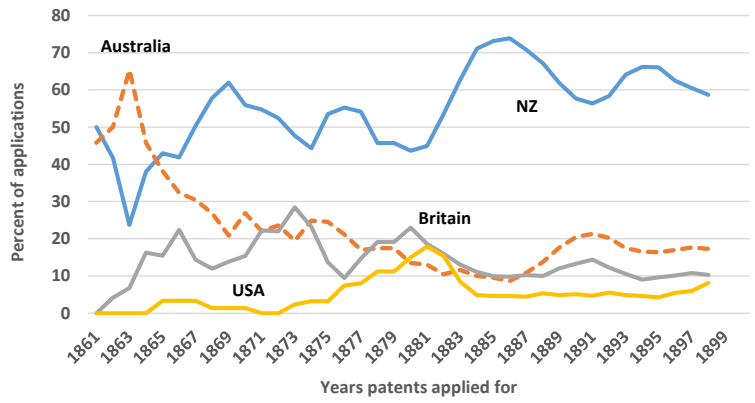
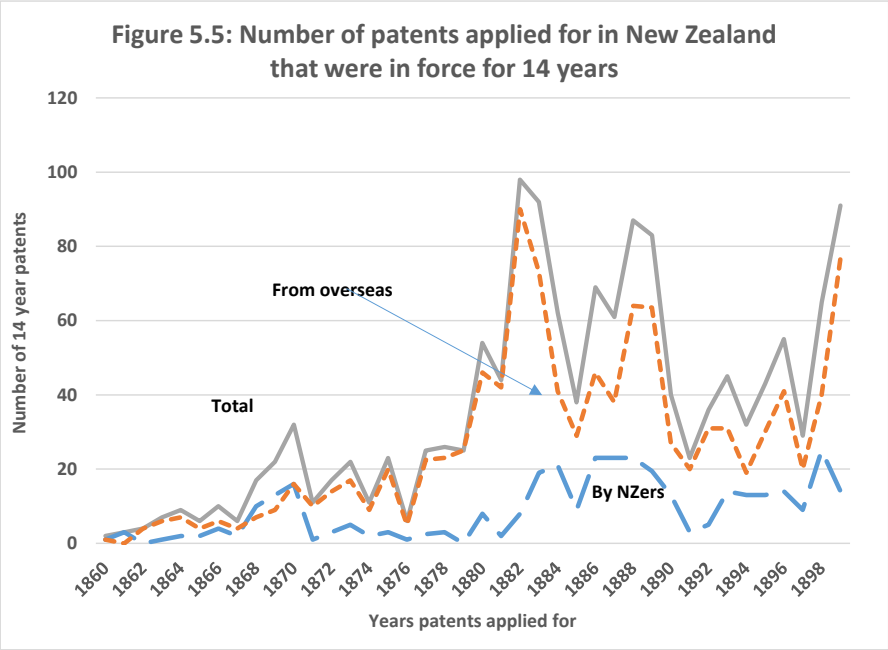


Table 5.1: Patent applications in New Zealand for patents originating in different countries between 1860 and 1899; and equivalent data for Victoria, Australia, 1859-1903

NZ rank	Country	Number New Zealand applications	Percent New Zealand applications	Percent of applications in Victoria
1	New Zealand	7,653	62.3	5.1
2	Australia	2,016	16.4	66.4
3	Great Britain	1,388	11.1	14.7
4	USA	732	6.0	9.0
5	Germany	121	1.0	1.0
6	France	99	0.8	1.0
7	Canada	57	0.5	0.7
8	Not codable	41	0.3	-
9	South Africa	34	0.3	0.2
10	Denmark	28	0.2	0.3
11	Belgium	25	0.2	0.2
12	Sweden	24	0.2	0.4
13	Austria	16	0.1	-
14	Italy	8	0.1	-
15	India	5	0.0	-
16	Russia	5	0.0	-
17	Netherlands	4	0.0	-
18	Norway	4	0.0	-
19	Switzerland	4	0.0	-
20	Argentina	3	0.0	-
21	Brazil	3	0.0	-
22	Chile	2	0.0	-
23	Fiji	2	0.0	-
24	Singapore	2	0.0	-
25	Spain	2	0.0	-
26	Hungary	1	0.0	-
27	Finland	1	0.0	-
28	Japan	1	0.0	-
29	Luxembourg	1	0.0	-
30	Nicaragua	1	0.0	-
31	Portugal	1	0.0	-
32	Uruguay	1	0.0	-
	Others			0.90
	Total	12,283	100	100

Patent renewals data provides the basis for Figure 5.5. The results show that overwhelmingly patents that ran for 14 years were for inventions by people living overseas. Even during periods when New Zealanders applied for more patents than people living overseas, overseas inventors were much more likely to renew their patents.



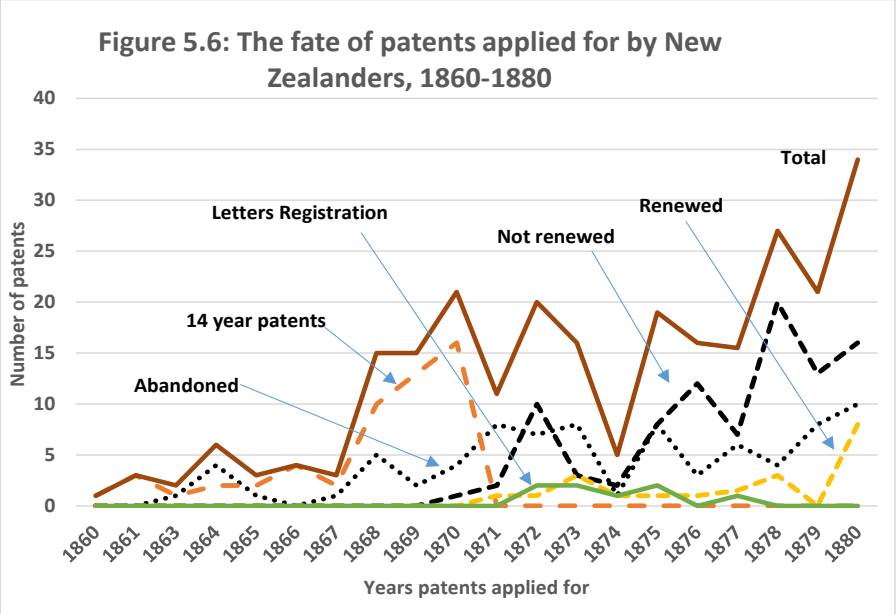
5.2.1 Patent applications by New Zealand inventors

Figure 5.6 shows the fate of patents applied for by New Zealanders between 1860 and 1880, and provides more comprehensive and accurate results than are possible using published aggregate statistics. The results for the 1860s differ from those using *Annual Report* statistics, because abandoned or lapsed applications were added to the dataset for the 1860-1870 period, whereas these are missing from the official data. Furthermore, the year patents were applied for in the 1860s, rather than the year they were approved, has been used.

The data shows that up to 1871 New Zealanders protected intellectual property using letters patent that expired at the end of a 14 year term, and applications for letters of registration for patents registered overseas were rare. Total patent applications were low with only a few letters patent usually being applied for per year until the late 1860s, before a record 15 in both 1868 and 1869. 1871 was a transitional year, with some New Zealanders continuing with applications under the old patent rules, presumably to gain 14 years protection at a lower cost than under the new legislation. Three of the four

successful applications under the new legislation were not renewed. Similar patterns occurred for the rest of the 1870s.

Indeed, during the 1870s (when a 15 pound renewal fee existed) the number of renewed patents was at most three, and therefore similar to the number of 14 year patents during the 1860s. Although there was growth in patent applications during the 1870s, most of these patents ran for just one term, indicating that the owners were not receiving sufficient return to justify renewing the patent. The low level of patenting in 1874 reflects low levels of applications following a high level of applications in late 1873. The same result holds using contemporary patent summary statistics (Registrar Patents Office, 1890, p. 4). A check of *Papers Past* revealed no patent applications for 1874 that had not been in the *Gazette*, but did locate the applications that were in the *Gazette*.

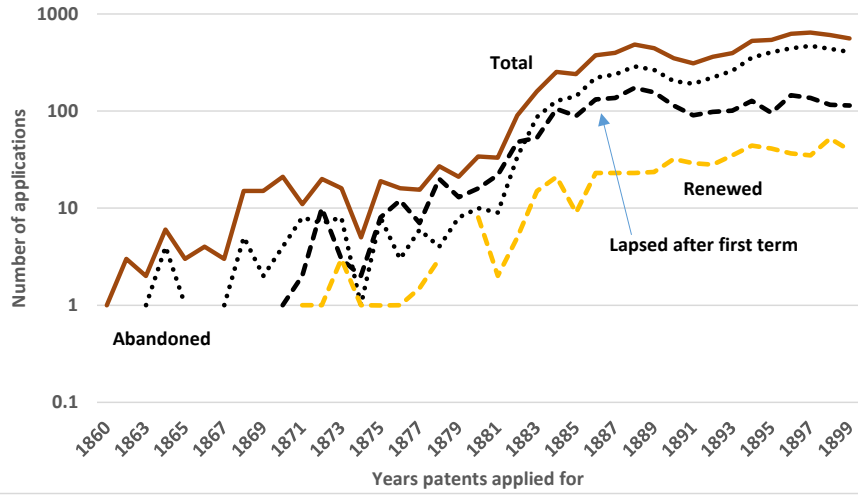


Reductions in fees and in newspaper advertising requirements during the early 1880s were associated, as Parliament had intended (Barron, 1881, p. 607), with an increase in patenting. The reduction in application fees to ten shillings in late 1882 and the reduction in advertising requirements was followed by a sharp increase in the total number of patents applied for by New Zealanders. Indeed applications by New Zealanders increased from 33 in 1881, to 90 in 1882, and 159 in 1883, and then reached 489 in 1888. The number of renewed patents by New Zealanders also jumped from five in 1882 to a record 15 in 1883, and reached 32 in 1890. However, the proportion of abandoned patent

applications increased from 29.4% in 1880 to 60% by the mid-1880s. The proportion of patents renewed for a second term was usually less than ten percent.

The Registrar's *Annual Report* did not comment on the decline in New Zealand patent applications between 1888 and 1891. However, as newspapers commented at the time and has been shown in chapter three, the real cost of taking a patent for 14 years considerably increased in the 1889 Patents Act that came into force in 1890 (New Zealand Herald editor, 1889, p. 4). There was a recovery in total patent applications by New Zealanders from 1891, and patent applications peaked in 1897 at 643 before declining to 530 in 1899. More patents initially applied for in the 1890s by New Zealanders were renewed, with 40 of the patents applied for in 1890 being renewed for at least a second term.

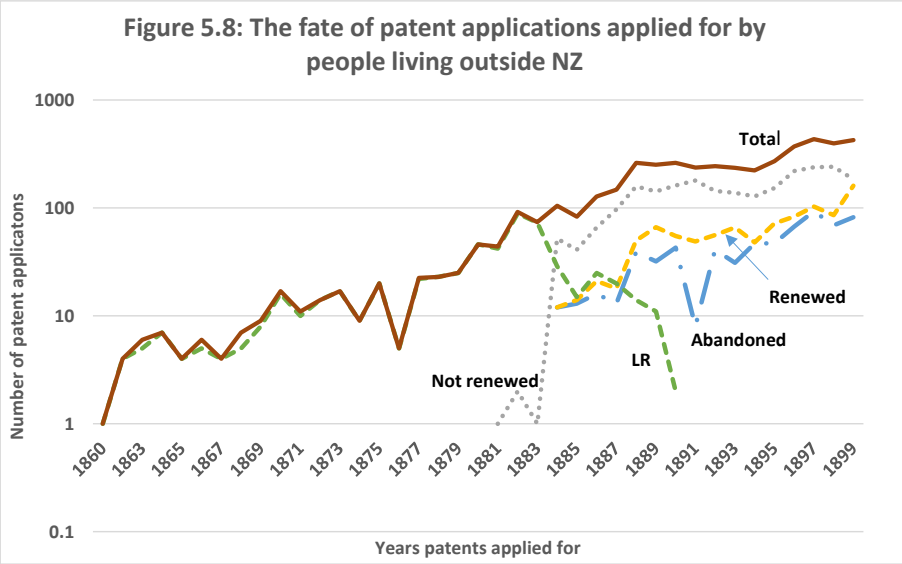
Figure 5.7: The fate of patents applied for by New Zealanders, 1860-1899



5.2.2 Patent applications by overseas inventors

Inventors who lived overseas usually used letters of registration to protect intellectual property in New Zealand during the 1860s and 1870s, although there was some use of letters patent. In 1870, letter of registration applications by those living overseas reached double figures for the first time, and grew to 92 in 1882. There was some growth in letters patent applications abandoned or lapsed after 1882 by people living overseas, but this was occurred more slowly than for patent applications by New Zealanders. Instead, increased use of the patent system by inventors living outside New Zealand during the 1880s resulted in them filing patents that lapsed through non-payment of the first

renewal fee. The results suggest that from the early 1880s overseas intellectual property of unknown worth was being protected in New Zealand by letters patent, with overseas owners sealing these patents but not usually renewing them. However, the results indicate continued, albeit reduced, use of the flat ten pound letter of registration system to gain protection for intellectual property considered to have a long period of economic value until this option was removed from the beginning of 1890. A decline in total patent applications by those living overseas occurred from 1891, which is later than for applications by those living in New Zealand, and continued until overseas patent applications began increasing again in 1895.



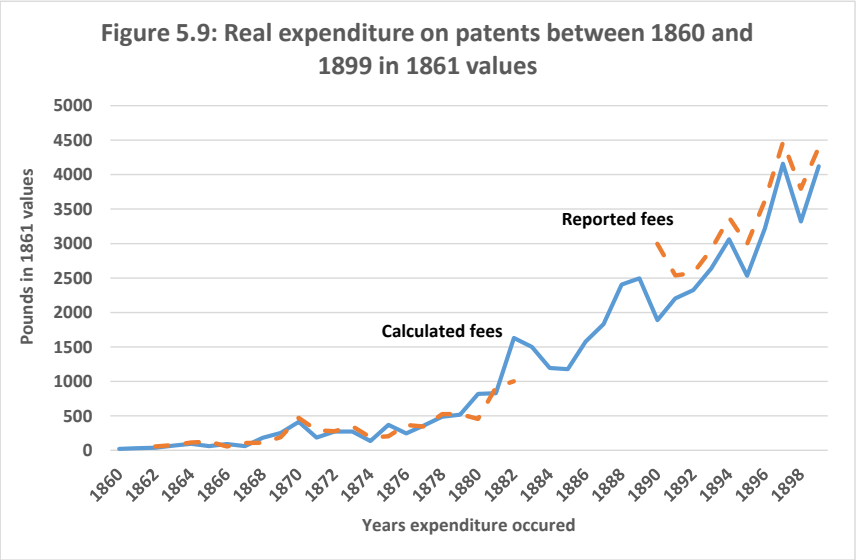
5.3 Expenditure on patents

Since the cost of applying for a patent dramatically fell over time, and increasingly many patent applications lapsed, total expenditure on patents is also of interest. Chapter three discussed the attribution of patent fees to patents. Patent renewals were attributed in the year payment was made.

Figure 5.9 shows the author's calculation of patent fees expenditure follows a similar trend to the available official data. The match is imperfect, partly because the calculated fees are on a calendar basis. In contrast, the official expenditure data is for financial years that initially ended 30 September, and from 1867 to 1882 ended 30 June, although from 1890 the official data is for calendar years. In addition, the fee charged for unsuccessful

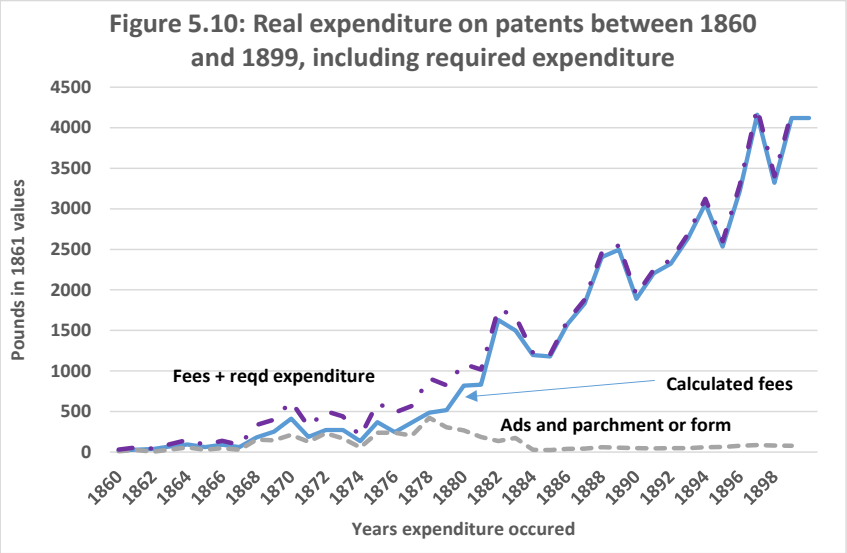
patent applications was estimated up to 1871 since officials made decisions about partial refunds on a case by case basis. More importantly, the official data includes other fees, such as these levied for assigning patents and letters of registration, and systematic published data on this topic is only available from 1890 (Haselden, 1891, pp. 1081-1082) and has not been included here. Caution is needed when evaluating the results for the 1860 and 1861 because specific acts were passed for the first patent and letter of registration, making calculating fees particularly difficult. Indeed, the patent records for the 1860s were not complied until the 1870s, and different expert judgements would alter the results for some years. Nevertheless, the similarity of the results is reassuring, especially for the late 1890s.

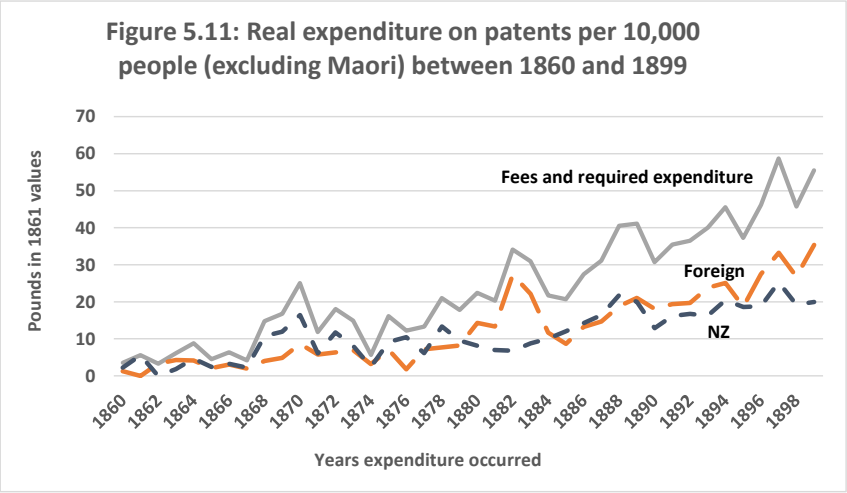
The calculated results show real expenditure on patent fees reached 100 pounds for the first time in 1868, and reached 412 pounds in 1870. Lower initial fees for patent applications then reduced expenditure on patenting until the late 1870s. The reduced application and renewal fees introduced in 1880 and 1882 were associated with expenditure on patent fees spiking at 1,630 pounds in 1882. Further reductions in fees initially reduced patent fees expenditure, but in 1889 a new peak of 2,495 pounds was reached. Higher renewal fees were then associated with lower patent fees expenditure in 1890 and 1891. Thereafter patent fees expenditure grew again, peaking at 4,159 pounds in 1897.



However, it is also necessary to also impute advertising and related expenses, particularly since legal requirements that determined these costs changed considerably over time. Concentrating on required payments, Figure 5.10 shows real expenditure on patents after including costs for advertising and for producing the patent on parchment, or from 1884

purchasing the standard form. These costs increase expenditure on patents, especially in the 1870s when two insertions of patents notices was required in regional newspapers, and in some years almost doubles expenditure on patents. Figure 5.11 shows that even after allowing for growth in New Zealand's non-Maori population total real expenditure on patents considerably increased. However, patenting fees and required expenditure remained a very small component of expenditure in New Zealand.





Adding agent fees and other preparation costs might reduce the growth in per person expenditure. With lower application fees and provisional applications not being available to others, the incentive for inventors to seek professional help on applications would have fallen. Instead, inventors with poorly prepared patents could file a new provisional application after their protection lapsed, and delay seeking professional help with specifications and drawings until they were sure they had a valuable invention.

Figure 5.12 shows a three year moving average of the percentage of patent fees and required costs paid on patents originating from the four countries at the top of Table 5.2. The results indicate that New Zealand patents accounted for the largest share of payments, but rarely the majority. From the mid-1880s the share of fees and required costs paid on patents by New Zealanders was in gradual decline, and for 1897-1899 accounted for 40% of expenditure. Australian and British patents usually accounted for more expenditure than patents from the United States. Over the entire time period, patents originating in New Zealand accounted for 42% of patent fees expenditure, and 45% including advertising and parchment costs. Both these numbers are substantially lower than New Zealand's 62% share of patent applications. Patents originating in Britain accounted for 21% of expenditure on patent fees, those from Australia 19.3%, and patents from the United States 10.9% of expenditure on patents. The required expenditure statistics for many countries are higher than for patent fees largely because parchment, and then from 1884 standard form, costs have been attributed.

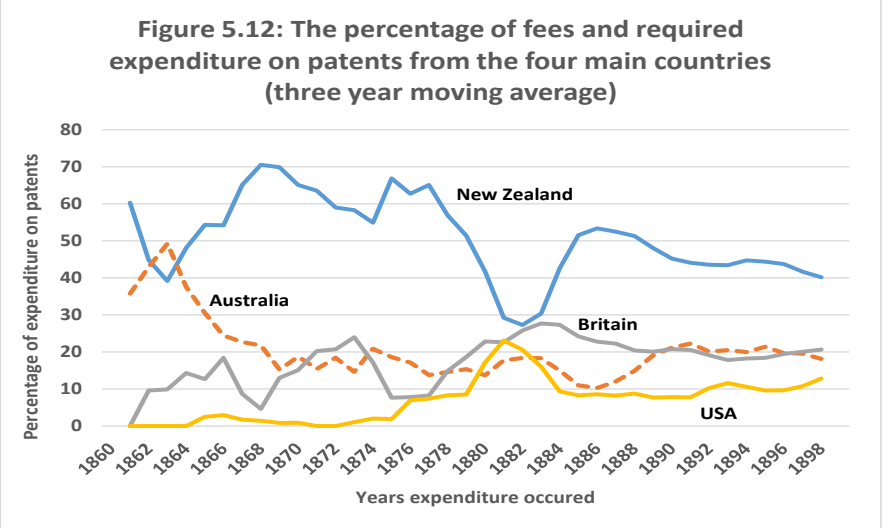


Table 5.2: Expenditure on patent fees and on required expenditure in New Zealand on patents originating in different countries between 1860 and 1899 (1861 values)

	Nation	Fees expenditure	Percent	Cum %	Fees and required expenditure	Percent	Cum%
1	New Zealand	20,556	42	42	24,191	45	45
2	Great Britain	10,411	21	63	10,673	20	65
3	Australia	9,498	19	82	9,800	18	83
4	USA	5,376	11	93	5,499	10	94
5	Germany	784	2	95	800	1	95
6	France	739	2	96	758	1	97
7	Canada	326	1	97	331	1	97
8	Not codable	310	1	98	316	1	98
9	Sweden	184	0	98	187	0	98
10	Belgium	170	0	98	173	0	99
11	South Africa	153	0	99	155	0	99
12	Denmark	136	0	99	140	0	99
13	Austria	117	0	99	121	0	99
14	Italy	88	0	99	90	0	99
15	India	48	0	100	49	0	100
16	Norway	41	0	100	41	0	100
17	Brazil	23	0	100	23	0	100
18	Russia	21	0	100	21	0	100
19	Argentina	20	0	100	20	0	100
20	Singapore	20	0	100	21	0	100
21	Chile	17	0	100	17	0	100
22	Luxembourg	16	0	100	16	0	100
23	Switzerland	14	0	100	15	0	100
24	Portugal	13	0	100	13	0	100
25	Spain	8	0	100	8	0	100
26	Hungary	6	0	100	6	0	100
27	Japan	5	0	100	5	0	100
28	Fiji	5	0	100	5	0	100
29	Finland	4	0	100	4	0	100
30	Nicaragua	4	0	100	4	0	100
31	Uruguay	4	0	100	4	0	100
32	Netherlands	3	0	100	3	0	100
	Total	49,118	100	200	53,510	100	100

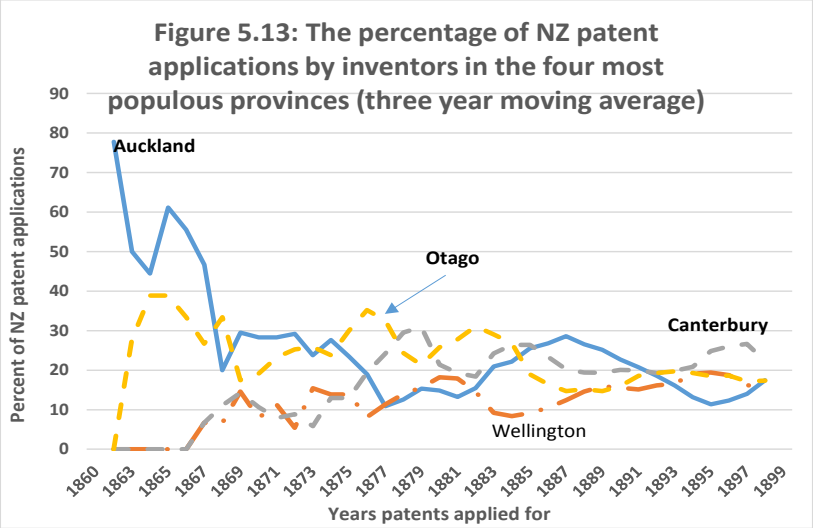
5.4 Regional patenting activity

A noted in chapter four, New Zealand statistical publications for the period covered here usually reported regional demographic economic statistics on the basis of traditional provincial boundaries. Although the patent data was coded on a more finely grained regional basis, no regional population statistics are available for modern regions such as Northland, the Waikato, Bay of Plenty (all of which were part of the Auckland region) and the Manawatu and Wairarapa (which were part of the Wellington region). Furthermore, the Otago region included Southland.

Table 5.3 shows the regional distribution of patent applications by inventors living in New Zealand. The results indicate that Otago, followed very closely by Auckland, then Canterbury and Wellington were the most important regions for patent applications, with the other regions being less important. These four regions also had the biggest populations over the period covered. However, there were considerable fluctuations from the 1870s, and Figure 5.13 shows both Otago and Canterbury had periods when they accounted for the most patent applications.

Table 5.3: The regional distribution of patent applications by New Zealand inventors between 1860 and 1899

Rank	Region	Number	Percent
1	Otago	1,784	23.3
2	Auckland	1,777	23.2
3	Canterbury	1,690	22.1
4	Wellington	1,574	20.6
5	Taranaki	226	3.0
6	Hawke's Bay	223	2.9
7	Nelson	144	1.9
8	Marlborough	142	1.9
9	Westland	91	1.2
	Total	7,653	100.0



Otago, followed by Canterbury, Auckland and Wellington accounted for the biggest percentage of expenditure on patents. Adding required expenditure does not change the order of the provinces in Table 5.4, but does increase the proportion of expenditure in provinces with more patenting in early years. For the remainder of this chapter, all expenditure statistics and graphs include required expenditure.

Table 5.4: The regional distribution of patent fees and required expenditure in New Zealand between 1860 and 1899

Rank	Region	Fees expenditure in pounds	Percent	Fees & required expenditure in pounds	Percent
1	Otago	4,960	24.1	5,984	24.7
2	Canterbury	4,802	23.4	5,556	23.0
3	Auckland	4,568	22.2	5,361	22.2
4	Wellington	3,957	19.2	4,474	18.5
5	Hawke's Bay	620	3.0	697	2.9
6	Taranaki	532	2.6	646	2.7
7	Nelson	445	2.2	572	2.4
8	Marlborough	384	1.9	519	2.1
9	Westland	287	1.4	382	1.6
	New Zealand	20,556	100.0	24,191	100.0

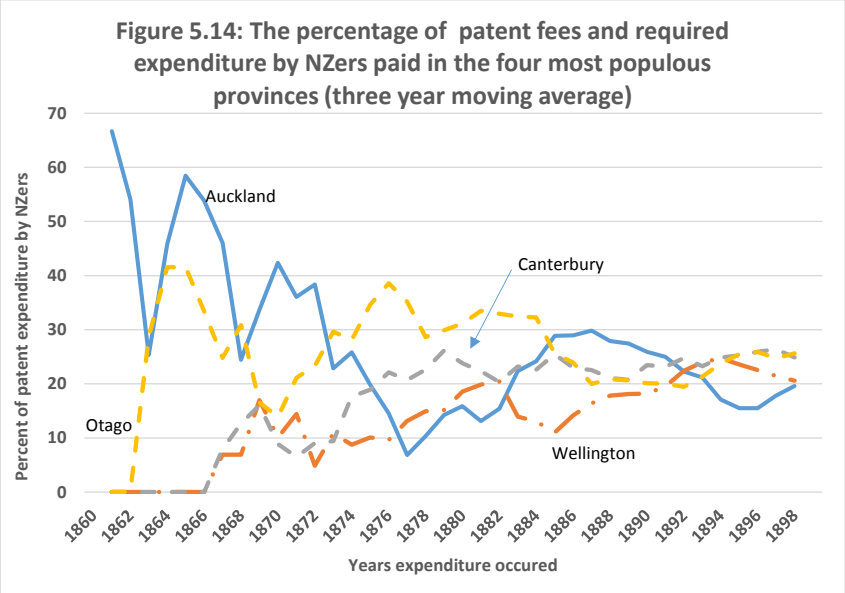
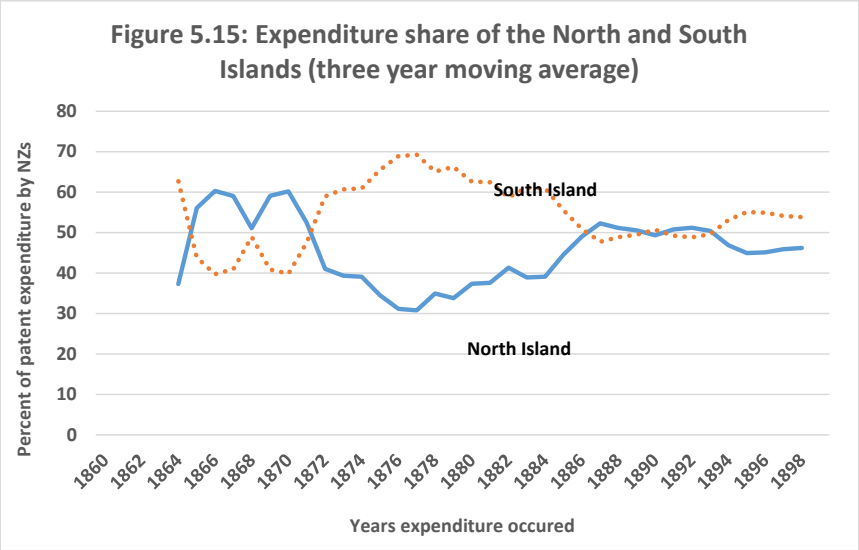


Figure 5.15 shows that North Island patentees spent more on patent fees and required expenditure during most of the 1860s. However, South Island inventors were ahead between the early-1870s and mid-1880s, and less dramatically ahead towards the end of the century.

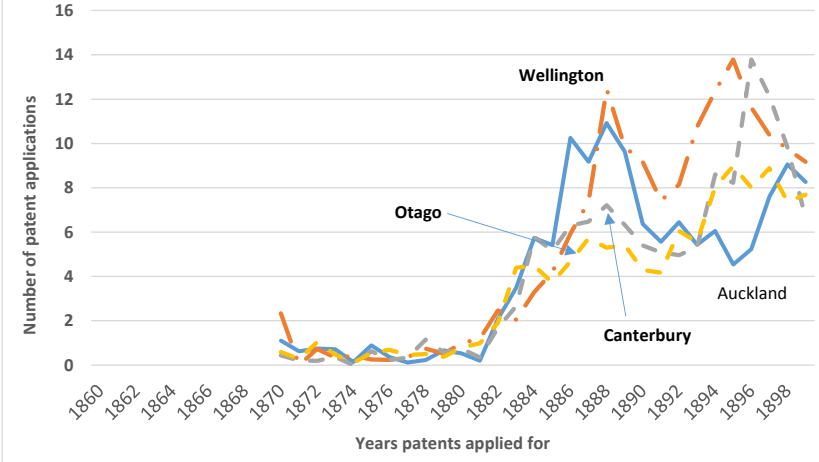


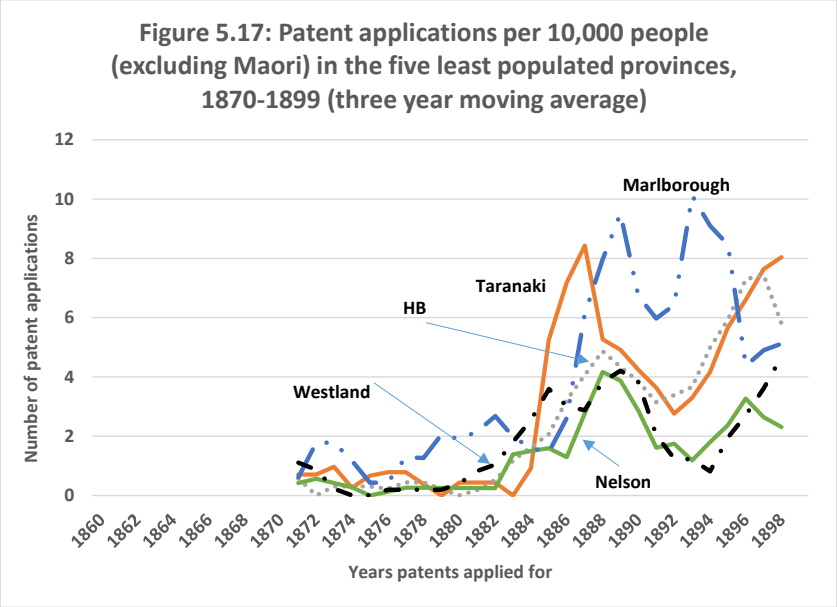
The patent application results, and to a lesser extent the expenditure results, appear to reflect the distribution of New Zealand's population. Accordingly, applications and expenditure were divided by each region's non-Maori population. As noted in chapter four, equivalent data on New Zealand's indigenous Maori population is not available. A moving average was calculated for each region after 1870, with the years before 1870

excluded since patent applications were very low. The results for patent applications (Figure 5.16) for the four most populous provinces suggest economic regional cycles may have affected which provinces patented most, with Auckland, Wellington and Canterbury all making the most applications per capita at some stage. For the less populous provinces, Figure 5.17 shows that Marlborough or Taranaki usually had the most patent applications per capita. Marlborough usually had the lowest population density per square mile between 1874 and 1901, while Taranaki had become one of the highest population density provinces by 1901 (Office of the Registrar General, 1902, p. 6).

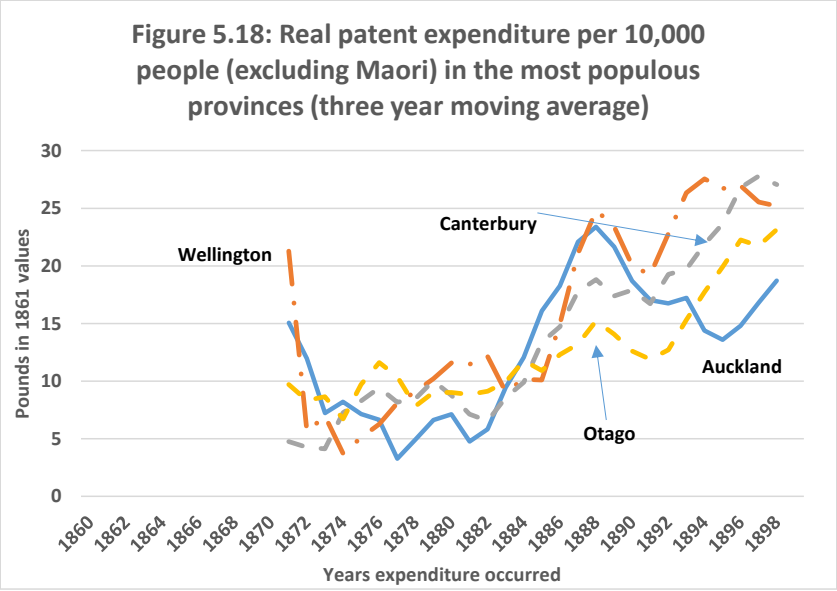
Applying a Chi-Squared test supported Magee's finding from Victoria that population in itself does not explain the level of patenting in different regions. However, unlike Victoria, where patenting was concentrated in the area around Melbourne, suggesting population density boosted patenting (Magee, 2000, p. 45), there was no single New Zealand region dominant for patent applications over time. This probably reflects the similar urban populations (see chapter four) of Auckland, Christchurch and Dunedin, with Wellington usually not being very far behind. Furthermore, the rate of patenting in Taranaki when its population density was increasing, and in low population density Marlborough, show patenting rates could be high in low population density areas.

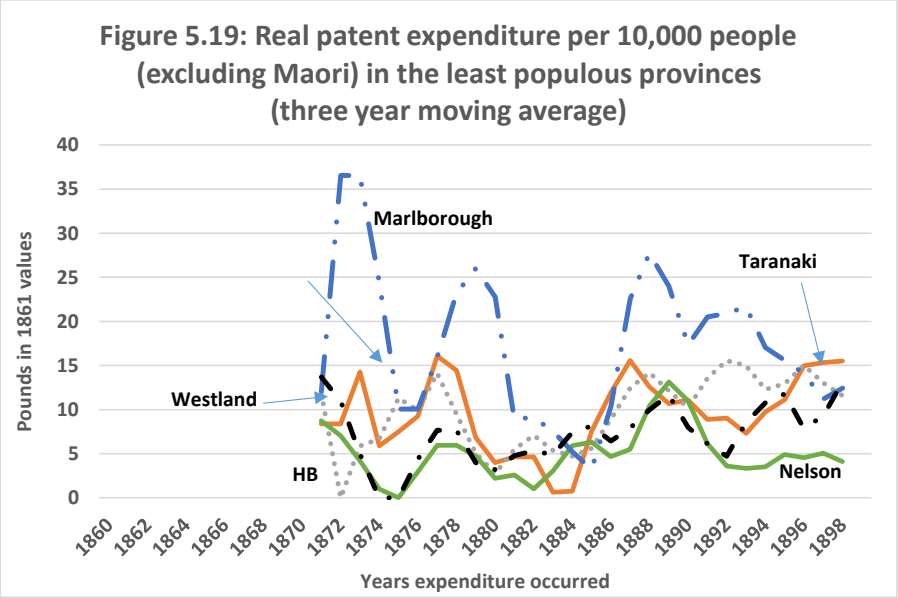
Figure 5.16: Patent applications per 10,000 people (excluding Maori) in the most populous provinces, 1870-1899 (three year moving average)





Figures 5.18 and 5.19 show that Auckland, Wellington and Canterbury all had periods when they had the highest per capita expenditure on patents fees and required expenditure, while Otago was top during 1899. Among the less highly populated regions, Marlborough, and to a lesser extent Taranaki, had high expenditure on patents.





5.4.1 Patenting in the four main metropolitan centres

This section examines whether the major metropolitan centres accounted for a relatively high share of patent applications. One difficulty is that sometimes, particularly in early years, applicants sometimes gave their address as Auckland, Wellington or Nelson, and it was unclear whether they were referring to their province or city. As a result, 12.1% of New Zealand patent applications are excluded from the following analysis.

Excluding missing cases, New Zealand's four largest metropolitan centres accounted for 53.3% of patent applications by New Zealanders after 1871, which is the first year urban population data are available. In contrast, the four main centres had just 28% of New Zealand's non-Maori population over this period. Even allowing for the population statistics continuing to exclude some of the urban fringes of Auckland and Christchurch, it is clear that the main centres were disproportionately the focus of patenting. Christchurch's 15% of total New Zealand patent applications and Dunedin's 14% are not compared here to the Auckland and Wellington metropolitan population results due to missing data for the North Island centres. However, Invercargill was the fifth most important centre for patenting by a considerable margin. Indeed, people living in Invercargill made 3.6% of total patent applications by New Zealanders between 1871 and 1899, despite averaging about 1.5% of New Zealand's population.

The results for individual provinces show people living in the Auckland metropolitan area made 60% of the province's total patent applications, despite Auckland and its suburbs averaging about 37% of the province's non-Maori population. Similarly, in Wellington the

metropolitan area had only 34% of the province's non-Maori population, but people there made 51% of the patent applications. Furthermore, Christchurch had only 35% of Canterbury's non-Maori population, but accounted for 67% of the province's applications, while Dunedin had only 30% of Otago's non-Maori population but 60% of the province's applications. The results for Canterbury and Otago are particularly informative since there are almost no cases when applicants could not be coded accurately into a local body area.

The expenditure results were similar to those for patent applications, with inventors in the four main centres paying 51% of total patent fees and required expenditure by New Zealanders after excluding cases where the location of the patentee was unclear. Dunedin was slightly ahead of Christchurch in total patenting expenditure, but only just, and Christchurch was ahead during periods such as the late 1890s. Christchurch and Dunedin dominated patenting expenditure in their regional provinces. However, Invercargill was also an important place for patenting expenditure in the Otago-Southland region, as was Wanganui in the North Island. The results also show that modern day Thames was the locality whose residents made the most expenditure on patents in 1870 and 1871, when this booming settlement was experiencing a gold rush.

One limitation of this analysis is that urban patenting was sometimes for agricultural, pastoral and mining equipment for the surrounding hinterland. The distribution of patenting by industry is therefore the next topic studied.

5.5 Distribution of patenting by industry

Table 5.5 illustrates how manufacturing patents dominated patent applications in New Zealand, while Table 5.6, which contains sector shares of patent expenditure (including advertising costs), shows likewise. However, primary sector patents, which were almost entirely about farming, but also included a small number of fishing and forestry patents, accounted for 16.9% of patent applications. This was substantially more than the 11.9% of such applications in Victoria (Magee, 2000, p. 54). Furthermore, the primary sector inventions in New Zealand were disproportionately by New Zealanders. Indeed, Table 5.6 indicates the primary sector accounted for 22.4% of expenditure on patents by New Zealanders. Services and distribution accounted for 10.8% of patent applications, although including patents for improved vehicles, including bicycles, would more than double patents in this category. Household consumption and production accounted for

10.5% of patent applications, while the household sector was noticeably less important in terms of patent expenditure than in terms of patent applications. The 9.4% of patent applications accounted for by mining was slightly less than the 11.1% of patents about this industry in Victoria. However, expenditure on mining patents accounted for 11.0% of total expenditure on New Zealand patents.

Table 5.5: Sector shares of patent applications in New Zealand between 1860 and 1899 and in Victoria between 1857 and 1901

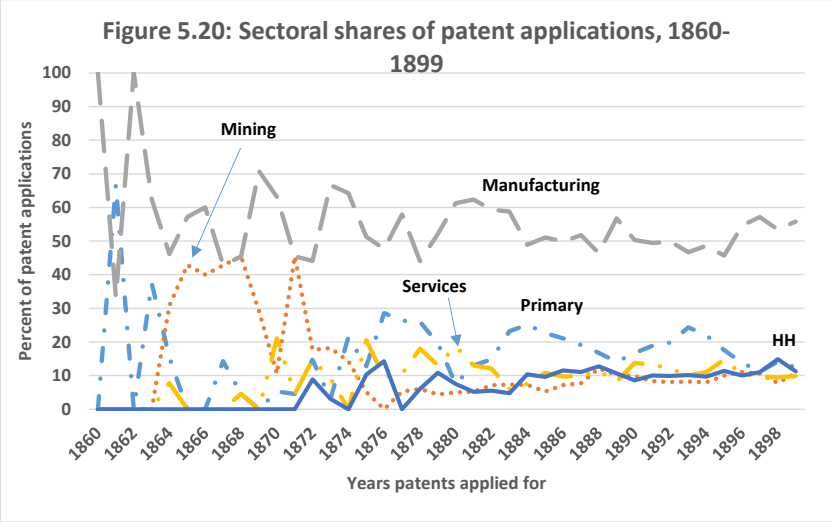
	All patents in New Zealand		New Zealand patents		All patents in Victoria (Magee)	
Industry sector	Patents	Percent	Patents	Percent	Patents	Percent
Primary	2,081	16.9	1,585	20.7	-	11.9
Mining	1,151	9.4	478	6.3	-	11.1
Manufacturing	6,392	52.0	3,770	49.3	-	56.2
Services and distribution	1,321	10.8	773	10.1	-	12.7
Household	1,289	10.5	1,014	13.2	-	8.1
Uncodable	48	0.4	32	0.4	-	-
Total	12,283	100	7,653	100	-	100

Table 5.6: Sector shares of expenditure on patents in New Zealand between 1860 and 1899, including required expenditure

	All patents in New Zealand		New Zealand patents	
Industry sector	Patents	Percent	Patents	Percent
Primary	8,861	16.6	4,429	22.4
Mining	5,867	11.0	1,835	7.6
Manufacturing	29,104	54.4	12,015	49.7
Services and distribution	5,750	10.7	2,301	9.5
Household	3,776	7.1	2,554	10.5
Uncodable	153	0.3	66	0.3
Total	53,510	100.0	24,191	100

Figures 5.20 and 5.21 show that manufacturing's share of patenting stayed relatively stable over time. The percentage of mining patent applications grew sharply during the early 1860s, following the Otago 1860s gold rush, and discoveries later in the 1860s on the West Coast and Coromandel Peninsula, and peaked at 45% of patent applications in 1868. Mining patents then fell, and were rarely more than 10% of patents from 1874.

However, the share of patents relating to the primary sector recovered from the mid-1870s. Services and household patents increased over time, but rarely exceeded 15% of patent applications and expenditure.



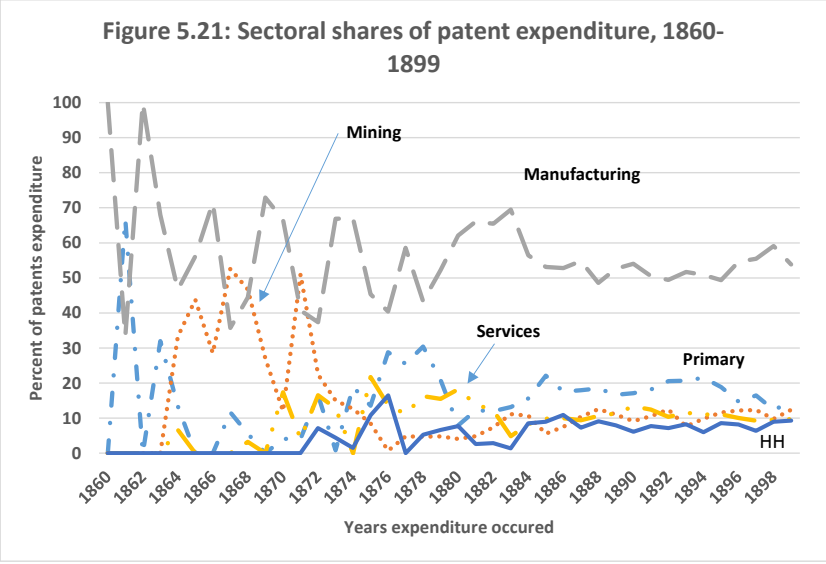


Table 5.7 shows the importance of individual categories for the entire period. Patent applications and expenditure about metal extraction from rock and ore were considerably higher than for patenting relating to actual mining. Within manufacturing, engineering equipment (4.9% of applications, 5.7% of expenditure) was an important sector, as were clothes and textiles (6.2% of applications and 6.3% of expenditure), and heat, light and

power (5.3% of patent applications, 7.5% of expenditure). Dairying (1.6% of applications, 1.3% of expenditure) and refrigeration (1.1% of applications and 1.1% of expenditure), however, were relatively unimportant sectors for patenting.

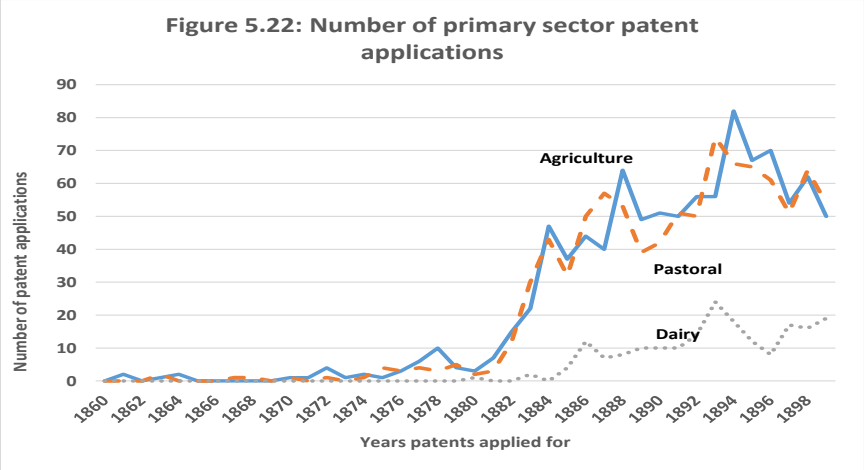
Table 5.7: Number and percent of patent applications about each industry and the amount and percent of patent fees and required expenditure on these patents

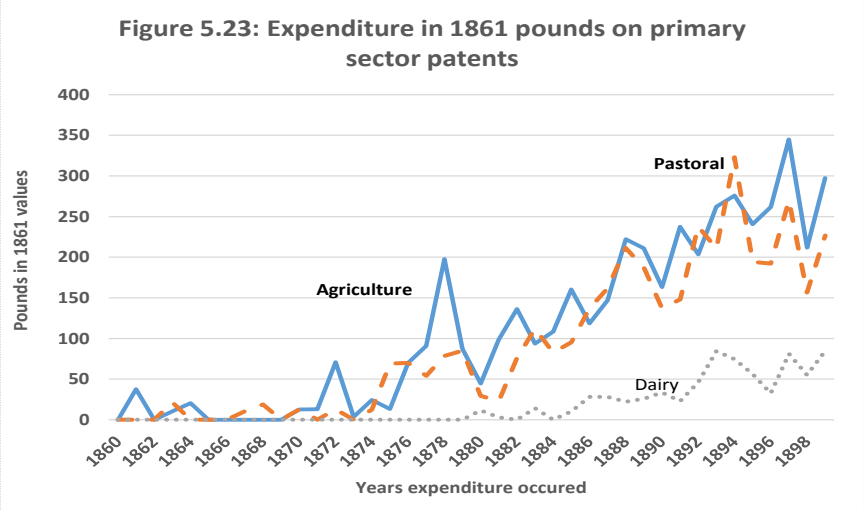
Sector	Industry	Applications number	Applications percent	Expenditure total (pounds)	Expenditure percent
Primary	Agriculture	964	7.9	4,491	8.4
Primary	Pastoral	925	7.5	3,656	6.8
Primary	Dairying	192	1.6	714	1.3
Mining	General Mining	385	3.1	1,684	3.1
Mining	Metal extraction	766	6.2	4,183	7.8
Manufacturing	Construction & infrast	420	3.4	1,833	3.4
Manufacturing	Cement & stone	84	0.7	496	0.9
Manufacturing	Bricks and pottery	82	0.7	530	1.0
Manufacturing	Wood working	110	0.9	518	1.0
Manufacturing	Furniture	216	1.8	714	1.3
Manufacturing	Carriages	933	7.6	2,706	5.1
Manufacturing	Engineering equip	607	4.9	3,038	5.7
Manufacturing	Industrial metals	159	1.3	1,146	2.1
Manufacturing	Machinery & metal	350	2.9	1,738	3.2
Manufacturing	Clothes & textiles	760	6.2	3,353	6.3
Manufacturing	Skins & leather	212	1.7	791	1.5
Manufacturing	Preserving food	180	1.5	859	1.6
Manufacturing	Refrigeration	137	1.1	590	1.1
Manufacturing	Food & drink	442	3.6	1,913	3.6
Manufacturing	Alcohol	50	0.4	276	0.5
Manufacturing	Tobacco	114	0.9	483	0.9
Manufacturing	Printing	165	1.3	613	1.1
Manufacturing	Heat light power	655	5.3	4,033	7.5
Manufacturing	Chemicals	185	1.5	974	1.8
Manufacturing	Pharm & medical	182	1.5	682	1.3
Manufacturing	Fuel & explosive	318	2.6	1,696	3.2
Manufacturing	Other manufacturing	31	0.3	121	0.2
Services	Railway	298	2.4	1,867	3.5
Services	Shipping	259	2.1	991	1.9
Services	Communications	265	2.2	1,112	2.1
Services	Services & distribution	499	4.1	1,779	3.3
Household	HH consumption	572	4.7	1,556	2.9
Household	HH production	717	5.8	2,220	4.1
Other	Not codable	48	0.4	153	0.3
Other	Missing	1	0.0	1	0.0
Total	Total	12,283	100	53,510	100

Looking at the results in more detail, Figures 5.22 and 5.23 show agricultural and pastoral patents and expenditure consistently considerably exceeded those on dairying, which

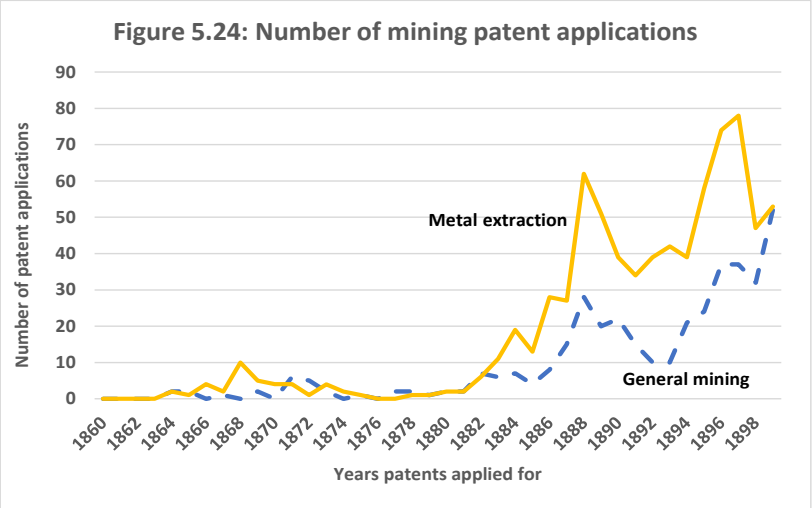
expanded later in New Zealand. Results for subcategories, not shown here, indicate patents for threshing and chaffing machines, ploughs, reaping and harvesting, dominated agricultural patenting. In contrast, very few patents related to fishing (eight over the entire period) and only slightly more to forestry (34 applications, almost all after 1894). Pastoral patents were often explicitly about fences and hedges (these accounted for 3.5% of total patent applications), controlling rabbits (1.2% of total applications), and shearing and sheep (1.8% of applications). The series for primary sector expenditure usually follow a smoother growth path than the series for primary sector patent applications.

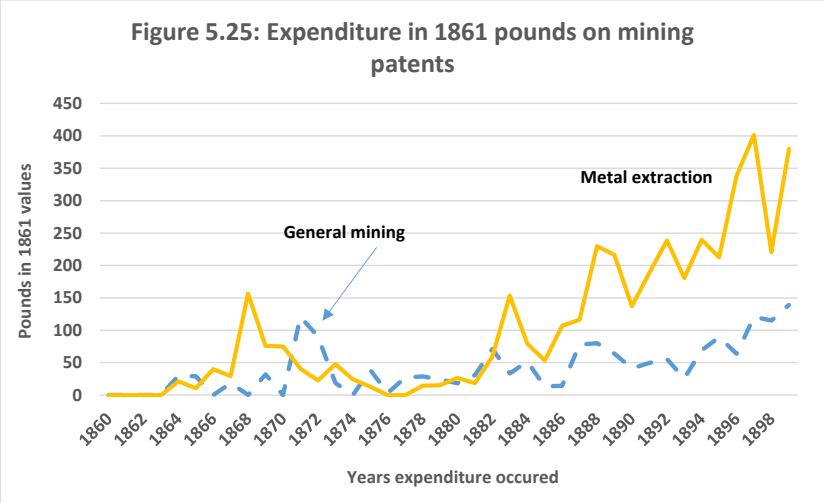
Patents are only one measure of knowledge, with some types of knowledge being freely shared by farmers at agricultural shows and other events. In addition, some improvements could not be patented, such as better seeds and stock from selective breeding, but innovators still got a return from improvements. Other types of knowledge were freely published in newspapers and in agricultural journals (Wood & Pawson, 2011, pp. 140-141, 151). Nevertheless, farming patents still covered important topics.



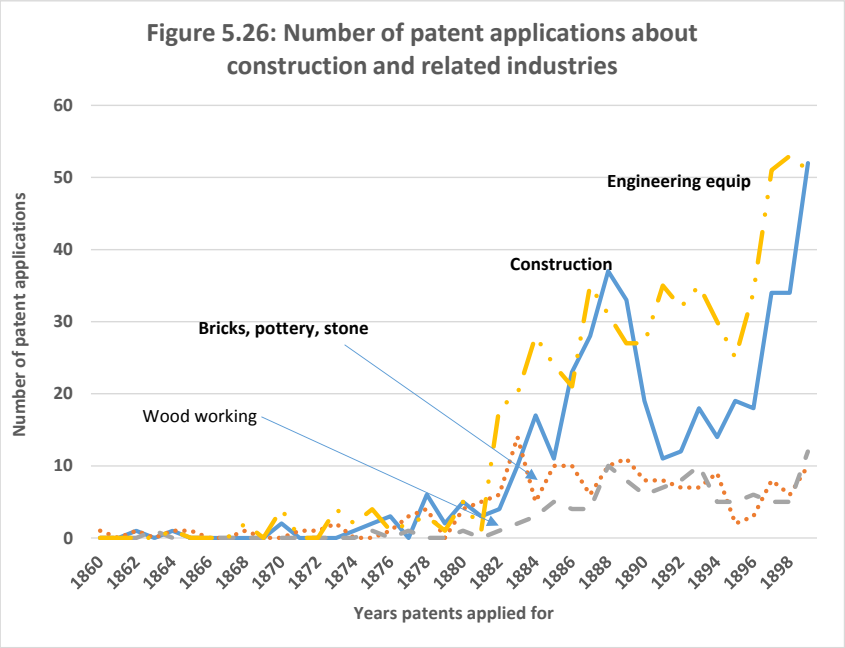


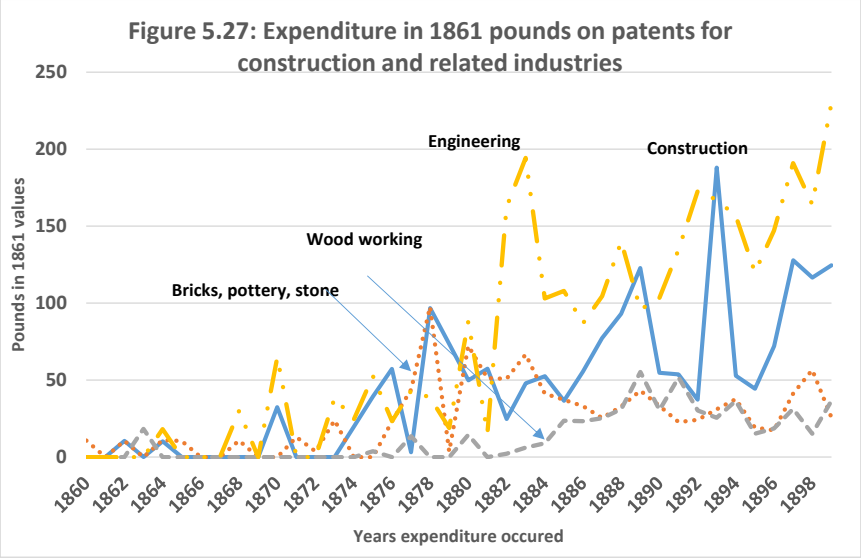
Although the percentage of mining applications and mining patent expenditure was highest in the 1860s, the absolute number of applications and expenditure increased over time. However, growth was less for expenditure on patents than for patent applications. Furthermore, not all the mining patents were about gold and silver: some related to iron sand or other types of mining. Patenting relating to metal extraction increasingly considerably exceeded patents about general mining, as the sector's use of technology, such as chemical extraction of gold, increased.



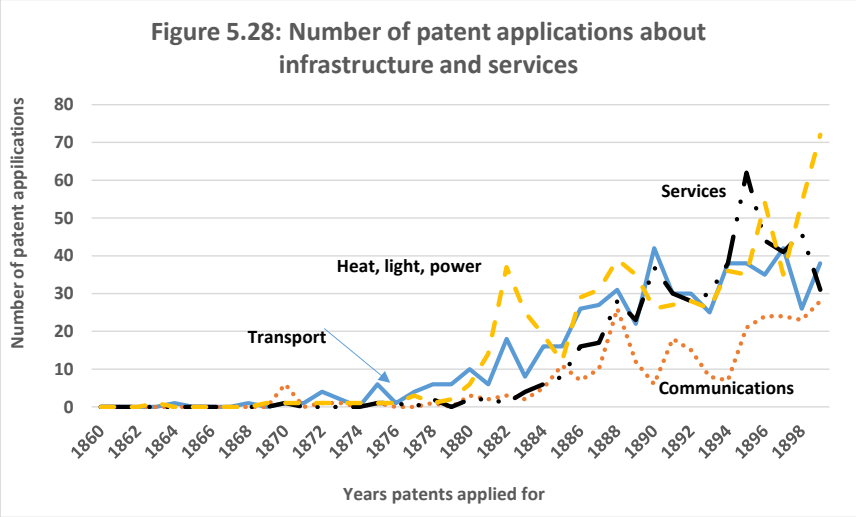


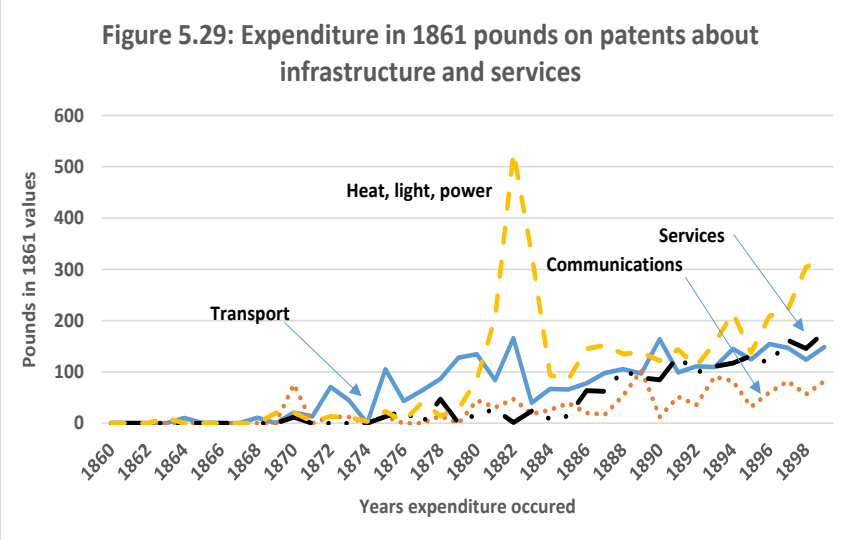
For construction, the number of patents increased from very low levels, but with a sharp decline in the early 1890s that lasted until 1897. The expenditure statistics show more stable growth, with the decline in expenditure in the early 1890s being interrupted by a brief recovery in 1893. There is also much less evidence of a decline in patents relating to engineering equipment.



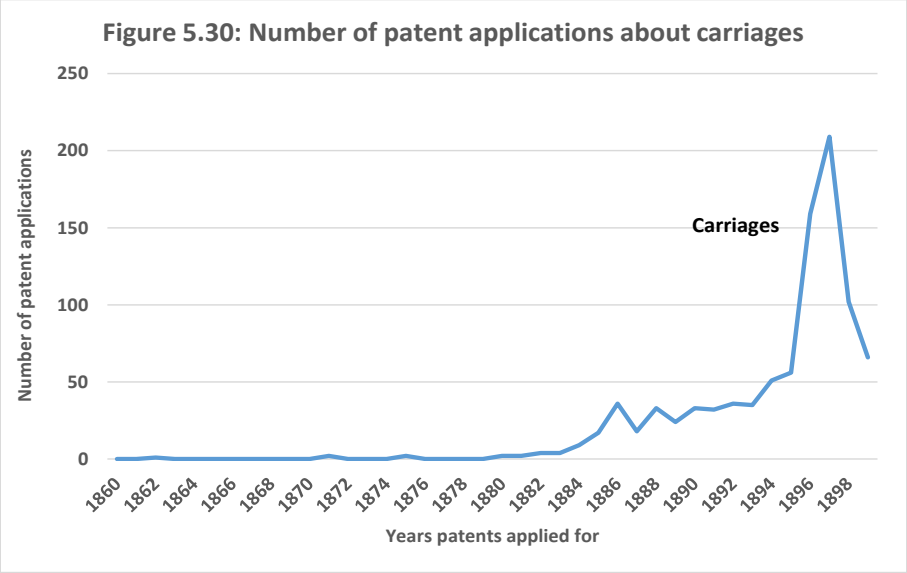


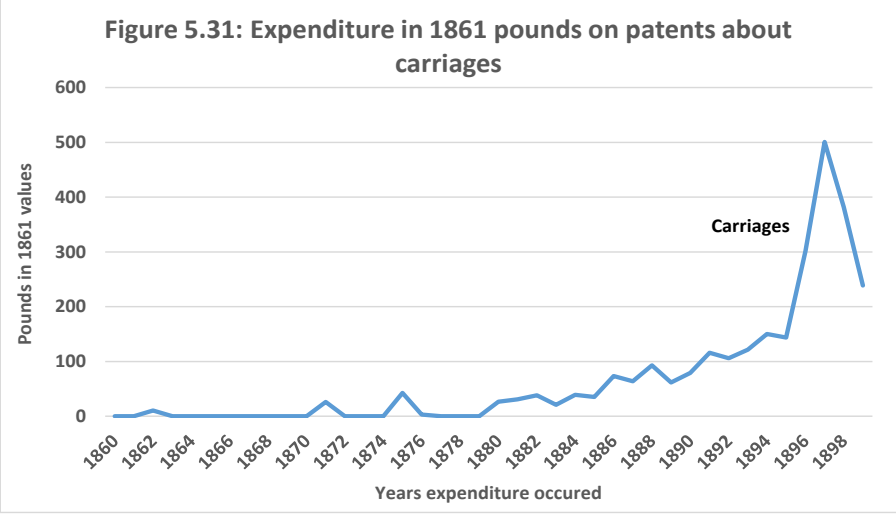
For infrastructure and services, there was a spike in heat, light and power patents in 1882 because of 33 letters of registration by inventors such as Joseph Wilson Swan of England, and Marcellus Hartley and Thomas Edison of the United States, for patents protecting intellectual property on electricity and lamps. This high expenditure, which also occurred to a lesser extent in 1881 and 1883, was sufficient to substantially increase the United States' share of expenditure on patents in New Zealand during the early 1880s (see Figure 5.12).





Patent applications and expenditure about carriages grew rapidly in the 1880s and early 1890s before spiking in 1896 and 1897 and then falling sharply. During the 1890s there was growth in patenting about motor vehicles and horse carriages. However, the spike in the 1890s reflected a sharp increase in patents about bicycles, with 28 patents being about bicycles in 1895, but 112 patents being on this topic in 1896, and 150 in 1897. The number of patents about bicycles then declined to 69 in 1898, and 34 in 1899. Census data shows employment in cycle factories increased from 125 people in 1895 to 395 people in 1900, and the value of economic output of these factories quadrupled during this period (Office of the Registrar General, 1902, p. xxv).



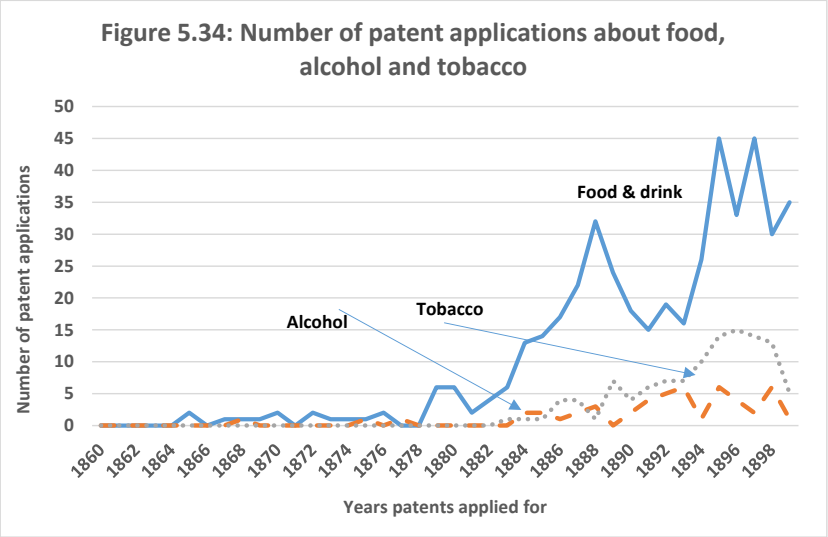


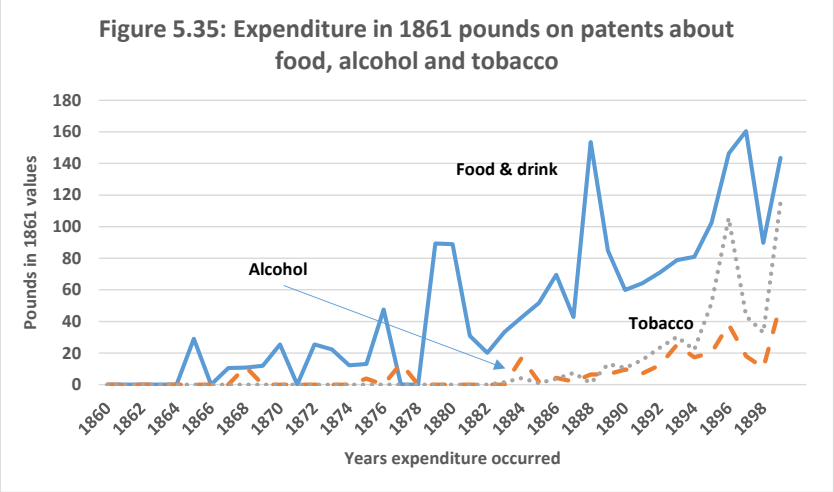
Expenditure on fees and required advertising for clothing, textiles, hides and skins patents fluctuated more than applications for these patents. The 1870 spike in expenditure in Figure 5.33 reflects 10 inventors each filing a patent or a letter of registration, which then cost 10 pounds each in nominal terms, about flax preparation and processing. For some New Zealand patentees a motivation may have been the opportunity to gain 14 years protection at a lower cost than under the fees and advertising requirements that came into effect during 1871. However, 1869 and 1871 were also years with high numbers of patents about processing flax. This was because high flax prices in 1869 had been followed by a government report into how flax processing needed to be improved to ensure the long-term viability of the industry (Flax Commissioners, 1870). The spike in clothes and textiles patents in 1889, reflected a number of inventors patenting improvements in clothing design. By 1899 there was renewed patenting of inventions about flax, but also strong interest in improvements to clothing.

Figure 5.32: Number of patent applications about clothes, textiles, skins and hides

Figure 5.33: Expenditure in 1861 pounds on patents about clothes, textiles, hides and skins

The food, tobacco and alcohol results reveal more spikes in expenditure than in patent applications. Food and drink includes both new and improved food products, and also improved packaging, such as crates and bottles.





For preserving food and refrigeration, the growth path fluctuates less when these categories are added together.

Figure 5.36: Number of patent applications about preserving food and refrigeration

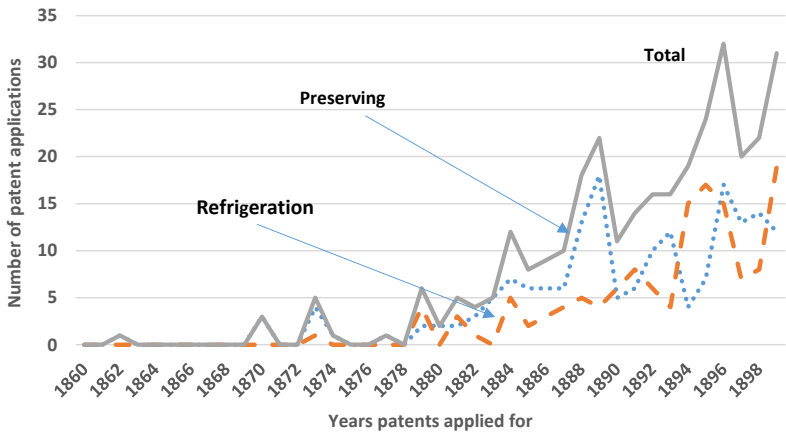
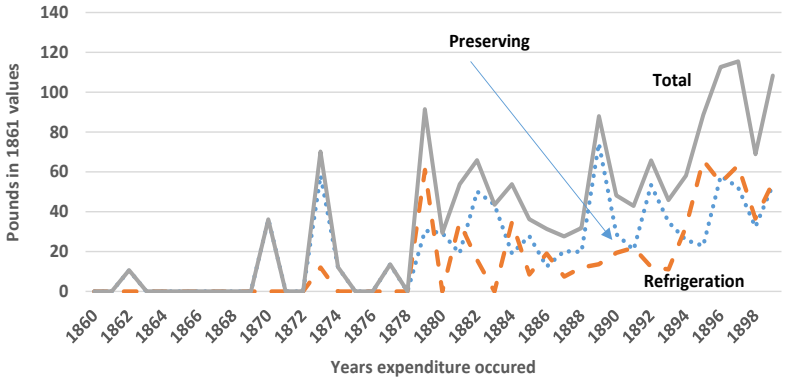


Figure 5.37: Expenditure in 1861 pounds on preserving food and on refrigeration



5.6 Revealed technological advantage

A revealed technological advantage (RTA) index was used to compare technological strengths, while normalising patent shares and eliminating the problem of scale (Magee, 2000, p. 51). RTA equals the number of national applicants' patents in a technological field divided by the total number of patents in that country in a specific technology field, all divided by the total number of national patent applications divided by the total number of patents applied for from all countries. In algebra,

$$RTA_{ij} = \frac{P_{ij} / \sum_j P_{ij}}{\sum_i P_{ij} / \sum_{ij} P_{ij}}$$

Here RTA_{ij} is the Revealed Technological Index in technology i for country j. P_{ij} is the number of patents in area i from country j. $\sum_j P_{ij}$ is the total number of patents from all j countries in area i. $\sum_i P_{ij}$ is the total number of patents from country j in all technological areas, and $\sum_{ij} P_{ij}$ is the total number of patents from all j countries in all i technological areas (Khramova, Meissner, & Sagieva, 2013, p. 13).

The applications RTA results showed that New Zealand had high RTA scores of 1.26 in agriculture and 1.21 in pastoralism. New Zealand's RTA in dairying was only just above average at 1.04, indicating that New Zealand did not have a substantial technological advantage in patents for dairying during the nineteenth century. The high New Zealand RTA for clothes and textiles of 1.21 reflected the development of technology for the flax and wool industries, and New Zealand also had an RTA of 1.14 for skins and leather. In manufacturing, New Zealand also had a slightly above average RTA of 1.07 for carriages. New Zealand had the highest RTA on medical and pharmaceutical goods of 1.22, but home remedies dominated this sector. For services, unexpectedly New Zealand had the highest RTA for shipping at 1.16. New Zealand also had strong RTAs of 1.25 for household production and consumption, perhaps indicating a focus on specifically New Zealand needs.

Australia had the highest RTA on mining at 1.12, while Australia (1.86) and Britain (1.87), and to a lesser extent the United States (1.67), had high RTA's on metal extraction. The United States also had high RTAs relating to tobacco (4.56), printing (2.03), heat, light and

power (3.17), railway equipment (1.91) and to communications (1.49). Britain's high RTAs included fuel and explosives (1.81) and heat, light and power (1.82). As in Victoria, Britain also had the highest RTA in refrigeration and in food and drink at 1.26 (Magee, 2000, p. 200).

Table 5.8: Revealed technological advantage results for patent applications for New Zealand, Australia, Britain and the United States

Sector	Industry	NZ	Australia	Britain	USA
Primary	Agriculture	1.26	0.64	0.45	0.70
Primary	Pastoral	1.22	0.97	0.52	0.26
Primary	Dairying	1.04	1.05	0.67	0.26
Mining	General Mining	1.07	1.12	0.41	1.00
Mining	Metal extraction	0.47	1.86	1.87	1.67
Manufacturing	Construction & infrastructure	1.21	0.59	0.76	0.52
Manufacturing	Cement & stone	0.85	1.12	1.16	0.30
Manufacturing	Bricks and pottery	0.80	1.04	1.62	1.84
Manufacturing	Wood working	1.08	0.89	0.97	0.30
Manufacturing	Furniture	1.19	0.85	0.74	0.16
Manufacturing	Carriages	1.07	0.99	0.99	0.56
Manufacturing	Engineering equipment	0.94	0.87	1.15	1.57
Manufacturing	Industrial metals	0.68	1.07	1.45	2.11
Manufacturing	Machinery & metal work	0.81	1.20	1.39	2.01
Manufacturing	Clothes & textiles	1.21	0.57	0.86	0.66
Manufacturing	Skins & leather	1.14	0.75	0.96	0.40
Manufacturing	Preserving food	0.95	0.86	1.20	0.84
Manufacturing	Refrigeration	0.92	1.11	1.36	1.10
Manufacturing	Food & drink	0.99	1.03	1.26	0.72
Manufacturing	Alcohol	0.67	0.85	1.42	1.68
Manufacturing	Tobacco	0.68	1.02	0.85	4.56
Manufacturing	Printing	0.73	1.18	1.36	2.03
Manufacturing	Heat, light, power	0.56	0.98	1.82	3.17
Manufacturing	Chemicals	0.75	1.09	1.95	1.09
Manufacturing	Pharmaceuticals & medical	1.22	0.64	0.58	0.83
Manufacturing	Fuel & explosives	0.59	1.53	1.81	1.21
Manufacturing	Other manufacturing	0.93	1.18	2.00	0.00
Services	Railway	0.73	1.46	1.31	1.91
Services	Shipping	1.16	0.99	0.68	0.39
Services	Communications	0.93	1.13	1.02	1.49
Services	Services and distribution	0.95	1.34	1.09	0.60
Household	Household consumption	1.25	0.85	0.46	0.26
Household	Household production	1.27	0.84	0.41	0.23

Switching to expenditure data, which includes required expenditure, shows a broadly similar picture. New Zealand's RTA in agriculture, pastoralism, clothes and textiles, skins and leather, and household production and consumption all increase. Australia's RTA in pastoralism jumps from 0.97 to 1.32, but decreases from 1.86 to 1.57 for metal extraction. In addition, Australia's RTA in tobacco production goes from 1.02 to a strong 1.66, and slightly reduces American dominance in this area from 4.56 on patent applications to 3.36

on patent expenditure. Nevertheless, the United States' RTA on alcohol increases from 1.68 to 2.46, indicating that the United States had a strong RTA in New Zealand for patents relating to the production of alcohol and tobacco. Using the expenditure data, Britain's RTA in refrigeration increases from 1.36 to a more substantial 1.76. The United States' RTA in machinery and metal work increases from a high 2.01 to an even higher 2.22.

Table 5.9: Revealed technological advantage results for expenditure on patents for New Zealand, Australia, Britain and the United States

Industry	NZ	Australia	Britain	USA
Agriculture	1.43	0.74	0.52	0.79
Pastoral	1.35	1.32	0.52	0.31
Dairying	0.93	1.27	0.77	0.28
General Mining	1.18	0.99	0.60	1.05
Metal extraction	0.50	1.57	1.31	1.18
Construction & infrastructure	1.45	0.66	0.72	0.41
Cement & stone	0.99	1.42	0.56	0.45
Bricks and pottery	1.14	0.63	1.19	1.12
Wood working	1.12	0.95	0.94	0.31
Furniture	1.50	0.69	0.69	0.11
Carriages	1.10	1.03	1.09	0.56
Engineering equipment	0.87	0.69	1.23	1.46
Industrial metals	0.88	0.92	0.91	1.32
Machinery & metal work	0.60	1.11	1.27	2.22
Clothes & textiles	1.50	0.55	0.77	0.50
Skins & leather	1.17	0.72	1.06	0.36
Preserving food	0.86	1.03	1.15	0.81
Refrigeration	0.58	1.09	1.76	1.22
Food & drink	0.86	1.23	1.45	0.50
Alcohol	0.48	1.10	1.03	2.46
Tobacco	0.40	1.66	0.34	3.36
Printing	0.66	1.26	1.12	1.18
Heat, light, power	0.40	0.71	1.58	2.63
Chemicals	0.73	1.09	1.69	0.64
Pharmaceuticals & medical	1.51	0.68	0.60	0.49
Fuel & explosives	0.36	1.38	1.62	1.11
Other manufacturing	0.93	0.88	2.10	0.00
Railway	0.64	1.21	1.21	1.44
Shipping	1.41	0.75	0.73	0.47
Communications	0.58	1.06	1.15	2.46
Services and distribution	1.04	1.21	1.02	0.75
Household consumption	1.44	0.98	0.61	0.25
Household production	1.53	1.01	0.50	0.14

5.7 Conclusion

This chapter has considered the level of patenting in New Zealand, and the origin and types of inventions patented in New Zealand between 1860 and 1899. The results showed strong growth in total patent applications between 1860 and the late 1880s, although growth in total applications thereafter was slower. Per capita applications by people living in New Zealand sharply increased during the early 1880s after application fees and other costs were reduced to encourage patent applications. The data on expenditure on patents also showed considerable growth, even when considered on a per capita basis.

However, the growth in the number of patent applications by New Zealanders became much less dramatic when the number of applications allowed to lapse after a short period of time was considered. New Zealand made 62% of patent applications, but these applications disproportionately lapsed or were not renewed. As a result, even considering required advertising expenditure, New Zealand patent applicants only paid 45% of patenting fees and required expenditure. New Zealand therefore remained heavily dependent on imported intellectual property. The main sources of foreign patents in New Zealand were Britain and Australia, which respectively accounted for 20% and 18% of patenting expenditure, followed by the United States, which accounted for 10%. Relatively little intellectual property from non-English speaking countries was licensed in New Zealand.

Patenting rates per capita in each province fluctuated, and no province had the highest per capita patenting rate for very long. New Zealanders living in the main centres patented at higher rates than other New Zealanders, although many of these patents were for products designed for the surrounding hinterland. Furthermore, even provinces with low populations and population densities sometimes had high levels of patent applications and patent expenditure for prolonged periods of time. Living in a province with a small population evidently did not preclude people patenting.

Manufacturing usually dominated patent applications in New Zealand, although for a few years during the 1860s more patents were about mining. However, patents specifically about producing primary products accounted for 16.9% of patent applications, which was more than the 11.9% they comprised in an equivalent dataset for Victoria, Australia, and amounted to 22.4% of patenting expenditure by New Zealanders. Graphs of individual

categories showed expenditure on patents generally followed a smoother path than patent applications. However, the spike in heat, light and power patents in the early 1880s and in flax patents in 1870 were important exceptions. A spike in bicycle patents in 1896 and 1897 coincided with the rapid expansion of cycle works in New Zealand. Revealed technological advantage results confirmed New Zealand had a strong comparative advantage in pastoral and agricultural patents, but less so for dairying patents. However, other countries usually had a revealed technological advantage in manufacturing and in metal extraction, although not in mining itself.

Chapter 6: The characteristics of inventors in New Zealand

6.1 Introduction

This chapter investigates the extent to which people from different economic and social backgrounds used New Zealand's patenting system to protect intellectual property between 1860 and 1899. As well as analysing the occupations of inventors, the gender of inventors is quantified, and limited information on their ethnicity has been collected. Furthermore, data has been collected on where the most prolific inventors were born, where they lived, whether they moved, on their religious beliefs, and on their education.

Section two of this chapter examines the occupations of inventors, and makes a comparison with equivalent data for the same period for Victoria, Australia, and also with broadly equivalent 1886 Census occupation data for New Zealand males. Assignments and patenting by companies is considered in section three. Section four identifies the most prolific patentees, while section five considers the overlap between prolific patenting and high expenditure on patents. Furthermore, section five examines the industry, education, economic fortunes and other characteristics of the twenty New Zealanders who spent most on patent fees and other required expenditure. In section six the focus switches to increased patenting by women, the almost non-existence of patenting by New Zealand's indigenous Maori population, and patenting by Chinese living in New Zealand.

6.2 Occupation results

Excluding declarations partly about status, such as "gentleman", almost 90% of patentees listed their occupation. This is the same percentage as in the Australian state of Victoria (Magee, 2000, p. 66), facilitating comparisons of which occupational groups applied for patents. The HISCO coding framework used, which was described in chapter four, contains 650 codes and 422 of these were used for coding the patent data. In contrast, the 1886 Census data required only 283 codes, perhaps suggesting that some occupations were merged before publication. The 1886 Census data on the occupations of males has considerable limitations, but is the most comparable data available.

As in other countries, engineers dominated patenting in New Zealand. Indeed, 12.9% of patent applicants simply gave their occupation as “engineer”, and patents by this group accounted for 15.3% of expenditure on patent fees and required expenditure. Aggregating these responses with those who listed more detailed engineering occupations, Table 6.1 shows that 21.1% of patentees stated they were engineers, and patents by these engineers incurred 24.1% of expenditure on patents. In the nineteenth century the occupation of “engineer” was widely used by those who had received technical training through apprenticeships and practical experience (Magee, 2000, p. 65). The percentage of patent applications by engineers fell to 16% of applications for patentees living in New Zealand, and was lower than the 26.8% share of patents held by engineers in Victoria. Only 1.8% of males in the 1886 New Zealand Census described themselves as an engineer, indicating that New Zealand engineers were patenting at much higher rates than the entire male workforce.

Farming occupations applied for 8.4% of patent applications in New Zealand, which was more than twice the 2.9% of patents farmers applied for in Victoria. This proportion jumped to 12.1% of patent applications by New Zealanders. Although farmers only accounted for 6.4% of total expenditure on patents in New Zealand, a more substantial 12.3% of patent expenditure by New Zealand inventors was by farmers. Just over 29% of New Zealand’s male working population stated that they worked on a farm in the 1886 Census, although some of these were farm labourers (7% of the male population), or forestry workers (1.6%), or shepherds (1.0%), and these occupations were rarely listed on patent applications. Nevertheless, patenting by New Zealand farmers was substantially lower than the 20.7% of patent applications by people living in New Zealand that were about primary sector inventions (see Table 5.5). This was because other occupational groups, such as engineers and blacksmiths, applied for a substantial proportion of primary sector patents. Farmers also shared some types of knowledge without payment, and although farmers could make money from selling improved seeds and animals to other farmers they were unable to patent these improvements (Wood & Pawson, 2011, pp. 140-141, 151).

Merchants and sales people accounted for 7.8% of patent applications in New Zealand. This was substantially higher than their 4.8% share of patent applications in Victoria. The 7.6% of patent applications by New Zealand merchants and sales people was only slightly higher than the 6.8% of the male workforce in the 1886 Census who stated these occupations.

Managers and manufacturers accounted for almost 4.8% of patent applications in New Zealand, which was higher than the 2.9% in Victoria, but just 3.0% of patent applications by New Zealanders. Furthermore, 5.7% of total expenditure on patents was by managers and manufacturers, compared to 3.3% of expenditure by New Zealanders in these occupational groups. The 1886 Census data indicated only 0.6% of the male population were managers or manufacturers, although this probably partly reflects managers specifying other occupations. Since manufacturing was expanding quickly in the 1880s (Greasley & Oxley, 2010b), consolidating data from a later census would probably show more people stating they were manufacturers. Similar caution is also necessary when interpreting the results for electricians, who by 1896 made up 0.08% of New Zealand's male workforce.

Blacksmiths made 3.5% of total patent applications in New Zealand, and 4.8% of patent applications by New Zealanders, and both these proportions were higher than the 2.4% in Victoria. On an expenditure basis, patents by blacksmiths involved 3.0% of total expenditure, and 4.9% of expenditure by New Zealanders. In the 1886 Census 2.5% of men in the workforce stated they were a blacksmith, indicating that New Zealand blacksmiths were patenting at a relatively high level. Machinists were a relatively unimportant group for patent applications in New Zealand, accounting for only 0.9% of applications compared to the 5.0% of patent applications they made in Victoria. However, machinists were also only a small part of New Zealand's population in the 1886 Census, with only 0.8% of the male workers reporting an occupation that indicated they were a machinist.

Miners made 1% of total patent applications, but adding to this occupation metallurgists and mining engineers and proprietors more than doubles the proportion of patentees working in mining, and makes the proportion slightly higher than in Victoria. New Zealand miners accounted for 1.1% of patent applications, but other mining occupations were less important than for all patent applications. The expenditure results reveal similar patterns. The 1886 Census data indicated 7.0% of the male population were miners. Data from other censuses also shows that mining employed a substantial proportion of New Zealand men (Bloomfield, 1984, pp. 126-133). This indicates that mining technology development was primarily occurring among other occupational groups. The very low proportion of other mining sector workers in the 1886 Census may reflect the way in which the census data was reported.

Trades workers were represented in patenting in New Zealand through occupations such as plumbing (1.5% of all patent applications, 2.1% by New Zealanders), coach building (1.6% and 2.3% of applications), carpentry (1.2% and 1.7% of applications) and building (1.0% and 1.3% of applications). Some of these occupations, such as coach builders and other builders, were overrepresented in patenting by New Zealanders relative to the 1886 Census data.

However, the occupations usually thought of as least skilled accounted for few patents. Adding together all the occupations that included the word labourer (except agricultural occupations), 0.5% of all patent applications and 0.7% of applications by New Zealanders were by labourers. In contrast, over 10% of New Zealand working men at the 1886 Census simply stated they were a "labourer", and adding railway and waterfront labourers would increase the size of this group to 14% of the male population. Using data from other censuses produces similar results, and for later censuses more occupations include a category for labourers working in that occupation.

Just over 3.4% of patentees stated they were a "gentleman", which often meant that they were of independent means, while 0.6% gave their occupation as "inventor". Among patentees living in New Zealand the proportion of gentlemen more than halved to 1.6%, and this percentage fell sharply from the early 1880s. Just 0.06% of the male workforce gave their occupation as being a gentleman at the 1886 Census. However, the comparable statistic for the 1896 Census was 0.65%, suggesting that the 1886 Census count for gentlemen is not representative of the entire time period.

The percentage of patentees who were chemists and pharmacists was 1.3% in New Zealand, compared to 0.24% of males in the 1886 Census, and 2.0% of all patentees. On average, 2.1% of New Zealand patentees, and also all patentees, were doctors and other medical workers, although this group were only 0.6% of New Zealand's male workforce in 1886. Comparing the results for engineers, manufacturers, chemists, and electricians suggests that New Zealand patentees on average tended to be less skilled than foreign patentees.

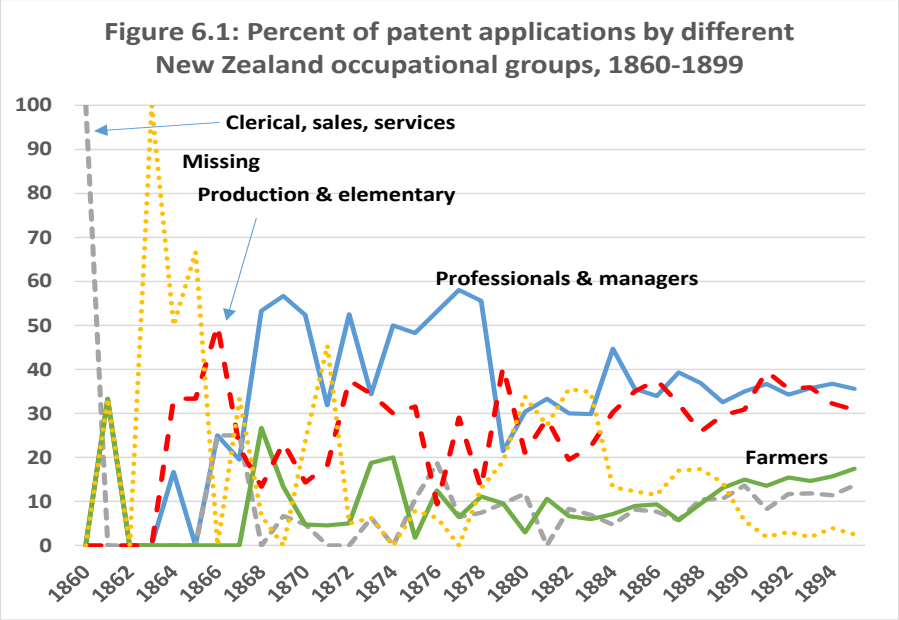
The results for the nine main HISCO groups in Table 6.2 confirm that professionals and managers dominated patenting applications and expenditure in New Zealand. The professionals group includes most engineers, although though many of the self-described engineers were highly skilled metal tradespeople or manufacturers who were in business and sometimes, particularly in their youth, had used less prestigious occupational titles.

None of the New Zealand engineers who were among the top twenty spending New Zealand patentees (see Table 6.7) are profiled in a text that discusses civil engineers who designed New Zealand's infrastructure projects (Furkert, 1953). Professionals accounted for 40.2% of total patent expenditure and 29.8% of patent expenditure by New Zealand patent applicants. In contrast, at the 1886 Census just 6.7% of New Zealand's male working age population were professionals using the alphabetical occupation listings.

Elementary occupations and labourers, who are in HISCO group nine, made 6.4% of patent applications by New Zealanders and paid 5.6% of patent expenditure, but were 21% of New Zealand's male working age population. Applications and expenditure by this group were predominantly by carpenters, joiners, printers, and painters. Production trades workers, who are the second lowest group in HISCO, paid 18.2% of patent fees and associated costs by New Zealanders, but were only 10.0% of the 1886 male working age population. This group includes occupations such as blacksmiths, coach makers, saddlers, bootmakers, and electrical workers. Table 6.2 shows that the main HISCO groups who patented at the lowest levels were clerical workers (such as office workers) and service workers (such as restaurant and household workers, and protective service workers). The 6.9% of patent expenditure by New Zealand sales workers was similar to their 6.8% share of the male workforce in 1886.

Merging applications by New Zealanders into four main categories for Figures 6.1 and 6.2 reveals that in the late 1860s production and elementary occupation workers, who were in the bottom HISCO groups, briefly made the most patent applications and expenditure. This reflects patent applications by millwrights, a rope maker, a shoe maker, and a miner. Professionals and managers then dominated New Zealand patent applications and expenditure during the 1870s, which was when initial fees and required advertising costs were particularly onerous. The reduction in the cost of an initial patent application in the early 1880s appears to have been associated with a decrease in the proportion of patenting by New Zealand professionals and managers, a higher percentage of New Zealanders who did not report their occupation when applying for a patent, and a gradual increase in patenting by other occupational groups. Indeed, from the early 1880s combined patent applications and also expenditure by New Zealanders in the three lowest HISCO occupational groups were almost as high as for professionals and managers. Together with the increase in total patent applications by New Zealanders (see chapter five) this suggests that reductions in the cost of an initial application fulfilled their intended goal of increasing patenting by skilled trades workers (Hutchison, 1879, p. 66).

However, the proportion of applications from the least skilled occupations, such as labourers and miners, remained low. Indeed, during the 1890s New Zealand labourers paid only 0.75% of patent expenditure by New Zealanders.



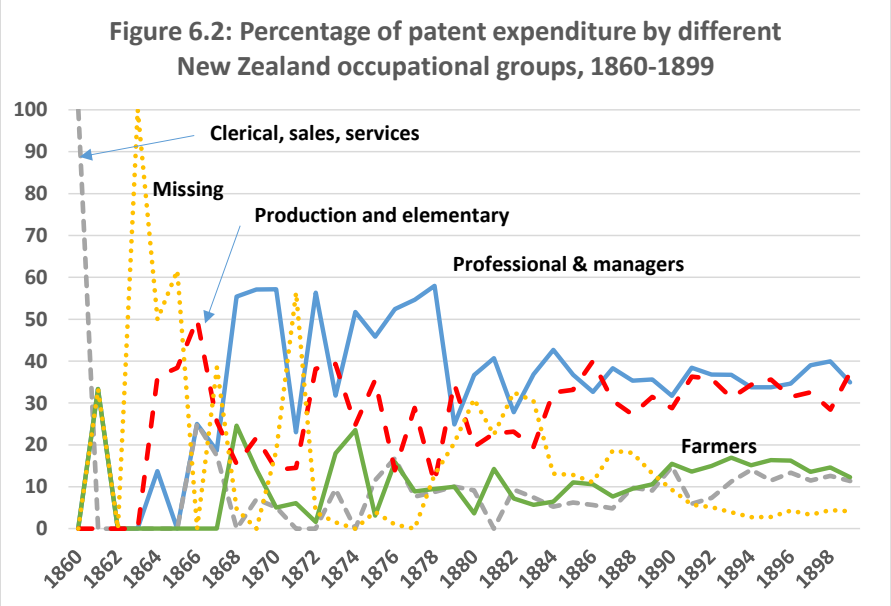


Table 6.1: Occupations of applicants for patents weighted by their share of patent applications and also for New Zealand by their expenditure on patents

	All patentees			New Zealand patentees			1886 NZ Census	Victoria (Magee)	
Occupation	Patents	Percent applications	Percent expenditure	Patents	Percent applications	Percent expenditure	Percent male working popn	Patents	Percent applications
Engineers	2,594	21.1	24.1	1,221	16.0	16.6	1.8	2719	26.8
Farmers, forestry & fishing	1,037	8.4	6.4	927	12.1	12.3	29.3	298	2.9
Merchants & sales	957	7.8	7.0	580	7.6	6.9	6.8	490	4.8
Managers & manufacturers	586	4.8	5.7	233	3.0	3.3	0.6	298	2.9
Blacksmiths & metal workers	435	3.5	3.0	368	4.8	4.9	2.5	246	2.4
Gentlemen	415	3.4	4.5	121	1.6	2.6	0.06	98	1
Doctors and other medical	261	2.1	2.0	160	2.1	2.0	0.3	-	-
Chemists and pharmacists	245	2.0	2.3	100	1.3	0.8	0.2	242	2.4
Coach builders	192	1.6	1.2	178	2.3	2.4	0.6	114	1.1
Plumbers and pipe makers	185	1.5	1.0	157	2.1	1.8	1.3	134	1.3
Architect	151	1.2	1.0	116	1.5	1.8	0.1	117	1.2
Carpenters and joiners	148	1.2	0.8	133	1.7	1.4	3.7	113	1.1
Other mining sector	139	1.1	1.3	34	0.4	0.3	0.02	-	-
Electricians & lines	138	1.1	2.4	33	0.4	0.3	0.01	162	1.6
Miners	126	1.0	0.8	88	1.1	1.3	7.0	216	2.1
Builders	120	1.0	0.8	98	1.3	1.4	1.4	98	1.0
Machinists	113	0.9	1.1	69	0.9	0.8	0.8	504	5
Labourers	57	0.5	0.3	56	0.7	0.6	10.2	-	-
Other	4,385	35.7	34.3	2,983	39.0	38.5	33.3	-	42.2
Total	12,283	100	100	7,653	100	100	100		100

Table 6.2: Occupation results for the nine main HISCO groups, with patent applications weighted by share of patent applications and also by expenditure on patents

		All patentees			New Zealand patentees			1886 NZ Census
Group	Occupation group	Patents	Percent applications	Percent expenditure	Patents	Percentage applications	Percentage expenditure	Percent male working popn
1	Professionals	4,661	38.0	40.2	2,324	30.4	29.8	6.7
2	Administrators and managers	1,080	8.8	9.3	543	7.1	8.0	2.3
3	Clerical	178	1.5	1.0	144	1.9	1.7	5.1
4	Sales	957	7.8	7.0	580	7.6	6.9	6.8
5	Services	126	1.0	0.8	86	1.1	1.0	4.2
6	Farmers	1,037	8.4	6.4	927	12.1	12.3	29.3
7	Processing including metal	668	5.4	4.6	508	6.6	6.7	14.5
8	Production trades workers	1,790	14.6	13.4	1,400	18.3	18.2	10.0
9	Elementary occupations & labourers	576	4.7	3.3	488	6.4	5.6	21.0
	Other	1,210	9.9	13.9	652	8.5	9.8	0.01
	Total	12,283	100.0	100.0	7,653	100.0	100.0	100.0

6.3 Assignments and patenting by companies

Almost 4.4% of patents had been legally assigned to another person, with this being indicated in the patent dataset either explicitly, or occasionally by names in brackets. In these cases the other person's name was included in the dataset, rather than the name of the assignee. The person assigning the patent was not necessarily the original inventor. However, the patent records often provided the name of the original inventor, and further information on the original inventor was often available from original patent records for other countries that were found through the internet.

Just over 3.1% of patents had either been filed by a company, or the patentee noted that they worked for a company. This is fractionally higher than the 2.9% for patents in Victoria (Magee, 2000, p. 65), but substantially lower than the 6.6% in Norway between 1840 and 1885 (Basberg, 2014, p. 5). However, some inventors, such as Thomas Edison, gave addresses that were associated with businesses, and obviously had substantial support from the company they owned or worked for. Furthermore, Table 6.7 shows the highest spending New Zealand patentees were almost invariably associated with a partnership or company.

6.4 Number of authors and multiple patenting

Overwhelmingly patent applications were by individuals, with 81.7% being by one person. Table 6.3 shows that almost 16% of patents involved two people, but having more than two authors for a patent was unusual.

Table 6.3: The number of authors on each patent application in New Zealand, 1860-1899

Author number	Frequency	Percent of applications
1	10,029	81.7
2	1,953	15.9
3	256	2.1
4	32	0.3
5	8	0.1
6	1	0.0
7	2	0.0
9	1	0.0
Total	12,283	100

The number of multiple patentees was found both for the entire period, and for specific sub-periods. For the entire period, 9,002 individuals were involved in a patenting application. The most common number of applications people were involved in (either jointly or individually) was one, with 6,553 people, which was 72.6% of total applicants, involved in one application. In contrast, 1,325 people, which was 14.7% of the total, were involved in two applications. Less than 5% of applicants were involved in four or more patent applications.

On a more robust weighted basis (Table 6.4), where each patent has been weighted by the number of applicants, over the entire period 4,371 individuals made the equivalent of one patent application, 1,843 made the equivalent of half a patent application, and 827 made the equivalent of two applications. Only 9% of applicants made more than three patent applications. Since many inventors patented in several time periods, the percentages for numbers of patents are sometimes higher for individual time periods than for the entire time period.

Table 6.4: Number of patent applications per person between 1860 and 1899 for different numbers of applications and different years with percent in brackets (not all categories shown)

Applications	1860-1879	1880-1889	1890-1899	Entire period
0.5	94 (20.3%)	525 (17.9%)	1,424 (28.2%)	1,843 (20.5%)
1.0	248 (53.5%)	1,575 (58.8%)	3,167 (49.5%)	4,371 (48.6%)
1.5	8 (1.7%)	76 (2.6%)	179 (2.9%)	285 (3.2%)
2.0	31 (6.7%)	295 (10.1%)	580 (9.1%)	827 (9.2%)
3.0	9 (2.0%)	93 (3.2%)	182 (2.4%)	294 (3.3%)
3+	11 (2.4%)	217 (7.4%)	475 (7.4%)	811 (9.0%)
Most living overseas	5 by Sir William Thomson	36 by Thomas Edison	12.5 by Benjamin Garver Lamme	46 by Thomas Edison
Most living NZ	3.5 by Edwin Wise Hollis	28 by Robert Cockerell	25.5 by Arthur John Cuming	55 by Robert Cockerell
Total individuals	464	2,926	6,404	9,002

The results show that during the 1860-1879 period, when many patentees patented under both the 1860 and 1870 Acts, high levels of patenting were rare, with just eleven individuals making the equivalent of three or more patent applications. As discussed in chapters three and five, high fees and required advertising expenditure limited patenting during this period. The most prolific patentee in New Zealand, but only by half a patent, was Edwin Wise Hollis, an architect turned Thames council clerk (New Zealand Herald Correspondent, 1906; Thames Star reporter, 1906, p. 2). Hollis' three and a half patents during this period were about gold mining and gold and iron sand smelting. However, Sir William Thomson of North Britain, which was then the term usually used by people living in Scotland to denote their location, made the equivalent of five patent applications relating to telegraphs. Thomson was also considerably ahead of England's Cromwell Fleetwood Varley, who was the second highest overseas patentee. Varley made 2.5 patent applications, which were also about telegraphs.

Table 6.5: Most prolific New Zealand patentees

	1860-1879 (2.5+)	1880s (6.5+)	1890s (11+)	Entire period (14+)
1	Edwin Wise Hollis, Auckland, Architect (3.5)	Robert Cockerell, Southland , Agricultural Implement Maker (28)	Arthur John Cuming, Canterbury, Journalist and Printer (37.5)	Robert Cockerell, Otago and Southland, Blacksmith (55)
2	Charles James Pownall, Auckland & Wellington, Gentleman (3)	Henry Corrick, Canterbury, Implement Maker (17)	David Ranken Shirreff Galbraith, Auckland, Analytical Chemist (30)	David Ranken Shirreff Galbraith, Auckland, Analytical Chemist (42)
3	Edward Metcalf Smith, Taranaki, Armourer (3)	Thomas Danks, Canterbury, Engineer (15)	Robert Cockerell, Otago and Southland, Blacksmith (27)	Arthur John Cuming, Canterbury, Journalist and Printer (38.5)
4	Horatio Bunting, Canterbury, Nursery man (3)	Charles McQueen, Otago, Engineer (15)	Alfred Launcelot James Tait, Otago, Food specialist (25.5)	Henry Corrick, Canterbury, Boot maker (28)
5	John Alves, Otago, Contractor and Engineer (3)	Walter Greenshields, Auckland, Bracist (12.5)	John Anderson, Otago, Engineer (19)	Job Osborne, Canterbury, Farmer (25.5)
6	Robert Atkinson, Otago & Nelson, Miner (3)	Francis Henry Asbury, Otago (12)	William Tyree, Wellington, Photographer (19)	Alfred Launcelot James Tait, Otago, Food specialist (25.5)
7	Robert Haworth, Otago, Iron merchant (3)	David Ranken Shirreff Galbraith, Auckland, Analytical chemist (12)	William Toogood, Wairarapa, Storekeeper (16)	Thomas Danks, Canterbury, Engineer (24.5)
8	William Douslin, Marlborough, Architect (3)	Job Osborne, Canterbury, Farmer (11.5)	Joseph Gaut, Hawke's Bay, Artist (15)	John Anderson, Otago, Engineer (22)
9	John Henry Noding, Canterbury, Gentleman (3)	William James Dalton, Auckland, Civil Engineer (11)	James Gray, Otago, Agricultural engineer (14)	James Gray, Otago, Agricultural engineer (20.5)
10	Decimus Atkinson, Taranaki, Gentleman (3)	Donald Donald, Wairarapa, Sheep farmer (9)	Job Osborne, Canterbury, Farmer (14).	William Andrews, Canterbury, Engineer (20.16)
11	William Andrews, Canterbury, Engineer (2.67)	Francis Blundell Warre Malet, Canterbury, Accountant (8.5)	James MacAlister, Southland, Engineer (13)	Donald Donald, Wairarapa, Sheep farmer (20)
12	Alexander Peyman, Otago, Gentleman (2.5)	James Barclay Blaikie, Auckland, Slater (8.5)	Henry George Beddell, Wellington, Plumber (13)	William Tyree, Wellington, Photographer (19)
13		William Hooker, Wellington, Gas engineer (8)	Henry Ashworth, Wellington, Engineer (12)	Charles McQueen, Otago, Engineer (18)
14		John Clare, Auckland, Analytical Chemist (7)	Ranald Macintosh Macdonald, Canterbury, Engineer (12)	William Toogood, Wellington, Storekeeper (17.5)
15		Joseph James Macky, Auckland, Agent (7)	John William Mcdougall, Hawke's Bay, Journalist (12)	William James Dalton, Auckland, Civil Engineer (17)
16		William Rainbow, Canterbury, Engineer (7)	John Greenslade, Canterbury, Engineer (11)	Walter Greenshields, Auckland, Bracist (15.5)
17		William Andrews, Canterbury, Engineer (6.83)	William Boyens, M'borough, Engineer (11)	Henry George Bedell, Wellington, Plumber (15)
18		Edward Elliott, Canterbury, Storekeeper (6.67)	Henry Corrick, Canterbury, Boot maker (11)	Joseph Gaut, Hawke's Bay, Artist (15)
19		Walter Cole, Wellington, Architect (6.5)	Donald Donald, Wairarapa, Sheep farmer (11)	James Keir, Canterbury, Blacksmith (14.5)
20				Joseph James Macky, Auckland, Agent (14.5)

The results for the 1880s cover a period when fees and required expenditure fell sharply, and patenting considerably increased. During the 1880s, 217 people, who accounted for 7.4% of total patent applications, made the equivalent of three or more patent applications. The most prolific patentee was the American inventor and businessman Thomas Edison, who registered 36 patents relating to electricity, lamps, and telephones. Edison modestly described himself as an electrician, which places him in HISCO occupational group eight. The next highest overseas patentee was Marcellus Hartley, also from the United States, with nine patents. The highest New Zealand patentee during the 1880s, was Robert Cockerell, an agricultural implement maker who lived in Otago and Southland.

For the 1890s the most prolific New Zealand patentee was Arthur John Cuming, a journalist and printer who lived in Christchurch. Cuming's inventions were about popular topics for patenting during the late 1890s, such as bicycles, flax processing and meat branding. Three quarters of his applications did not proceed beyond provisional status, another 16% lapsed before being sealed, and only one of his patent applications was renewed. After a troubled business career, Cuming left New Zealand in late 1900, and was divorced by his wife in 1912 for desertion (Press Association, 1912, p. 8; Star reporter, 1895, p. 2). His place and year of death was unknown by his descendants (Cuming, 2003), but was probably London, England, in 1939 (General Register Office, 1939, p. 305). The most overseas patents during the 1890s were the 12.5 filed by Benjamin Garver Lamme, an American electrical engineer. Thomas Edison and the English chemical manufacturer Francis Ellershausen, were second equal and both made ten New Zealand patent applications.

6.5 The 20 New Zealand inventors who spent most on patents

However, patent applications are not equal across time since the cost of applying for a patent varied considerably. It is therefore desirable to weigh the data by the amount of money spent on patents, and Tables 6.6 and 6.7 show these results for people living in New Zealand. Seven patentees in the top twenty for the 1860s and 1870s were in the top twenty for the entire time period.

However, two of the top spenders over the entire period (Bunting and Wolff) just patented during the 1860s and 1870s, and are included in Table 6.6 only because they

patented during the 1870s when advertising costs and fees were particularly high. Wolff's interest in New Zealand gold patents appears to have been fleeting, and he seems to have moved to New South Wales in 1872 (Daily Southern Cross, 1872, p. 2; Sydney Morning Herald reporter, 1873, p. 8). He is unknown to a New Zealand mining historian (Hart, 2016) and not mentioned in the key text on Germans in New Zealand (Bede, 1993).

Table 6.7 shows the highest spender on patent fees and required advertising expenditure was the Otago agricultural engineer James Gray at 215 pounds in 1861 values. William Andrews was second at almost 168 pounds, and his Canterbury company also produced agricultural equipment. For the last six inventors in Table 6.7 the difference in expenditure is small. The correlation between total patent applications by individuals between 1860 and 1899 and total real expenditure on patents by them over the same period is high at 0.60 and for those living in New Zealand is fractionally higher at 0.62. As a result, although there is considerable overlap with those who made the most patent applications, some of the most prolific patent applicants do not appear because relatively few of their applications were sealed or renewed. Although eight inventors (Robert Cockerell, David Ranken Shirreff Galbraith, Job Osborne, James Gray, William Andrews, Charles McQueen, William Toogood and James Keir) are on the list of both the twenty most prolific New Zealand patent applicants and the twenty biggest New Zealand spenders on patents, the other names differ. In other words, it was possible to be a high spender on patent fees and required advertising while applying for a relatively small number of patents.

The 14 year patents column in Table 6.7 includes patents renewed after 1899, even though these are not included in the cost calculations, and this column is intended to provide insights into how enduring an inventor's ideas were. Gray, followed by Greenslade, Andrews, and then Beaven had the most 14 year patents. Robert Cockerell had none, and further analysis of his applications shows that none of them were renewed, even for a second term. In addition, only 3.5% of Galbraith's patents were renewed for a second term. Table 6.7 therefore includes two inventors (Cockerell and Galbraith) who made a large number of applications, and used their applications to publicise their businesses (New Zealand Herald reporter, 1886, p. 3; Otago Daily Times reporter, 1893, p. 4), but whose ideas were not considered worth protecting for more than a short period. However, both these inventors tended to file new provisional applications that were similar to lapsed applications, and may have considered this a cost-effective way of protecting innovations that were still being refined.

As well as being the biggest spender on patents over the entire time period, James Gray was also the biggest spender on patent fees and other required payments during both the 1880s and 1890s. Gray's company manufactured agricultural equipment, such as double-furrow ploughs, chaff-cutters and seed drills. These were exported to Australia, Britain, and South America, and by 1900 his company employed 200 people (Cyclopedia Company Limited, 1905; Otago Daily Times reporter, 1900, p. 4).

There were four other successful agricultural equipment suppliers among the top ten New Zealand spenders on patents, and six among the top twenty. In particular, William Andrews and Arthur Ward Beaven, whose company, Andrews and Beaven, specialised during this period in chaff cutters, were the second and tenth highest spenders on patents respectively between 1860 and 1899. During the 1880s and 1890s Andrews and Beaven exported chaff cutters to Australia, the United Kingdom and South America (Andrews & Beaven, 1978, pp. 3, 5; Cyclopedia Company Limited, 1903b, p. 313). Job Osborne, who was the third highest spender, developed new technology for sinking wells for farmers and other groups (Gavin, 2013), which he patented from the 1880s, while he also patented inventions relating to gorse cutting and other related farming problems. Further down the list at number eight, Robert Cockerell's patents were often about ploughs and harrows, while he also patented extensively on stump extraction. John Greenslade, who spent the eleventh highest amount, also designed cultivators and threshing machines, while James Keir, who spent the twelfth highest amount, had similar interests.

The level of patenting by those producing agricultural equipment is remarkable considering that the number of New Zealand agricultural implement firms peaked at 36 in 1891, and these firms employed just 528 staff (Office of the Registrar General, 1892, pp. xv, xxi). A high level of investment in patenting was therefore being made by a relatively small sector of the economy.

Table 6.6: The 20 New Zealand patentees who spent the most on patent fees and required advertising and preparation costs in three time-periods

	1860s and 1870s	£ spent	1880s	£ spent	1890s	£ spent
1	William Douslin, Marlborough, Architect	92.2	James Gray, Otago, Agricultural engineer	70.4	James Gray, Otago, Agricultural Engineer	126.8
2	William Andrews, Canterbury, Engineer	69.0	John Alves, Otago, Engineer	68.6	Job Osborne, Canterbury, Farmer	94.7
3	Horatio Bunting, Canterbury, Gentleman	64.5	Francis Henry Asbury, Otago, Heating engineer	63.6	William Toogood, Wairarapa, Storekeeper	91.6
4	Gustavus Wolff, Auckland, Dr Philosophy	64.2	Charles McQueen, Otago, Engineer	55.1	John Greenslade, Canterbury, Engineer	72.0
5	Robert Haworth , Otago, Iron Merchant	61.8	Job Osborne, Canterbury, Farmer	51.0	James Keir, Canterbury, Machinist	61.9
6	Robert Atkinson, Otago and Nelson, Miner	60.7	Robert Cockerell, Southland, Agricultural Implement Maker	49.9	William Andrews, Canterbury, Engineer	55.5
7	Charles James Pownall, Auckland, Gentleman	57.4	Samuel Parker, Auckland, occupation not given	46.2	Arthur Ward Beaven, Canterbury, Engineer	54.1
8	Alexander Peyman, Otago, Gentleman	50.9	William Andrews, Canterbury, Engineer	43.5	John Anderson, Otago, Brassfounder	53.3
9	Frederick Lowe Jeffcoat, Otago, Saddler	46.6	Walter Greenshields, Auckland, Bracist	37.8	Thomas Danks, Canterbury, Engineer	50.3
10	Edwin Wise Hollis, Auckland, Architect and council clerk	45.6	Donald Donald, Wairarapa, Sheep farmer	37.7	Josiah Clifton Firth, Auckland, Miller	49.6
11	Charles McQueen, Otago, Engineer	45.4	Andrew Smith Hallidie, Auckland, Engineer	37.6	Gilbert Anderson, Canterbury, Freezing works manager	47.2
12	Edward Metcalf Smith, Taranaki, Gunsmith	44.5	James Barclay Blaikie, Auckland, Slater	37.6	John Mitchell, Auckland, Architect	46.9
13	James Caughley, Auckland, Boiler maker	44.3	Peter Duncan, Canterbury, Agricultural Engineer	36.2	Alexander Storrie, Southland, Implement Maker	46.7
14	Decimus Atkinson, Taranaki, Gentleman	44.0	James Palmer Black, Nelson, Settler	34.9	Thomas Thatcher, Wanganui, Farmer	46.4
15	John Henry Noding, Canterbury, Chemist	42.5	Samuel Bawden, Auckland, Assayer	32.9	Arthur John Cuming, Canterbury, Journalist and printer	45.2
16	William Speedy, Hawke's Bay, sheep farmer	42.4	Thomas Danks, Canterbury, Engineer	32.8	David Ranken Shirreff Galbraith, Auckland, Chemist	42.5
17	Henry Daniel Manning, Canterbury, Goldsmith	41.7	William Cook Dean, Canterbury, Tin plate worker Guy H. Gardner, Canterbury, Merchant	31.8	William Benjamin Walters, Otago, Engineer	46.9
18	George Gledhill, Auckland, Aerated water manufacturer	42.0		31.4	James Macalister, Southland, Engineer	41.6
19	Henry Cain, Canterbury, Shipping	42.0	William Hooker, Wellington, Gas engineer	29.8	James Copeland, Wanganui, Farmer	40.7
20	Abiel Gifford Howland, Canterbury, Coachbuilder	41.8	Thomas Ellis, Wanganui, Settler	29.7	Walter Gee, Canterbury, Blind-manufacturer	37.9

Table 6.7: The 20 New Zealand patentees who spent the most on patent fees and on required expenditure between 1860 and 1899

	Inventor, region and usual occupation	£ spent	Number of patent applications	Number of 14 year patents	Patenting applications	Firms associated with	Died in New Zealand
1	James Gray, Otago, Agricultural Engineer	215.2	20.5	7	1872-1898	Reid & Gray	Yes
2	William Andrews, Canterbury, Engineer	167.9	20.2	5	1875-1899	Andrews and Beaven	Yes
3	Job Osborne, Canterbury, Farmer	145.7	25.5	2	1882-1897	Own firms	Yes
4	William Douslin, Marlborough, Architect	134.3	8	3	1876-1888	Own firm	No, migrated to Rhodesia in 1893 to work with son
5	William Toogood, Wairarapa, Storekeeper	113.1	17.5	2	1870-1899	Featherston Store	Yes
6	Charles McQueen, Otago, Engineer	113.3	18	1	1872-1890	Numerous that he owned	No, migrated to work in Victoria mining industry
7	John Alves, Otago, Engineer	103.3	11	2.5	1868-1895	Include Fernhall Colleries	No, to Victoria then England in old age
8	Robert Cockerell, Southland, Agricultural Implement Maker	84.1	55	0	1884-1899	R Cockerell and Sons	Yes
9	Thomas Danks, Canterbury, Engineer	81.3	24.5	3	1882-1898	Providence Works	Yes
10	Arthur Ward Beaven, Canterbury, Engineer	81.9	13	4.3	1883-1899	Andrews and Beaven	Yes
11	James Keir, Canterbury, Blacksmith	73.1	14.5	3	1884-1895	P. and D Duncan partner	Yes
12	David Strang, Southland, Coffee& spice manufacturer	73.4	5	2	1883-1899	David Strang Ltd	Yes
13	John Greenslade, Canterbury, Engineer	71.1	11	6	1893-1899	Own firm	Yes
14	Francis Henry Asbury, Otago, Heating Engineer	66.4	12	2	1883-1889	F.H. Asbury	In 1890 sold business, in Victoria 1890-1892, then US
15	David Ranken Shirreff Galbraith, Auckland, Chemist	66.0	42	0	1885-1899	Own firm	No, retired to England 1906
16	Horatio Bunting, Canterbury, Gentleman	64.5	3	0	1878-1879	Own firm	No, died Victoria 1906
17	William Nelson, Hawke's Bay, Sheep farmer	64.4	6.5	2.5	1870-1899	Nelson Brothers	Yes
18	Gustavus Wolff, Auckland, Dr Philosophy	64.2	2	1	1871	None in NZ	No, to NSW, then died at sea
19	Robert Haworth, Otago, Iron Merchant	61.8	3	1	1867-1876	R and T Haworth	No, but usually lived there
20	Edward Metcalf Smith, Taranaki, Gunsmith	61.2	7	4	1869-1896	Iron and Steel Co	Yes

The fifth highest spender on patents was William Toogood, whose patents largely related to the processing of flax. Toogood also applied for two patents about bicycles during the late 1890s. Similarly, William Nelson's patents focussed on flax and wool drying, before becoming about refrigeration. Furthermore, some of the inventions by Canterbury engineer Thomas Danks related to windmills and fencing and were therefore aimed at farmers (Cyclopedia Company Limited, 1903a), while two of Robert Haworth's patents were about fencing. However, Danks also applied for patents about more general engineering problems and hot water systems, while one of Haworth's patent applications was about mining.

Five of the twenty biggest spenders on patents focussed on mining patents. For instance, Charles McQueen, who was the sixth biggest New Zealand spender on patents at 113 pounds, made a significant contribution to New Zealand's mining industry. McQueen formed the engineering company Kincaid and McQueen in 1860, which carried out large, innovative and important engineering works throughout New Zealand (Otago Witness reporter, 1906, p. 57). McQueen also formed several companies that pioneered gold dredging (Hearn, 2012). Gold dredging and retrieval was also the focus of most of McQueen's patents and in a newspaper obituary he was described as "the originator of the dredging industry" (Grey River Argus reporter, 1906, p. 2). Similarly, John Alves, who was also a Dunedin engineer, was the seventh biggest spender on patent fees. Alves organized the building of a "remarkable aerial railway for conveying coal from mines", whose design he patented, and was also famed for his gold recovery inventions and patents (Otago Daily Times London reporter, 1911, p. 5) Furthermore, Gustavus Wolff's patents were about gold separation, David Ranken Shirreff Galbraith's patents often were about gold and silver extraction, while Edward Metcalf Smith's patents were about iron sand and fuel. Robert Cockerell also applied for mining patents.

David Strang's patents were usually about roasting coffee, and he is now considered one of the inventors of instant coffee (Daly, 2015), but he also applied for patents on drying grain. Asbury patented and built hot water systems, and also patented inventions for drying wool and evaporating milk. Horatio Bunting's patents related to reaping, and he succeeded in selling the rights to at least one of his inventions (North Otago Times reporter, 1879, p. 7).

Engineers dominate the list of inventors whose patents involved the biggest fees and advertising expenditure, with eight of the top twenty New Zealand patentees including

the term “engineer” in their occupation, one being an agricultural implement maker, and two others being a blacksmith and iron merchant respectively. In addition, while William Toogood listed his occupation as “storekeeper”, he had completed an engineering apprenticeship and had worked as an engineer in a flax mill for nine years (Cyclopedia Company Limited, 1897c). Furthermore, while Job Osborne reported his occupation as farmer, from 1865 he had also run a contracting firm known for its innovative use of technology (Press reporter, 1931, p. 14). However, other occupations were also represented with Douslin being an architect, Strang a coffee and tea merchant, Nelson describing himself as a sheep farmer, Bunting being a nurseryman, and Galbraith a chemist. Robert Cockerell, whose occupation as a blacksmith placed him in HISCO occupation group eight, and Edward Metcalf Smith, whose occupation as an armourer also placed him in group eight, were the only high spending patentees to be below HISCO occupational group six.

Two of the top twenty referred to their academic credentials in patent applications, with Gustavus Wolff citing his Doctorate in Philosophy and David Ranken Shirreff Galbraith his degree in chemistry. Publications were written by Alves (on mining), by Galbraith (on gold), by Keir (on ploughing), and by Wolff (on gold mining) (Galbraith, 1895, p. 6; Otago Daily Times London reporter, 1911, p. 5; Press reporter, 1935, p. 12; Sydney Morning Herald reporter, 1877, p. 3).

Table 6.8 shows many of the inventors had completed apprenticeships. For instance, Andrews had completed an engineering apprenticeship in Salisbury (De Vries, 1927, p. 11), while Beaven had studied engineering with a firm in Devizes (Press reporter, 1935a, p. 11), and McQueen had completed a ship building apprenticeship (Grey River Argus reporter, 1906, p. 2). Gray had worked for his father’s engineering foundry in Scotland (Otago Daily Times reporter, 1900, p. 4), and received his engineering training there. However, Osborne, who was an assisted migrant to New Zealand in 1859, had only worked in a factory (Gavin, 2013), and while Strang had worked in a coffee warehouse (Southland Times reporter, 1916, p. 5) there is no evidence he had completed an apprenticeship. Alves started working in the Victorian mining industry age 17 (Kent and Sussex Courier reporter, 1910, p. 7), suggesting his formal education was brief.

With the exception of Wolff, and perhaps also Bunting, the biggest patentees were also active in the management of business enterprises. For instance, James Gray, whose father had owned a large engineering foundry in Scotland, but was reported on Gray’s death

certificate more modestly as a ploughman, was a founder of the firm of Reid and Gray in 1868 (Gray, 1922a). Gray took sole control following Reid's death in 1879 (Otago Daily Times reporter, 1900). Andrews and Beaven cofounded an engineering firm in 1878. Even in his twenties, when he was living in Wiltshire, Andrews was receiving royalties on improvements to haymaking and food-preparing machinery (Andrews & Beaven, 1978, pp. 3, 5). William Toogood, who recorded his occupation as "storekeeper", was also a direct importer and agent for several firms (Cyclopedia Company Limited, 1897c). Douslin, who patented on a variety of topics, successfully worked in Blenheim as an architect and was mayor in 1887 (Cyclopedia Company Limited, 1906; Marlborough Express, 1902).

Several of the biggest spenders on patents went bankrupt. Toogood faced bankruptcy proceedings in 1879 (Evening Post reporter, 1879, p. 3), but successfully recovered and prospered in later decades (Evening Post reporter, 1903, p. 5). Furthermore, John Alves went bankrupt in the 1880s and had to sell patents to pay his creditors (Otago Daily Times reporter, 1886, p. 6). Similarly, McQueen's mining companies sometimes encountered severe financial problems and were liquidated (Hearn, 2012). A newspaper obituary noted that McQueen was "esteemed", and had made a substantial contribution to the development of infrastructure and useful technology, without managing to become rich from his inventions (Otago Witness reporter, 1906, p. 57). Similarly, Edward Metcalf Smith received glowing obituaries due to his on-going work to develop Taranaki's mineral and oil resources and work as a Member of Parliament (New Zealand Herald correspondent, 1907, p. 6; Taranaki Herald reporter, 1907, p. 2). After his death, however, his widow petitioned Parliament for assistance on the grounds she had been left "practically destitute" (New Zealand Herald reporter, 1907, p. 5). Bunting went bankrupt both in England in 1857, where a previously prosperous family nursery business also took many years to recover from his brief period in charge, and in New Zealand in 1869 (Berkshire Chronicle reporter, 1857; Denney, 2006, p. 146; Slater, 1869, p. 3).

William Nelson, who came from a well-off family, encountered financial problems that required disposing of assets, but avoided bankruptcy (Boyd, 2013). Indeed, Table 6.8 shows that Nelson left the biggest estate, which was valued for probate at £32,869 in 1932 (Nelson, 1932b). Job Osborne, who had also become a large landowner, and whose estate was valued for probate at £29,444 in 1931 was close behind. Andrews and Beaven both also left substantial estates (Andrews, 1927b; Beaven, 1944b), while before his death James Gray transferred most of his shares to his son who was managing the business (Gray, 1922b). David Strang also left a substantial estate, and when he died most of his

assets were shares in a limited liability company that his sons were helping to run (Strang, 1917). An obituary noted that Strang's "application to business combined with the use of his own ideas and patents, has resulted in the gradual development of one of the town's chief manufacturing industries" (Southland Times reporter, 1916, p. 5). The available data suggests that patentees who applied for mining patents tended to be less economically successful than those who developed patents for other purposes, such as agriculture.

Table 6.8 shows the top twenty patentees were overwhelmingly born in the British Isles. The exceptions were Wolff, who was from Germany or Austria (McQueen, 2011, p. 77; Sydney Morning Herald reporter, 1877, p. 3), and Cockerell, who was born in Tasmania (Cockerell, 1902). However, Haworth had worked in Victoria for about six years before he migrated to Dunedin in 1862 (Haworth, 1862, p. 3), while Douslin had spent eight years in Tasmania before he migrated to Marlborough during the 1864 Wakamarina gold rush (Cyclopedia Company Limited, 1906). Furthermore, Asbury's early advertisements emphasised he had worked in the United States (Asbury, 1882, p. 4). Although census data shows the proportion of New Zealanders of European origin who were born in New Zealand reached a low point of 24% in 1864 (Office of the Registrar General, 1875, p. 78; 1902, p. 122), none of the top patentees were born in New Zealand. Even though people born in New Zealand tended to be much younger than migrants, some of the top spending patentees were born in the 1850s. While many of the top patentees migrated to New Zealand in their thirties, some were older. For instance, Greenslade was in his forties and a person of the same name patented ploughing equipment in England before Greenslade migrated to New Zealand (Birmingham Daily Post reporter, 1874, p. 3).

Six of the top twenty patentees were from Scotland, and as a result Presbyterianism is well-represented among their religions. Two of the twenty are Methodists. Comparing those whose religious affiliation was available to the results for the New Zealand population in 1864 who gave a religious affiliation, a Chi-Squared test indicated the differences were probably due to chance. Only one of the top patentees for whom death certificates are available died before the age of sixty, and all of those in the top ten married and had children.

There were only two people from the Auckland provincial district in the list of the top twenty spenders over the entire period, and none in the top ten. Looking just at the results for the 1880s and 1890s (Table 6.6), the picture changes only slightly. However, Josiah Clifton Firth, who was actively involved in the development of the Waikato region,

made the top ten in the 1890s. This may partly reflect the earlier development of large scale agriculture in other regions, and renewal fees on earlier patents keeping established inventors in other regions ahead.

Most of the high spending patentees stayed in New Zealand. However, six left New Zealand in search of better opportunities, while another left New Zealand to retire in Britain. For instance, Douslin migrated to Rhodesia in 1893 with his son having found opportunities in Marlborough limited, and died in Bulawayo in 1907 (Free Lance reporter, 1907, p. 3). Wolff was involved in the New South Wales and Queensland mining industry during 1872 and 1873, and died about 1874 while at sea (McQueen, 2011, p. 77).

Four of the highest spending patentees moved to Victoria, with McQueen and Alves both returning to Victoria to work in its mining industry (Otago Daily Times reporter, 1910, p. 8; Otago Witness reporter, 1906, p. 57). Bunting also lived and patented in Victoria from the early 1880s (South Australian Weekly Chronicle reporter, 1885, p. 14) and died in Victoria in 1906 (Bunting, 1906). In addition, Asbury sold his business and patents in 1890 and subsequently patented and advertised his services in Melbourne (Asbury, 1891, p. 1; James A. Park and Co., 1890, p. 4; Sydney Mail reporter, 1890). From 1893 Asbury resided largely in the United States, although he also spent time in South Africa and in Britain (Asbury, 1921; National Home for Disabled Volunteer Soldiers, 1920, p. 601). Alves left Victoria to retire in England about six years before his death, while Galbraith also returned to England in his mid-fifties when ill health curtailed his business career (New Zealand Herald reporter, 1912; Otago Daily Times London reporter, 1911).

The results for inventors from other countries showed that the 636 pounds spent by Thomas Edison dwarfed the expenditure by individual New Zealand inventors. Edison's compatriot Elihu Thomson, who also reported his occupation as an electrician, spent 243 pounds, which was also more than any New Zealander. Marcellus Hartley's expenditure of 141 pounds, all in 1882 and all on patents relating to electricity, is also notable. England's James Gresham spent 131 pounds on patents relating to brakes and engines, while John Cunninghame Montgomerie from Scotland spent 87 pounds on mining patents. The biggest spender living in Australia was Frederick York Wolseley, who spent 111 pounds patenting shearing machines. Carl Gustaf Patrik De Laval from Sweden spent a total of 55 pounds from 1886 to protect dairy farming equipment patents in New Zealand.

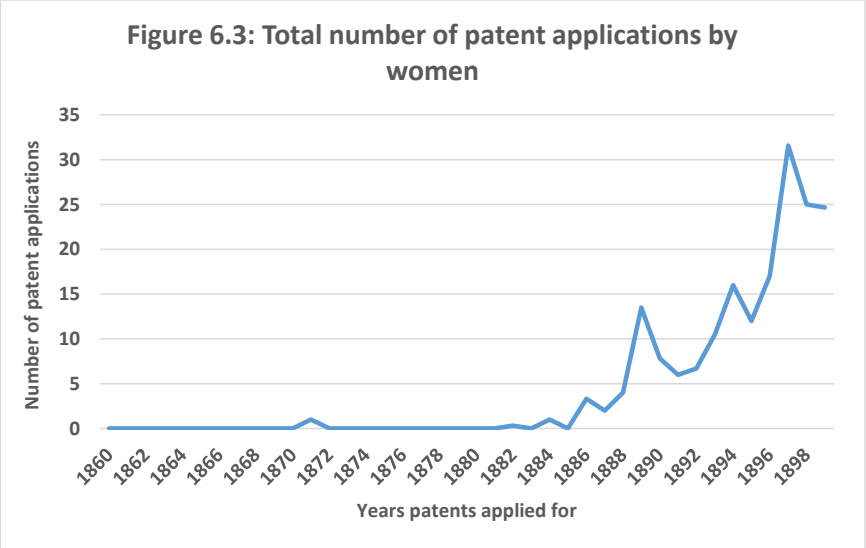
Table 6.8: Background characteristics of the highest spending New Zealand inventors for 1860-1899

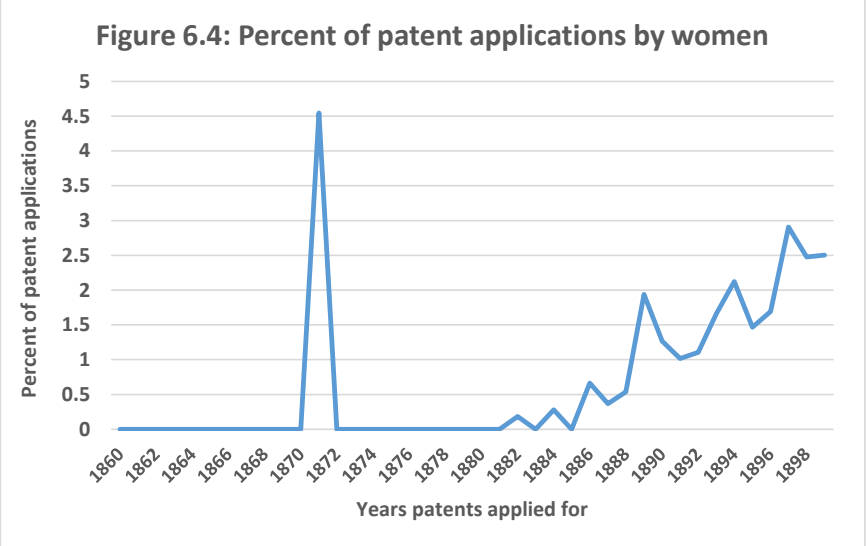
N	Name	Born	Alive	In NZ	Age died	Religion or buried by	Children	Occupation given at death	Education/work experience	Father's occupation	Bankrupt	Estate in pounds at time death
1	James Gray	Renfrew, Scotland	1833-1922	1863-	89	Presbyterian Minister	4	Engineer	Father's foundry	Ploughman and foundry owner		2,582, but son already held most shares
2	William Andrews	Dorset, England	1839-1927	1875-	88	Anglican Minister	6	Engineer	Engineering apprenticeship	Farmer		13,626
3	Job Osborne	Somerset, England	1843-1931	1860-	88	Active Methodist	2	Farmer	Candle factory	Farmer		29,444
4	William Douslin	Yorkshire, England	1829-1907	1863-1893	78	Anglican family	8	Architect	Joiner (1851), builder (late 1850s)	Shipwright		Unknown but prosperous
5	William Toogood	Hull, England	1839-1903	1861-	64	Presbyterian Minister	8	Storekeeper	Engineering apprenticeship	Sea captain	Yes	Over 100 pounds
6	Charles McQueen	Renfrew, Scotland	1836-1906	1862-1893	70	Active Presbyterian	11	Engineer	Boiler maker's apprenticeship	Fender maker	Yes	Obituary noted "esteemed" but not rich
7	John Alves	At sea, ties Tunbridge W England	1834-1910	1863-1890	76	Congregationalist Minister	5	Civil engineer	First working in Australia 1851, aged 17	Planter		Unknown but prosperous and esteemed
8	Robert Cockerell	Tasmania, Australia	1834-1902	1884 at latest-	68	Catholic Priest	3	Blacksmith	Presumably apprenticeship	Blacksmith		Successful business
9	Thomas Danks	Wednesbury, Staffordshire, England	1840-1906	1878-	66	Wesleyan Methodist family	9+	Engineer	Apprenticeship in father's firm	Iron tubing manufacturer		Less than 9,000
10	Arthur Ward Beaven	Wiltshire, England	1848-1944	1878-	96	Protestant Minister	4	Engineer	Engineering apprenticeship	Farmer		18,376 and will notes previous gifts
11	James Keir	Scotland	1856-1935	1863	79	Presbyterian	7	Engineer	Engineering apprenticeship	Farmer		6,480

12	David Strang	Glasgow, Scotland	1847-1916	1863	69	Active Presbyterian	11	Coffee Merchant	Worked coffee warehouse	Contractor		9,984
13	John Greenslade	Somerset, England	1839-1931	1881	92	Anglican Minister	None, never married	Civil engineer	Farmer when 22	Farmer		Unknown but successful in business
14	Francis Henry Asbury	Glasgow, Scotland	1842-1921+	1880-1890	79+	Catholic Priest for marriage	1	Engineer	Apprentice, uncle iron plater	Merchant		Could afford to travel in old age
15	David Ranken Shirreff Galbraith	Edinburgh, Scotland	1852-1912	1885-1906	60	Presbyterian baptism	5	Analytical chemist	Chemistry degree Edinburgh	Wood merchant		Unknown
16	Horatio Bunting	Colchester, England	1822-1906	1850-1880	84	Non-conformist family	No issue, married 3x	Nurseryman	Family nursery	Nurseryman	Yes in England and NZ	Modest
17	William Nelson	Warwick, England	1843-1932	1870	89	Anglican Minister	11	Freezing works manager	Secondary school till left at 15 and family firm	Chemist	Various setbacks	32,869
18	Gustavus Wolff	Germany or Austria	-1874?	-1872?	?	Unknown	Unknown	Unknown	Dr Philosophy	Unknown		Unknown
19	Robert Haworth	Lancashire, England	1833-1886	1862-	55	Anglican funeral	7	Gentleman & mining speculator	Plumber and glazier aged 17	Plumber		Under 2,000
20	Edward Metcalf Smith	Staffordshire, England	1839-1907	1861- with breaks	67	Anglican funeral with military honours	10	Armourer and MP	Gun trade apprenticeships	Monument mason	Iron & Steel Company unsuccessful	“Practically destitute” according to widow

6.6 Patenting by women

The level of patenting by women is an important indicator of their level of participation in the economy. Between 1860 and 1899 just 1.5% of patent applications were by women, although this is higher than the 1.1% of patent applications that were made by women in Victoria between 1854 and 1901 (Magee, 2000, p. 64). Both total applications by women and the proportion of applications by women trended upwards over time to reach 2.5% in 1899. In contrast, by the late 1890s women accounted for just under a percent of patents granted in the United States, although the trend there was also upwards (Khan, 2005, p. 135).





The first woman to appear in the dataset is Matilda Lang, who lived in Melbourne, Victoria, and who in 1871 patented an improvement for "washing, scouring, or cleaning clothes, wool, or fibrous manufactured goods". Since there were only 38 patent applications in 1871, her letter of registration caused the spike in Figure 6.3. The second patent application solely by a woman was by Elisabeth Barton of Dunedin, New Zealand, for a new bedspread in 1884, and occurred in the same year as the *Married Women's Property Act* increased property rights for women. Barton's invention was widely reported as the first patent by a New Zealand woman, and as pleasing advocates of women's rights (New Zealand Herald reporter, 1885, p. 4; Timaru Herald reporter, 1885, p. 2). However, one paper commented that an advisor on patent applications had been dismissive of another women's plan for a patent for improvements in dresses (Auckland Star reporter, 1885, p. 4).

By 1889 newspapers were positively commenting on how patents had been filed by Alice McLeod and Helen Maclean (Marlborough Express reporter, 1889). It was also argued that women should invent more, particularly for household purposes (Evening Star reporter, 1889). Technological innovation in mining by former Dunedin resident Alice Cornwall, who had recovered from a disastrous marriage to rebuild her family's economic fortunes, was favourably commented upon by a Dunedin newspaper (Otago Daily Times reporter, 1889, p. 3). When an 1892 patent application by Harriette Allen relating to visiting cards was made, however, reporting of this invention was followed by a jocular suggestion that an invention to reduce the number of such calls would be desirable (Press reporter, 1893). The 1899 *Annual Report* noted that there had been 30 applications by women inventors during 1898, five of which had related to clothing (Registrar Patents Office, 1899, p. 1). By the late 1890s patents applications by women such as Mary Squire of South Canterbury were sometimes outlined in newspapers without reference to the gender of the inventor (Timaru Herald reporter, 1897, p. 2).

Table 6.9 lists the New Zealand women who made the most patent applications, while Table 6.10 lists the New Zealand women who spent the most on patent fees and required expenditure. There is considerable overlap, although because some of the women who made the most patent applications did so in the last few years of the period covered, their expenditure on patents is relatively low. The correlation for the number of patent applications by woman and expenditure by them is only 0.24, which is much lower than the 0.60 correlation for men.

In terms of expenditure, the highest spending women were Elizabeth Gibbons of Auckland and Mary Rider of Christchurch. Gibbons' two patents related to washing machines. Her 1892 patent machine, which sold for thirty shillings, was advertised in newspapers in Auckland and the Waikato, without reference to her gender or her first name (Gibbons, 1893, p. 3; Souter and Co, 1893, p. 4). Gibbons was married with children and her husband, who had been bankrupt in 1869 and acquitted of arson in 1887, worked in their factory (Auckland Star reporter, 1869, p. 3; Gibbons, 1902, p. 3; Press Association, 1887, p. 4). Mary Rider maintained the patent on her "Grandmother's Cancer Salve", and through extensive advertising offered personal consultations (Rider, 1887, p. 7; 1891, p. 7). Slightly behind them was Mary Vialou whose "magic salve", on which she renewed the patent, was sold throughout New Zealand and received glowing testimonials (New Zealand Herald reporter, 1889, p. 4).

Of the other New Zealand women in Table 6.10, Margaret Foreman's patents were also about lotions, while Marie Liliethan Squire, Elizabeth Ann Louisa Mackay and Luendah Eliza Abercrombie also patented medical products. Margaret Angell's invention, on which she also paid a renewal fee, was an appliance for securing hats, while Emma Barrett's patents related to making clothes. Susan Emily Francis' patent, which she also patented in the United States, was for a cycling skirt (Khan, 2005, p. 148). Household production and consumption were represented in Table 6.10 through patents for inventions such as fireguards, visiting cards, improved pastry, and an improved iron.

In contrast, Alice Mary McLeod's patents related to processing flax and crushing quartz for mining. Ada Frances Cole's inventions for well-sinking equipment during the 1880s were also positively commented upon by newspapers (Evening Star reporter, 1889, p. 1). Inventions by women often focussed on household production and consumption, and medicinal products and clothing. Nevertheless, women also patented engineering, mining, and manufacturing inventions.

Table 6.9: The New Zealand women inventors who filed two or more patent applications, 1860-1899

Number	Name	Applications	Years	Location	Occupations given	Inventions about
1	Alice Mary McLeod	5	1889, 1890, 1894	Auckland	Lady	Flax processing and reducing quartz
2	Constance Clarice Anne Hall	5	1897, 1898	Wellington	Widow and Inventress	Improved trousers, tyres, candlesticks and fish scaler
3	Mary Anne Johnson	4	1896, 1899	Wairarapa	Married woman and Nurse	Prams, tires, nursing equipment, and washing equipment
4	Margaret Foreman	3	1896-1898	Waikato	Married	Lotions
5	Elizabeth Ann Louisa Mackay	2	1888, 1889	Nelson	Wife of hotelkeeper	Rheumatism treatment and improved pot for cooking
6	Florence Joice Leonard	2	1897, 1898	Auckland	Wife of agent	Clothes washing & cutting toilet paper
7	Bessie Fergusson Hume	2	1888, 1889	Otago	Not given	Protecting children from accidents
8	Annie Hamann	2	1896, 1897	Otago	Wife of customs agent	Improved pasty and bucket
9	Jessie Levinge	2	1897-1899	Manawatu	Medical Practitioner	Ink, oil and sundial
10	Annie Cussen	2	1894	Waikato	Wife of surveyor	Brooch pin and umbrella carrying
11	Mary Lambert Jackman	2	1899	Auckland	Wife of accountant	Belt clip and better pins
12	Elizabeth Gibbons	2	1892, 1897	Auckland	Wife of millwright	Washing machine and wash board
13	Jessie Miller	2	1899	Otago	Married	Bicycle break and steam boiler
14	Adelaide Ritchie McDonald	2	1896	Otago	Gentlewoman	Sports equipment and upholstery
15	Eliza Shadgett	2	1898, 1899	Wellington	Married	Fire regulation
16	Emma Barrett	2	1891	Wellington	Dressmaker	Clothes making
17	Lena Bedell	2	1895, 1896	Wellington	Settler	Spouting
18	Ada Frances Cole	2	1887, 1888	Hawke's Bay	Machinist	Well-sinking

Table 6.10: The twenty New Zealand women who spent most on patent fees and required expenditure, 1860-1899

	Name	Location	Paid	Number patents	Years patenting	Occupations given	Inventions about
1	Elizabeth Gibbons	Auckland	16.4	2	1892, 1897	Wife of millwright	Washing machine and wash
2	Mary Rider	Canterbury	16.4	1	1886	Farmer	Cancer salve
3	Elizabeth Vialou	Auckland	16.3	1	1887	Not given	Medicinal salve
4	Margaret Angell	Otago	12.2	1	1893	Domestic	Securing hats
5	Emma Barrett	Wellington	8.5	2	1891	Dress maker	Clothes making
6	Alice Mary McLeod	Auckland	7.5	5	1889, 1890, 1994	Lady	Flax processing and reducing quartz
7	Margaret Foreman	Waikato	6.5	3	1896-1898	Married	Lotions
8	Kate Evenden	Wellington	6.3	1.5	1889	Wife of joiner	Improved nails
9	Ada Frances Cole	Hawke's Bay	5.4	2	1887, 1888	Machinist	Well-sinking
10	Bessie Fergusson Hume	Otago	5.2	2	1888, 1889	Spinster	Protecting children from accidents
11	Elizabeth Ann Louisa Mackay	Nelson	5.1	2	1888, 1889	Wife of hotelkeeper	Rheumatism treatment and improved pot for cooking
12	Harriette Allen	Wellington	5.0	1	1892	Wife of insurance manager	Visiting cards receptacle
13	Annie Hamann	Otago	4.9	2	1896, 1897	Wife of customs agent	Improved pastry and bucket
14	Jessie Levine	Manawatu	4.9	2	1897-1899	Medical practitioner	Ink, oil and sundial
15	Susan Emily Francis	Wellington	4.9	1	1897	Spinster	Cycling skirt
16	Marie Lilienthal Squire	Canterbury	4.8	1	1898	Tesoro Manufacturer	Improved medicine
17	Luendah Eliza Abercrombie	Canterbury	4.8	1	1898	Wife	Abdominal support
18	Helen Garden Moore	Wairarapa	4.8	1	1898	Wife of sheep farmer	Improved iron
19	Frances Ann Fisher	Canterbury	4.3	1	1889	Wife of navy captain	Butter cooler
20	Alice Cornwell	Otago connection	4.2	1	1888	Mining Speculator	Mining batteries

The highest spending female patentees were New Zealanders, although Lucy Hooker, a married gentlewoman of Australia, spent 16.1 pounds on five New Zealand patents relating to lighting. The second highest spender from overseas was Elizabeth Merrillees, who was also from Australia, and who spent over 13 pounds on two New Zealand patents for improvements to corsets.

6.7 Patenting by Maori

New Zealand's indigenous Maori population constituted at least 6% of New Zealand's population at every census during the nineteenth century that data on Maori were collected (Pool, 1991, p. 76). However, patenting by New Zealand's Maori population was very low during the nineteenth century. Indeed, the only Maori to make a patent application was Tare Ruka of Westport, who in 1884 was involved in an application with Alfred Gibson Stephenson for a toothache treatment. The application lapsed, and Ruka was therefore attributed five shillings expenditure for his half share of the application. Newspapers noted that Ruka was the "first of his race to make such an application" (New Zealand Herald reporter, 1885). Ruka was actively involved in the Maori community, and in promoting the political and cultural needs of Maori (Ruka, Mahniki, Row Row, & Notti, 1886, p. 2). He stated his occupation as "dairyman", but was also involved in importing, and faced bankruptcy proceedings in 1884 (Westport Times reporter, 1884, p. 2).

Careful checks were made to identify other possible Maori patentees. Although Henry Nicholas Quick and Alfred John Knocks gave their occupations as "Native Interpreter" neither of them were Maori (Cyclopedia Company Limited, 1897b; New Zealand Herald reporter, 1882, p. 3). Nor was Charles Brown, who was a Native Civil Commissioner (Cyclopedia Company Limited, 1908) or Alexander Bow, a Native School Teacher in the Hokianga (Duffy, 2002). However, four inventors used Maori culture to differentiate their inventions for a Maori oven (patent 2571), a fern vase (patent 3271), a flax dressing device (patent 3929) and a stumping machine (patent 8924).

The low level of patenting by Maori reflected their relatively weak economic situation. Maori land ownership fell dramatically during the period studied because of land confiscations and sales. Language and cultural differences also limited Maori participation in the economy. By the 1870s Maori were largely engaged in subsistence farming and wage labour in isolated rural areas, although some Maori were becoming successful sheep

farmers (Monin, 2009, pp. 141, 145). Maori expertise was acknowledged in areas such as flax growing and processing (Firth, 1959, pp. 61-67, 87; Flax Commissioners, 1870, pp. 24,39), but this expertise did not result in patent applications by Maori.

6.8 Patenting by Chinese

During the nineteenth century New Zealand migrants overwhelmingly came from the British Isles. However, New Zealand also had a small Chinese population from the 1860s, which at the 1874, 1878 and 1881 censuses was over 1% of New Zealand's non-Maori population. Three Chinese inventors living in New Zealand have been identified, all from the 1890s when New Zealand's Chinese population was falling (Office of the Registrar General, 1902, p. 9) as a result of restrictive immigration practices and the very low number of Chinese women living in New Zealand.

Chew Chong of Taranaki applied for three patents relating to butter preservation and manufacturing in 1891. His successful business career in the Taranaki, which went into gradual decline from 1892, has been well documented (Ng, 2012). A second Chinese patentee was Wong Yong Wah, a miner in Southland (who made applications in 1897 and 1898), for improvements in hoses. In addition, Ah Pat a storekeeper of Inglewood, Taranaki, took patents for a velocipede crank and also bicycle gearing (1898). Ah Pat went bankrupt in 1898 (Taranaki Herald reporter, 1898, p. 2), but filed additional patents after the period covered by this thesis. John Chew of Wellington was an important patentee, but was from Lancashire and not of Chinese origin (Cyclopedia Company Limited, 1897a).

6.9 Conclusion

This chapter investigated the extent to which people from different nineteenth century New Zealand population groups used the patent system to protect intellectual property. Occupation data showed that patents applied for by engineers accounted for almost a quarter of total expenditure on patents. New Zealand engineers patented at a much higher rate than the male population as a whole. Farmers were a more important group for patent applications than in equivalent data for the Australian state of Victoria, and their patents involved about 12% of patent expenditure by New Zealanders. Nevertheless, the farming sector patented at a lower rate than its share of New Zealand's workforce. Skilled trades workers, such as blacksmiths, electricians and builders were over-

represented in patent applications and expenditure. Lower patenting costs in the early 1880s were associated with an increase in patenting by lower ranking occupational groups, indicating that a wider range of occupational groups were finding patenting affordable. However, unskilled workers, such as labourers and miners, continued to make relatively few patent applications. Companies filed about 3.1% of patents applications.

Most patent applications involved one person, although 16% involved two. Furthermore, most applicants were involved in just a single patent application. The most prolific inventors were not always the highest spenders on patent fees, although the correlation between patent applications and patent expenditure was high. The highest spending New Zealand inventors were usually engineers who patented agricultural equipment, stayed in New Zealand, and tended to leave substantial estates. There were also five inventors who specialized in mining patents among the twenty highest spending New Zealand patentees. This group tended to be less economically successful, while still being well respected, and were more likely to leave New Zealand. Other occupations, such as merchant and architect, were also represented among the top twenty New Zealand patentees.

The data showed that participation by women in the patent system was low. However, women accounted for a growing share of patent applications from the early 1880s, and made 2.5% of patent applications in 1899. Patents by women tended to be about home production and consumption and patent medicines, although they also lodged some patents relating to engineering and mining. Only one patent application by a Maori was identified. Three Chinese inventors who had migrated to New Zealand also made patent applications. Nevertheless, patenting by New Zealanders was overwhelmingly by men of European origin.

Chapter 7: Explaining patenting in New Zealand and the relationship between patenting and output

7.1 Introduction

This chapter seeks to identify the determinants of patent applications and expenditure over the 1860-1899 period, including the relationship between applications and expenditure with economic output. As well as examining the total level of patenting, the effect of patenting by people living in New Zealand and overseas and patenting in different economic areas is studied. Because the expenditure on each patent has been calculated, this chapter is the first New Zealand study to analyse the relationship between expenditure on patents and economic output.

Having expenditure data on patents is important, because from the 1870s onwards most initial patent applications lapsed. Including data on the amount paid to seal and renew patents may provide a more accurate representation of the value of patents. Expenditure on patents over time is therefore potentially more closely related to economic output than simply initial patent applications. However, because unit record data weighted by expenditure has been generated, the time period covered is shorter than for studies that have used published summary data on patent applications (Cotter, 2006; Greasley & Oxley, 2010b). This limits the number and type of variables that can be used in the statistical analysis. Nevertheless, insights can be gained into the important question of whether patenting led or followed output, and how this varied for different output areas.

Section two of this chapter outlines key theoretical and methodological concepts relating to the time series econometrics used in this chapter. Then section three examines changes in patenting levels and the effect of changes in patenting costs, with a focus on per capita patenting levels by New Zealanders. In section four the focus shifts to the relationship between per capita patenting and per capita economic output in New Zealand. Section five then tests the relationship between particular types of output and patent applications and expenditure relating to these topics.

7.2 Theoretical and methodological background

In modern time-series econometrics the order of integration, which is the number of times a variable needs to be differenced to ensure stationarity, is important. The order of integration of all the variables in an equation must be the same to ensure a balanced statistical relationship (Greasley & Oxley, 2010a, p. 974). Most economic time-series are non-stationary processes that have no tendency to return to a deterministic trend. They are therefore difference stationary and integrated of order one, which is often written as I(1), since they must be differenced once to become stationary. Indeed, Nelson and Plosser argued that relatively few United States economic variables show a trend stationary process, which involves stationary fluctuations around a deterministic trend (Nelson & Plosser, 1982, p. 139). However, other economists, such as Pierre Perron, have argued that allowing for occasional structural changes, such as the Great Depression, undermines these findings (Hansen, 2001, p. 125; Perron, 1989, p. 1382). Dickey-Fuller unit root tests are often used to distinguish between trend and different stationary processes, although other unit roots are also frequently used.

When a linear combination of two I(1) series is I(0) they are cointegrated and their linear combination constitutes a cointegrating equation. However, not all integrated variables are cointegrated (Greasley & Oxley, 2010a, pp. 981-982). Often Engle-Granger or Johansen cointegration tests are used. The Johansen method used in this chapter uses trace and maximum eigenvalue tests for cointegration. Granger causality tests are often used to establish causality between variables. When two variables are both I(1) and cointegrated a causal relationship exists in at least one direction (Engle & Granger, 1987, p. 275).

Causality therefore involves determining the order of integration of the variables, and then for I(1) data investigating bivariate cointegration. When cointegration exists there must be one or two way Granger causality, although this may not be detectable in small samples. Granger causality is about testing whether one time series is useful for forecasting another time series. If the data are I(1) and cointegrated an error correction model can be constructed in differences (Greasley & Oxley, 2010a, pp. 987-988). This will now be outlined using equations.

Granger causality tests can use I(1) data if the data is cointegrated. Following Greasley and Oxley's notation (Greasley & Oxley, 2010a, pp. 987-988), for variables X and Y:

$$X = \propto + \sum_{i=1}^{m} \beta_i X_{t-i} + \sum_{j=1}^{n} \gamma j\, Y_{t-j} + u_t \quad (1)$$

$$Y = a + \sum_{i=1}^{q} b_i Y_{t-i} \sum_{j=1}^{r} cj\, X_{t-j} + v_t \quad (2)$$

Here u_t and v_t are zero mean and serially uncorrelated random disturbances and the lags m, n, q and r are decided using information criteria. This equation is also used for data that is already I(0) (Engle & Granger, 1987, p. 254).

Secondly, for cointegrated variables I(0) data in differences can incorporate an error correction mechanism (ECM).

$$\Delta X = \propto + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \sum_{j=1}^{n} \gamma j \Delta\, Y_{t-j} + \delta ECM_{t-1} + u_t \quad (3)$$

$$\Delta Y = a + \sum_{i=1}^{q} b_i \Delta Y_{t-i} \sum_{j=1}^{r} cj\, \Delta X_{t-j} + dECM_{t-1} + v_t \quad (4)$$

Thirdly, when data are I(1) but not cointegrated, they can be differenced to produce stationarity. The equations used are then the same as three and four, but without the error correction term.

$$\Delta X = \propto + \sum_{i=1}^{m} \beta_i \Delta X_{t-i} + \sum_{j=1}^{n} \gamma j \Delta\, Y_{t-j} + u_t \quad (5)$$

$$\Delta Y = a + \sum_{i=1}^{q} b_i \Delta Y_{t-i} \sum_{j=1}^{r} cj\, \Delta X_{t-j} + v_t \quad (6)$$

For equations one and two, Y Granger causes (GC) X if H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \cdots = \gamma_n = 0$ is rejected against the hypothesis H_1:= at least one $\gamma_j \neq 0$, j=1,….,n.

Furthermore, X GC Y if H_0: $c_1 = c_2 = c_3 = \cdots = c_r = 0$ is rejected against the hypothesis H_1: at least one $c_j \neq 0$, j=1,….,r.

For equations three and four, ΔY GC ΔX if H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \cdots = \gamma_n = 0$ is rejected against the hypothesis H_1:= at least one $\gamma_j \neq 0$, j=1,….,n or $\delta \neq 0$.

Furthermore, ΔX GC ΔY if H_0: $c_1 = c_2 = c_3 = \cdots = c_r = 0$ is rejected against the hypothesis H_1:= at least one $c_j \neq 0$, j=1,….,r or $d \neq 0$.

For equations five and six, which involve non-cointegrated data, ΔY GC ΔX if H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \cdots = \gamma_n = 0$ is rejected against the hypothesis $H_1 :=$ at least one $\gamma_j \neq 0$, j=1,….,n.

In addition, ΔX GC ΔY if H_0 : $c_1 = c_2 = c_3 = \cdots = c_r = 0$ is rejected against the hypothesis $H_1 :=$ at least one $c_j \neq 0$, j=1,….,r.

7.3 Patenting levels and the effect of changes in patenting costs

Some researchers have identified patent costs as a key factor affecting the level of patenting (Khan, 2005, p. 7; MacLeod, 1988, pp. 37, 41). Chapter three discussed the main costs of patenting in New Zealand. Briefly, however, the initial cost included government fees, required advertising until late 1881, parchment costs up to 1884, and the much smaller cost of the standard form after 1884. The initial cost would have affected the number of applications, but so could other fees. For instance, from 1870 there was also a cost for getting a patent sealed, and the level of this fee is likely to have affected patenting decisions. Furthermore, the cost of 14 years' protection was relevant for those developing inventions, particularly for those who thought their invention had enduring worth. The cost of a letter of registration is also important for understanding total patent applications because chapter five found evidence of overseas applicants sometimes applying for letters patent, rather than letters of registration, after the initial cost of letters patent was reduced. The logs of the main expense variables are graphed in Figures 7.3 to 7.8, with the truncation of the cost axis sometimes considerably exaggerating changes.

The Eviews computer program (version 9.0) was used (Eviews, 2016). Using an Augmented Dickey Fuller (ADF) test, the time series for the natural log of patent applications per capita was I(1). Applications by New Zealanders per capita (where the population statistics exclude Maori) and the fees for an initial application were also I(1). In contrast, the cost of required newspaper advertising and parchment combined was I(2), and so was the total cost of an application including advertisements and parchment.

However, the cost of getting a patent sealed, the cost of a 14 year patent, and the cost of a letter of registration were all I(1).

One potential problem is that there are apparent discontinuities in both the number of applications per capita, particularly by New Zealanders, and even more clearly in the costs of taking out a patent. When there are structural changes in variables, Dickey-Fuller statistics are biased towards non-rejection of a unit root (Enders, 2015, pp. 227, 229). Indeed, switching to break test unit root tests suggests some application cost series are I(0) and so are per capita applications by New Zealanders. Eviews put the break date for combined application fees and required newspaper costs at 1881, and Figure 7.5 confirms that there was a clear break in this series in 1881. Using a trend and intercept specification, and allowing for a break in the intercept, Eviews put the break date at 1883 for applications per capita by New Zealanders, which are shown on a log basis per 100,000 people. The changes for total applications are more complex. This is partly because changes in fees have occurred at different times for New Zealanders patent applicants than for people living overseas who wanted to protect existing intellectual property in New Zealand.

Variations in the real cost of sealing a patent, which only became necessary from 1871, reflect a reduction in the nominal cost from 1880 and changes in prices. Even with a break point allowed for, the log of the cost of getting a patent sealed was not I(0). Similarly, the total cost of a 14 year patent was not I(0). Instead, both the cost of getting a patent sealed and of the total cost of a 14 year patent appear to be characterised by multiple breakpoints. However, these results suggest that patent applications by New Zealanders per capita over the period studied can be cautiously modelled using OLS regression involving the cost of initial applications.

Table 7.1: Unit root test results using modified Hannan-Quinn criterion

	Without a break					With a break				
Variable (in logs)	Integrated	Lags	Equation	ADF	P-value	Integrated, break	Lags	Trend specification	ADF	P-value
Applications per capita	I(1)	9	I	-3.32	0.02	I(1), 1878	9	I	-11.75	<0.01
Applications by NZers per capita	I(1)	9	I	-3.59	0.01	I(0), 1883	9	T, I; break I	-4.87	<0.05
Initial fees cost	I(1)	9	I	-6.58	0	I(0), 1882	9	T,I; break T,I	-5.25	0.04
Ads & parchment/form	I(2)	9	I	-13.98	0	I(0), 1881	9	T, I; break I	-8.53	<0.01
Initial fees, ads & form	I(2)	9	I	-4.06	0	I(0), 1881	9	I, break I	-20.89	<0.01
Cost of sealing	I(1)	7	T,I	-5.94	0	I(1), 1889	7	I, break I	-6.07	<0.01
Total cost 14 years	I(1)	9	T,I	-3.67	0	I(1), 1882	9	I, break I	-5.57	0.02
Cost letter registration	I(1)	7	T,I	-4.00	0.02	I(1), 1873	7	I, break I	-4.53	0.04

I=intercept, T=trend

Figure 7.1: Log of total applications per 100,000 people (excluding Maori)

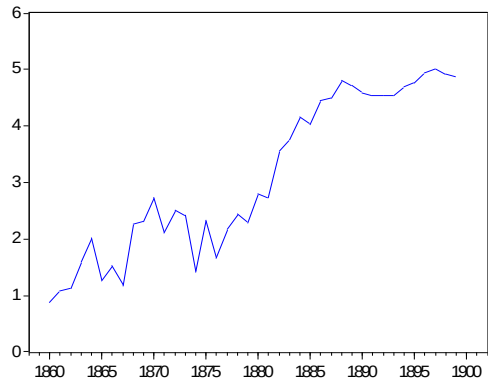


Figure 7.2: Log of New Zealand applications per 100,000 people (excluding Maori)

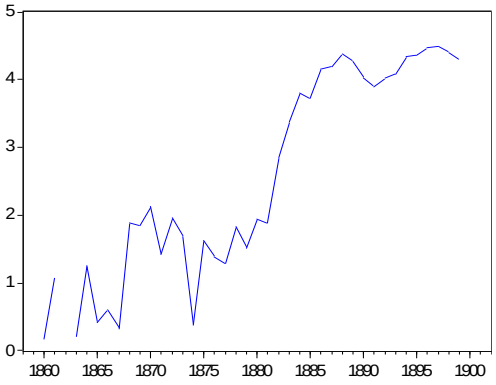


Figure 7.3: Log of fees cost of initial application

Figure 7.4: Log of cost of newspaper ads and parchment or form

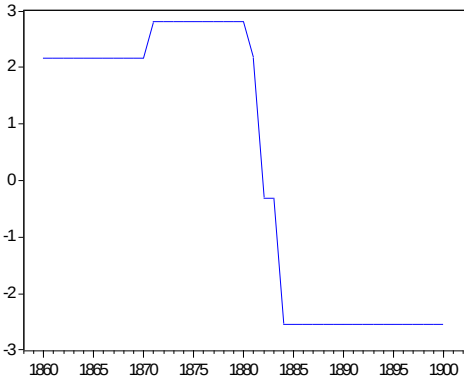


Figure 7.5: Log of total cost of application fees and ads and parchment or form

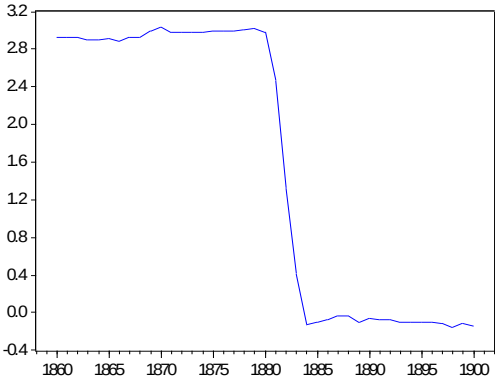


Figure 7.6: Log of cost of sealing a patent

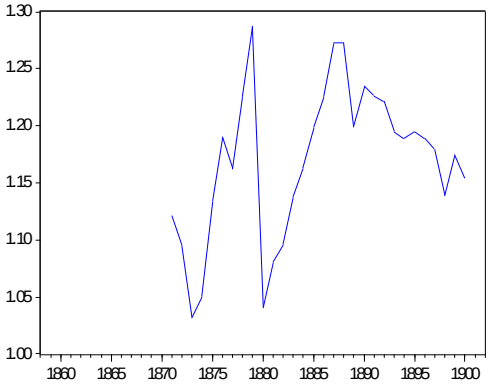


Figure 7.7: Log of the cost of a 14 year patent

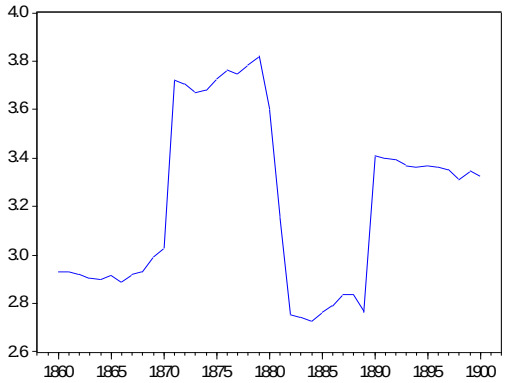


Figure 7.8: Log of the cost of a letter of registration

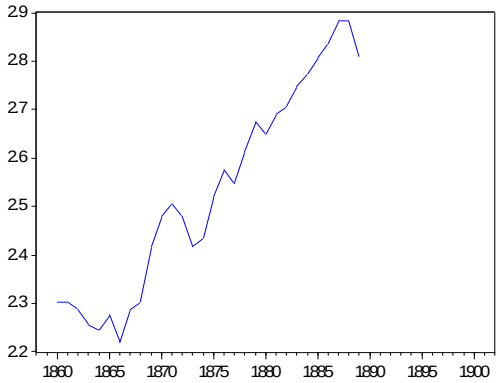


Table 7.2 shows pair-wise Granger causality results for the variables that a break point unit root test indicated were I(0). Granger causality tests how much of the current value of a variable can be explained by its past values, and then tests whether adding lagged values of another variable improves the explanation. Two way causality is frequent. However, Granger causality measures precedence and correlation, but not necessarily causality (Enders, 2015, p. 306).

Table 7.2: Pairwise Granger causality probabilities between the log of variables relating to New Zealand applications(two year lag and using F-statistics)

	Dependent variable p-values			
	Applications per capita by NZers	Application fees cost (no refund)	Advertising and parchment	Total cost application including ads
Applications per capita by NZers	-	0.0739	0.5473	0.1926
Application fee costs	0.5477	-	**0.0049**	0.3297
Ads and parchment	0.1489	**0.0059**	-	0.5173
Total cost application including ads	**0.0177**	**0.0042**	**0.0000**	-

Values in bold are significant at a 5% level

The pair-wise results in Table 7.2 show Granger causality between the total cost of an application, including advertisements, and applications per capita by New Zealanders. There is also Granger causality between total application costs and both fees costs and advertising and parchment costs. The latter two relationships reflect changes in initial fees and advertising preceding changes in other application costs. Indeed, application fee costs

Granger cause advertising and parchment costs, while advertising and parchment costs Granger cause initial fees. This occurs because during the early 1880s required newspaper advertising costs fell after application fees were reduced, but also preceded further reductions in application fees, which occurred before the requirement to produce patent specifications on parchment was replaced by a much less expensive standard form. However, it is the total cost of an initial application, including advertising and parchment costs, that Granger causes applications, rather than just the initial required fees, even though the advertising costs could be avoided by quickly letting an application lapse.

Increased newspaper advertising requirements in 1871 almost exactly negated the effect of the 1871 reduction in application fees. As a result, a single steep reduction in the early 1880s dominates the changes in total costs for applying for and advertising a patent (Figure 7.5). Of the potential explanatory cost variables, total costs including advertisements is therefore the cost variable best modelled as I(0), and this is confirmed by the break test ADF unit root results. These results suggest that the total cost of an initial application is the most suitable explanatory variable for explaining total patent applications per capita by New Zealanders.

Regressing the log of total applications by New Zealanders per capita on the log of the total cost of fees and advertising costs explained 88% of the variance in patent applications by New Zealanders. The residuals show that applications before 1868 were lower than expected, suggesting some omitted variable bias. For instance, New Zealand's low population may have meant that patent agent fees were higher in real terms in the 1860s than they were in later years.

Table 7.3: Using OLS to explain New Zealand patent applications per capita

Dependent: Ln NZ patents per 100,000 people	Model 1	Model 2
Constant	4.07 (0.08)***	2.29 (0.30)***
Ln fees, advertising and form cost	-0.95 (0.08)***	-0.64 (0.06)***
Trend	-	0.06 (0.01)***
Dummy 1869-1871	-	0.87 (0.19)***
Year>=1890	-	-0.31 (0.16)*
AR(1)	-	-0.38(0.18)***
Adjusted R^2	0.88	0.94
Durbin-Watson	1.13	1.99

*=significant at a 10% level, **=significant at a 5% level, ***=significant at a 1% level

Model 2 includes an AR(1) term to reduce autocorrelation. Furthermore, a dummy variable for the 1869-1871 period to allow for inventors delaying or bringing forward

applications to choose the fee structure that best suited them was significant. A dummy variable for years from 1890 when the cost of a 14 year patent increased was also significant, albeit at a 6% level. A Breusch-Godfrey serial correlation LM test showed that the null hypothesis of serial correlation could be rejected. The reported results for model 1 use robust standard errors because the White test indicated heteroscedasticity. A Jarque-Bera test indicated the residuals in the models were normally distributed. The fit of the model could be improved by dropping the initial years when the number of patent applications was low and variable.

Figure 7.9: Applications per 100,000 people using the sum of initial fees, advertising costs and parchment costs as the explanatory variable

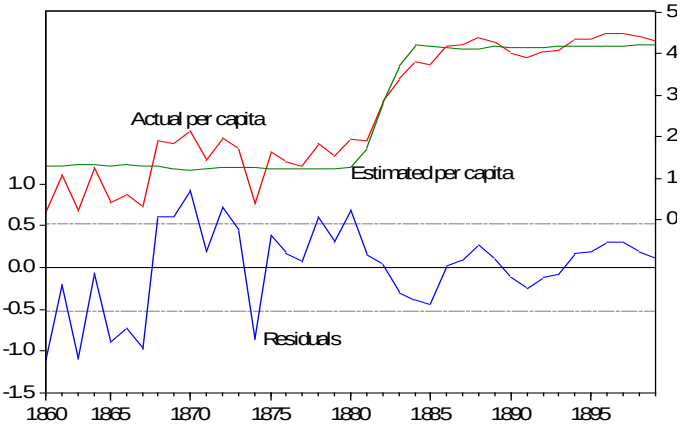
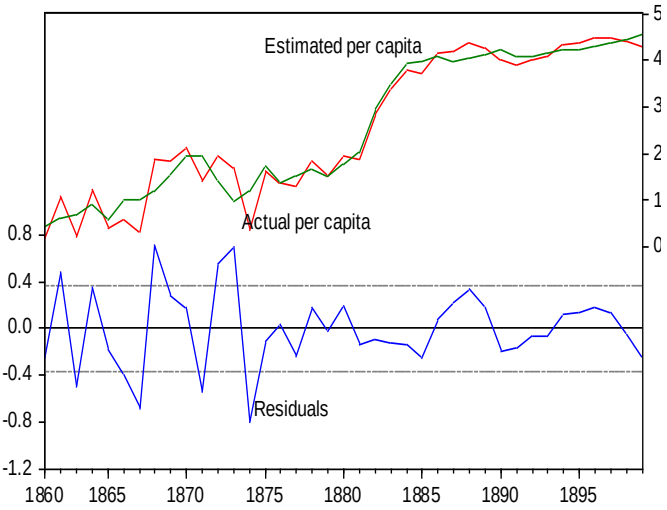


Figure 7.10: Applications per 100,000 people, after adding an AR(1) term and dummy variables



7.4 Total per capita patent applications and expenditure and their relationship with output

However, Table 7.1 showed that the natural log of total patent applications per capita, irrespective of whether these applications were by New Zealanders or by people living overseas, is I(1) without a break. Figure 7.11, which graphs total expenditure on patents per capita (including required advertising and parchment expenditure and shown per 100,000 people), shows even less of a change in trend in the early 1880s than the application data (see Figure 7.1). Nevertheless, the growth in expenditure per capita appears to have slowed over time. Per capita expenditure on patents is I(1).

The total production statistics and a number of possible explanatory variables that Magee found were important for explaining total patent applications in Victoria (Magee, 2000, p. 97) are also often I(1). For instance, the log of GDP per capita is I(1). Figure 7.13 shows New Zealand's average real GDP per capita peaked in 1878, but even allowing for a break and change in trend it remains I(1). The log of real output per capita, which provides an alternative measure of economic activity, is also I(1). However, the natural log of population is I(0), which has also been found over a longer time period (Cotter, 2006, p. 40). This makes analysing the data on a per capita basis desirable, when taking population into account, despite changes in the age and gender composition. Data for capital inflows into New Zealand are only available from Britain (Stone, 1999). The real value of British capital investment fluctuated within a narrow band after 1871, and the log of these inflows is I(1).

Magee argued that total patent applications in Britain and the United States represented the level of knowledge in other countries, and were therefore useful for explaining patenting in Victoria (Magee, 2000, p. 92). Figure 7.18 shows a sharp jump in British patenting in 1884 when its patent application fees were considerably reduced (MacLeod et al., 2003, p. 555). Patenting in Britain is the only variable in Table 7.4 that was I(0) using a breakpoint unit root test. There was a more gradual increase in United States patenting during the 1860s, which reflected the continuation of a long-running trend and law changes that made patenting easier (Khan, 2005, pp. 157, 191).

Some potential variables could not be included because of limited availability, lack of variation over time, because the short period of time covered restricts the number of variables that can be included in a model, and because percentage variables can be expected to be I(0). Although Magee found native born engineers were an important

variable explaining patenting in Australia (Magee, 2000, p. 98), training of engineers in New Zealand only began in 1887 at the University of Canterbury (University of Canterbury, 2016). Statistics only available for the 1874 and 1878 censuses show there were only six civil engineers in 1874 and nine in 1878 stating they had a degree (Office of the Registrar General, 1875, p. 178; 1880, p. 314). Self-reported data on those who considered themselves an engineer is unfortunately only available from the 1886, 1891 and 1898 censuses. From 1874 the census reports engineers, architects and scientists, although the number in this group is very small. Data on the populations of New Zealand's main cities is available from the early 1870s, but showed (see chapter four) that the populations of the four main centres collectively grew at about the same rate as New Zealand's total population. While Cotter included money supply in her models, this was used by Rankin to calculate GDP (Rankin, 1992), and therefore not considered by this study. Furthermore, there are no accurate statistics on total government expenditure for the period covered, and generating these statistics would involve consolidating a number of different central and provincial government accounts.

Table 7.4: Unit root test results using modified Hannan-Quinn criterion

	Without a break					With a break				
Variable (in logs)	Integrated	Lags	Equation	ADF	P-value	Integrated, break	Lags	Trend specification	ADF	P-value
Applications per capita	I(1)	9	I	-3.32	0.02	I(1), 1878	9	I	-11.75	<0.01
Expenditure per capita	I(1)	9	I	-10.14	0	I(1), 1874	9	T,I; break I	-11.53	<0.01
Real GDP per capita	I(1)	9	I	-8.33	0	I(1), 1878	9	T,I, break T,I	-9.83	<0.01
Output per capita	I(1)	9	I,T	-6.49	0	I(1), 1876	9	T,I, break T,I	-7.09	<0.01
British capital flows	I(1)	9	I,T	-8.05	0	I(1), 1895	9	I, break I	-8.52	<0.01
British patent applications	I(1)	9	I	-8.52	0	I(0), 1883	9	T, I, break I	-12.38	<0.01
US patent applications	I(1)	9	I	-4.61	0	I(1), 1883	9	I,I	-4.71	0.02
New Zealand population	I(0)	9	I,T	-4.39	0	I(0), 1873	9	T,I, break I	-5.17	<0.01

I=intercept, T=trend

Figure 7.11: The log of expenditure on patents per 100,000 people

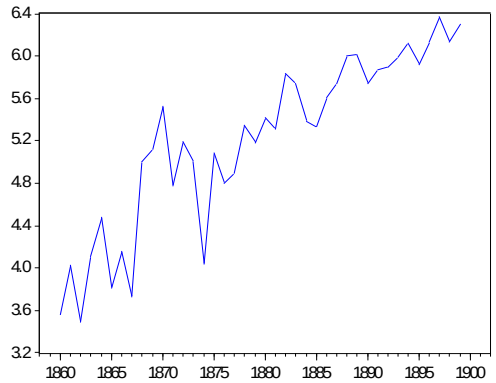


Figure 7.12: Log population (excluding Maori)

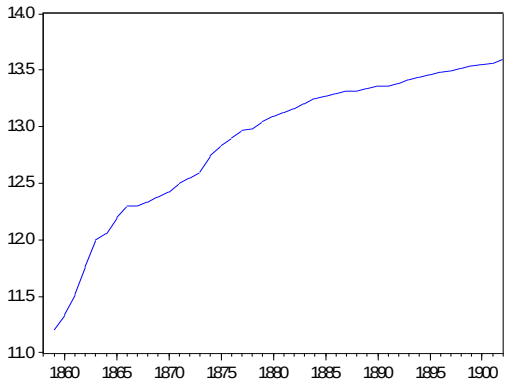


Figure 7.13: Log of real GDP per 100,000 people

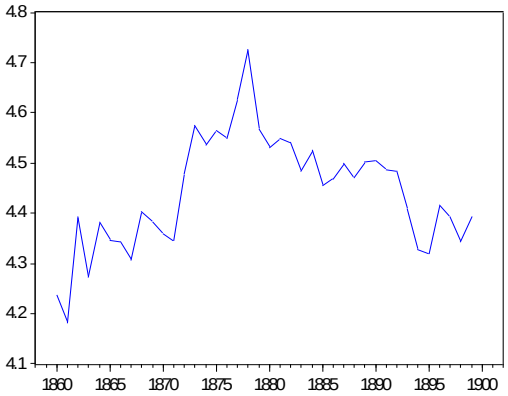
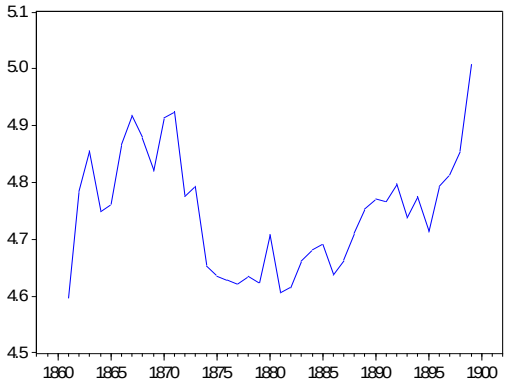


Figure 7.14: Log of aggregate output per 100,000 people



7.15 Log of British capital inflows into New Zealand

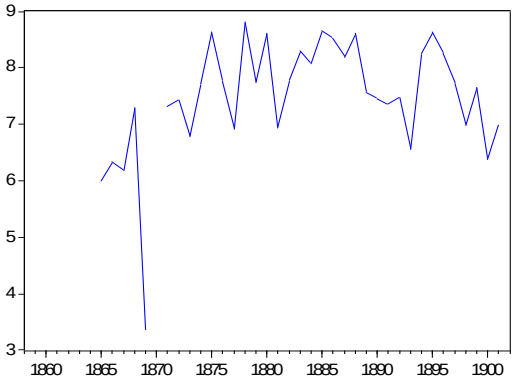


Figure 7.16 Log of British patent applications

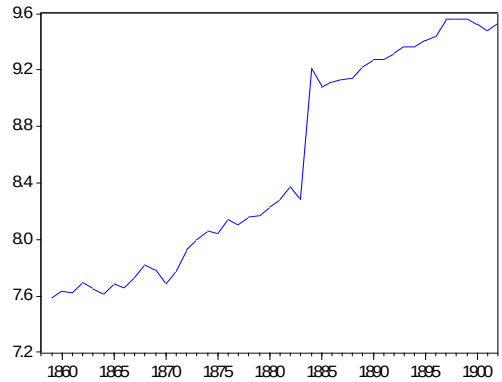


Figure 7.17: Log of United States patent applications

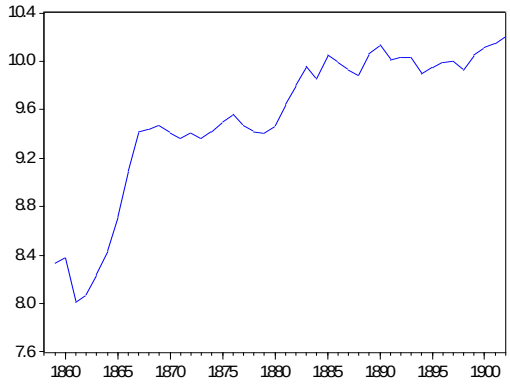


Table 7.5 shows New Zealand GDP per capita was cointegrated with applications per capita (maximum eigenvalue test only), expenditure per capita (trace test only), and United States patent applications (trace test only). The coefficients for applications per capita and expenditure per capita are both positive, which is in accordance with theoretical expectations, and statistically significant. However, GDP per capita was not cointegrated with British capital investment in New Zealand. British patents have been excluded since there is considerable evidence that this variable was I(0), but even when they were treated as I(1) were not cointegrated with New Zealand GDP per capita. Some of the Eviews options necessary to find cointegration, such as options one and five, are rarely used by researchers, who prefer option three, or sometimes option four, over the other options (IHS Global, 2014, p. 851).

Table 7.5: Testing for bivariate cointegration with GDP per capita, Johansen method

Variable	Option	Lag	Trace test	Maximum eigenvalue	Normalised coefficient
Applications per capita	1	3	0	1	1.00 (0.16)
Expenditure per capita	5	3	1	0	1.23 (0.32)
US patents	1	1	1	0	-0.47 (0.12)
British capital investment	All	-	0	0	-

Table 7.6 shows applications per capita were cointegrated with United States patents applications, with expenditure per capita (trace test only), and with GDP per capita (maximum eigenvalue test only). Table 7.7 shows there is at best weak evidence that

some variables were cointegrated with patent expenditure per capita, with most of the normalised coefficients not being statistically significant.

Table 7.6: Testing for bivariate cointegration with patent applications per capita in New Zealand, Johansen method

Variable	Option	Lag	Trace test	Maximum eigenvalue	Normalised coefficient
GDP per capita	1	3	0	1	1.00 (0.13)
Output per capita	All	-	0	0	-
Expenditure per capita	5	2	2	0	741.2 (206.6)
US patents	3	1	1	1	4.28 (0.60)
British capital investment	All	-	0	0	-

Table 7.7: Testing for bivariate cointegration with patent expenditure per capita in New Zealand, Johansen method

Variable	Option	Lag	Trace test	Maximum eigenvalue	Normalised coefficient
GDP per capita	5	3	1	0	0.81 (0.56)
Output per capita	5	3	2	0	0.02 (0.16)
Applications per capita	5	2	2	0	0.00 (0.16)
US patents	2	2	2	2	1.91 (0.19)
British capital investment	5	2	1	1	0.02 (0.07)

Granger causality between I(1) variables and patent applications per capita, patent expenditure per capita, and GDP per capita is shown in Table 7.8 to establish the direction of causality. The results imply applications per capita and expenditure per capita both do not Granger cause GDP per capita. The reverse is also true, with GDP not Granger causing patent applications or expenditure. United States patents, however, Granger cause patent expenditure per capita in New Zealand. When British capital investment was not cointegrated with the other variables, differences had to be used to calculate the relationship between variables.

Table 7.8: Pairwise Granger causality between the log of variables that were I(1), with New Zealand patent expenditure and GDP per capita (two year lag and using F-statistics)

	Dependent variable p-values		
Independent variables	Patent applications per capita	Patent expenditure per capita	GDP per capita
Applications per capita	-	0.5012	0.3484
Patent expenditure per capita	0.6542	-	0.4992
Output per capita	0.4553	0.6813	0.2485
GDP per capita	0.3054	0.7346	-
United States patents	0.4054	**0.0297**	0.4111
British capital investment	0.9528	0.9339	0.4063

Bold p-values are of 0.05 or less and indicate Granger causality

Since these results are disappointing, the next section considers relationships between patent applications and expenditure with GPD and output, both in aggregate and in individual areas. Totals, rather than per capita variables, have been used because there was considerable growth in the proportion of children, women, and older people in New Zealand during the period studied (Macdonald, 1999).

7.4 Explaining output in different parts of the economy

Total patent applications and total patent expenditure both summarise a diverse range of topics, making it important to look at the relationship between patenting and output in particular areas. Indeed, Greasley and Oxley's output statistics since 1860 show mining and manufacturing followed considerably different trends to the other output areas (Greasley & Oxley, 2010b).

The output statistics used are predominantly from Greasley and Oxley. Their summary output statistics are used, largely because some of their more disaggregated output series were I(0) over the relatively brief period covered here. However, Appendix B reports disaggregated output results for pastoralism. Manufacturing output was I(2) over the period covered and therefore excluded. Rankin's GDP statistics were used as a measure

of total output, largely because over the short time-period covered there was some evidence that total output (and this depended on how output was defined) was I(0).

The patent application categories are also similar to those used by Greasley and Oxley. As a result, here pastoralism includes patents about dairying and refrigeration (Greasley & Oxley, 2010b, p. 451). However, construction was excluded since construction applications were I(0) over the period covered, while print and publishing patents were dropped since there were relatively few patents on this topic before 1899. Total patenting was divided into New Zealand and foreign categories to see if there were any differences in the economic effectiveness of patents from different countries. This was because Cotter found a causal relationship between real GDP and New Zealand patent applications that did not exist for foreign patent applications, suggesting that only New Zealand patenting caused GDP to grow between 1871 and 1938 (Cotter, 2006, p. 20). Furthermore, 14 year patent applications and expenditure were also included to see if the most costly patents had a stronger economic effect than other patents.

Figure 7.18: Log of patent applications

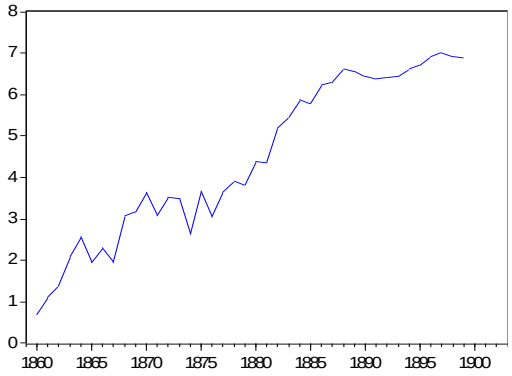


Figure 7.19: Log of total expenditure on patents

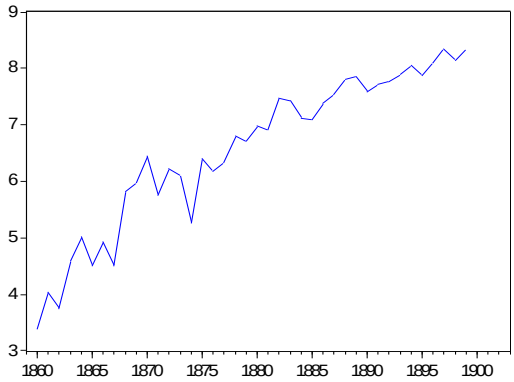


Figure 7.20: Log of total New Zealand patent applications

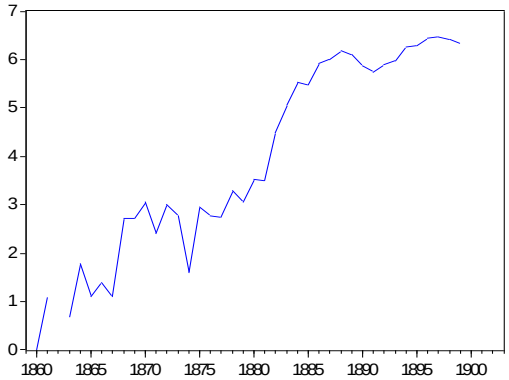


Figure 7.21: Log of New Zealand patent expenditure

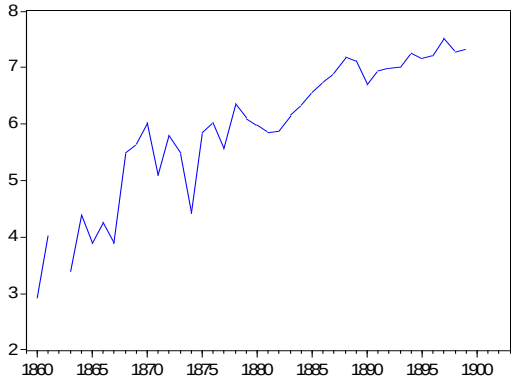


Figure 7.22: Log of foreign patent applications

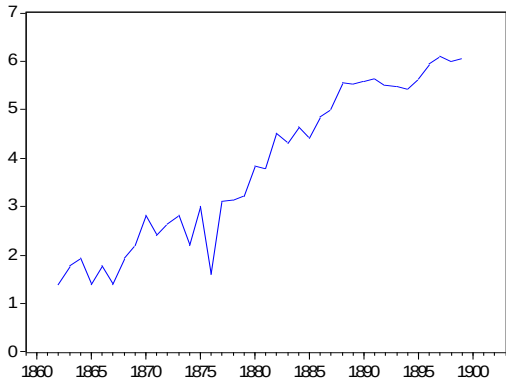


Figure 7.23: Log of foreign patent expenditure

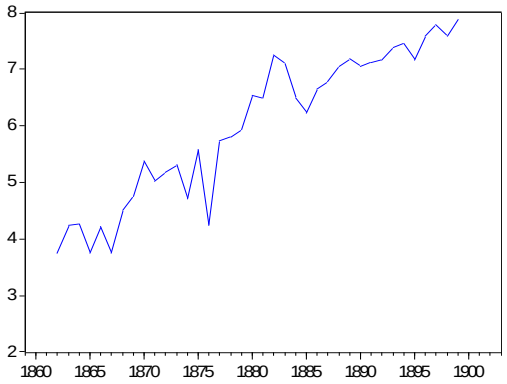


Figure 7.24: Log of 14 year patent applications

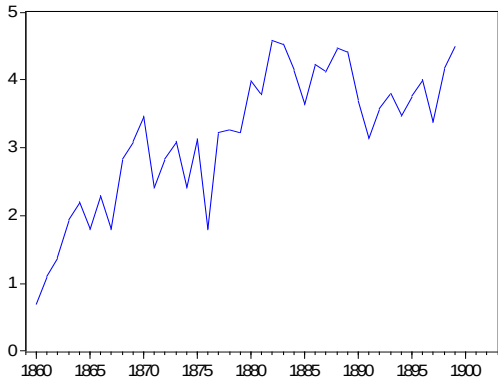


Figure 7.25: Log of 14 year patent expenditure

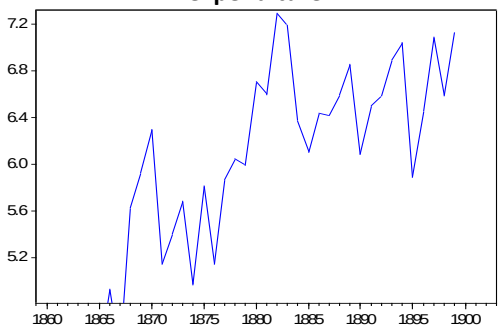


Figure 7.26: Log of real GDP

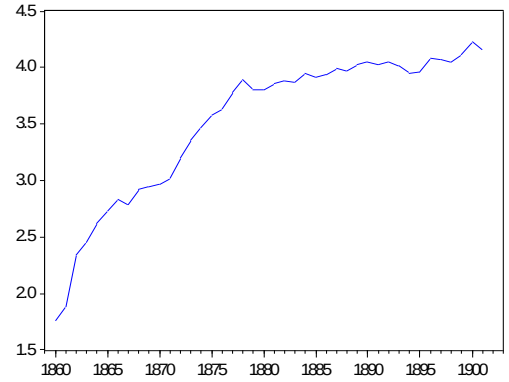


Figure 7.27: Log of total commodity output

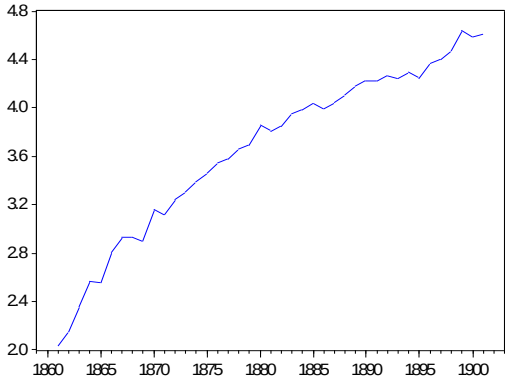


Figure 7.28: Log of agricultural patent applications

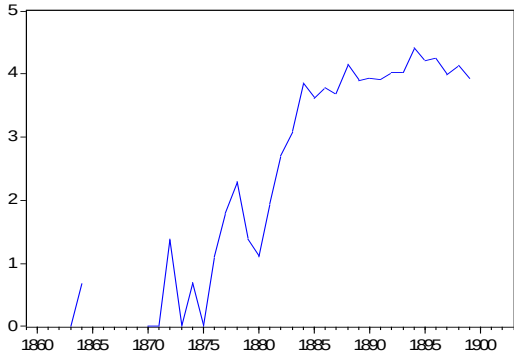


Figure 7.29: Log of agricultural patent expenditure

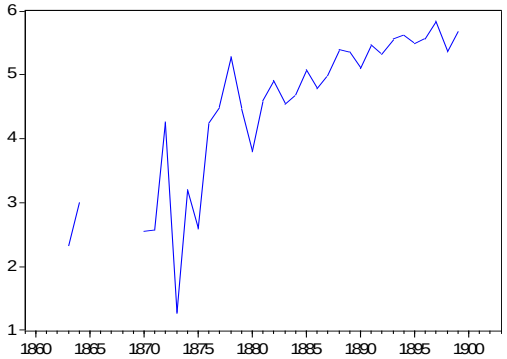


Figure 7.30: Log of agricultural output

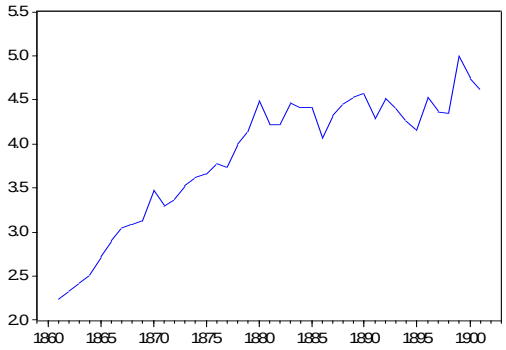


Figure 7.31: Log of pastoral patent applications

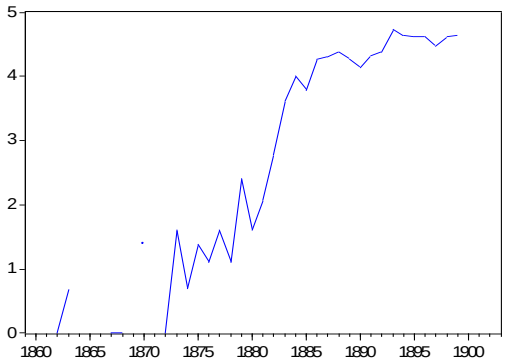


Figure 7.32: Log of pastoral patent expenditure

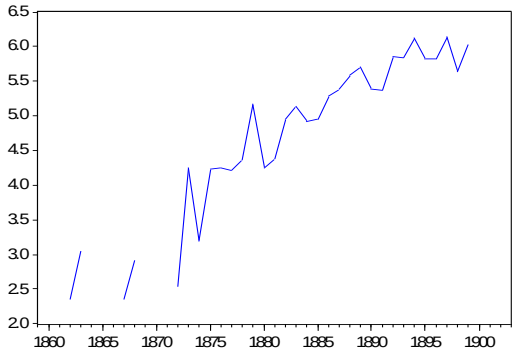


Figure 7.33: Log of pastoral output

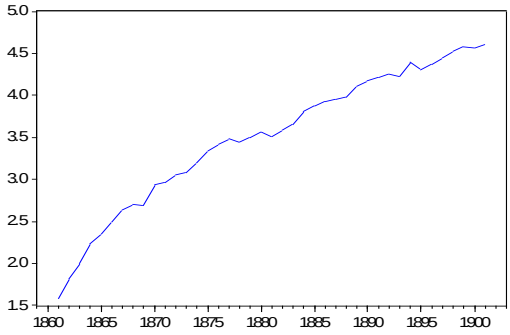


Figure 7.34: Log of clothing and textiles patent applications

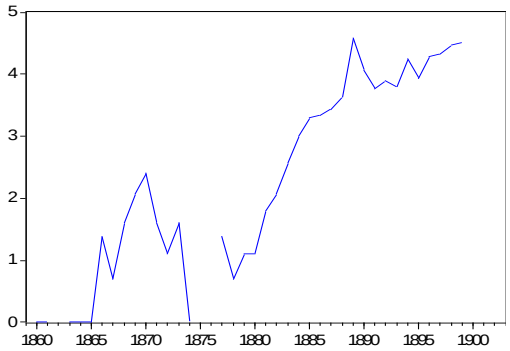


Figure 7.35: Log of clothing and textiles patent expenditure

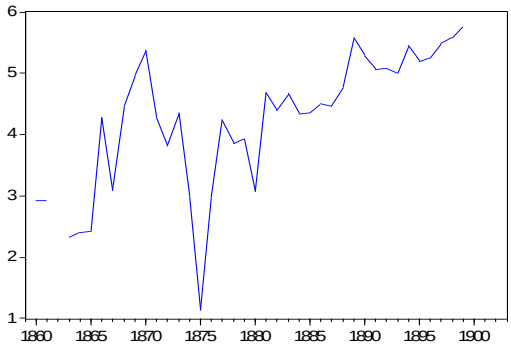


Figure 7.36: Log of clothing output

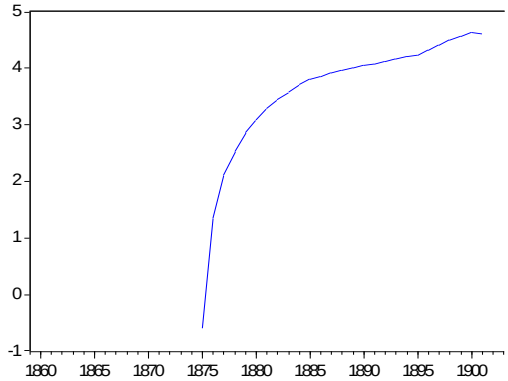


Figure 7.37: Log of transport, communications, power applications

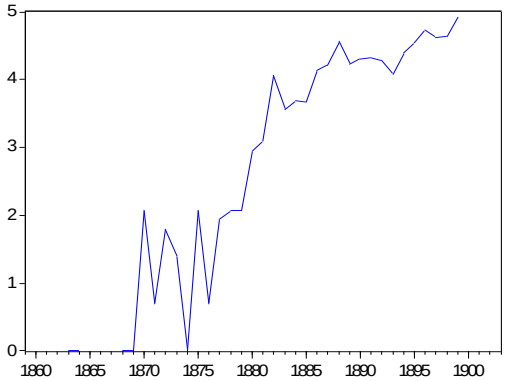


Figure 7.38: Log of transport, communications, power patent expenditure

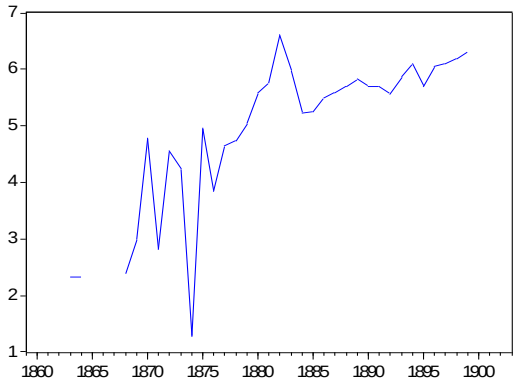


Figure 7.39: Log of manufacturing output

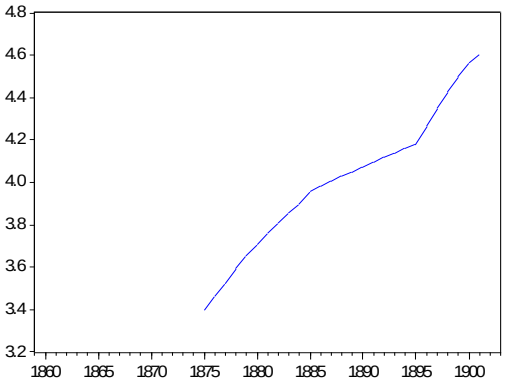


Figure 7.40: Log of mining patent applications

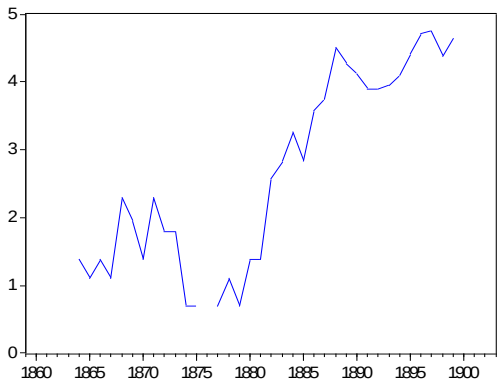


Figure 7.41: Log of mining patent expenditure

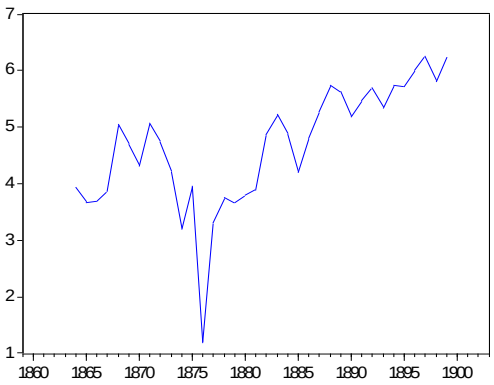
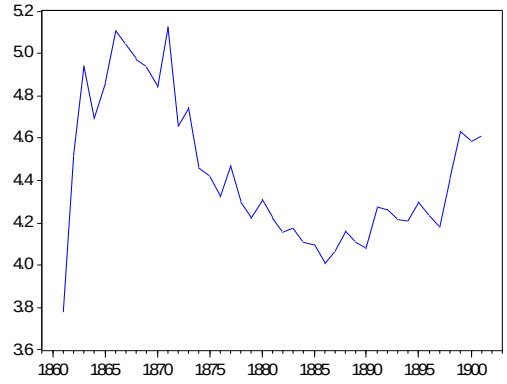


Figure 7.42: Log of mining output



The applications, expenditure and output series in this section do not exhibit the sharp and persistent step changes apparent in some series in section two of this chapter, although there are sometimes considerable fluctuations. Table 7.9 therefore does not report unit root tests that allow for a break.

Table 7.9: Unit root test results using modified Hannan-Quinn criterion

	Ln applications					Ln expenditure					Ln output				
Variable (in logs)	I	Lags	Equation	ADF	P-value	I	Lags	Equation	ADF	P-value	I	Lags	Equation	ADF	P-value
Agriculture	1	8	I	-7.27	0	1	8	I	-10.48	0	1	9	I	-8.13	0
Pastoralism	1	8	I,T	-11.20	0	1	8	I,T	-11.92	0	1	9	I	-3.57	0.01
Mining	1	8	I	-2.90	0.06	1	8	I	-8.45	0	1	9	I,T	-7.50	0
Transport, comms, power	1	8	I,T	-11.89	0	1	7	I	-8.37	0					
Engineering											2	6	I	-4.87	0
Manufacturing											2	6	I	-3.00	0.05
Clothing	1	9	I	-8.52	0	1	9	I	-7.43	0	0	6	I,T	-5.16	0.00
Total patents & Rankin GDP	1	9	I	-3.41	0.02	1	9	I	-10.1	0	1	9	I	-3.20	0.03
Output											0	9	I,T	-3.58	0.04
New Zealand patents	1	9	I	-3.51	0.01	1	9	I	-9.37	0					
Foreign patents	1	9	I	-3.15	0.03	1	9	I	-3.55	0.01					
Fourteen term patents	1	9	I	-9.61	0.02	1	9	I	-9.47	0					

I=intercept, T=trend

Tables 7.10 and 7.11 report cointegration and Granger causality results. The top number for each row of patent data tests for causality from patents to output, while the number below tests for causality from output to patents. For instance, the p-value for total patent applications Granger causing real GDP in Table 7.10 is a non-significant 0.4960, while the p-value for GDP Granger causing total applications is also non-significant at 0.6138.

Some of the series are not cointegrated (N,N) using either the trace (denoted in the table by a T) or maximum eigenvalue (E) test, which meant that they had to be differenced before conclusions could be drawn about relationships between the variables. Mining output was usually not cointegrated with patent applications or expenditure variables. In addition, clothing patent applications and expenditure were often not cointegrated with output variables. However, output from the dominant pastoral sector was cointegrated with most patent expenditure variables. The Eviews option used to find cointegration has been reported since the unusual time series characteristics of some series, such as mining, meant that cointegration was only found using rarely used options such as one or five (IHS Global, 2014, p. 851). Only coefficients where Granger causality existed are shown.

Greasley and Oxley tested pair-wise Granger causality between patent applications and output between 1871 and 1939, and found that the statistically significant relationships indicated that patenting usually led output (Greasley & Oxley, 2010b, p. 452). Over the earlier and shorter 1860-1899 period, and relying more on summary data, this study finds the reverse. Indeed, applications Granger caused output in four statistically significant causal linkages, while output Granger caused patent applications in seven such linkages. For expenditure on patents, which Greasley and Oxley did not have data on, there were considerably more cases of Granger causality, even after ignoring cases where the coefficient was not statistically significant. Expenditure on patents Granger caused output in three statistically significant causal linkages, while output Granger caused expenditure in thirteen such causal linkages. This indicates that over the period covered, and using summary data, output and expenditure on patents were more closely linked than output and patent applications. Furthermore, output usually seems to have led patenting, rather than vice versa.

The applications results show total applications, New Zealand applications, and foreign patent applications all Granger caused pastoral output. For expenditure the reverse is true for these patents, with pastoral output Granger causing patenting expenditure. For

expenditure on foreign patents the relationship is statistically significant in both directions.

Although pastoralism patent applications did not Granger cause pastoral output, pastoral output Granger caused expenditure on pastoral patents. Expenditure on pastoral patents also Granger caused GDP, while GDP Granger caused expenditure on pastoral patents, suggesting linkages between invention in pastoralism and the economy as a whole.

Agricultural output Granger caused agricultural patent applications, but the reverse was not true. Furthermore, expenditure on agricultural patents, which includes patents by many of the highest spending inventors on ploughs, sowing, threshing, reaping, and harvesting machines, Granger caused agriculture output. However, agriculture output did not Granger cause agricultural patent expenditure. This suggests that the high spending agricultural implement inventors and makers discussed in the previous chapter, such as James Gray, William Andrews, Arthur Beaven and John Greenslade, made an important contribution to the development of the agricultural output in New Zealand. In addition, expenditure on agricultural patents does not seem to have been responsive to short term agricultural output, although the total number of agricultural patent applications filed was responsive to agricultural output.

In contrast, specifically pastoral patents, which chapter five noted were often about fencing, hedges and rabbit control, and were patented by a wide range of people who were not among the highest spending patentees, seem to have sometimes been responsive to more short-term pressures, and sometimes had a lesser economic effect. However, looking at more detailed data in Appendix B, the coefficient for pastoralism applications Granger causing cheese output (Table B2) is significant, as it was for Greasley and Oxley, at a 5% level (Greasley & Oxley, 2010b, p. 449). Similarly, the coefficient for expenditure on pastoral patents Granger causing cheese output (Table B3) is almost significant at a 5% level, suggesting patent expenditure may have also boosted cheese output. A longer time period would give clearer insights into this. This is because the dairying industry was still small in 1899, and the number of pastoralism patents specifically about dairying was low.

The level of GDP Granger caused mining patent applications, suggesting that investment in mining often reflected the state of the economy. Indeed, mining patent applications did not Granger cause mining output. Mining output Granger caused agricultural patent applications and expenditure, but the variables for mining output had negative

coefficients. This suggests that during times when mining was doing well, investment in agricultural patents, which was also sometimes quite speculative, fell since there were other opportunities for risk takers.

Mining patent expenditure Granger caused pastoral output, although the normalized cointegrating coefficient was not statistically significant. Furthermore, mining output did not seem to have Granger caused pastoralism output with a probability of 0.3881 (not shown in a table).

There were considerable linkages between output variables and expenditure, but not applications, on patents relating to transport, communications and power. This suggests that economic prosperity increased investment in these areas. There was less evidence, even experimenting with changes in lags, that this investment boosted output.

The relationship between fourteen year patent applications and expenditure and subsequent economic output is sometimes different to the relationship between total patent applications and expenditure and output. For instance, real GDP was more likely to Granger cause expenditure on fourteen year patents than on total patent expenditure. This is not surprising because of the high cost of taking out a patent for fourteen years.

Table 7.10: Patents applications and output: Cointegration, Granger causality and selected coefficients

	Output variables (two year lead for Granger causality) and difference if not cointegrated											
	Rankin GDP real			Agriculture output			Mining output			Pastoral output		
Patent application variables (difference if CR is NN)	CR (option, lag)	GC	Coeff if causal	CR (option, lag)	GC	Coeff if causal	CR (option, lag)	GC	Coeff if causal	CR (option, lag)	GC	Coeff if causal
Total applications	T E (3,1)	0.4960		T,E (2,1)	0.7047		N,N	0.9320		T, E (3,1)	**0.0030**	0.28 (0.03)
		0.6138			0.1754			0.2609			0.4602	
NZ applications	2T,2E,(3,3)	0.1378		T,N (2,1)	0.7131		N,N	0.9234		T, E (3,1)	**0.0201**	0.27 (0.03)
		0.0210	1.63 (0.59)		**0.0297**	1.74 (0.77)		0.1467			0.2496	
Foreign applications	T,E (3,3)	0.3714		T,N (2,1)	0.7724		N,N	0.6843		T,E (3,1)	**0.0031**	0.32 (0.03)
		0.0965			0.8992			0.8441			**0.0330**	3.07 (0.23)
14 year patent applications	T,E (3,3)	0.6562		T,N (1,1)	0.0834		N,N	0.0834		2T,2E (3,1)	0.1888	
		0.0554			0.0585			0.0585			**0.0195**	-3.71 (1.00)
Agriculture applications	2T,2E (3.2)	0.6074		T,N (3,2)	0.3643		T,E (5,1)	0.4420		T,E (2,1)	0.6376	
		0.3685			**0.0466**	3.84 (0.53)		**0.0001**	-3.19(0.60)		0.5524	
Clothing applications	2T,2E (3,2)	0.1061		N,N	0.7243		N,N	0.9576		T,E (2,2)	0.1165	
		0.2960			0.9554			0.4456			0.8060	
Transport, comms, power applications	2T,2E (3.2)	0.3372		T,N (2,2)	0.9745		T,E (2,2)	0.4846		T,E (2,1)	0.1680	
		0.0615			0.6530			0.2506			0.8020	
Mining applications	T,E (1,2)	0.6620		N,N	0.8806		2T,N (3,2)	0.5047		T,E (2,1)	**0.0240**	0.31 (0.08)
		0.0164	1.21 (0.11)		0.3536			0.4457			0.2944	
Pastoralism applications	2T,2E (3,2)	0.3072		2T,2E (3,2)	0.2398		T,N (2,3)	0.8087		T,E (2,1)	0.3872	
		0.1098			0.5844			0.2135			0.1453	

The top statistics for Granger causality for each row of applications data tests for causality from patents, the lower number tests the reverse. Bold values have a p-value of 0.05 or less and are considered significant.

Table 7.11: Expenditure on patents and output: Cointegration and Granger causality results

	Output variables (two year lead) and difference if not cointegrated											
	Rankin GDP real			Agriculture output			Mining output			Pastoral output		
Patent expenditure variables	CR (option, lag)	GC	Coeff if causal	CR (option, lag)	GC	Coeff if causal	CR (option, lag)	GC	Coeff if causal	CR (option, lag)	GC	Coeff if causal
Total expenditure	2T, N (3,1)	0.3989		2T, 2E (5,1)	0.1362		T, E (5, 1)	0.2847		2T, 2E (3, 1)	0.1391	
		0.1506			0.1108			0.5691			**0.0068**	0.66 (0.23)
NZ expenditure	2T, N (3,3)	0.0617		T,E (2,2)	0.5105		N, N (5, 1)	0.5256		2T, 2E (3, 1)	0.6177	
		0.9341			0.7694			0.5238			**0.0048**	1.32 (0.12)
Foreign expenditure	T, E (3,3)	0.1141		T, E (3,3)	0.6949		N, N (5,1)	0.8080		2T, 2E (3.1)	**0.0186**	0.37 (0.06)
		0.7048			0.9548			0.7724			**0.0026**	2.66 (0.25)
14 year patent	2T, 2E (3,3)	0.3180		2T, 2E (3,1)	0.6194		N, N (5,1)	0.5911		2T, 2E (3,2)	0.4965	
expenditure		**0.0171**	1.02 (0.14)		**0.0174**	1.12 (0.10)		0.4653			**0.0008**	0.21 (0.21)
Agriculture expenditure	2T, 2E (3,2)	0.9384		2T, N (3,3)	**0.0324**	2.06 (0.50)	T, E (5,1)	0.2138		T,E (3,3)	0.8993	
		0.0611			0.1504			**0.0000**	-2.07 (0.46)		**0.0394**	1.36 (0.23)
Clothing expend	2T, 2E (3,2)	0.6097		N, N	0.4812		N, N (1,1)	0.5462		2T, N (5,1)	0.7353	
		0.9058			0.8183			0.2082			0.1793	
Transport, comms,	2T,2E (3,1)	0.2349		T, E (3,1)	0.3428		T,E (1,2)	0.2150		2T, 2E (3,0)	0.5753	
power expenditure		**0.0098**	1.68 (0.40)		**0.0092**	2.16 (0.21)		0.0907			**0.0456**	1.59 (0.24)
Mining expenditure	T, E (2,2)	0.0599		T, E (5,3)	0.4347		N, N (1,1)	0.5274		2T, N (5,1)	**0.0095**	-0.04 (0.03)
		0.1787			0.8637			0.7876			0.3196	
Pastoralism	2T, 2E (3,1)	**0.0451**	0.16 (0.03)	T,E (2,2)	0.7372		2T, N (3,2)	0.5298		T, E (3,2)	0.8283	
expenditure		**0.0283**	6.18 (0.72)		0.4821			0.1445			**0.0335**	1.51 (0.09)

The top statistics for Granger causality for each row of expenditure data tests for causality from patents, the lower number tests for the reverse. Bold values have a p-value of 0.05 or less and are considered significant.

7.6 Conclusion

This chapter has examined the relationship between patenting and patent fees, and between patenting and economic output. The results in section three showed that changes in the initial cost of a patent application, which involved both official fees, required advertising, and parchment or a form, were useful for understanding changes in patent application rates by New Zealanders. Indeed, the step change decrease in initial application costs in the early 1880s was associated with a sharp increase in New Zealand patenting applications. However, a trend variable and dummies for other changes were also important in modelling this relationship.

Examining the relationship between total patenting and total output, GDP per capita was cointegrated with applications per capita, patent expenditure per capita, and United States patents. However, the results indicated patent applications and expenditure per capita in New Zealand both did not Grange cause GDP per capita over the short period considered. The reverse was also true, with GDP per capita not Granger causing patent applications or expenditure.

This chapter then examined the relationship between patenting and output using data on several different sectors of the economy and without controlling for changes in population. Contrary to the Greasley and Oxley, who covered a longer time period and used more disaggregated output data (Greasley & Oxley, 2010b, p. 452), output Granger caused patent applications more often than applications Granger caused output. This chapter's unique expenditure results followed the same pattern, although Granger causality from output to patents occurred considerably more frequently with patent expenditure data than with patents applications. This suggests that the expenditure data is more useful than just the applications data for understanding the relationship between patenting and output. Overall, output seems to have more often caused patenting applications and expenditure than patenting caused economic output. However, in some of the results patenting Granger caused output, with the relationship between agricultural patent expenditure and agricultural output being an important example.

Chapter 8: Conclusion

8.1 Introduction

One key question in this thesis has been *the extent to which patenting promotes economic development*. Some economists argue that patents facilitate economic development by rewarding research, invention, and original thinking. By providing a temporary monopoly, patents allow inventors to sell products based on their invention, or to license their intellectual property. Patents also encourage the diffusion of knowledge by ensuring that inventions are written down, and that on the expiry of the patent the invention becomes available for everyone to use (Auger, 1992, p. 10). However, other economists argue that patents encourage opportunistic rent-seeking and monopolies (Boldrin & Levine, 2013; Economist, 2015c). Furthermore, empirical research shows patenting often seems to lag increased output (Greasley & Oxley, 2007, p. 245; Schmookler, 1966, pp. 136, 138, 147). While this suggests that inventors are seeking to respond to economic needs, and there is strong evidence businesses value patents (Schmookler, 1966, pp. 50, 51, 53, 136), it also suggests that patents may not drive economic growth.

The other key question considered in this thesis is *the extent to which different economic and demographic groups make use of the patenting system*. Patenting laws and fees that encourage patenting can ensure people from a wide range of backgrounds have an incentive to innovate and to develop new technology. Patenting fees also affect which areas of the economy it is cost-effective to apply for patent protection. The inclusiveness of the patenting system is an important indicator of the level of economic equality of opportunity. Furthermore, if patenting has economic benefits, a patenting system where a wide range of people can patent may be more effective at promoting economic growth. This is because the ideas, creativity, and hard-work of all population groups are being utilised (Khan, 2005, pp. 7, 13).

Data to test these questions has been primarily collected from unit record data on 12,283 patents applied for in New Zealand between 1860 and 1899. The topic of each patent was coded using a system previously applied to data for Australia and New Zealand (Cotter, 2006; Greasley & Oxley, 2007; Magee, 2000). The authors of each patent were identified. Their contribution has also been weighted both by their share of the patent application, and by total expenditure on that patent over time. Expenditure on patents has been

quantified both for government fees and for required advertising of patent applications. Since the cost of applying for a patent fell sharply during the early 1880s, weighting the data by expenditure creates a potentially more accurate picture of the level of patenting activity. Furthermore, the relationship between patents and output has been able to be tested using expenditure on patents, as well as patent applications.

This chapter initially summarises the main findings about the inclusiveness of New Zealand's patenting system. The focus then switches to the relationship between patenting and economic output. Areas for future research are then noted.

8.2. The inclusiveness of New Zealand's patent system

The results show that patent applications in New Zealand increased from only a few a year in the 1860s to over a thousand a year in the 1890s. On a per capita basis there was also a sharp increase in patent applications by people living in New Zealand. Furthermore real, and real per capita, expenditure on patents also increased, albeit less dramatically. Patent applications by New Zealanders grew rapidly in the 1880s after the cost of an initial application was sharply reduced. However, foreign patents accounted for the majority of expenditure on patents, with most of these patents coming from Australia, Britain, and the United States. Which New Zealand regions had the highest per capita patenting and expenditure rates varied, with no region having the highest patenting rate for very long. Patenting by New Zealanders was stronger in the four metropolitan areas than in their surrounding hinterlands, although some of these patents were primarily used outside metropolitan centres.

Engineers who had trained through an apprenticeship made the most patent applications in New Zealand. New Zealand farmers patented at higher levels than farmers in Victoria, Britain or the United States, and more New Zealand patents were about farming than in those places. Nevertheless, New Zealand farmers patented at a lower rate than the male workforce as a whole, with many farming patents being developed in urban areas by agricultural engineers and blacksmiths. Skilled New Zealand tradespeople, such as blacksmiths and builders, patented at relatively high levels, and made a higher percentage of patent applications after initial patenting costs were reduced in the early 1880s. However, low income earners, such as labourers, continued to patent at low rates. Furthermore, clerical and service workers made relatively few patent applications.

Patenting by women increased from the early 1880s. Even at the end of the 1890s, however, women were only making 2.5% of patent applications. Nevertheless, women were patenting at a higher rate in New Zealand than women in the United States and in Victoria (Khan, 2005, p. 135; Magee, 2000, p. 64). Only one patent application by an indigenous Maori New Zealander was identified, and Chinese New Zealanders also made very few patent applications. Use of the patent system was therefore still limited for some important population groups in 1899 due to economic and cultural barriers. Indeed, the highest spending patentees were all male, and were frequently engineers who owned their own firm.

8.3 The relationship between patenting and economic output in New Zealand

A wide range of topics relevant to the economy were covered in patent applications. New Zealand had a strong revealed technological advantage in its economically dominant agricultural and pastoral sectors. However, for the period covered by this study, this was not the case for dairying, which in the 1890s was still an emerging industry. Spikes in patenting, such as for flax patents in the 1870s and bicycle patents in the late 1890s, usually reflected strong demand for associated products. The highest spending New Zealand patentees disproportionately owned successful companies supplying agricultural products, such as ploughs and harvesters, to a wide range of customers in New Zealand and overseas. They often left prosperous businesses to their descendants. High spending mining patentees were often less successful in business, but in obituaries were nevertheless seen as contributing to New Zealand's infrastructure and technological base. Other patentees also developed innovative new products and made an important contribution to the New Zealand economy. Foreign intellectual property patented in New Zealand included numerous telegraph patents in the 1870s, electricity and lighting patents in the 1880s, and sheep shearing and dairy farming patents in the 1890s.

A stronger relationship was found between total expenditure on patents and economic output variables than between total applications for patents and economic output. This vindicated the decision to methodologically break new ground by weighting the data by annual expenditure on each patent. Contrary to a previous New Zealand study, which covered a longer time period using summary applications data and more detailed output data (Greasley & Oxley, 2010b, p. 452), output led patenting more frequently than the reverse occurred. The tendency for output to Granger cause patenting was particularly

strong for the unique patent expenditure data. These results indicate patentees were responding to economic problems and patenting accordingly, and are similar to patent applications results for other countries (Greasley & Oxley, 2007, p. 245; Magee, 2000, pp. 95-96; Schmookler, 1966, p. 136). Nevertheless, there were important cases where expenditure led output, such as the relationship between agricultural patent expenditure and agricultural output.

There was some evidence that agricultural patents, which were more likely to be by high-spending patentees, had more economic impact than pastoralism patents, which were sometimes applied for by a wider range of amateur inventors. There was little evidence of mining patent applications, or mining patent expenditure, or mining output, contributing to output in other parts of the economy. However, pastoral output seemed to increase total patent applications and expenditure, but to reduce foreign patent applications and expenditure in New Zealand.

8.4 Areas for further research

This thesis has shown there are considerable gains in knowledge from analysing patent data using unit record data, and from adding information on when patents lapse or are renewed, and on the fees paid. Those studying other patent systems may therefore also want to add information on the status of patents, and on official fees and required expenditure. If further information on patent agency fees could be found these expenses could also be attributed to patent applications.

Although the period covered by this study is similar to that of a study of patenting in Victoria (Magee, 2000), there would be advantages in extending the database in future to cover the twentieth century. Adding data from the twentieth century would enable the relationship between patenting and emerging industries, such as dairying and frozen meat, to be studied using unit record data rather than just the summary data currently available. Furthermore, with more years of data it would be possible to effectively study linkages between patenting and the rapid growth of manufacturing. Since the author has aimed to create a high quality dataset, with an easy to understand Stata program, extending the dataset would be straightforward, although still time consuming.

More work on the backgrounds of patentees, including some inventors who only patented once, would be desirable. A comparison could then be made with the background

characteristics of prolific and high spending patentees. Although New Zealand has not kept historic census data on individuals, more information on patentees should become available as further historic newspapers are scanned.

8.5 Conclusions

This thesis has shown that New Zealand's patenting system became used by a wider range of New Zealanders during the nineteenth century. In particular, lower patenting costs in the early 1880s were associated with an increased number and proportion of patents by tradespeople. Farmers in New Zealand consistently made greater use of the patenting system than farmers in other countries, and patenting by farmers increased over time. However, most New Zealand patent applications continued to be by engineers who had completed apprenticeships. Furthermore, low income groups, such as labourers, made few patent applications during the nineteenth century. Patenting by women was still very low in 1899. Despite Maori being a substantial New Zealand population group, only one patent application by a Maori was discovered.

Many of the highest spending New Zealand patentees became prosperous through mass production of the goods they had patented. Even the less financially successful mining sector patentees were often seen as making an important contribution to New Zealand's infrastructure and technological base. Usually total output series led total patenting series, and this was particularly true for the unique patent expenditure data generated for this thesis. These results indicate patentees were responding to economic problems. Nevertheless, in some of the results patent applications and patent expenditure Granger caused total output in particular areas of the economy. There is therefore some evidence that patent applications and expenditure helped increase living standards in New Zealand.

Appendix A: Industry of use patent codes

The coding scheme for patents in this thesis is based on the methodology used by Gary Magee, who categorised patents into three sectors and 33 categories "according to their primary intended use (rather than origin): that is, the industry where the principle and ideas embodied in the patent were expected by the patentee to be employed". Magee used this method rather than categorising inventions according to either their technological properties, or by the industry that produced the invention (Magee, 2000, pp.29-33).

Three studies have since applied Magee's methodology to New Zealand. In an economics dissertation, Cotter applied this methodology to New Zealand patents for 1871 to 1894. Cotter collected annual summary data on patent applications for different activities that had been published in nineteenth century statistics books (Cotter, 2006, pp. 9, 12). Cotter's dataset was then extended up to 1939 (Greasley & Oxley, 2010b, p. 457). Furthermore, Craigie used Magee's framework to code individual patent applications, but also included subcategories for primary sector patents (Craigie, 2009, p. 17).

The following descriptions are based on a section of Cotter's dissertation. Some subcodes have been added. Cotter's dissertation includes a more detailed description of the categories.

Primary Sector

1. Agriculture

Includes patents relating to agricultural machinery, processes in agriculture, ways to protect and encourage agricultural growth and profits.

1.1 Threshing and chaff cutters

1.2 Ploughing

1.3 Reaping and harvesting and cultivating and sowing

1.4 Not allocated

1.5 Fishing

1.6 Forestry

2. Pastoral

The development of techniques and equipment relating to sheep farming and particularly shearing. Includes fencing and exterminating rabbits.

2.1 Fences

2.2 Hedges and gorse

2.3 Rabbits

2.4 Sheering and sheep

3. Dairying

Patents relating to dairy farming and in particular to the usage and storage of cream, milk and butter.

Mining

4. General Mining

Boring through rock, excavating machines, dredging, rock drilling.

4.1 Gold mining

Gold extracting, gold saving, gold dredging pick, cradle, auriferous-sand collecting.

5. Mechanical and Chemical Mining and Metal extraction

Amalgamating, pulverising and crushing of ores, extraction of chemicals, metal etc. Ironsand goes in 13.

5.1. Gold

Secondary Sector

6. Construction and infrastructure

Include patents on earthworks, sewage works, building construction, large man-made objects, such as iron bridges, and new designs of buildings.

7. Treatment of Non-metalliferous and Quarry Products

Cement and cement goods, asphalt, lime, coal and coke works, stone and masonry.

8. Bricks, Pottery and Glass

Earthenware, china, terra-cotta, brick and other kilns for making bricks, pottery, pumice insulation. Glass bottles are 19.

9. Wood Working and Basketware

Sawmills, joinery and cooperage, boxes and cases, wood turning and carving, basketware, making casks.

10. Furniture and Bedding

Billiard tables, household furniture, furniture making, beds, mattresses, picture frames, window and veranda blinds etc.

11. Carriages

Carriage construction and repair. Stirrups.

11.1 Bicycles

11.2 Other vehicles. Articulating wheels and axles, brakes; driving apparatus, vehicle springs, vehicles, wheels, trucks, buses.

12. General Engineering Equipment

Includes all otherwise unspecified engines, valves, gauges, pumps, cables and apparatus and goods used for general engineering tasks.

13. *Industrial Metals*

Treatment of metals and metal goods, goods such as furnaces used in the processes of smelting (smelting itself is 5), converting and refining of iron steel and other metals, moulds.

14. Machinery, Implements and Metal working

Machinery and machine parts. Lifting machines, blowing machines, etc. Processes for manipulating metal. Metal implements – wire working, agricultural implements, cutlery, small tools, small metal parts.

15. Clothing and Textiles

Clothing and clothing repairs, boots, shoes, repairs of and accessories, cleaning and preparing for use, rope, bags and tarpaulins, flax and treatment and preparation of flax and flax goods, fibres.

15.1 Wool pressing and washing

15.2 Flax

16. Skins and Leather

Saddlery, harnesses, bags and leather goods. Preparing and using skin and leather goods.

16.1 Saddles (stirrups are 11), horse collar

17. Preserving and curing Food

Processes and preservation of foods, meats and fish, includes tins for preserving food.

18. Refrigeration

Ice making, refrigerating and cooling.

19. Foods and Drink

Foods, food producers and preparing, food factories and bakeries, aeration, bottling of foods and drink etc. Tilting casks normally.

20. Alcoholic Beverages

21. Tobacco

Cigars, cigarettes, cigarette machines and tobacco products. Match boxes, but not matches.

22. Paper, Stationary, Printing and Bookbinding

All paper goods and paper or cardboard making, pens and pencils, photography, the process of engraving.

23. Heat, Light and Power

Patents used in generating electric light, power and heat. Includes heating equipment, and lighting equipment such as lamps and gas works.

24. Chemicals, Dyes, Paint, Oils and Grease

Chemicals, paints and varnish, all oil types, processes used for creating, soaps and candles, inks and polishes.

25. Pharmaceutical and Medicinal

26. Fuels Firearms & Explosives

27. Other manufacturing

<u>Tertiary sector</u>

28. Railway

Increasing the efficiency of railways and rail services.

29. Shipping and Boats

Increasing the efficiency of ships, shipping goods, and shipping services.

30. Communications

Goods used to allow better and more efficient communication and navigation.

Telegraphs, telegraphic wires and cables, telephone, switchboard, loading coil and wireless technology. Letters, fire-alarms, clocks, post boxes, advertising.

31. Services and Distribution

New technologies for the shop, office and warehouse. Surveying equipment.

Cash register, typewriter, signals, alarms. Surveying equipment, use of packing cases. Fire hydrant, totalisator, rubber-stamps. Leisure outside the home.

Household Sector

32. Household Consumer Goods

Goods used and consumed for enjoyment and/or need.

Parlour games, ornaments, water and earth closets, tea strainers, bread boxes, bathtubs.

33. Household Producer Goods

Goods which are used in the running of a household i.e. goods used in performing the necessary household jobs/work/chores.

Washing machines, stoves, ovens, clothes pegs, garden instruments, fire-extinguishers.

Appendix B: Detailed pastoral sector results

This appendix contains unit root test results and cointegration and Granger causality results for selected pastoral sector output series. The results show that pastoral patent applications Granger cause cheese output. Furthermore, there is some evidence (at a 6.7% level) that expenditure on pastoral patents Granger caused cheese output.

Table B.1: Unit root test results using modified Hannan-Quinn criterion for pastoral output series

	Ln output				
Variable (in logs)	I	Lags	Equation	ADF	P-value
Meat	1	9	I,T	-6.35	0
Butter	0	9	I,T	-4.31	0.01
Cheese	1	9	I	-7.93	0
Wool	1	9	I,T	-3.65	0.01

I=intercept, T=trend

Table B.2: Patents applications and selected pastoralism output series: Cointegration, Granger causality and selected coefficients

	Output variables (two year lead for Granger causality) and difference if not cointegrated								
	Meat output			Wool output			Cheese output		
Patent application variables (difference if CR is NN)	CR (option, lag)	GC	Coeff if causal significant	CR (option, lag)	GC	Coeff if causal significant	CR (option, lag)	GC	Coeff if causal significant
Total applications	T, E (2,1)	0.1460		T,E (23,2)	**0.0090**	0.23 (0.03)	T,E (1,2)	0.0850	
		0.3589			0.5585			0.8470	
NZ applications	T,E (2,1)	0.2897		T,E (3,1)	**0.0474**	0.21 (0.04)	T,E (2,2)	**0.0307**	0.43 (0.05)
		0.0970			0.2843			0.7750	
Foreign applications	T,E (2,1)	0.1093		2T,2E (3,2)	**0.0075**	0.20 (0.04)	T,E (2,2)	0.2291	
		0.0308	2..26 (0.43)		0.0712			0.1868	
14 year patent applications	2T,2E (1,1)	**0.0378**	2.07 (0.20)	2T,2E (3,2)	0.1964		T,E (2,2)	0.4290	
		0.0729			**0.0449**	-1.51 (0.65)		0.4033	
Agriculture applications	N,N	0.6081		T,E (2,1)	0.9804		T,E (2,2)	0.2390	
		0.9892			0.3951			0.5241	
Clothing applications	T,E (1,1)	0.6296		T,E (3,1)	0.0787		T,E (2,2)	0.1920	
		0.1595			0.5240			0.2340	
Transport, comms, power applications	T,E (2,1)	0.2623		T,E (2,2)	0.2562		T,E (2,2)	0.2301	
		0.0947			0.3462			0.4234	
Mining applications	T,E (1,1)	0.6428		T,N (3,2)	**0.0239**	0.31 (0.06)	T,N (2,2)	0.4071	
		0.0501			0.3443			0.3534	
Pastoralism applications	T,E (1,1)	0.2964		T,E (2,1)	0.2293		T,E (5,1)	**0.0099**	0.11 (0.04)
		0.5827			0.4198			0.4297	

The top statistics for Granger causality for each row of applications data tests for causality from patents, the lower number tests for the reverse.

Table B.3: Expenditure on patents and selected pastoralism output series: Cointegration and Granger causality results

	Output variables (two year lead) and difference if not cointegrated								
	Meat output			Wool output			Cheese output		
Patent expenditure variables	CR (option, lag)	GC	Coeff if causal significant	CR (option, lag)	GC	Coeff if causal significant	CR (option, lag)	GC	Coeff if causal significant
Total expenditure	T,E (2,1)	0.2570		2T, 2E (3,2)	0.0848		T,E (1,2)	0.5556	
		0.0032	1.06 (0.36)		**0.0445**	2.74 (0.31)		0.0673	
NZ expenditure	2T,2E (2,1)	0.7907		2T, 2E (3,1)	0.6294		T,E (3,4)	0.4799	
		0.0153	1.18 (0.31)		**0.0063**	1.54 (0.13)		0.0506	
Foreign expenditure	2T, 2E (1,2)	**0.0477**	0.86 (0.08)	2T, 2E (3,2)	**0.0241**	-0.20 (0.14)	T,E (2,2)	0.3549	
		0.0001	1.15 (0.17)		**0.0148**	-4.96 (1.45)		0.1456	
14 year patent expenditure	T,E (1,2)	0.2700		T, E (3,2)	0.5817		T,E (2,2)	0.5160	
		0.0048	0.85 (0.22)		**0.0028**	0.00 (0.24)		0.2029	
Agriculture expenditure	T,E (2,1)	0.9227		T, E (3,3)	0.5581		T,E (3,3)	0.9859	
		0.0741			**0.0377**	1.59 (0.26)		0.0997	
Clothing expend	T, E (2,2)	0.6173		T, E (4,1)	0.7599		T, E (2,2)	0.5552	
		0.0512			0.2488			0.1206	
Transport, comms, power expenditure	T,E (2,2)	0.6766		T,E (4,1)	0.7344		T,E (1,2)	0.6199	
		0.0122	7.83 (5.41)		0.0598			0.1528	
Mining expenditure	T,E (1,2)	0.2656		T, N (3,1)	**0.0165**	0.34 (0.12)	T,E (1,2)	0.5284	
		0.0117	-3.97 (1.48)		0.3985			0.1978	
Pastoralism expenditure	T, E (3,2)	0.5749		T,E (3,2)	0.5508		T,E (3,2)	0.0672	1.035 (0.075)
		0.0086	1.22 (0.08)		0.0788			0.0754	

The top statistics for Granger causality for each row of expenditure data tests for causality from patents, the lower number tests for the reverse.

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