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Re-inventing New Zealand: Institutions Output and Patents 1870-1939

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Abstract. New estimates of commodity output and patenting are used to explore New Zealand's transition from extensive to intensive growth. By investigating the cointegrating and causal relationships among the output of 25 industries we show that a small number of common trends shaped the contours of her economic development. In turn the leading industries were driven by knowledge growth as reflected in patents statistics. New Zealand's distinctive institutions and human capital fostered the knowledge which transformed the farming landscape, promoted wider land ownership, and created a production system which integrated farm and factory to promote intensive growth.

Keywords: growth, institutions, patents, common trends, commodity output, New Zealand.

JEL classifications: O31, O43, O14, N17, N77

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1. Introduction

The attractions of her natural resources, initially timber, seals and whales, and by the 1850s and 1860s tussock grass and gold, drew, eventually, New Zealand into the international economy (Hawke, 1985, Lloyd-Prichard, 1970). The era of land extensive growth, however, was short-lived and we explore here how knowledge abundance subsequently re-invigorated New Zealand's economy and promoted intensive growth. New estimates of commodity output are utilized to show how the composition and growth of her economy shifted in the era of diminished natural resources per capita. Patents data are matched with the commodity output estimates to investigate how new technology influenced rates and patterns of economic growth. By 1900 New Zealand patenting activity per capita was the highest in the world and more than twice the rate of the UK and the USA. Together the new data sets for patents and for commodity output are used with modern time series methods to explain the re-direction of New Zealand's economy and the shift to intensive growth.

Endogenous growth theory places knowledge creation firmly within the economic system and highlights the importance of innovation and human capital for economic growth (Romer, 1990, Grossman and Helpman, 1991). New Zealand endowments of human capital and her institutions were distinctive and shaped by the homogeneity of her settlers and high public investment in health and education. Her institutional milieu differed from many primary producers including in the area of property rights (Condliffe, 1930). On two measures of human development, school enrolments and life expectancy, New Zealand led the world by 1913 (Crafts, 1997). New Zealand immigrants were substantially from Great Britain and literate. They added to the stock of human capital and constructed New Zealand's economic institutions. The consequences for economic development however are unclear. Alesina and La Ferrara (2005) have argued that homogenous populations are not likely to be notably creative. Gauging whether or not New Zealand's particular endowment of

human capital or her idiosyncratic institutions promoted inventiveness and knowledge-based intensive growth forms our central purpose.

Staple trades and the concomitant flows of people and capital were at the core New Zealand's early economic development, but natural resources did not offer a simple growth pathway. Gold production peaked in 1871 and wool or kauri gum exports offered limited development prospects.[1] In the nineteenth century contemporaries estimated New Zealand incomes were high by international standards (Dowie, 1966). Her growth experience though is uncertain since reconstructed historical national income accounts, including those adopted by Maddison (2001) rest on fragile estimate of money stock and velocity (Greasley and Oxley, 2000a). The new commodity output estimates reported here show per capita growth was stagnant before 1890, but accelerated thereafter.

Land ownership was concentrated initially in relatively few hands raising a danger of extractive institutions (Acemoglu et al, 2002, Galor et al, 2008). Immigration encouraged by public works and assisted passage, surged from the 1870s (Easton, 2001). Population growth soon outpaced that of land expansion and after 1890 New Zealand became less land abundant; both her occupied and cultivated land areas per capita fell.[2] Knowledge-related progress, including pasture formation and improvement, animal selection, and new leading industries were needed thereafter to sustain economic development (Gould, 1976). The new commodity output series show that a sequence of industries emerged including frozen meat, cheese and butter manufacturing, but also printing and publishing, to lead economic development

Modern theories often highlight the role of institutions in knowledge creation and use (North 1990, Parante and Prescott 2000). European colonization, most obviously in South America but also

[1] Kauri gum is the fossil resin of kauri pine and used as a varnish or in linoleum manufacture.
[2] Cultivated land per capita peaked at around 15 acres 1895-1907 and then fell sharply (*Statistics of New Zealand*).

in New Zealand was associated initially with highly concentrated, possibly inimical, land ownership (Denoon, 1983). Public investment in education and health, and the social depth of enterprise may be hindered if landed elites dominate polity (Galor et al 2008). New Zealand was idiosyncratic in that initially high concentrations of land ownership did not embed extractive institutions. Representative government co-existed with highly concentrated land ownership and democracy was reinforced by the abolition of plural voting in 1889 and female suffrage in 1893, to set New Zealand apart from the settler economies of South America. The Liberal (with minority Labour support) governments of 1891-1912 are often credited with innovative social programmes, which included abolishing the private property rights of some landowners (Reeves, 1902).

Land policy and barriers to closer settlement dominated New Zealand's early political economy.[3] A limited access to land curtailed European settlement of the new British colony.[4] The 1878 Census put the population at 458,000 of whom around 10% were Maori. Most Europeans at that time were on the South Island, reflecting the success of Christchurch and extensive wheat and sheep farming on the Canterbury Plain, and the growth of Dunedin (Clark, 1945). Prospects for further economic development though were uncertain. The barriers to closer settlement of the South Island were connected to extensive sheep farming on the great estates, and on the North Island to the less penetrable landscape and hostile Maori. At the end of the 1880s New Zealand experienced net out-migration as land congestion and urban unemployment thwarted many settlers' ambitions (Mein Smith, 2005).

Knowledge-related opportunities for re-invigorating development were connected primarily to the more intensive use of land and to the integration of farm and factory within a New Zealand

[3] In the wider context issues of representative government (the first National Parliament met in 1854) and self-government for local and native affairs (formally conceded by the Colonial Office in 1863) were at the centre of early New Zealand politics.

[4] New Zealand Company migrants' arrival in 1840 marked the start of organized European settlement and the borders of New South Wales were extended to include New Zealand.

system of mass production. Dairying was central in the rise of farm-related manufacturing although canning, bottling and fruit peeling also created factory employment. The spread of ideas was helped by farming periodicals and the literate population (Wood and Pawson, 2008). By the beginning of the twentieth century average income per capita in New Zealand was similar to that of California, and thus around 50% higher than the USA more generally.[5] Several forces combined to raise New Zealand's productivity from the 1890s and most of these were associated with a fundamental shift in land ownership, closer settlement of the land, and the rise of new leading industries (Greasley and Oxley, 2008).

New Zealand governments in the 1870s had sought to promote development most obviously by borrowing overseas for public works and by promoting immigration. However, in the absence of setting aside public land for the immigrants, large landowners consolidated their position, and land hunger persisted. Indeed many assisted immigrants in the 1870s took-up manufacturing employment (Condliffe, 1930). Reduced public works in the following decade, along with cheaper transport induced falls in import prices impacted adversely on New Zealand manufacturing. One consequence of the surrounding discontent was the imposition of tariffs on clothing, machinery and metal imports in 1888.

Import substitution was not the route by which the New Zealand economy was re-invented from the 1890s. The successful lobby for protection, however, illustrates the responsiveness of New Zealand governments to popular opinion and the limits to the power of the landed elite. The myriad of state involvement in New Zealand's economy ranged from insurance, trustee, land and financial advances offices, through transport provision, education and health, technical support for farmers, and wage regulation. Goods production, with the exception of coal remained outside state control.

[5] This estimate is based upon back-projecting Maddsion's (2001) GDP per capita benchmark for 1939 with the commodity output index reported here and population data.

Institutional quality, though hard to measure, plays a central role in modern growth theory. Several New Zealand institutions including the public provision of insurance and trustee services, tariffs, and most obviously the insecurity of private property rights run counter to modern norms of good institutions.

Hawke (1979) though argues that the small homogeneous colony of New Zealand had a singular social purpose which allowed the state to be a positive instrument for development.[6] Others, including Alesina and La Ferrara (2005) argue heterogeneity among populations may be more conducive to creativity, although homogeneity may have advantages connected to trust and public investment (La Porta et al, 1997) New Zealand migrants were substantially from Great Britain and in Hawke's view both settlers and state were united in their pre-occupation with development. The settlers and the state were willing to countenance the revocation of private property rights or constrain private enterprise in some areas, if that served a collective development purpose. In relation to land taxation and the promotion of closer settlement their legislation was distinctive, and framed against a backcloth of land congestion, urban discontent and net out-migration. The compulsory re-purchase of land for re-sale to smaller farmers contributed to closer settlement after 1890 (Gould, 1970). At issue is whether or not the economic landscape shaped by New Zealand's governments and the settlers was conducive to enterprise and inventiveness.

Historians have utilized patents data widely to measure inventive activity (Sullivan, 1989, Khan and Sokoloff, 1990, Magee, 2000, Nuvalori, 2004, and Greasley and Oxley 2007). New Zealand's patents legislation essentially followed a British template and in conjunction with the Paris convention of 1883 which harmonized patent rules internationally, set high standards for securing intellectual property rights. New Zealand patents data are used here to reflect the proclivity of her settlers to create and utilize new knowledge. Our contention is not that New Zealand

[6] Hawke draws upon Tawney's (1921) idea that property rights not justified by social purpose should be removed.

technology led the world, but rather that her patenting activity per capita, shaped by her institutions and human capital, reflects the social depth of her inventiveness to provide a proxy for knowledge creation, adoption and innovation.

Several strands of the technology central to New Zealand's economic development, including refrigeration and the centrifugal separation of cream, had overseas origins (O'Rourke, 2007). How these were assimilated, adapted and utilized in New Zealand are central in the shift to intensive growth. On New Zealand farms integrated machine-milking and centrifugal cream separation forged ahead more quickly than in the USA (Philpott, 1937). Further, farm and factory were integrated in a distinctive New Zealand system of mass dairy production (Belshaw, 1927). By the 1920s New Zealand's largest co-operative dairy factories in the Waikato region had twice the capacity and higher productivity than plants in Wisconsin (Russell and Macklin, 1926). The quality yardstick of price parity with Danish dairy products on the London market were also attained in the 1920s (Greasley and Madsen, 2006). How New Zealand inventiveness contributed to knowledge-related growth in New Zealand's pastoral sector and indeed in her wider economy will be explored below via a statistical analysis of the relationship between patenting and commodity output.

By estimating the cointegrating relationships among 25 categories of commodity output we show that a small number of industries drove New Zealand's economic development. The dairy sector was central to the re-invention of New Zealand, but other kinds of manufacturing, including printing and publishing, played a leading role. In turn we demonstrate how patenting activity associated with 40 industry groups had causal links to the expansion of the key industries. To anticipate the argument, on balance patenting activity led the growth of commodity output. By implication New Zealand's technological proclivity promoted dairy product and frozen meat exports, helped to transform the farming landscape and patterns of land ownership by raising the productivity of smaller land-intensive dairy and mixed farms, and stimulated the re-organization

and expansion of manufacturing. Ultimately it was the local responses to the opportunities of global trade in pastoral-related products shaped by particular economic institutions and human capital that underpinned New Zealand's shift from extensive to intensive growth.

2. Commodity output: new estimates

Colonial governments reported piecemeal economic statistics of New Zealand from 1840, but their scope and frequency increased greatly in 1861 with the publication of *Agricultural and Pastoral Statistics*, and in 1873 with the annual *Statistics of New Zealand*. Annual output series have been constructed for 25 commodities for years since 1861. The *Census* of 1878 was the first to collect economic data beyond occupation statistics, and included for example information on manufacturing output, employment, materials purchased, and for some industries the value of the capital stock. Thereafter, from 1881 New Zealand censuses were carried out every five years, with the exception of 1931 when the census was cancelled due to financial exigencies. The census data provide a basis for estimating value added weights for the 26 commodity producing sectors, constructed here for the years 1877, 1885, 1895, 1905, 1915, 1925 and 1935. Annual quantity time series are matched, as far as possible, with the valued added weights for years since 1861. Frozen and domestic meat is combined as one time series.

For exposition purposes the 25 commodity series are grouped into wider sectors: Pastoral (wool, meat, cheese, butter), Agricultural (wheat, oats, barley, potatoes), Mining (gold, coal, kauri gum), Manufacturing (wool cloth, beer, soap/candles, grain mills, biscuits, saw mills/doors, printing/publishing, carriages/vehicles, clothing, shoes/boots), and Other (fishing, gas, construction). A key priority in the construction of these data was to avoid double counting in the value added weights, and the conventions used sometimes reflect practical data constraints. In the case of the vital Pastoral sector though, value added weights are estimated to reflect the integration

of farm with factory which was central to the emergence of a New Zealand system of mass pastoral production. For example, in the case of butter, mechanized cream separation increasingly took place on the farm, and the higher values of materials purchased by largely co-operative dairy factories meant their gross output rose more quickly than their value added.

2a. Commodity Value Added.

Table 1 shows the proportion of value added by each of the 26 commodities, and the contribution of the specified sector groups. Generally the pastoral sector became relatively more important, and agriculture and mining less so. Within the pastoral sector wool dominated in 1877, but meat and dairy products were larger by 1935. Wheat contributed substantially to the New Zealand economy in the 1870s, but its role generally diminished thereafter, although wheat production varied widely year to year. Gold's importance also lessened from the 1870s as did that of minerals despite some growth of coal. Manufacturing increased in relative size, and according to Table 1 contributed around 23% of commodity output in 1935. Woodworking was a major part of manufacturing throughout, although it was overtaken by printing and publishing by the 1930s. It should be remembered however that meat and dairy factory output appears in the Pastoral sector. In 1938 value added by frozen meat and dairy factories was around 13% of total pastoral sector value added, and if included under manufacturing would raise the share of manufacturing in commodity output to around 30% by the 1930s.

2*b. Commodity Output Volumes.*

The majority of output series are gross volumes measured by weight. The exceptions are the manufacturing series and that for construction where gross output values are deflated by prices. Indexes of commodity output are constructed for 1861-75 using all of the pastoral and agricultural output series and those for gold and kauri gum output, in conjunction with the 1877 value added weights. From 1875 the aggregate index utilizes all 25 commodity series, and they are constructed

for 1875-84 (1885 weights), 1884-94 (1895 weights), 1894-1904 (1905 weights), 1904-14 (1915 weights), 1914-24 (1925 weights), and 1924-39 (1935 weights). In all cases output volume in the final year of each sub-period is defined as 100, and an 1861-1939 index created by chaining the sub-period indexes, and scaling such that 1939 equals 100. Indexes of output for the Pastoral, Agricultural, Mining, and the Manufacturing sectors are constructed using the same methods and the results shown in Appendix Table 1.

New Zealand's aggregate commodity output grew by 4.1% p.a. 1861-1939, with pastoral output rising by 5.5% p.a. Agricultural output was volatile, but never regained 1899 levels before 1939 and mining output peaked in 1871. Manufacturing grew strongly and averaged 3.5% p.a. 1875-1939. The aggregate index shows accelerating output per capita growth after 1890. Thorns and Sedgwick (1997) report New Zealand's population grew 4.7% p.a. 1874-90, a near identical rate to that of aggregate output over the same period. Subsequently population growth slowed to 2.3% p.a. 1890-1913 and 1.4% p.a. 1913 to 1939. The retardation of aggregate output growth was less marked, down from 4.67% p.a. 1874-1890, to 2.78% p.a. 1890-1913, and 2.05% p.a. 1913-39. New Zealand's commodity output per capita growth accelerated after 1890, highlighting the new direction of the economy.

Table 1. Proportion of value added by commodities and sectors in New Zealand

	1877	1885	1895	1905	1915	1925	1935
Wool	0.32961	0.240485	0.242866	0.190111	0.219328	0.211167	0.092839
Frozen Meat	0	0.02748	0.081536	0.092765	0.159507	0.125429	0.167024
Other Meat	0.047023	0.111242	0.105681	0.101098	0.094407	0.098018	0.092682
Cheese	0.005675	0.007201	0.01162	0.012465	0.063218	0.071077	0.061588
Butter	0.024773	0.033431	0.038025	0.075617	0.088902	0.13927	0.229004
Pastoral	*0.40708*	*0.419838*	*0.479729*	*0.472057*	*0.625361*	*0.644961*	*0.643137*
Wheat	0.114855	0.082513	0.037637	0.053338	0.04441	0.022091	0.0194
Oats	0.051977	0.083982	0.064622	0.044868	0.037288	0.014638	0.003414
Barley	0.009729	0.008082	0.010071	0.007644	0.004318	0.003042	0.001491
Potatoes	0.027745	0.022777	0.022143	0.045005	0.015554	0.010709	0.013879
Agriculture	*0.204306*	*0.197355*	*0.134474*	*0.150856*	*0.10157*	*0.050479*	*0.038185*
Wool Cloth	0.001531	0.009258	0.013041	0.00792	0.006262	0.006522	0.007757
Beer	0.030988	0.021087	0.018464	0.016666	0.008984	0.011158	0.01558
Soap/Candles	0.002432	0.009625	0.009813	0.006129	0.005669	0.006039	0.007509
Grain Mills	0.01135	0.01205	0.014332	0.007713	0.004707	0.008408	0.008084
Biscuits	0.00054	0.001396	0.002195	0.00396	0.002169	0.009047	0.010635
SawMills/Doors	0.083146	0.086554	0.058037	0.07331	0.038864	0.064196	0.04899
Foundary/Engineering	0.0109	0.014107	0.013557	0.014359	0.012136	0.017938	0.016613
Printing/Publishing	0.016935	0.020132	0.025113	0.036776	0.03475	0.04948	0.052849
Carriage/Vehicles	0.00054	0.001396	0.006972	0.005957	0.008698	0.016568	0.026202
Clothing	0.002793	0.010066	0.008393	0.005337	0.007122	0.006207	0.01974
Shoes and Boots	0.012882	0.020353	0.023112	0.017251	0.014858	0.01136	0.013029
Manufacturing	*0.172507*	*0.206025*	*0.193028*	*0.195379*	*0.14422*	*0.206924*	*0.22699*
Gold	0.134763	0.069655	0.075016	0.072071	0.034668	0.006129	0.01626
Coal	0.005945	0.014034	0.041252	0.022348	0.043694	0.02859	0.02547
Kauri	0.012431	0.021969	0.026985	0.019318	0.00571	0.004647	0.001033
Minerals	*0.153139*	*0.105658*	*0.143254*	*0.113736*	*0.084072*	*0.039366*	*0.042763*
Fishing	0.003603	0.003674	0.003615	0.002445	0.006692	0.006028	0.004513
Gas	0.006846	0.014328	0.011491	0.010881	0.0132	0.017579	0.015188
Construction	0.050986	0.053123	0.034409	0.054647	0.024886	0.034663	0.033148
Sum	1	1	1	1	1	1	1

3. Commodity output: common trends and causality

3.1. Common trends.

The initial analysis of the 25 commodity output series seeks to identify the leading industries in New Zealand's economic development. Of particular interest are the 18 industries with non-

stationary output series (see Table 2), since knowledge-related productivity innovations in these industries may have permanent effects on overall commodity output. Stock and Watson (1988) introduced the notion of a common trends representation of non-stationary series by showing how systems can be divided between stationary components (cointegrating vectors) and stochastic common trends (Greasley and Oxley, 2000b). In their decomposition the stochastic common trend components are the fundamental persistent driving forces of economic growth. One implication is that the industries with trend stationary output including wool, barley and coal did not shape the contours of New Zealand economic development.

The analysis shows New Zealand's economic development was driven by the 18 industries with the non stationary output trends. At issue is how many of these trends were common to more than one industry. If trends were common then the possible sources of growth are simplified, as the effects of output innovations, including those from new technology will spill across industries. The cointegration tests show (see Table 3) that a small number of stochastic common trends drove output in most sectors. Both the pastoral and agricultural sectors have two stochastic trends, and the manufacturing sector only one. A cointegrating relationship was not observed for the mineral sector, and gold and kauri gum have individual output trends. The finding of two stochastic trends in the pastoral sector may indicate that the dairy and the meat industries were not simply connected by the

Table 2: Unit Root tests (logs)			
PASTORAL		**AGRICULTURE**	
Wool	-4.675*	**Wheat**	-2.993
Meat	-0.833	**Oats**	-2.307
Cheese	-1.113	**Barley**	-3.704*
Butter	-2.998	**Potatoes**	-1.667
MANUFACTURING		**MINERALS**	
Wool cloth	-2.897	**Gold**	-1.858
Beer	-1.979	**Coal**	-9.474*
Soap/Candles	-27.363*	**Kauri**	-1.416
Grain Mills	-1.222	**MISCELLANEOUS**	
Biscuits	-2.526	**Fishing**	-5.856*
Saw Mills/Doors	-0.977	**Gas**	-0.411
Foundry and Engineering	-2.439	**Construction**	-1.798
Printing/Publishing	-0.623		
Carriages/Vehicles	-10.08*		
Clothing	-4.840*		
Shoes and Boots	-2.569	* denotes rejection of n.h. at the 5% level	

opportunities of refrigeration, but that different forces shaped their output. For example, much of the frozen meat trade originated in the South Island corporate enterprises, whereas North Island co-operatives dominated dairying. Not only did dairying expansion require the clearing and cultivation of wetter, forested North Island land, but it also needed different technology, most especially that connected to cream separation. In the case of agriculture the existence of two stochastic trends probably relates to differences between the output drivers of potatoes and the two grain crops (wheat and oats).

3.2 Causality

The finding that a small number of stochastic common trends drove commodity output simplifies subsequent investigation of the role played by knowledge-related innovations by highlighting the possible industries central to the re-direction of New Zealand's economic development. Further progress in narrowing the list of leading industries can be made by considering the causal relationships between the industries. For example, sectors which shared common trends may have

been led by one particular industry. Of particular interest is whether or not the impact of any industry spanned beyond its sector to lead other sectors and overall commodity output.

Table 3: Summary of output cointegration results		
Variable	**Number significant cointegration relations**	**Number of stochastic trends**
AGGREGATE	**1**	**1**
NZ real GDP		
All commodity output		
PASTORAL	**1**	**2**
Meat		
Cheese		
Butter		
AGRICULTURAL	**1**	**2**
Wheat		
Oats		
Potatoes		
MANUFACTURING	**7**	**1**
Wool cloth		
Beer		
Grain mills		
Biscuits		
Saw mills		
Foundry		
Print and Publish		
Shoes		
MINERALS	**0**	**2**
Gold		
Kauri		
MISCELLANEOUS	**1**	**1**
Construction		
Gas		

The causal links between the 18 industries with non-stationary output are summarized in Table 4. Total commodity output is also included in the causality results. Generally, manufacturing, the pastoral sector and construction have the most causal links. However, construction and most manufacturing industries were followers, while pastoral industries' output often led the output of other industries. Thus beer has 15 causal links, including that with total commodity output, but in 10

cases beer followed, and in one other the causality was bi-directional. Similarly wool cloth has 15 causal links, with 13 of these as a follower or bi-directional. Construction has 13 causal links, but was unambiguously led by output in other industries. Several other manufacturing industries, including saw mills and doors, and foundry and engineering have multiple causal links, but principally these show bi-directional causality within manufacturing or a follower relationship with the pastoral sector. Within manufacturing, printing and publishing is the industry with the most leading causal links. Printing and publishing accounted for around 23% of (non-pastoral) manufacturing from 1915, becoming the largest element of the sector by 1935. The results show printing and publishing had bi-directional causality with all commodity output and wool cloth, and led beer, saw mills and doors, foundry and engineering, shoes and boots, potatoes, kauri gum and construction.

In the mining sector, gold was of principal importance and still contributed around 7% of commodity output in 1905. Gold had bi-directional causal links with all commodity output and the pastoral sector, and led beer output. The pastoral sector dominates the leading causal links with other industries. Meat and butter are the only industries which led all commodity output. Meat led the output of 9 industries, and had bi-directional causality with two others. Interestingly though, no evidence was found of causality between the meat and dairy industries. In addition to all commodity output butter also led 7 industries, and cheese led the output of 6 industries, including butter.

3.3 Implications.

Overall the analysis of common trends and causality clearly reveals the key drivers of New Zealand commodity output. The pastoral sector dominated economic development in New Zealand, but the meat and dairy sectors each had individual driving forces, although cheese and butter were inter-linked. Gold was important, at least until the early years of the twentieth century, and made a

contribution to stimulating pastoral and all commodity output. The manufacturing sector (other than the manufacture of pastoral goods) did form a unified block which shared a single stochastic trend, but most linkages of the sector, with one exception, were bidirectional or following. The exception is printing and publishing, which comprised a sizeable element of New Zealand manufacturing, and led four other manufacturing industries as well as potatoes, kauri gum and construction.

A small number of key industries, specifically, meat, cheese, butter, gold, and printing and publishing, shaped the directions of New Zealand's economic development. The role played by each differed over time, and the growth trends shown in Figure 1, illustrate the changing importance of the individual industries. The impact of the gold discoveries in the 1860s diminished through the next two decades as gold output peaked in 1871. Reduced gold production retarded trend commodity output growth through the 1870s and 1880s, but renewed gold expansion around the turn of the twentieth century contributed positively then to New Zealand's economic growth. Rapid expansion of printing and publishing also contributed to New Zealand's commodity output trend acceleration in the mid 1890s. Meat and cheese show accelerating growth from the 1880s, whereas butter's faster growth came later, with a spurt form the mid-1890s and most especially after 1918. Cheese also witnessed more dramatic acceleration early in the twentieth century. The two pre-1914 trend growth accelerations of cheese may explain why the causality results show cheese led butter, even though butter eventually became the dominant dairy industry between the world wars.

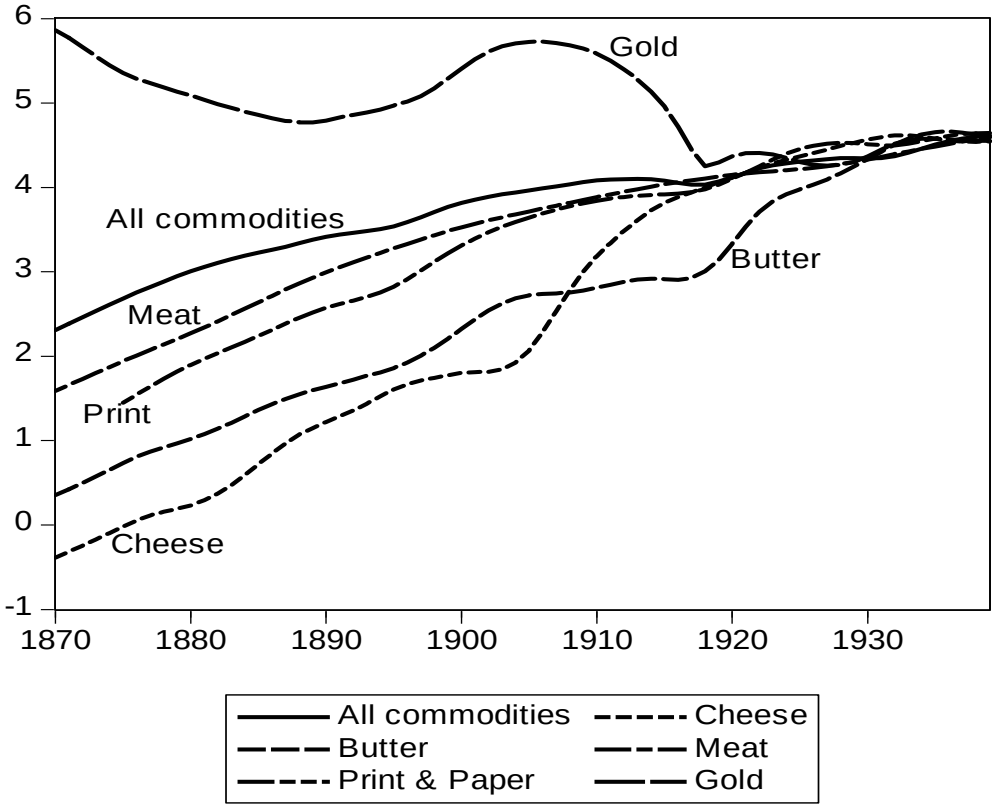
Table 4: Granger causality between industries: (log of output and two year lags).

	All commodity	Meat	Cheese	Butter	Wool cloth	Beer	Grain Mills	Bisc	Saw Mills/ Doors	Found Engine	Print/ Pub	Shoes & Boots	Wheat	Oats	Pots	Gold	Kauri	Gas
Meat	⇒																	
Cheese	-	-																
Butter	⇒	-	⇐															
Wool cloth	⇐	⇐	⇐	⇐														
Beer	⇐	⇐	-	⇐	⇔													
Grain Mills	-	-	⇐	-	⇒	⇒												
Biscuits	-	⇔	⇐	⇐	⇒	⇒	-											
Saw Mills/Doors	⇐	⇐	⇔	⇐	⇒	⇒	⇐	⇐										
Foundry Engineering	⇐	⇐	⇐	⇐	⇔	⇒	⇔	⇒	-									
Printing/ Publishing	⇔	⇐	-	-	⇔	⇒	-	-	⇒	⇒								
Shoes and Boots	-	⇔	-	-	⇔	⇒	⇐	-	⇒	⇒	⇐							
Wheat	⇐	-	-	-	-	-	-	-	-	-	-	-						
Oats	-	⇐	⇐	⇐	⇐	-	⇔	-	-	-	-	⇒	⇒					
Potatoes	-	⇐	-	-	-	⇐	-	-	-	-	⇐	-	-	-				
Gold	⇔	⇔	⇔	⇔	-	⇒	-	-	-	-	-	-	-	-	-			
Kauri	⇔	-	-	-	⇒	⇐	-	⇒	⇔	-	⇐	⇒	-	⇐	-	-		
Gas	-	-	⇒	-	⇔	⇐	⇐	-	⇔	⇒	-	-	-	⇒	-	⇐	-	
Construction	⇐	⇐	⇔	⇐	⇐	⇐	-	⇐	⇐	⇐	⇐	⇐	-	-	-	-	⇔	⇐

⇒ denotes "row variable causes column variable unidirectionally" ; ⇐ denotes "column variable causes row variable unidirectionally"; ⇔ "denotes bi-directional causality;

- denotes "no statistical causal relationship identified"

Figure 1: Leading Industry Output Trends (Logs): Hodrick-Prescott Filter.



4. Patents: precocity and taxonomy.

4.1. New Zealand's precocity.

New Zealand's patent system was created by a sequence of legislation from 1860 and essentially followed the British system. New Zealand's 1889 Act did allow provisional or complete specifications to be submitted (at a cost of £0.5) and if provisional 9 months were allowed to submit the complete specification (again a cost of £0.5). Letters patent (for uncontested patents) were issued within 15 months for a further payment of £2. Patents could remain in effect for 14 years, on payment of a further £5 after 4 years, and £10 after 7 years. Earlier patent legislation followed similar procedures (other than the provisional specification)

and generally reduced the cost of patenting, for example the 1882 Act reduced the cost of applications to £1, the cost of letters patent to £2, and post-5 year extension costs to £7.[7] Most patents did not run for 14 years; in 1905 around one-third of patents were extended after 4 years, and around half of that total were extended again after 7 years.[8]

Patenting activity in New Zealand was unusually high. The Registrar of Patents (C.J. Haselden) noted in 1893, *'it is believed in proportion to its population there are more applications for patents (in New Zealand) than in any other country in the world.'*[9] Details of patent application were initially reported in the *New Zealand Gazette* (and two months given for appeals) and summarized in the annual reports of the Registrar of Patents in the *Appendixes to the Journals of the House of Representatives*, hereafter *AJHR*. Shorter summaries appear in *Statistics of New Zealand* (1871-1919) and subsequently in *New Zealand Official Yearbooks*. These records provide data on the numbers and the purpose of patent applications as well as the names and addresses of applicants. Annual applications reached 50 in 1878, 503 in 1886, 1093 in 1897 and 2199 in 1920. In the period 1871-1939 patents applications peaked at 2251 in 1929. In 1913 around 66% of applications were from New Zealand residents; by 1939 the ratio had fallen to 38%. Before 1914 New Zealand had a lower rate of overseas patenting than Australia (Encel and Inglis, 1966), although Magee (1999) shows that higher rates of foreign patents do not necessarily indicate technological backwardness.

Haselden's belief that patenting in New Zealand around the start of the twentieth century was unusually high receives support from the summary data in Table 5. In 1900 patenting per capita in New Zealand was around 20% higher than its nearest rivals, Belgium and Austria, and more than twice the rate of most western European countries and the USA. Some English-

[7] *Appendixes to the Journals of the House of Representatives*, 1888, H1, p. 24.
[8] *Appendixes to the Journals of the House of Representatives*, 1905, H10.
[9] *New Zealand Official Yearbook*, 1893, pp. 350-2.

speaking settler regions, including the Australian state of Victoria and Canada had relatively high patenting activity, of around two-thirds the New Zealand rate. In contrast Argentina, Brazil and Japan had low patenting activity.

Table 5: Patent applications in 1900

	Applications	Population (000s)	Applications per capita
Argentina	318	4693	0.06776
Australia	1610	3741	0.430366
Victoria	972	1175	0.827234
Austria	6409	5973	1.072995
Belgium	6943	6719	1.033338
Brazil	389	17984	0.02163
Canada	4628	5457	0.848085
Denmark	1430	2561	0.558376
France	12789	40598	0.315016
Germany	20321	52753	0.38521
Hungary	3511	7127	0.492634
Italy	4033	33672	0.119773
Japan	2006	44103	0.045484
Mexico	629	13607	0.046226
New Zealand	1009	807	1.25031
Norway	1451	2230	0.650673
Portugal	283	5404	0.052369
Sweden	2258	5117	0.441274
Switzerland	2759	3300	0.836061
UK	23924	41555	0.575719
USA	39673	76391	0.519341

Sources: World Intellectual Property Organization 2008, *Annual Patent Statistics. Official Yearbook of the Commonwealth of Australia*, 1, 1901-07.

4.2 Taxonomy.

Following Schmookler (1966), most analyses which consider the economic effects of inventiveness using patents classify patents by intended industrial use, rather than by industrial origins or technological criteria (Magee, 1996). Scrutiny of the patents descriptions in the *AJHR* shows clearly how patent applications evolved with New Zealand's economy. In 1890 45 patents were sought for separating metals, but only two for separating cream, reflecting the comparative contemporary interest in mining and dairying. By 1910 dairying related applications were commonplace, with 34 for milking machines, including two each from inventors in

Denmark and Sweden, and one each from Scotland, Australia, and Germany. Patenting activity also shows variation within New Zealand, for example most early applications for improved ploughs and seeds were lodged by South Island inventors. Ascribing all patent applications to a particular industry use does, however, raise difficulties since some inventions are relevant to more than one industry and others to none.

In a careful study of Australian, or more specifically Victorian patents Magee (2000, p.26-7) adopted 33 classes to summarize the data. His taxonomy attempts to identify the industries or sectors to which patents relate, but also includes a household sector to which for example, patents for water closets, parlour games, stoves and clothes pegs are assigned. Our need here is to match as far as possible patents to the commodity output groups considered in section 2. Ascribing patents to highly disaggregate industry groups is unrealistic as individual patents are likely to be relevant for several of the defined industries. To simply, the 25 commodity output categories are reduced to 8 key industry groups where for example, related manufacturing activities, including engineering and vehicles, the pastoral industries, construction and woodworking, and the agricultural industries are conflated. New Zealand patent applications are then attributed as far as possible to each wider industry group.

Our categorization of the New Zealand patent data draws on and extends Magee's classes, but they are also are revised to correspond to New Zealand's circumstances and the defined 8 key industry groups. For example, preserving food and refrigeration patents are included in the pastoral group. Full details of the procedures are shown in Appendix 2. Patents each year were initially allocated between 40 categories using as far a possible the summary information in *Statistics of New Zealand* and from 1920 *New Zealand Official Yearbooks*. For several years around the turn of the twentieth century *Statistics of New Zealand* does not provide summary information and in these cases the short patent descriptions provided in the *AJHR* are

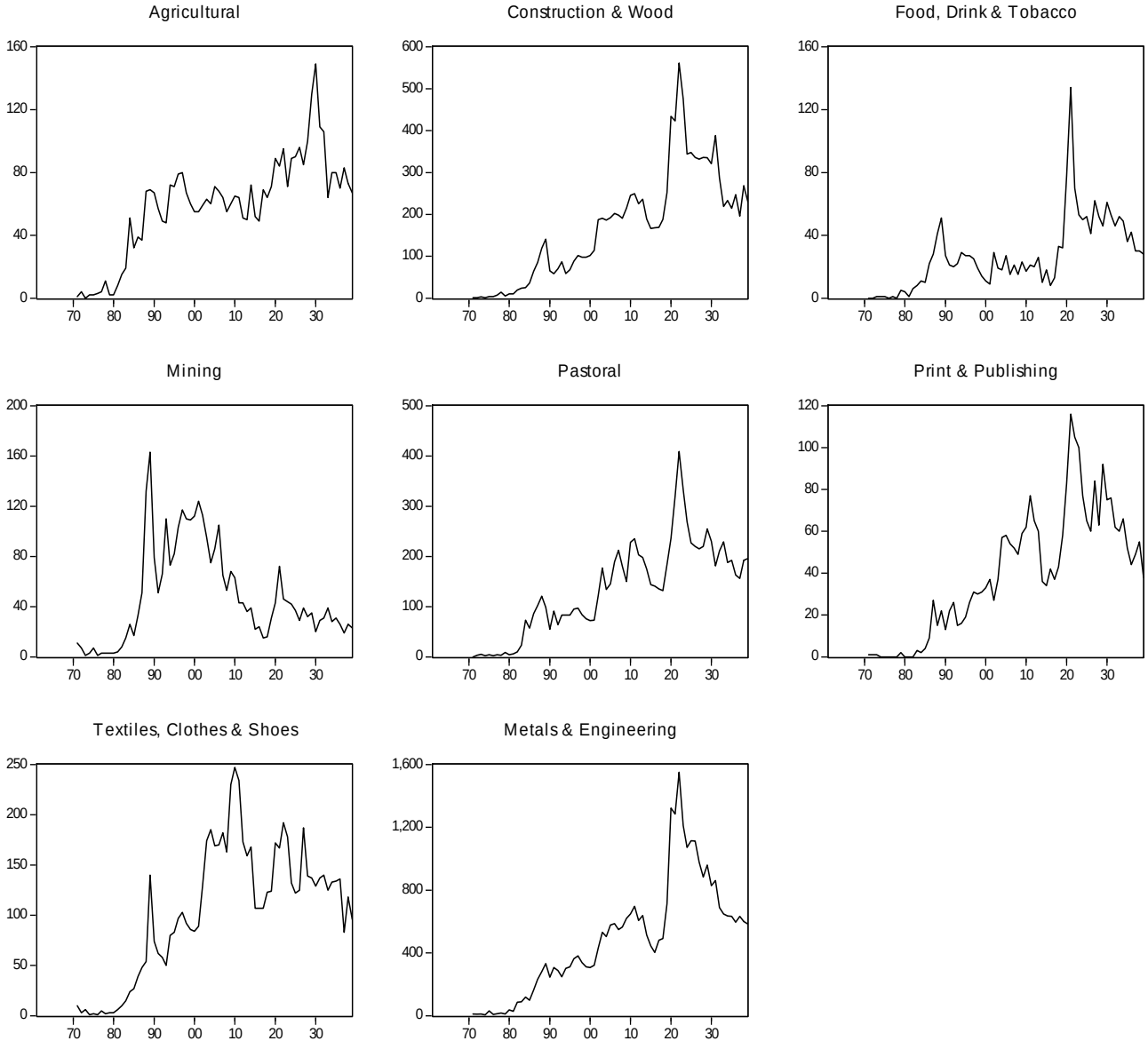
used to produce corresponding data. In the conflation of the patents data to 8 categories to correspond to the major industry groups some patents, including those for classes Magee (2000) associates with households and services, were not included in the category counts, but all patents are included in the aggregate counts.

The 8 commodity groups and the associated patent classes are shown in Table 6 (and more fully in Appendix 2) and the patents data illustrated as Figure 2. The largest numbers of patents are in the metals and engineering groups, which probably reflect the greater opportunities for invention in these industries, and illustrate the difficulty of ascribing the impacts of patents to more narrowly defined industries.

Table 6: Categories of Patents

A. Commodity output groups	*B. Classes of patents allocated*
Agriculture	Agriculture
Pastoral	Pastoral, dairying, refrigeration, preserving food
Mining	General mining, metal extraction
Construction and woodworking	Construction, quarry products, bricks, glass, furniture, wood.
Metals and engineering	Engineering, metals, machines, tools, vehicles, railways, ships, heat, light, power
Textiles, clothes and shoes	Clothing, textiles, skins, leather
Food, drink and tobacco	Food, drink, alcoholic beverages, tobacco.
Printing and publishing	Paper, stationary, printing, bookbinding

Figure 2: Numbers of Patents by Commodity Output Group



5. Patents, commodity output and causality.

Five key industries, gold, meat, printing and publishing, butter, and cheese shaped the contours of New Zealand's economic development and underpinned the transition from extensive to intensive growth. Now we consider how new technology, as reflected in patenting activity, influenced the growth of the leading industries. The statistical properties of the 8 patent group series and

aggregate patenting are shown in Table 7, and in all cases these data are non-stationary. Tests for cointegration (not reported here) for the 8 patents groups and aggregate commodity output show long run cointegrating relationships and one stochastic common trend. This result highlights that patenting and commodity output moved together in the long run, but does not inform the direction of causality or the position of particular industries.

Table 7. Unit Root Tests: Patents	**ADF**
Pastoral patents	-2.54
Agricultural patents	-2.34
Mining patents	-1.59
Construction & Wood patents	-2.28
Metals & Engineering patents	-1.73
Textiles, clothes & shoes patents	-1.71
Food, drink, tobacco patents	-2.88
Print & publishing patents	-0.39
Total patents	-0.76
Sum of patents	-1.55

The results in Table 8 show a matrix of casual links between 18 categories of commodity output (the non-stationary series) and the 8 patent groups identified in Table 5. Two aggregate measures of patents and all commodity output are also included. The results show a complex variety of causal links, where chiefly patenting led output, but in some cases output led patenting. Overall, with 18 industries and 8 patent sectors, there are a possible 144 causal links. The results show 56 statistically significant causal linkages, illustrating the breadth of the relationship which principally runs from patenting to output. Only 15 of the significant causal links run uni-directionally from output to patents. At the aggregate level overall commodity output was also led by total and the sum of patents.

Turning to the five key industries on balance output was caused by total (or the sum of total patents – used here to indicate knowledge stock) patents; in particular cheese, butter, and printing and publishing outputs were led by aggregate patents. Mining patents also led gold output.

However, meat output led aggregate and several sub-categories of patents. For the other 13 industries again, on balance total or the sum of patents led output, specifically for beer, saw mills/doors, foundry/engineering, and oats, whereas output led in only two cases, namely wool cloth and grain mill. Evidence of bi-directional causality is observed in two of the 13 cases, and for only 6 industries was no causality found with aggregate patenting. The patent sector with the highest patent applications, metals and engineering had the most (10/18) pervasive links across industries. In 5 cases (including butter and printing/publishing) metals/engineering patents led output, but there are four cases of bi-directional causality (including cheese), and meat output led metals/engineering patents.

Some general observations can be made from the analysis of causal links between patenting and output. Most importantly the output of four of the five key drivers of commodity output, butter, cheese, gold, and printing and publishing was led by total or own sector patenting. Additionally patents of the largest sector group, metals and engineering had causal links to output in 10 industries, and typically led output. However the direction of causation between patents and output is complex, and the output of one key industry, meat, unambiguously led patenting.

Table 8: Granger causality between patents and output (levels data and lag of 4 years)

	All commod output	Meat	Cheese	Butter	Wool cloth	Beer	Grain Mills	Bisc	Saw Mills/ Doors	Found Engine	Print Pub	Shoes Boots	Wheat	Oats	Pots	Gold	Kauri	Gas	Const
Pastoral patents	⇔	-	⇒	-	-	-	⇐	⇒	-	-	-	⇐	-	⇒	-	-	-	⇐	-
Agricultural patents	-	-	-	-	-	-	-	⇒	⇒	⇒	⇒	-	-	-	-	-	-	⇒	⇒
Mining patents	-	-	-	-	-	-	-	-	-	-	-	-	-	-	⇒	⇒	-	-	-
Food, drink, tobacco patents	⇔	⇐	⇐	⇒	⇐	⇐	⇐	-	⇐	-	⇔	-		-	-	⇐	-	-	-
Metals & Engineering patents	⇐	⇐	⇔	⇒	⇔	⇒	⇔	-	-	⇒	⇒	⇔	-	-	-	-	⇒	-	-
Construction & Wood patents	-	⇐	⇒	⇒	⇐	-	-	-	-	⇐	⇒	⇔	-	-	-	-	⇒	⇐	-
Textiles, clothes & shoes patents	⇒	-	⇒		⇐	-	-	-	-	-	-	-	⇐	⇐	-	-	⇔	⇒	-
Print & publishing patents	⇐	⇐	⇔	⇒	⇐	-	⇐	-	-	-	⇔	⇐	-	-	-	-	⇒	-	-
Total patents	⇒	⇐	⇒	-	⇐	-	⇐	-	⇒	⇒	-	⇔	-	⇒	-	-	⇔	-	-
Sum of patents	⇒	⇐	⇒	⇒	⇐	⇒	-	-	-	-	⇒	⇔	-	-	-	-	⇒	-	-

⇒ denotes "row variable causes column variable unidirectionally" ; ⇐ denotes "column variable causes row variable unidirectionally"; ⇔ "denotes bi-directional causality;

- denotes "no statistical causal relationship identified"

6. Concluding remarks.

This paper has explored New Zealand's transition from extensive to intensive growth. Unlike many land abundant primary producers with initially high incomes New Zealand was able to create new directions in economic development that led to sustained output per capita growth in the half century after 1890. Knowledge assimilation, creation and application lay at the center of New Zealand's economic re-invention. Analysis of the new commodity output estimates shows that a sequence of leading industries, including gold, meat and dairy products, and printing and publishing, emerged to shape the contours of economic development. By utilizing patenting data to reflect New Zealand's technological proclivity we demonstrate how new knowledge led economic development.

The shift from land to knowledge abundance was underpinned by New Zealand's distinctive institutional milieu. Integration of farm with factory was central to the emergence of a 'New Zealand System' of manufacturing, and required more intensive settlement and wider land ownership to facilitate knowledge-related higher productivity. Knowledge growth spanned the selection of cultivated grasses and animals, the mechanization of milking and cream separation, the preservation of meat and dairy products, and the realization of factory scale economies. Integration of farm and factory and indeed of finance, transport and distribution was facilitated by co-operative enterprise in dairying. The breadth of the knowledge-related economic transformation points to a social depth of enterprise in New Zealand and concomitantly to her levels of human capital and the institutional setting.

The wider debates surrounding economic growth are inconclusive on whether or not homogeneous or heterogeneous populations are likely to be technologically more creative, and our future work will explore this issue further using a wider sample of immigrant-receiving countries. On balance the evidence of New Zealand's experience highlights the benefits of a homogeneous

population with unified social purpose, public investment which spans beyond health and education to include financial and transport services, and a polity that is able and willing to reconstruct property ownership to benefit collective economic development. In the period to 1939 these elements combined to promote exceptionally high incomes and levels of human development. Subsequently New Zealand's economy experienced pronounced comparative decline, and explaining that reversal of fortune would inform further the process of economic growth.

7. Appendixes.

Appendix 1: Estimates of Commodity and Sector Output

Appendix Table 1. Indexes of Commodity Output (1939=100)

	Aggregate	Agriculture	Pastoral	Manufacturing	Mining
1861	4.213237	31.6009	1.479772		84.11101
1862	6.502705	34.84989	1.873889		175.6807
1863	8.794384	38.0989	2.250038		268.2388
1864	8.371738	41.58744	2.839677		208.4339
1865	9.819911	51.58428	3.202751		247.3243
1866	12.03823	61.58111	3.719068		316.5824
1867	12.57989	71.61567	4.294534		296.837
1868	12.51851	74.13845	4.551884		275.8235
1869	12.36489	76.66125	4.488696		266.6217
1870	14.28068	109.0252	5.735453		242.1416
1871	15.46073	91.15888	5.949774		321.899
1872	13.93604	98.24701	6.521751		201.3221
1873	15.00946	115.9622	6.672803		220.73
1874	15.09281	125.9068	7.484042		165.6965
1875	16.28905	130.7322	8.618693	11.39472	158.8145
1876	17.1685	148.2391	9.328381	12.13785	143.9285
1877	18.31122	142.8458	9.950789	12.89796	167.1482
1878	18.74728	185.3414	9.604089	13.80058	140.7444
1879	19.86253	212.9209	10.09843	14.69491	130.5269
1880	22.64378	300.8251	10.74869	15.53369	142.601
1881	21.0923	230.3351	10.19398	16.3659	130.5174
1882	21.96798	230.4947	11.05232	17.17687	122.3773
1883	24.10037	295.9763	11.7199	18.00083	124.0772
1884	25.66495	279.2415	13.85862	18.78818	116.2197
1885	26.68289	277.9718	14.7466	19.84662	114.7458
1886	25.58021	195.811	15.60034	20.32478	105.0478
1887	26.93269	254.0509	15.80899	20.8126	111.6624

1888	28.37961	288.7878	16.43302	21.29707	123.0917
1889	30.23875	314.8749	18.52967	21.79193	116.6885
1890	31.35462	326.3877	19.75104	22.31419	113.3608
1891	31.36757	245.3466	20.60514	22.7881	137.5452
1892	33.206	310.4375	21.36177	23.29963	135.9569
1893	32.30416	275.3446	20.97614	23.7488	129.998
1894	34.26415	238.1987	24.7149	24.29449	128.7843
1895	32.65911	215.2211	22.57875	24.83279	141.2678
1896	36.30466	315.2499	24.02249	27.17149	131.7234
1897	37.49463	265.3575	26.13064	29.51679	125.461
1898	40.14658	260.2276	28.07498	31.88225	157.933
1899	47.74106	500.3353	29.51166	34.22754	196.8918
1900	45.82592	387.3553	29.34299	36.56327	187.1359
1901	46.72369	338.6354	30.57	37.97869	191.4594
1902	48.87424	287.5351	33.36885	39.42308	206.1031
1903	52.56016	385.9648	34.27283	40.8407	227.6022
1904	48.15924	354.716	28.81591	42.28509	224.2647
1905	49.85225	358.1642	30.22837	43.55173	234.9261
1906	52.32831	288.7399	34.4322	45.32329	238.5729
1907	54.46808	263.0818	38.04401	47.12396	219.6243
1908	53.65014	285.6597	35.80914	48.90937	199.6814
1909	61.21086	406.8763	41.04018	50.70102	216.7578
1910	63.00487	356.1472	44.28155	52.57041	213.0041
1911	57.39919	305.9298	39.41919	51.83848	198.3517
1912	59.52821	318.3649	43.37156	51.15039	167.269
1913	58.94249	269.7046	44.49619	50.41113	180.5971
1914	63.45854	264.5786	52.19875	49.7259	136.6975
1915	61.30273	232.1984	50.99388	48.8648	171.709
1916	58.67332	204.9872	49.24961	48.65349	143.0599
1917	52.36539	154.521	43.88983	48.4715	117.432
1918	46.95655	157.5504	37.06304	49.62231	58.02003
1919	68.09504	183.7909	61.20072	57.42831	136.1145
1920	65.12131	173.8285	55.38017	64.36721	116.3735
1921	65.61795	176.2179	57.6172	60.21683	92.6291
1922	80.79407	226.1377	73.77532	66.55697	97.09839
1923	73.00539	185.6195	62.67093	73.06097	109.9149
1924	70.73927	92.48068	63.26721	76.89763	99.11647
1925	72.22093	127.062	63.27839	79.51428	99.05863
1926	72.50437	123.8133	64.38913	76.04558	101.3029
1927	74.1101	146.7844	67.3279	73.33324	104.4604
1928	78.84642	154.0808	72.85071	75.47432	103.0923
1929	80.17761	145.418	74.45309	77.97915	108.7397
1930	78.63948	133.9891	76.95181	70.05783	104.625
1931	75.06126	148.2585	79.43517	58.78224	90.23819
1932	81.2609	120.4939	90.02608	61.23822	81.13876
1933	89.41908	173.1087	98.48555	67.87702	83.56864
1934	90.20239	150.3966	93.95399	77.73572	89.88922
1935	91.43255	107.4429	95.21962	84.57021	92.86049
1936	100.2141	144.9066	102.0134	95.65522	93.21705
1937	99.24677	132.3126	98.6878	100.2764	97.52508

1938	95.37213	128.8996	93.77503	96.26861	91.75062
1939	100	100	100	100	100

Notes: See A, B and C below.

A. Value added weights

Pastoral. Wool: sum of export values and wool used in New Zealand textiles. Meat: frozen meat exports and estimates of domestic consumption per capita multiplied by population. Butter: factory output from 1905, for earlier years export values plus estimate of per capita consumption multiplied by population. Cheese: as for butter.

Agricultural. Wheat, bushels for threshing and price at mills. Oats: as for wheat. Barley: bushels for threshing and price at breweries. Potatoes: value of output from holdings above one acre.

Manufacturing. Wool cloth: gross factory output less materials used. Beer: gross value (excluding duty) less barley/malt values used. Soap/candles: gross output as tallow not counted under pastoral. Sawmills and doors: gross output as forestry not separately measured. Foundry and engineering: gross output less import values of iron, steel, brass, and copper. Printing and publishing: gross output as paper/pulp not included elsewhere. Grain mills: gross output less wheat/oats purchases. Biscuits: gross output less purchases of flour, sugar and cocoa. Carriages and vehicles; gross output less iron, engineering and wood purchases. Clothing: gross factory output less materials purchased. Shoes and boots: gross output less only imported leather as domestic leather not measured elsewhere.

Mining. Gold: gross output value. Coal: gross output less sales to gas, pastoral and beer counted elsewhere. Kauri gum: gross output.

Other. Gas, gross gas output from gas works. Construction: gross output less wood purchases. Fishing: gross catch value.

B. Quantity time series.

Pastoral. Wool: export volumes from 1861 and New Zealand factory purchases from 1882, which equated to 3.25% of export volumes in 1882. The first New Zealand mill opened in 1871 and four operated in 1882. Wool used domestically before 1882 is estimated from the number of mills and their average wool purchases. Meat: frozen meat exports from 1882. Domestic meat is based on estimates for consumption per capita, 1.26, 1.59 and 1.85 hundredweights per capita for 1861-85, 1886-1914, and 1915-39 respectively, and annual population. Cheese: factory output from 1919. For earlier years export volumes are added to estimates of domestic consumption of 4.8 pounds per capita and population. Butter: as for cheese, with domestic consumption of 17.6 and 20.4 pounds per capita for 1861-85 and 1886-1918 respectively.

Agriculture: Annual volumes for whet, oats, barley and potatoes available from 1869, except for 1912-15 where estimates are based on acres under cultivation and yields. For 1861-68 the data are also based on estimated acres and yields.

Manufacturing: Annual output values are available for the 11 industries from 1918, and at 5 year intervals from 1885-1915. These data are deflated the consumer price index. Estimates of gross output are constructed for 1877 by scaling the estimates of 1877 value added by the ratio of gross output to value added in 1885. Interpolations between the five year intervals 1885-1915 and for 1915-1918, 1875-1877 and 1877-1885 assume manufacturing reflects the output shifts in the other sectors.

Mining. Gold and kauri gum volumes from 1861 and coal from 1875.

Other. Gas: data availability as for manufacturing and similar methods of construction used. Fish: quantity of catch data for years from 1917. For earlier years output is approximated by employment. Construction: Annual output values are available from 1925 and these are deflated by consumer prices. For earlier years sawmills and doors output is used to approximate that of construction. The correlation between the two series 1925-1939 is 70%.

C. Sources.

For the years 1873-1919 the annual *Statistics of New Zealand* is the key source. For 1861-1872 *Agricultural and Pastoral Statistics* provide data on these two central industries. The *New Zealand Census* of 1878 collected information on manufacturing output, employment, and materials purchased, and these data are utilized in constructing 1877 estimates of value added. The Census reports of 1885-1915 are also used in the construction of value added weights during these years. From 1920 onwards the various parts of *Statistics of New Zealand* appear in separate and augmented volumes, including *Trade and Shipping, Agricultural and Pastoral Production, Factory Production* and *Miscellaneous* (which includes prices, wages and employment data. *New Zealand Official Yearbooks* for years from 1893 chiefly summarize data first reported in the above sources and in the *Appendixes to the Journal of the House of Representatives*, but occasional reports including on the per capita consumption of meat and dairy products provide extra information used here.

Appendix 2. Patents Classification System

Following Magee (2000), Schmookler (1966) and Sokoloff, K.L. (1988), patents are classified in terms of the industry where the principles/ideas behind the patent are most likely or expected to be used. The class numbers refer to Magee's taxonomy and the group numbers to the 8 group classification adopted here

Group 1. Agriculture
Class 1: Agriculture. Includes patents relating to agricultural machinery, processes in agriculture, ways to protect and encourage agricultural growth and profits.
Group 2. Pastoral
Class 2: Pastoral. Equipment relating to sheep farming and particularly shearing, fencing and exterminating rabbits. *Class 3: Dairying.* Dairy farming and the usage and storage of cream, milk and butter. *Class 17: Preserving and curing Food.* Processes and preservation of foods, meats and fish. Tins for preserving food. *Class 18: Refrigeration.* Ice making, refrigerating and cooling.
Group 3. Mining.
Class 4: General Mining. Class 5: Mechanical and Chemical Mining and Metal extraction
Amalgamating, pulverising and crushing of ores, extraction of chemicals and metal/
Group 4. Construction and woodworking.
Class 6: Construction. Earthworks, building construction, iron bridges *Class 7: Treatment of Non-metalliferous and Quarry Products.* Cement and cement goods, asphalt, lime, coal and coke works. Stone quarrying, moving, breaking and shaping. *Class 8: Bricks, Pottery and Glass*
Glass bottles, earthenware, china, terracotta, brick and other kilns for making bricks, pottery. *Class 9: Wood Working.* Sawmills, joinery and cooperage, boxes and cases, wood turning and carving. *Class*

10: Furniture and Bedding. Billiard tables, household furniture, furniture making, beds, picture frames, window and veranda blinds.

Group 5. Foundry and Engineering.

Class 11: Carriages and Coaches. Carriage construction and repair. Construction, repair and advances on all types of vehicles and vehicle parts. *Class 12: General Engineering Equipment*
Includes all otherwise unspecified engines, valves, gauges, pumps, cables and apparatus and patents for goods used for general engineering tasks. *Class 13: Industrial Metals*. Treatment of metals and metal goods; goods such as furnaces used in the processes of smelting, converting and refining of iron steel and other metals. *Class 14: Machinery.* Machinery and machine parts. Sewing machines, lifting machines, blowing machines. *Metal Working and implements*. Processes for manipulating metal. Metal implements – wire working, agricultural implements, cutlery, small tools, small metal parts. *Class 23: Heat, Light and Power*. Electric light, power and heat. Heating equipment, lighting equipment.
Class 28: Railway. Railway goods and rail services. *Class 29 : Shipping and Boats.* Ships, shipping goods and services.

Group 6. Clothing and Footwear.

Class 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. *Class 16: Skins and Leather.* Saddles, harnesses, bags and leather goods. Preparing and using skin and leather goods.

Group 7. Food and Drink

Class 19: Foods and Drink. Foods, food producers and preparing, food factories and bakeries, aeration, bottling of foods and drink. *Class 20: Alcoholic Beverages. Class 21: Tobacco.* Cigars, cigarettes, cigarette machines and tobacco products.

Group 8. Printing and Publishing.

Class 22. Paper, Stationary, Printing and Bookbinding. Paper goods and paper or cardboard making, pens and pencils, photography, the process of engraving.

Unallocated to industry groups (but included in the total counts).
Class 24: Chemicals, Dyes, Paint, Oils and Grease
Class 25: Pharmaceutical and Medicinal, Surgical, Veterinary, Dentistry, optical etc
Class 26: Fuels Firearms & Explosives
Class 27: Other manufacturing
Class 30: Communications
Class 31: Services and Distribution
Class 32: Household Consumer Goods
Class 33: Household Producer Goods

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