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Essays in Quantitative Economic History

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Thesis submitted to Trinity College, Dublin In fulfillment of the requirements for the degree of Doctor of Philosophy (Ph.D.)

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## Contents

1 Introduction  

2 Some economic geography aspects of late nineteenth century industrialisation  
   2.1 Introduction  
   2.2 Review of the literature  
   2.3 Historical industrial development: Data issues  
   2.4 Construction of economic geography metrics  
   2.5 Methodology and results  
      2.5.1 Benchmark results  
      2.5.2 Robustness checks  
   2.6 Discussion  
   2.7 Conclusion  

3 Anthropometrics and occupations in nineteenth century Britain and Ireland: Some evidence from the East India Company army  
   3.1 Introduction  
   3.2 Literature review  
   3.3 The EIC army records  
   3.4 Methodology and results  
   3.5 Discussion of results  
   3.6 Conclusion  

4 Irish financial markets 1913 to 1923  
   4.1 Introduction
4.2 Literature Review ............................................................... 90
4.3 Data overview: Government stocks ........................................ 93
4.4 Empirical results ................................................................. 101
  4.4.1 Structural break analysis ................................................. 101
  4.4.2 Volatility analysis ......................................................... 103
  4.4.3 Cointegration analysis .................................................... 108
4.5 Share prices: An exploratory analysis ..................................... 111
  4.5.1 Background ................................................................. 111
  4.5.2 Analysis of share prices ................................................ 112
4.6 Discussion ............................................................................. 116
4.7 Conclusion ............................................................................ 121

5 Conclusions ............................................................................ 127
List of Figures

2.1 Per capita levels of industrialisation (Bairoch). (UK=100 in 1900) . 15
2.2 Market access: 1860-64 to 1910-14. (UK=100 in 1860-64) . . . . . . . . 22
2.3 Market potential: 1860-64 to 1910-14. (UK=100 in 1860-64) . . . . . 22
2.4 Foreign market potential: 1860-64 to 1910-14. (UK=100 in 1860-64) 23
2.5 Population density: 1860-64 to 1910-14. (UK=100 in 1860-64) . . . 23
2.6 Per capita levels of Industrialisation and the four measures compared 27
2.7 Wages, GDP and Industry ................................................................. 49
2.8 Correlation between different Industry measures .......................... 50

3.1 Structure of EIC recruits’ previous occupations ............................ 61
3.2 Share of category IV recruits (%) ..................................................... 63
3.3 Share of Irish born recruits (%) ......................................................... 64
3.4 Probability of being in each occupational group ............................... 73
3.5 Whipple index for recruits ............................................................... 79

4.1 Frequency of trading ( % of days trading) ........................................ 95
4.2 Daily price data: Consols and land stocks ..................................... 98
4.3 Daily returns: Land stocks ............................................................... 100
4.4 Daily returns: Consols .................................................................... 100
4.5 Conditional variance of daily return: 2.75% Land stock relative to 
consols .................................................................................................. 107
4.6 Conditional variance of daily return: 3% Land stock relative to consol 107
4.7 Impulse response functions ............................................................... 110
4.8 Bank of Ireland daily share prices ................................................. 113
4.9 Hibernian Bank daily share prices .................................................. 113
4.10 Great Southern and Western Railways, Great Northern Ireland Railways daily share prices ............................................. 114
4.11 Midland Great Western Railways Daily share prices ............................................ 114
4.12 Example of a BCP test on Land stock returns relative to consols ............... 125
# List of Tables

2.1 Pairwise correlations ................................................................. 24
2.2 Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14 ................................................................. 28
2.3 Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14 (lagged approach) ................................................................. 31
2.4 Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14. 2SLS-IV ................................................................. 32
2.5 Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14. Spatial lag approach ................................................................. 36
2.6 Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14 ................................................................. 38
2.7 Data sources ............................................................................. 47
2.8 Determinants of industry as a share of GDP(BR Mitchell), 1860-4 to 1910-14 ................................................................. 48
2.9 Manufacturing growth rates, 1870-1914 ................................................................. 49
3.1 Summary statistics by occupation grouping ................................................................. 67
3.2 MNL model of EIC recruits’ previous occupations (RRRs) ................................................................. 70
3.3 MNL model with the addition of age heaping(RRRs) ................................................................. 77
3.4 Occupational classification groupings ................................................................. 82
3.5 Data labels and description ................................................................. 83
3.6 RRRs for stature: Birthplace groups ................................................................. 84
3.7 RRRs for stature: Changes over time ................................................................. 85
3.8 Ordered probit model of previous occupations ................................................................. 86
3.9 Likelihood ratio test of combining categories ................................................................. 86
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Daily holding returns (%): 1916-23</td>
<td>99</td>
</tr>
<tr>
<td>4.2 Bai-Perron tests of 0 v 1 sequentially determined breaks</td>
<td>102</td>
</tr>
<tr>
<td>4.3 GARCH(1,1) Daily consol and land stock spreads. 1916: 1923</td>
<td>105</td>
</tr>
<tr>
<td>4.4 Unit root tests</td>
<td>123</td>
</tr>
<tr>
<td>4.5 Johnansen cointegration tests</td>
<td>123</td>
</tr>
<tr>
<td>4.6 Key dates in Ireland, 1913-23</td>
<td>124</td>
</tr>
<tr>
<td>4.7 Key dates in Britain, 1913-23</td>
<td>126</td>
</tr>
</tbody>
</table>
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Summary

The thesis explores three historical questions using novel datasets and the most up to date econometric methods available. The thesis is motivated by the growing success of economic history in addressing a range of issues through the use of quantitative techniques.

The first essay examines how much of the cross-country dispersion of late nineteenth century industrial development can be explained by economic geography factors. The essay’s empirical strategy closely resembles that of Redding and Venables (2004). Using a panel of 19 countries between 1860-4 and 1910-14, I find a positive link between market access measures and industrial development. Notwithstanding the small panel nature of the data, the findings have three advantages when it comes to interpretation. Firstly, they can be given a structural interpretation. Secondly, the essay incorporates endogeneity and spatial correlation into the modeling. Finally, since both “own” and “foreign” elements make up total market access, the findings are consistent with familiar themes that emphasise the role of both domestic and external factors in understanding historical economic growth. The essay notes that market access has also been increasingly linked to migration, foreign direct investment and human capital accumulation in the literature and could be useful to explore historically. While included principally for econometric purposes, the persistence of spatial lag effects also warrant further investigation. One possibility is that they reflect “spillovers” between countries.

Essay two analyses the recruitment records of 30,000 British and Irish-born recruits in the East India Company army between 1830 and 1857 to explore the role of stature in explaining their previous occupations. A multinomial logit model shows that taller recruits were around 30% more likely to have previously held sedentary non-manual occupations rather than physically demanding manual occupations. The results are subjected to a battery of robustness checks that include analysis of individual groups and the inclusion of a simple proxy for a recruit’s human capital
and literacy. These quantitative findings point to more similarities between modern and historical labour markets than one might have expected. Two important related themes in the literature can help to shed light on the findings. Firstly, the modern research showing that nutritional status and height are rewarded in the labour market through traits such as cognitive skills, confidence, intelligence, social skills as well as physical strength. And second, the findings from the biological standard of living literature showing how the wealthier are better fed and likely to experience superior physical growth and cognitive development, and enter high status occupations. Linked to this, class, parental income and background were also major determinants of access to human capital in nineteenth century Britain.

The third essay explores Government stock prices in Dublin to understand investor sentiment between 1913 and 1923. In one of the essay’s main contributions, the daily prices of little known Irish land stocks are reconstructed. Conventional tests find no evidence of structural breaks in prices. However, as is typical with daily financial data, GARCH and more powerful change point tests do find frequent short-term bursts of volatility and high probabilities of erratic change points in prices and returns. Given the continued British guarantee of land stocks after partition, the continuing payment by the Free State of land annuities during the 1920s and the historical stability of British consols, these findings are perhaps not unexpected. The essay shows how ordinary Irish shares that might be less contaminated by wider British or international events of the day could provide a better insight into market reactions in this period.

All three essays can be viewed as case studies in the use of historical data for quantitative historical analysis. Working with historical data presents challenges and often necessitates compromise. These are recurring issues throughout all three essays. For example, some data that modern scholars have access to are simply unavailable historically. Several novel approaches to overcoming these are addressed in each of the three essays.
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Chapter 1

Introduction

This thesis is a collection of essays exploring three historical questions through originally constructed datasets and latest econometric techniques. The thesis is motivated by the growing success of economic history in addressing a range of issues through the use of quantitative techniques.

The essays cover a range of issues that include early industrial development, occupational choices in the nineteenth century United Kingdom labour market, and the operation of financial markets against the background of civil and political disturbances in Ireland between 1913 and 1923. Each essay follows a similar structure: the historical question is first motivated, the data and methodology described, and the results set out before being discussed. Essays two and three focus on both islands of the then United Kingdom, however all three make wider historical and methodological contributions to the literature.

The first essay examines how much of the cross-country dispersion of late nineteenth century industrial development can be explained by economic geography drivers. These ideas are appealing to scholars of the nineteenth century, with their focus on ideas of core and periphery, and uneven economic development patterns. Industrial development and reduced reliance on agriculture in this period are generally accepted as key to understanding the onset of modern economic growth.
Baldwin (2007)\textsuperscript{1} notes how “Kuznets, Myrdal, and Rostow gave geography and agglomeration forces centre stage in their theories, but they lacked tools to formalize the links.” The seminal work of Redding and Venables (2004) provide an ideal framework to begin exploring these issues. While a large literature has looked at the importance of relative geography in shaping regional patterns of historical industrial development, the essay is the first to explore these issues in a cross-country setting.

The essay constructs four different country metrics from the spatial economics literature, primarily drawn from the new economic geography (NEG) literature, and explores their role in explaining industrial development between 1860 and 1914. I find a link between market access measures and industrial development, while population measures are erratic. The econometric problems encountered throughout the essay are familiar and include endogeneity, omitted variable bias and spatial correlation in the data. The essay deals with these in turn and I am able to show that the findings are robust to different historical industry measures, the inclusion of control variables, and approaches to dealing with endogeneity and the spatial correlation in the data.

While this approach has limitations in testing specific models of historical economic development, I briefly discuss how the findings link to the longstanding literature on wider historical economic development. Since both “own” and “foreign” elements make up market access, the findings are consistent with roles for both domestic and international factors. The essay’s findings could also provide the basis for new insights into understanding historical development. Two are noted as potential candidates for future research. Firstly, market access is increasingly linked into the literature to a range of outcomes other than trade in areas such as human capital accumulation. Secondly, while included principally for econometric purposes, the persistence of spatial lag effects warrant further investigation. One possibility is that it might reflect “spillovers” between countries.

The second essay analyses the recruitment records of 30,000 British and Irish-

\textsuperscript{1}Cited in Crafts and Venables (2001)
born recruits in the East India Company army between 1830 and 1857 to explore the role of stature in explaining their previous occupations. Notwithstanding Margo and Steckel's (1982) classic work on slave heights and value, the extent that height was rewarded historically in the labour market is a more open question. The lack of large and representative historical datasets, containing stature, wages and occupations, are obvious barriers to quantitative analysis. This leaves a gap in the literature since historical differences in heights between social groups were often much larger than today. Historical analysis also straddles the modern literature's dividing line between economies intensive in manual labour and those in skilled labour.

The essay begins by using the HISCLASS classification to organise recruits' previous occupations into four broad skill groupings for analysis. It then goes onto estimate a multinomial logit model of recruits' previous occupations. Consistent with modern developed labour markets, I find that taller recruits were more likely to have been in non-manual occupations than physically demanding manual occupations. To ensure that the findings for stature do not reflect individual heterogeneity, a vector of control variables are added as robustness checks. The findings suggest more similarities between modern and the nineteenth century labour markets than one might have expected.

The data that modern scholars increasingly use to further analyse these links are simply unavailable to historians, and against this background the essay attempts to explain the findings. The essay draws on the modern labour market literature, the biological standard of living literature and what is known about the historical accumulation of human capital.

Modern research shows that nutritional status, height and early childhood are rewarded in the labour market through traits such as cognitive skills, confidence, intelligence, social skills as well as physical strength (Currie, 2008). Secondly, the biological standard of living literature shows how the wealthier are better fed and likely to be taller, and have the potential to experience superior physical growth and cognitive development. Background was also particularly important histor-
ically because class and parental income were major determinants of access to human capital in nineteenth century Britain. These ideas do bring into question the use of modern “sorting” models to think about historical entry into occupations, notwithstanding the impressive empirical performance of the model in the essay.

While testing modern labour market ideas historically is of interest in itself, these ideas have the potential to shed further light on our understanding of the role of human capital in historical economic growth. The essay is also linked to several recent papers that typically extend the role of physical strength emphasised famously by Fogel (1994).

The final essay explores what insights can be gained from financial markets into the turbulent decade in Irish history between 1913 and 1923. The essay offers an alternative approach to a highly politicised historiography of this period (O’Day, 1998). In the vein of Willard et al. (1996), the approach exploits the ability of financial markets to provide incentives to reveal private expectations of historical events. A novel feature of the essay is the reconstruction of a price series for little known land stocks issued by the UK government to finance the transfer of land ownership from landlords to tenants. Surprisingly, given their historical importance and their trading popularity, until now no previous attempt has been made to even construct a price series for these assets.

This essay employs a battery of familiar modern econometric tests to explore stock price movements between 1913 and 1923. The analysis focuses on prices and returns, on volatility and levels, and to a lesser degree London and Dublin prices. Conventional (and low power) Bai and Perron (2003) tests find no evidence of structural breaks in prices or returns between the different assets across this period, or between London and Dublin prices. As is typical with daily financial data, GARCH and more powerful change point tests do find short term bursts of volatility and high probability of change in mean prices and returns. However, with the exception of the period 1920 and 1921 it is difficult to pinpoint any specific events linked to explain these erratic patterns. Perhaps the essays’ most important find-
ing is from a simple cointegration approach that confirms the tendency for land stocks to move in line with, and be anchored by, the benchmark British consol.

The essay discusses several reasons for these findings. Previous scholars have noted the longstanding stability of British consols and other guaranteed stock in this period, reflecting the hegemonic power of Britain and preeminent position of the London financial market. Given the continued British guarantee of land stocks after partition, the historical stability of British consols and the continuing payment by the Free State of land annuities during the 1920s, these findings are perhaps not surprising. The last part of the essay explores how ordinary Irish shares might be less contaminated by wider British or international events of the day and provide a better insight into market reactions. A handful of selected shares show much more volatility than Government stocks, as well as strong sectoral patterns. Interestingly, half of the stocks show conventional breaks around the end of 1919 and start of 1920. The essay concludes that separating out pure domestic events against the background of post-war austerity and deflation in this period remains a challenge and should be a priority for future analysis.

All three essays also make contributions to their respective mainstream literatures. For essay one, this includes a further empirical verification of the role of market access established by Redding and Venables (2004). For essay two it is further support for Deaton's (1997) claim that the height-labour market nexus is historically reliable. In essay three it is further evidence showing similarities between historical and modern financial markets. The thesis also points to another contribution that historical economic analysis can make. As Mittelstaedt and Zorn (1984) note, “these types of replication study, using the same statistical methods on a different data set, comes the closest to replication in the experimental sciences.”

All three essays can be seen as case studies in the use of historical data for quantitative analysis. They involve working with datasets that have been collected by hand from original sources. Two aspects of each dataset underlying the essay are systematically assessed. Firstly, is how representative the data was of
the period in terms of coverage. Second is how reliable the data were collected. These issues receive particular attention in essay two that deals with the records of the East India Company army, but these are overarching themes in any historical economic analysis.

Working with historical data presents challenges and often necessitates compromise. Some data that modern scholars have access to are simply unavailable historically. Data might be available in different formats, it might be available in much smaller samples or they may have been collected less frequently. These are issues in all three essays. In essay one some components of market access, such as detailed bilateral transport costs, are not available. Information on recruits' levels of literacy and father's occupation would undoubtedly have enhanced the analysis in essay 2. In essay three there are no detailed daily liquidity data on assets traded.

The thesis uses several novel ways to overcome these data shortcomings. First, is by using proxy variables to fill gaps where quantitative data are missing. Second is by drawing on more qualitative sources of information, such as from newspapers or other contemporary sources. Thirdly, comparative studies such as between countries or between financial assets can be a useful way to judge results against the background of data shortcomings.

The rest of the thesis is structured as follows. Chapters 2 to 4 set the individual essays and chapter 5 draws some conclusions.
Chapter 2

Some economic geography aspects of late nineteenth century industrialisation

2.1 Introduction

This essay examines how much of the cross-country dispersion of late nineteenth century industrial development can be explained by economic geography drivers. These ideas are appealing to scholars of the nineteenth century, with their focus on ideas of "core and periphery," and uneven economic development patterns (Krugman, 1999). Countries with low levels of industrial development in the nineteenth century were predominantly found at the geographical periphery of Europe and in richer countries in the centre. Adding to the geographical heterogeneity was the economic performance of the new world economies.

The essay finds a clear and positive link between market access and late nineteenth century industrial development. These differences in industrial development between countries that market access helps to understand were large. Bairoch’s (1982) per capita measure shows industrial development in the United Kingdom in 1870 was four times greater than in France or Germany, and up to ten times greater than in the agriculturally dominated periphery countries of Spain, Russia and Finland. Industrial production generally grew faster than GDP in Europe.
between 1870 and 1913, as Europe developed and agriculture declined in relative importance. Despite increasing economic integration and convergence by some in the periphery, these vast disparities were not fully eliminated (O'Rourke and Williamson, 1997).

The historical literature has long recognized these links between geography, market size, agglomeration economies and industrial development (Marshall, 1920). However, economic historians often lacked the analytic tools to assess these (Baldwin, 2007). Recently, the empirical methodology developed in the NEG literature has prompted a burst of research exploring the role of economic geography and provides a promising framework for historical research. Typically replicating Redding and Venables's (2004) findings on the positive link between market access and wages (or GDP) in different contexts, numerous studies show how measures of market access can also explain a range of economic outcomes that recently includes industrial development (Francis and Zheng, 2012).

Cliometric interest in economic geography models has tended to focus on exploring the strong regional clustering patterns of early industrial activity. This leaves a gap in the literature as between country differences were often larger than within country differences. The essay's empirical strategy closely resembles that of Redding and Venables (2004). The essay begins by constructing several variants of country market potential and access between 1860 and 1914. Originally introduced by Harris (1954) as ad-hoc measures of economic centrality, these are now seen as reduced form measures from NEG models.

Using a panel of 19 countries between 1860-4 and 1910-14, I find a positive link between market access measures and industrial development. Interestingly, the essay also finds, to a lesser extent, roles for the ad-hoc market potential measure and a pure foreign market potential access. Also consistent with the modern spatial economics literature is the mixed role for population density in explaining industrial development (Brakman et al., 2009). These key findings are robust to different historical industry measures and the inclusion of control variables. They

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1 Quoted in Crafts and Venables (2001)
are also robust to simple strategies for dealing with endogeneity and spatial correlation in the data, although there are small size caveats to these extensions.

Notwithstanding the small panel nature of the data, the findings have three advantages when it comes to interpretation. Firstly, they can be given a structural interpretation. Secondly, by explicitly incorporating endogeneity and spatial dependence into the modeling, the effect of market access is purged of any "spillover" effects that allows a more robust analysis of the spatial interaction between countries. Finally, since both "own" and "foreign" elements make up total market access, they are consistent with familiar themes that emphasise the role of both domestic and external factors in understanding historical economic growth.

The essay’s findings also touch on two other geographical considerations when thinking about historical industrial development. While the original impetus of the market access approach was based on trade considerations, there are growing links between market access and migration, investment, foreign direct investment, human capital as well as industrial development. All of these could be relevant historically and warrant further research. Secondly, while included principally for econometric purposes, the persistence of spatial correlation warrants further investigation. One possibility is that it could reflect "spillovers" between countries.

The topic of the essay does raise two natural questions that need to be immediately addressed. First, why diverge from much of the literature and focus on one sectoral element of GDP and not the aggregate? And second, how can such a complex process as historical industrial development be modeled, particularly one that has no role for policies, institutions or endowments such as coal reserves?

The essay appeals to a tradition that sees urban-industrial activities containing far more cost reducing and productivity-enhancing forces than traditional agriculture and services. Put simply, agriculturally dominated countries in the nineteenth century remained poorer and this was reflected in lower GDP per capita and wages (Figure 2.8). Williamson (2010) usefully sets out several mechanisms to understand these further. For example, urban clusters foster agglomeration
economics; denser markets imply more efficient markets; a denser urban-industrial complex generates more extensive productivity-enhancing knowledge transfer between firms.

By collecting data stretching back to 1860, country fixed effects can be used to control for time invariant factors. This captures the effects of so-called “first nature” geographical factors like rivers, mountains, climate and coastlines (Krugman, 1999). It also captures endowments, institutions and culture. This approach helps to avoid the problem inherent in many cross-section studies that often produce biased findings on the role of geography (Hering and Poncet, 2010).

While the essay focuses on industrial development in the nineteenth century, the findings are linked to two other strands of the literature. Firstly, is the wider modern spatial economic literature, including NEG, that seeks to explain a range of spatial economic outcomes both between and within countries (Brakman et al., 2009). The essay is also linked to a small cliometric literature that explores cross-country patterns of economic development in the late nineteenth century. One lesson from this literature, and a further motivation for the essay’s sectoral approach, is the poor historical performance of conventional economic models, such as those of Solow, that focus on GDP (Taylor, 1999).

The essay proceeds in five main sections. Section 2.2 sets out a brief review of the literature. Section 2.3 sets out the main measure of industrial production used. Section 2.4 constructs various historical country market access variants and population density measures for the period 1860-64 to 1910-14. Section 2.5 presents the main econometric results for industrial development determinants between 1860-64 and 1910-14. This documents the benchmark results and those derived from a series of robustness checks. These results are discussed in section 2.6.

2.2 Review of the literature

In one of the first empirical attempts to explore the links between economic development, country size and distance, Harris (1954) quantified access for US counties
by a weighted sum of their purchasing power across locations. The weight for each location depended inversely on its distance that reflected transport costs. He showed that heavily industrialized regions of the United States were in general also locations with exceptionally high "market potential." In its early form, this market-potential function of Harris (1954) performed reasonably well in understanding economic development, although it was often seen as ad-hoc by economic theorists (Head and Mayer, 2011).

Fujita and Venables. (1999) provide a fresh impetuous to the market-potential concept by showing how it can be derived from formal economic geography models of Krugman (1999). In its modern version, this market access function states that nominal wages (or GDP) are higher near concentrations of consumer and industrial demand. Redding and Venables (2004) were the first to establish empirically that market access matters for economic development, by showing how a structurally derived measure of market access could explain the cross-country variation in GDP per capita for 101 countries.

Many authors follow the approaches of Redding and Venables (2004) and apply their methodology to other countries and contexts. Breinlich (2006) highlights that regional income levels in the European Union displays a strong core-periphery gradient linked to market potential. Head and Mayer (2011) conduct a similar exercise based on European sectoral data over a shorter period and arrive at similar findings. Knaap (2006) show a strong positive effect of market access on income levels in US states. Hanson (2005) shows that market access, as opposed to the fixed characteristics of locations, provides a better way to characterize the forces that contribute to the geographic concentration of economic activity in the US.

In recent years, theory based market access measures are increasingly being used to explain economic outcomes between countries other than wages and GDP, and which rely on mechanisms other than trade. This includes FDI (Amiti and Smarzynska Javorcik, 2008), migration patterns (Kanes, 2011) and human capital (Hering and Poncet, 2010). Market access is also being used to look at industrial development. Using data on U.S. manufacturing industries between 1984 and 1996,
Francis and Zheng (2012) find strong evidence to suggest that access to markets positively affects industry growth. Breinlich and Cuat (2011) also draw empirical attention to the role of economic geography in explaining cross country industrial development.

The links between development, geography and market size have a long tradition in economics. Marshall (1920) explained the spatial concentration of industrial production through external economies of scale. Kuznets, Myrdal, and Rostow also gave geography and agglomeration forces center stage in their theories, but “they lacked tools to formalize the links” (Baldwin, 2007).

A large economic history literature shows how the US was uniquely blessed by its large domestic internal market Romer (1994). The corollary is that the internal market for European producers was small with international borders imposing significant restrictions on demand and productivity advances. The increasing openness that emerged in the late nineteenth century through falling transport costs and tariffs, are key themes in the nineteenth century globalisation literature (O’Rourke and Williamson, 1997).

Cliometric interest in economic geography models to date has tended to focus on exploring the strong regional clustering patterns of early industrial activity. This leaves a gap in the literature since between country differences were often larger than within country differences. Crafts and Mulatu (2006) show that geographical concentration of British industry between 1870 and 1914 initially responded to factor endowments, although it was later reinforced by economic geography forces and scale effects. For Spain between 1856 and 1929, Martinez-Galarraga (2012) reports that both comparative advantage and economic geography mechanisms were drivers of industrial location in Spain, although their relative strength changed over time. For Poland after the reunification in 1918, Wolf (2007) shows that the integration of the domestic market led to important changes in the spatial concentration of manufacturing. In an important methodological contribution, Klein and Crafts (2012) show that domestic market access was central to the historical emergence of the US “manufacturing belt” and that it mattered more
than factor endowments.

These papers follows a popular approach in the early cliometric literature of analyzing country case studies, reflecting that Europe was a continent of independent nation states and in some cases protected by high tariffs. However, Europe’s economies developed in a closely interrelated environment and no single country can be understood without these interconnections (Berend, 2012).

A relatively small quantitative literature explores cross-country patterns of economic development in the late nineteenth century. In an early contribution, Bairoch (1972) looks at the correlation between tariffs and growth among major European countries by comparing aggregate growth rates in free trade and protectionist periods. Crafts (1984) applies historical data to explore the stylised patterns of structural change designed by *Three Decades of Industrialization* (n.d.). Foreman-Peck’s (1995) comparative approach looks at the determinants of GDP per head in Spain and Britain in 1880 and 1910. He finds natural endowments (climate and coal deposits), economic policy (tariff protection and marginally the gold standard), and cultural heritage (as reflected in literacy) could help to explain differences between the two countries.

Taylor (1999) documents the poor historical performance of the textbook Solow growth model. As an alternative, he relates growth in output per worker to the land-labour and capital-labour ratios. O’Rourke (2000) and Lehmann and O’Rourke (2011) provide a more sophisticated analysis of the historical tariffs and economic growth nexus by using several different macroeconomic specifications. These latter papers are also a rare example in the literature of using industrial development as a dependent variable.

Several overarching themes from this latter literature are notable and provide motivation for this current essay. Firstly, modern approaches to economic growth, such as the textbook Solow model and new growth theories, often struggle to explain the key features of historical uneven development (Taylor, 1999). Secondly, the results are often highly sensitive to country sample or time period (Clemens
and Williamson, 2004). And finally, these studies also show the value of panel approaches that can help control for important (and difficult to model) time invariant factors central to the historical growth experience.

2.3 Historical industrial development: Data issues

The choice of historical industrial development measure is paramount in terms of reliability and coverage. Ideally, one would like to go back to a contemporary set of cross-country industrial production data. Lacking such information, the paper uses Bairoch's (1982) *International Industrialization Levels from 1750 to 1980* dataset. This continues to be the most comprehensive source of data tracing the evolution of industrial production over the nineteenth century.

Figure 2.1: Per capita levels of industrialisation (Bairoch). (UK=100 in 1900)
Bairoch (1982) assembled data on the production of key products at benchmark years from historical sources and weighted their relative share of total production. This measure included traditional sectors such as textiles, steel, chemicals, cement, and activities like furniture, food and clothing. The Bairoch (1982) dataset is reported at 10-20 year intervals. Broadberry et al. (2008) note that “the way in which Bairoch (1982) combined the procedures is not transparent, but with one important exception, the results fit well with the large secondary literature on the subject, and can at least be seen as providing a broad guide to the orders of magnitude.”

Figure 2.1 shows a snapshot of Bairoch’s (1982) original per capita levels of industrialisation for 1860-4 and 1910-14. All data are relative to the UK in 1900. In 1870 the UK was the world’s leading industrial nation. While other early industrialisers included Belgium and Switzerland, neither had achieved a per capita industrialization level half that of the UK. By 1914 the US had overtaken Britain as the world’s leading industrial nation. However, by 1913 five economies (the United Kingdom, Belgium, Switzerland, Germany and Sweden), had a per capita levels more than half that of the new industrial leader.

The data also reveal strong spatial patterns. Industrial development in much of southern and eastern Europe remained persistently weak in countries such as Spain, Italy and Greece. Notwithstanding some pockets of industrial development by 1913, these countries were unable to match the other newly industrializing economies. By contrast, successful industrial “catch up” was seen across Scandinavia and most dramatically in Germany.

Given the issues around reliability of historical measures of industrial devel-

---
2 Broadberry et al.'s (2008) main worry is British data in the early nineteenth century, and is potentially an issue since all data is relative to Britain. Since this is mainly a levels issue, the use of fixed effects in the analysis should mitigate any problems. The panel regression approach adopted later in the essay also drop Britain from the sample without any major impact on the results.

3 While both datasets are relatively modest in size by modern standards (20 countries), Bénétrix et al. (2012) remind us that where industrial/manufacturing output data was missing for these periods “one can surmise there was probably not much [industry] to measure.”
opment, it is important to exploit as much information as possible from different sources. Mitchell (2007) breaks national income down into percentages due to industry, agriculture, transport and communications, and services, and provides another historical source of information. This allows for comparative analysis of industrial development, although the dataset is smaller.

In recent years, work has been done to build up historical national accounts stretching back into pre-1914 period (Smits et al., 2013). Where these national accounts have been reconstructed using the output approach, they provide data on value added in constant prices for the manufacturing (or industrial) sector. Bénétrix et al. (2012) have recently put together manufacturing growth rates stretching back to 1870 for a large group of countries. While these are not suitable for levels analysis, they can be used for cross-country growth rate comparisons.

Encouragingly, Figure 2.8 in the Appendix shows the high correlation between the per capita index of Bairoch (1982) and the Mitchell (2007) measure. The correlation between the manufacturing growth rates of Bénétrix et al. (2012) and those implied by Bairoch (1982) is positive but lower. An exploratory spatial data analysis also reveals that all three industry measures are characterized by significant positive spatial dependence. Using inverse distances as weights, Morans I measures easily reject the null hypothesis of no autocorrelation with p-values of zero. This positive spatial autocorrelation provides further motivation for the essay.

2.4 Construction of economic geography metrics

In this section, four metrics that are widely used in the spatial economics literature are briefly described and then constructed for a group of countries between 1860-64 and 1910-14. Harris (1954) measured the size of the market in a particular

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4Mitchell (2007) data is annual and so five year averages across these periods are calculated. The Bairoch (1982) dataset is reported at 20 year intervals and a linear interpolation is used to compute the 5 year averages.

5Negative spatial autocorrelation describes a sample where proximate observations are less alike. A lack of spatial autocorrelation describes a sample with no meaningful spatial pattern.
location by what he termed market potential. This is calculated as the sum of the incomes of all locations (for a country $GDP$) weighted by each location's distance to the location under consideration ($dist$). In this context, distance is a proxy for trade costs and is typically computed between the main economic centres, usually capital cities.

The simple market potential measure for country $i$ is defined here as $MP_i$, where GDP is the GDP of country $j$ (including $i$); and $dist$ is the distance between country $i$ and country $j$:

$$MP_i = \sum_{i=1}^{n} \frac{GDP_i}{dist_i}$$  \hfill (2.1)

An adjustment is also made for own distance, or self-potential, within a country (Keeble et al., 1982) and is approximated by:

$$d_{ij} = \frac{1}{3} \sqrt{\frac{\text{countryarea}_i}{\pi}}$$  \hfill (2.2)

Because internal distance is generally smaller than external distances, domestic market potential is associated with a greater weight and is an important parameter for measures of market potential. Although an intuitive indicator of economic "centrality," and reasonably successful in the early empirical literature (Head and Mayer, 2011), market potential is often seen as ad-hoc. It is not built on a solid theoretical foundation and is not derived from a structural estimate. In particular, the weighting of foreign GDP is based purely on distance and not their true accessibility.

Formal NEG models show that locations are attractive for economic activity because they represent a large market, reflected by GDP, location or they are easy to trade with (Brakman et al., 2009). This yields a more realistic measure of market access that consists of looking not just at distance but also tariffs, transports costs and price indices. In this approach pioneered by Redding and Venables (2004), distance and tariff elasticities are extracted from gravity models
of trade and then applied to country distances and tariffs. This leads to a market access function between countries \( i \) and \( j \) that takes into account the freeness of trade between country pairs them in weighting GDP(\( \phi \)).

\[
\phi_{ij} = GDP_i(Distance_{ij})^6(Tariff_{si})^7
\]  

(2.3)

Five-year averages of both the ad-hoc Harris (1954) market potential in (2.1) and theoretical market access measures in (2.3) are computed for 19 countries across the period 1860-64 to 1910-14. The countries include Belgium, Denmark, France, Germany, Italy, Netherlands, Portugal, Finland, Spain, Sweden, Switzerland, UK, Greece, Portugal, Japan, Australia, Canada, Brazil and the United States.

Constructing these measures presents challenges, even for scholars with access to modern datasets, and invariably proxies are employed (Brakman et al., 2009). The GDP figures are obtained from Maddison (2010). Distances are calculated between capital cities using the the CEPII Bilateral Distances Database (Mayer and Zignago, 2011) and historical country sizes are taken from Banks (1975). Tariffs are constructed as customs revenue divided by imports from Mitchell (2007). The paper follows Crafts and Mulatu (2006) and Schulze (2007) in using distance (\( \delta \))

\[
MP_i = \sum_{j=1}^{n} \frac{GDP_j}{\phi_{ij}}
\]

(2.1)

\(^6\)So market potential can be thought of as \( MP_i = \sum_{j=1}^{n} \frac{GDP_j}{\phi_{ij}} \)

\(^7\) From a pure location perspective, the use of current price GDP might seem preferable to constant price-PPP adjusted GDP since that is what mattered to economic agents at the time. However, the Maddison dataset provides the largest available dataset of countries and allows the essay to go back to 1860. Moreover, the aim of the essay is not to understand the location of industry per se, but to assess macro relationships where real variables are more useful (Schulze, 2007). Market access measures for a smaller number of countries are also explored using the nominal GDP data from Prados De La Escosura (2000) and did not change the findings (in a much smaller dataset). Another issue with this type of analysis is changing boundaries. Countries were these are issues, such as Russia and Turkey, are not included in the analysis (Broadberry and Klein, 2012).

\(^8\) An alternative approach is to base bilateral distance between the biggest cities of each country weighted by their share in the overall country population. Earlier versions of the essay experiments with this approach, but for European countries the differences in the profile of market potential were small. Differences in the two approaches reflect mostly a level effect that are controlled for by country fixed effects employed in the paper.
and tariff ($\gamma$) elasticities of 0.8 and 1 respectively from Estevadeordal et al. (2003).

Transport costs in the simple market access measure are fully captured by the distance elasticity. However, distances, and hence transport costs, do not change over time and this ignores market access improvements from transport cost reductions (Holl, 2004). This is a potentially serious omission in a late nineteenth century characterised by dramatic falls in transport costs (Mohammed and Williamson, 2004).

Distance in the spatial context can also be interpreted as the "cost of distance." Taking into account the freight rates of different modes of transport, nodes and geographical location some regional studies construct bilateral transport costs (Schulze, 2007). While useful in a country, regional or city setting, this is more difficult in a macro setting. Accurate transport cost data between country pairs are very difficult to obtain, even with modern data (Hummels, 2001). The number of nodes between the nineteen countries in the sample would be too large to construct or interpret.

The essay’s approach is to weight distance by global freight indicies. The essay experiments with different transport weights (e.g. if a central European country is landlocked than ocean freight rates may be less relevant), however for space reasons I only present market access using a combined ocean (Kaukiainen, 2003) and rail (Cain, 1980) index. ⁹

Figures 2.2 and 2.3 show market access and potential at the start and end of the sample period, 1860-64 and 1910-14. All measures are relative to the UK in 1860-64. Market access measures are higher than market potential for all countries in the sample. This reflects the lower gravity equation distance elasticity weighting, falling transport costs and for some countries lower tariffs. ⁸ The rank orders ⁹⁰

⁹ Ocean freight rates fell faster than railway freight rates in this period and this combined index approach risks underestimating market access for those countries where shipping or perhaps canal expansion was a more important mode of transport. Sensitivity analysis shows that the econometric findings are not particularly sensitive to different weightings in the freight index. ⁸⁰Note that in (1) $\delta$ is implicitly set at -1, compared to the gravity elasticity of -0.8
of both market potential and market access are stable over the period. The largest values of both are consistently found in the UK and core countries of Belgium, Switzerland, France and Germany. As expected, the lowest market access (and potential) countries were scattered around the European periphery and in the new world countries.

The market access (and potential) findings also show a relatively modest US market access that was only on par with some of the middle ranking European countries (Figure 2.5). The reasons are straightforward. Firstly, the US is much further from the high GDP European countries and suffers from a strong distance discounting effect. Secondly, the size of the internal US domestic market limits own market potential.\(^{11}\)

A corollary is the high market potential of relatively small but geographically central countries like Belgium and the Netherlands. Indeed, under a set of market access measures that omit the home country from market access, geographically central Belgium and the Netherlands overtake the UK as the country with the highest Foreign Market Access (Figure 2.4). The foreign market access component of core Netherlands and Belgium reached two-thirds of the total compared to less than one-third for the US.

The new economic geography (NEG) literature is part of a wider spatial economics literature that also embraces regional and urban economics (Ciccone and Hall, 1996). These tend to focus more on population density measures (and variants) as indicators of proximity to the domestic market (Brakman et al., 2009). In these class of models, higher density translate into lower aggregate domestic transport costs. Population density is constructed for each country using population data from Mitchell (2007) and historical country size measures from (Banks, 1975).\(^{12}\)

\(^{11}\)Australia has the lowest market access in the sample and is the most extreme example of these effects.

\(^{12}\)These measures are very similar to those of Clemens and Williamson (2004) and are highly correlated with Bairoch and Goertz’s (1986) measure of urban population density.
Figure 2.2: Market access: 1860-64 to 1910-14. (UK=100 in 1860-64)

Figure 2.3: Market potential: 1860-64 to 1910-14. (UK=100 in 1860-64)
Figure 2.4: Foreign market potential: 1860-64 to 1910-14. (UK=100 in 1860-64)

Figure 2.5: Population density: 1860-64 to 1910-14. (UK=100 in 1860-64)
Although population density increases for all countries across the period, it shows more variation across European countries than market access. Figure 2.5 shows that it ranges from highs in Belgium to lows in Scandinavia. Densities for the vast new world countries were substantially lower by some orders of magnitude.

Table 2.1 shows the simple correlation coefficients between the ad-hoc market potential (MP), the theoretically derived market access (MA) and foreign market access (FMA) and population density (POPD) measures between 1860-64 and 1910-14. The sum of all distances to other countries in the sample is also included as a baseline. All three access measures are negatively correlated to distance. Despite differences in levels, the correlation between market access and ad-hoc market potential is very high at 0.952. The correlation between foreign market access and market access is 0.844 (and market potential slightly lower at 0.767).

<table>
<thead>
<tr>
<th></th>
<th>lnMP</th>
<th>lnMA</th>
<th>lnFMA</th>
<th>lnPOPD</th>
<th>lnDIS</th>
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<tr>
<td>lnMP</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnMA</td>
<td>0.952</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnFMA</td>
<td>0.767</td>
<td>0.854</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnPOPD</td>
<td>0.779</td>
<td>0.676</td>
<td>0.546</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>lnDIS</td>
<td>-0.4723</td>
<td>-0.443</td>
<td>-0.481</td>
<td>-0.392</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: Variables as defined in the text.

As expected, market potential and market access are positively correlated with population density, since they both capture the domestic economy component. The lowest pairwise correlation is between foreign market access and population density, and is expected because (by definition) the latter ignores access to foreign markets.

Two further features of these correlations are notable. First, is that they are less than perfect. This suggests that each can be seen as measuring a different aspect of a country’s geography. A second notable feature is the (remarkable) similarities between historical correlations and those recently reported for modern countries (Boulhol and de Serres, 2010).
2.5 Methodology and results

2.5.1 Benchmark results

Figure 2.6 visualizes the four metrics from Section 2.4 and the per capita levels of industrialisation measure of Bairoch (1982) for the full sample. Both market access (correlation coefficient of 0.739) and market potential (correlation coefficient of 0.725) are strongly and positively correlated to industrial development. The correlation is much lower for the foreign market access variant (0.487). Population density (0.382) is the most erratic metric and shows little discernible visual correlation with per capita levels of industrialisation.

Two features of the data are notable for the econometric analysis. Firstly, reflecting the panel nature of the sample, is the clustering of country observations. And secondly is the presence of outlier countries. As a first step in assessing the role of these geographical metrics in determining industrial development, a simple specification is estimated in 2.3 that will serve as a benchmark for more sophisticated approaches:

\[
\ln (\text{ind}_{it}) = \alpha_i + \beta \ln (\text{geog}_{it}) + \epsilon_{it} \tag{2.4}
\]

where \(\text{ind}_{it}\) is the Bairoch (1982) industry measure for country \(i\) in time period \(t\) and \((\text{geog}_{it})\) is the geographical metric. Country fixed effects are included to remove unobserved country heterogeneity, such as institutional quality or absolute ("first nature") geography. The latter might include physical geography, climate, coastal location, canal networks or access to natural resources (Krugman, 1999).

Time fixed effects are added to control for cyclical factors or other shocks affecting all countries. Historically, this could include technological innovations. Given the presence of outlier countries, Table 2.2 also present the results for a Europe only sample. Table 2.2 shows that both the theory based market access and ad-hoc

\[13\] All variables are 5-year averages and in logarithms.
market potential measures are positively associated with industrial development across both the European and world samples. Only market access is significant across both samples. Foreign market access and population density are both erratic, and the coefficients even swap signs across the samples.

Compared to unreported pooled OLS estimates, market access (and potential) coefficients are much higher and suggests a tendency to underestimate the effects in cross-sectional analysis. The high $R^2$ value is a typical finding in specifications controlling for both country and time effects. The sensitivity of the coefficients in the different samples appears to bear out concern with mixing European and world samples.

\footnote{Hausman tests easily reject a random effects model. The F statistic on the joint significance of the time dummies is around 30 and significant in all specifications.}

\footnote{Given the the long time period involved, this might also reflect a positive time trend in industrial development. However, a simple time trend performs poorly. Panel estimates in first differences, implying the inclusion of time fixed effects only, confirm much of the panel estimates in Table 2.2, albeit with a reduced coefficients. A drawback of the first difference approach is the loss of valuable data.}
Figure 2.6: Per capita levels of Industrialisation and the four measures compared
Table 2.2: Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>lnMP</td>
<td>0.785* (0.390)</td>
<td>0.364 (0.803)</td>
</tr>
<tr>
<td>lnMA</td>
<td>1.230*** (0.429)</td>
<td>2.003** (0.993)</td>
</tr>
<tr>
<td>lnFMA</td>
<td>0.617 (1.167)</td>
<td>-0.323 (1.132)</td>
</tr>
<tr>
<td>lnPOPD</td>
<td>0.189 (0.402)</td>
<td>-0.0799 (0.456)</td>
</tr>
<tr>
<td>N</td>
<td>209</td>
<td>209</td>
</tr>
<tr>
<td>DWH</td>
<td>0.445</td>
<td>0.768</td>
</tr>
<tr>
<td>Morans</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>R^2</td>
<td>0.859</td>
<td>0.877</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors clustered at country level in parentheses *** p<0.01, ** p<0.05, * p<0.1. All variables are 5-year averages and in logarithms. Fixed effects and 5 year time dummies included but are not reported. DWH is the Durbin-Wu-Hausman test for exogeneity. The p value for the null of an exogenous regressor is reported. Morans I is the p value for Morans I spatial autocorrelation in the Fixed effects residuals. (1)-(4) cover the full 19 countries and (5)-(8) cover the 15 European countries only.
2.5.2 Robustness checks

However, even tentative conclusions from Table 2.2 should proceed with caution. Previous literature and the diagnostic statistics point to two potential problems that I will deal with in turn.

Market access and potential on the right-hand side of 2.4 are a weighted sum of all GDPs that include its own. It is reasonable to assume that these depended on the degree of industrial development and so raise concerns of reverse causality. There might be reasons to worry about this as well for population density. In such cases, the error term would by construction be correlated with the explanatory variables and give biased estimates. The Durbin-Wu-Hausman (DWH) tests provide mixed findings on exogeneity, and these are in line with Bosker and Garretsen (2009). Given the difficulty of testing for endogeneity in small samples, much of the mainstream literature adopt specifications that mitigate any potential for this.

Table 2.3 shows the lagged variable approach favored by many in the literature. There is a similar pattern of results but with a generally lower order of magnitude. Again, market access continues to show the greatest significance with an elasticity in excess of unity. Lagged population continues to be erratic and show little economic significance but foreign market potential is positive across both samples. The DWH tests find no evidence of endogeneity for market access specification, but there is some evidence of traces in the smaller European sample. These lagged approach findings are not surprising as all of these variables are strongly persistent.\(^\text{16}\)

An alternative approach to deal with simultaneity is to find an instrument that is not influenced by industrial development, but is related to market access/potential and population density. Such instruments are scarce, and even

\(^{16}\)The DWH test, suggested by Davidson and MacKinnon (1993), includes the residuals of each endogenous right-hand side variable as a function of all exogenous variables in a regression of the original model. One of the problems with this approach is that suitable instruments are needed.

\(^{17}\)The foreign market access findings are surprising, since this variable does not include own GDP and is expected to go some way to reducing the circularity inherent in regressing industrial / economic activity on market access (Head and Mayer, 2011).
more so when searching for one offering variation over time as well as countries. One group of instruments popular in the mainstream literature, and which are available historically, are physical measures of geography (Head and Mayer, 2011). These include distance and country size measures, and can be justified as they arithmetically enter the market access / potential calculations.

However, a problem with physical geography instruments is that they are time invariant. Boulhol and de Serres (2010) overcome this by allowing (time invariant) distance to vary across time through interaction with the time dummies. The choice of distance is not itself immune from endogeneity, and to overcome this I follow previous studies in using the sum of the distances to countries in a sample, rather than a specific location (such as distance to Brussels or London).\(^{18}\)

\[^{18}\text{In other words, the proposed instruments are } Z_{it} = h_t \times \Sigma d_{ij} \text{ where the } h_t \text{ are time dummies and } d_{ij} \text{ the distances between countries } i \text{ and } j.\]
### Table 2.3: Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14 (lagged approach)

<table>
<thead>
<tr>
<th></th>
<th>World</th>
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<th></th>
<th>Europe</th>
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<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>lnMP(-1)</td>
<td>0.699*</td>
<td>(0.385)</td>
<td></td>
<td>0.221</td>
<td>(0.763)</td>
<td></td>
</tr>
<tr>
<td>lnMA(-1)</td>
<td>1.145***</td>
<td>(0.387)</td>
<td></td>
<td>1.774*</td>
<td>(1.000)</td>
<td></td>
</tr>
<tr>
<td>lnPOP (-1)</td>
<td>0.0762</td>
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<td>(0.436)</td>
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</tr>
<tr>
<td>lnFMP(-1)</td>
<td>0.772</td>
<td>(1.213)</td>
<td></td>
<td>0.0243</td>
<td>(1.075)</td>
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<td>209</td>
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<tr>
<td>Morans</td>
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<tr>
<td>DWH</td>
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<td>0.841</td>
<td>0.843</td>
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</table>

Notes: Robust standard errors clustered at country level in parentheses *** p<0.01, ** p<0.05, * p<0.1. All variables are 5-year averages and in logarithms. Fixed effects and 5 year time dummies included but are not reported. DWH is the Durbin-Wu-Hausman test for exogeneity. The p value for the null of an exogenous regressor is reported. Morans I is the p value for Morans I spatial autocorrelation in the Fixed effects residuals. (1)-(4) cover the full 19 countries and (5)-(8) cover the 15 European countries only. All explanatory variables are those for the preceding 5 year period.
Table 2.4: Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14. 2SLS-IV

<table>
<thead>
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<th>NA (3)</th>
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<td>(4.045)</td>
<td>(4.045)</td>
<td>(4.045)</td>
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<td></td>
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</tr>
<tr>
<td>lnPOPD</td>
<td>1.623***</td>
<td></td>
<td></td>
<td></td>
<td>2.185***</td>
<td>(0.883)</td>
<td>(0.883)</td>
<td>(0.883)</td>
</tr>
<tr>
<td></td>
<td>(0.653)</td>
<td></td>
<td></td>
<td></td>
<td>(0.883)</td>
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</tbody>
</table>

N     | 209       | 209      | 209    | 209     | 165        | 165        | 165        | 165        |
First F| 6.59      | 8.33     | 7.12   | 2.94    | 0.35       | 1.42       | 0.24       | 1.47       |
Hansen J| 1.867     | 1.233    | 3.034  | 0.709   | 4.072      | 13.808     | 4.306      | 2.124      |
Morans| 0.000     | 0.020    | 0.001  | 0.050   | 0.000      | 0.000      | 0.000      | 0.062      |

Notes: Robust standard errors clustered at country level in parentheses *** p<.001, ** p<.01, * p<.05. Fixed effects and 5 year time dummies (not reported). All variables are in logarithms. First stage f test and Hansen J over identification test reported. Instrument is the sum of distance to all countries in the sample multiplied by the time dummies. Morans I is the p value for Morans I spatial autocorrelation in the Fixed effects residuals. (1)-(4) cover the full 19 countries and (5)-(8) cover the 15 European countries only.
The 2SLS-IV estimates are shown in Table 2.4. Given the importance of systematically checking the validity of instruments, both first stage F statistics and and Hansen J over identification tests are reported. Table 2.4 continues to show a positive and economically significant market access and market potential coefficients in the world sample. Both foreign market access and population density are also significant in the world sample. However, findings for the smaller European sample are much more erratic.

As a warning sign, none of the first stage F statistics rise above the informal threshold suggested by Staiger and Stock (1997) of 10. There are strong indications of the weak instrument problem noted by numerous authors in this area (Klein and Crafts, 2012). Interestingly, however, there is little evidence that the instruments are correlated with industrial development. Unreported analysis also uncovers weak instrument issues when using country size.19

These mixed instrument findings are not surprising. Instruments for market access and population density require demanding identification assumptions (Redding, 2010). While distance is a good candidate in terms of exogeneity, since it depends only on the physical location of a country, countries are spatially integrated due to migration, inter-regional trade, technology and knowledge spillovers, and institutions (Buettner, 1999). Many of these can conflate the impact of distance on market potential/access.20

Since even mild instrument endogeneity or weak instruments can lead to IV being even more inconsistent than OLS (Bound et al., 1995), particularly in small samples, the lagged approach seems preferable. So far the only possible econometric problem occurring is from the possibility of feedback between industrial

---

19 First stage results also point to some cause for concern. In particular the distance coefficients are a mix of positive and negatives, and not as expected just negative coefficients.

20 A second set of instruments are explored which are inspired by the GMM strategy: the first and second differences in market access. Unfortunately this reduces the sample and are simply not viable when we turn to the preferred specification of adding control variables. In several cases Hansen's J-test of over identifying restrictions easily reject the validity of these instruments. Population in 1800 interacted with time dummies is also explored as an instrument for population density with little success.
envelopment and market access. One question is whether spatial interactions bias the market access coefficient in explaining industrial development? Worryingly, the Morans I test continue to show strong evidence of spatial autocorrelation in the residuals across all of the specifications. Perhaps surprisingly given the importance attached to the market access variable in the NEG literature, very few papers take this into account (Hering and Poncet, 2010).

Econometrically, one would be interested in fitting data with a spatial model for one of two reasons. First, a “spatial error” model places additional structure on the unobserved determinants of industrial development that would otherwise be captured by the traditional error term. Second, the estimation of a spatial autoregressive or “spatial lag” model accounts directly for relationships between industrial development that might be related in some spatial way.

For the essay’s purpose, the spatially-treated error structure might be seen as of secondary interest because although it may improve standard errors, it does not affect point estimates of market access. I estimate a simple spatial lag model in 2.4 where $W$ is the spatial lag weighting matrix and where $\rho$ indicates the strength and sign of any spatial relationship. I employ inverse distance between capital cities as weights.

$$\ln(\text{ind}_{it}) = \alpha_i + \beta \ln(\text{geog}_{it}) + \rho W \ln(\text{ind}_{it}) + \epsilon_{it} \quad (2.5)$$

Estimates of 2.4 are shown in Table 2.5. The inclusion of the spatial lag estimates continue to show a similar pattern of results for the geography variables although they are generally of a lower magnitude. The findings for the smaller European sample are again slightly more erratic. Market access and potential continue to be positively associated with industrial developmental and to a lesser extent foreign market in the full sample. Population density continues to be erratic in all of these specifications. The coefficients on the spatial lag ($\rho$) are positive.

---

21 More details available on request. This is analogous to a lagged dependent variable in time series analysis, and characterizes the contemporaneous correlation between one country's industrial development and other geographically-proximate countries industrial development.
across all specifications and significant in most of them, and so justifies this approach. The elasticity of around 0.5 suggests a link between country's industrial development and proximate countries development.
Table 2.5: Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14. Spatial lag approach

<table>
<thead>
<tr>
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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
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<tbody>
<tr>
<td>lnMP</td>
<td>0.682</td>
<td>0.302</td>
<td>0.302</td>
<td>0.373</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>(0.406)</td>
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<td>(0.373)</td>
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<tr>
<td>lnMA</td>
<td>0.892**</td>
<td>1.532*</td>
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<td></td>
<td>(0.428)</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>lnFMP</td>
<td>0.549</td>
<td>-0.013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.749)</td>
<td>(8.092)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>lnPOPD</td>
<td>0.210</td>
<td>-0.173</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(0.653)</td>
<td>(0.376)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ρ</td>
<td>0.678***</td>
<td>0.647***</td>
<td>0.548*</td>
<td>0.552*</td>
<td>0.6210*</td>
<td>0.553**</td>
<td>0.432</td>
<td>0.431</td>
</tr>
<tr>
<td></td>
<td>(0.221)</td>
<td>(0.273)</td>
<td>(0.291)</td>
<td>(0.297)</td>
<td>(0.332)</td>
<td>(0.278)</td>
<td>(0.294)</td>
<td>(0.403)</td>
</tr>
<tr>
<td>N</td>
<td>209</td>
<td>209</td>
<td>209</td>
<td>209</td>
<td>165</td>
<td>165</td>
<td>165</td>
<td>165</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors clustered at country level in parentheses. *** p<0.01, ** p<0.1, * p<0.5. Fixed effects and 5 year time dummies (not reported). All variables are in logarithms.
Tackling endogeneity and spatial correlation may still not provide us with accurate estimates. The fixed and time effects only control for time-invariant country-specific or country-invariant time-specific factors. In another robustness check, a series of control variables are added. The essay follows Redding and Venables (2004) in not attempting to build a sophisticated econometric model of nineteenth-century industrial development (in their case it is GDP). Instead, the main concern is whether their inclusion markedly changes the coefficients of the geography variables.

Breinlich (2006) suggests two useful control variables for market access: first human capital and second population density. Average years of schooling are included from Morrisson and Murtin (2009) and the population density measure as constructed. The historical literature also suggests other potential control variables. Relative land and labour endowments are particularly important in capturing the late nineteenth century reallocation away from agriculture, and these are taken from O’Rourke (2000).

Coal features in many historical accounts of industrialisation (Pomeranz, 2002), and a measure of annual coal production is included. While average tariffs appear in the construction of market access measures, they do not capture the mix of tariffs between those protecting agriculture and manufacturing, and the extent they could influence industrial development. Agricultural and manufacturing tariffs are taken from Lehmann and O’Rourke (2011).

Table 2.6 shows the addition of these variables with lagged values of all of the geography variables. The findings using instruments and spatial lag point to a similar findings, but the results do become more erratic when the smaller sample size is employed. These are available on request. The overall pattern of findings for market access and potential are similar to the benchmark estimates in Table 2.2. Note that the coefficients for both market access and potential actually increase as a result of adding control variables, and is counter to the findings in the modern literature. However the caveat is that the sample is reduced for data

\footnote{Data availability does not allow this for all of the variables}
availability reasons. Traces of both endogeneity and spatial correlation remain in the final specifications, but these are of different sample sizes to the benchmark results. Encouragingly, these findings are not overly sensitive to the reduced sample or its composition change. Data issues mean that some key core and periphery countries, including Greece, Portugal and Belgium cannot be included.

Table 2.6: Determinants of Per capita levels of industrialisation, 1860-4 to 1910-14

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnMP(-1)</td>
<td>1.847***</td>
<td>2.065***</td>
<td>(0.610)</td>
<td>(0.735)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnMA(-1)</td>
<td>1.644***</td>
<td></td>
<td>(0.626)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnFMP(-1)</td>
<td></td>
<td>0.926***</td>
<td>(0.322)</td>
<td></td>
<td>0.628*</td>
<td>(0.352)</td>
</tr>
<tr>
<td>lnPOPD(-1)</td>
<td>-0.711</td>
<td>-0.418</td>
<td>0.504</td>
<td>-0.687</td>
<td>-0.398</td>
<td>0.235</td>
</tr>
<tr>
<td></td>
<td>(0.600)</td>
<td>(0.608)</td>
<td>(0.291)</td>
<td>(0.726)</td>
<td>(0.857)</td>
<td>(0.845)</td>
</tr>
<tr>
<td>lnAGTARIFF</td>
<td>0.734</td>
<td>0.563</td>
<td>-0.00472</td>
<td>0.818</td>
<td>0.323</td>
<td>-0.138</td>
</tr>
<tr>
<td></td>
<td>(0.472)</td>
<td>(0.510)</td>
<td>(0.727)</td>
<td>(0.669)</td>
<td>(0.612)</td>
<td>(0.783)</td>
</tr>
<tr>
<td>lnMANTARIFF</td>
<td>0.511</td>
<td>0.722</td>
<td>0.688</td>
<td>1.162</td>
<td>1.362</td>
<td>1.609</td>
</tr>
<tr>
<td></td>
<td>(0.865)</td>
<td>(0.792)</td>
<td>(0.989)</td>
<td>(0.707)</td>
<td>(0.799)</td>
<td>(1.002)</td>
</tr>
<tr>
<td>lnLANDLAB</td>
<td>0.611***</td>
<td>0.723***</td>
<td>0.735***</td>
<td>0.414**</td>
<td>0.391</td>
<td>0.303</td>
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<tr>
<td></td>
<td>(0.137)</td>
<td>(0.149)</td>
<td>(0.188)</td>
<td>(0.221)</td>
<td>(0.263)</td>
<td>(0.422)</td>
</tr>
<tr>
<td>lnCOAL</td>
<td>0.109</td>
<td>0.130</td>
<td>0.269**</td>
<td>0.126</td>
<td>0.172</td>
<td>0.297**</td>
</tr>
<tr>
<td></td>
<td>(0.0946)</td>
<td>(0.0999)</td>
<td>(0.143)</td>
<td>(0.111)</td>
<td>(0.127)</td>
<td>(0.154)</td>
</tr>
<tr>
<td>lnSCHOOL</td>
<td>-0.204</td>
<td>-0.363</td>
<td>-0.696</td>
<td>-0.164</td>
<td>-0.369</td>
<td>-0.673**</td>
</tr>
<tr>
<td></td>
<td>(0.266)</td>
<td>(0.289)</td>
<td>(0.370)</td>
<td>(0.233)</td>
<td>(0.260)</td>
<td>(0.317)</td>
</tr>
<tr>
<td>Observations</td>
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<td>72</td>
<td>72</td>
<td>56</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>r squared</td>
<td>0.969</td>
<td>0.965</td>
<td>0.949</td>
<td>0.961</td>
<td>0.950</td>
<td>0.930</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors clustered at country level in parentheses *** p<0.01, ** p<0.1, * p<0.5. Fixed effects and 5 year time dummies (not reported). All variables are in logarithms. Fixed effects and 5 year time dummies included. Control variables as described in the Table 2.7.

Note that population density is now added alongside market access and remains
erratic. Including a measure of (lagged) urban population density from Bairoch (1986) arrives at similar results. Interestingly, foreign market potential is now significant in both samples, although this smaller sample excludes two countries with the highest foreign market potential in the sample: Belgium and the Netherlands.

Interpreting the control variables is much more difficult because they are all highly endogenous. The need to instrument tariffs is shown by Lehman and O'Rourke (2011). Exploring these is outside the scope of the paper. Indeed with the exception of the highly endogenous land-labour ratio, none of these other controls are significant.

In a final robustness check, all specifications are re-run on the two alternative measures of industrial development discussed in section 2.3. The first of these is the industry share of national income measure from (Mitchell, 2007).\textsuperscript{23} Table 2.8 shows that both market access and potential are positively associated with this alternative measure of industrial development, and interestingly with similar elasticities to those from the Bairoch (1982) dataset. Foreign market potential continues to show sensitivity to the sample, although its value in the Europe sample is similar to the main sample. Population density is now consistently negative. The second dataset that is used for comparison is the manufacturing growth rate series assembled by Bénétrix et al. (2012). Table 2.9 shows that manufacturing growth rates are all positively and significantly associated with the first difference of all the four spatial metrics, although only significant for market access and potential.

2.6 Discussion

Several aspects of these findings for late nineteenth century industrial development echo those from the modern spatial economics literature (Brakman et al., 2009). The essay provides further evidence to support Combes's (2008) view of the close link between the spatial structure of economic activity between coun-

\textsuperscript{23}The results are similar to a specification using a logistic transformation to account for the fact the industry share is limited to a range between 0 and 1.
tries and the measure of market potential. The mixed performance of population density in explaining between country differences is also consistent with this as a better metric to explain economic activity at smaller spatial scales, such as regions or cities (Brakman et al., 2009). The essay also provides further evidence of the reasonable performance of the ad-hoc market potential measure compared to more complex approaches that draw on gravity equations (Head and Mayer, 2011).

Making causal links in small panel datasets is hazardous, particularly where there are endogeneity (and spatial correlation) issues. The essay's findings have three advantages. Firstly, is using structural variables developed in the economic geography literature. While in some specifications the ad-hoc market potential variable performs reasonably well, it does not have the structural interpretation of market access. Secondly, by explicitly incorporating spatial dependence into the modeling, I ensure that market access is purged of any "spillover" effects that allows us to draw a more precise picture of the spatial interaction between countries.

A third advantage of the findings is the consistency with several features of historical industrial development. For example, the historical experience shows that high levels of population density were neither sufficient nor necessary for industrial development and support the essays finding in this regard. China and India (not included in the sample) had large population densities, but low levels of industrial development. By contrast, the US in the late nineteenth century had a vast territory and a relatively small population, yet achieved rapid growth (Lin, 2006).

The original impetus for the market access approach was trade and this is a good place to start interpreting the findings. The importance of market access, whether through favorable location or increasing openness through falling transport costs and tariffs, are key themes in the nineteenth century globalisation.

---

24Some of the results for market access do point to an elasticity in excess of unity which is consistent with industrial development growing in excess of overall GDP, which is one key elements of market access.
literature (O'Rourke and Williamson, 1997). One aspect relevant to industrial development was the ability of periphery countries to trade their cheaper manufactured goods abroad to build up their industrial base, while primary producers were able to sell goods cheaper into these core markets which further reduced their reliance on agriculture. European trade roughly quadrupled in real terms between 1870 and 1913 (Maddison, 2005).

The market access story fits the convergence of peripheral Scandinavia well (Edvinsson, 2011). Sweden saw a quadrupling of industry per capita between 1860-64 and 1910-14 (Bairoch, 1982), despite having a small domestic market and no coal resources. Sweden did see a five-fold increase in market access over this period, of which two-thirds was generated non-domestically. Capital imports after 1870 expanded the Swedish capital stock by 50% and timber exports surged. As Cameron (1985) notes, coal consumption in countries such as Sweden was not inhibited, given "the ease with which countries could obtain coal from Britain's north-eastern coalfields."

These patterns were also replicated on a smaller scale in Denmark and Norway (O'Rourke and Williamson, 1997). The foreign aspect of market potential is also consistent with successful industrial development in small countries such as Belgium, whose small domestic size was not a barrier to large scale factory production to exploit economies of scale (Hannah, 2008).

However, for many countries in the sample, the bulk of total market access was generated domestically. In Germany and Britain it was around two-thirds and in the US at the end of the period around 80%. The findings for market access cannot ignore the role of the domestic market. This is consonant with the emphasis in the economic history literature on domestic market size. Romer (1996) suggests that the US's internal market and its natural resources allowed it to overtake Britain by the late 19th century.

The US saw an approximate five-fold increase in both industrial development and market access. Two-thirds of this was generated domestically. Sokoloff (1988)
and others have argued that it was this large domestic market that incentivized inventive activity leading to productivity advances. Klein and Crafts (2012) using formal geography approaches shows how it was primarily domestic market access that was important to explain the emergence of the domestic US “Manufacturing Belt.”

Counter-factual analysis has proved useful in the literature to illustrate the effect of changes in geography (Redding and Venables, 2004). Based on these estimates, a peripheral European country like Portugal moving to the European core in 1870-74 would have seen per capita industrial development more than double to German levels. Bringing the US to the centre of Europe in 1870 would have seen it surpass Britain to become the world’s leading industrial nation. Shrinking the US to the size of France would have seen its industrial development on par with Britain in 1870. In the vein of NEG, this latter usefully reiterates how large distances in the United States also provided natural barriers to trade (Hannah, 2008). While these counterfactual exercises usefully reinforce some of the magnitudes involved, they need careful interpretation. Regression coefficients need to be seen as partial equilibrium in nature, and the assumption that other variable are unchanged unrealistic.

The essay’s findings could be read as showing that neither a purely domestic measure, such as population density, nor a purely external measures, like foreign market potential, can fully capture industrial development in this period. In fact, the foreign market potential variable is much more erratic than the market access variable, while population density does not always even have a consistent sign. However, Head and Mayer (2011) note that foreign market potential is a departure from the theory and is likely to produce erratic results. They caution against attempting to split out domestic and foreign components of market access.

25Calculated assuming a unit elasticity between market access and industry.
26Another consideration is that applying regression coefficients to outlier countries can produce unrealistic predictions (Bouhlool and Serres, 2008)
27Using an example of the United States, they note that while the USA has a much larger market access than Canada and Brazil, it has a much lower FMP. If foreign demand was the only driver of factor incomes in the NEG model, Canada and Mexico should both be richer than the USA. On the contrary, the “NEG model predicts that the United States should be richer
Unfortunately, the essays macro approach does have limitation in testing specific historical growth models, such as the role of external and internal factors. The essay's findings do have other implications for thinking about historical economic development. Two warrant further note. One is that market access is increasingly linked to outcomes other than trade. This essay explores one extension in the form of industrial development. Market access has also been increasingly been linked to migration, foreign direct investment and human capital accumulation in the literature (Brakman et al., 2009). All of these, and particularly the latter, are of potential interest to historians and warrant further research.

Another consideration is the persistent spatial correlation in the data across all of the different specifications. This spatial correlation can arise from the omission of variables with a spatial dimension. However, the panel nature of the data and use of control variables should have helped to mitigate this channel of influence. Countries are spatially integrated due to migration, inter-regional trade, technology, knowledge and institutions (Buettner, 1999). This spatial dependence can also be generated by "spillovers" (such as technology externalities) due to the mobility of goods, workers or capital. While the essay does not search for the sources of spatial dependence, all of these could be useful in thinking about historical development in an increasingly global nineteenth century.

The essay's aggregate approach might be seen to mask regional and sectoral developments that are are equally important in understanding historical industrial development. Relatively low industrial development in Italy masked significant development in the triangle between Genoa, Milan and Turin (Pollard, 1981). Around eighty percent of US manufacturing took place in less than 20% of the land space of USA in the "manufacturing belt" (Klein and Crafts, 2012). There was also uneven development across different sectors of industry. The period after 1870 saw the development of a new scientific approach to industry that was associated with new industries, such as synthetic dyestuffs, that were based around than its two neighbours precisely because it has a large internal demand that makes it a more profitable location for firms." (Head and Mayer, 2011)
on new chemical processes, electricity and sources of energy. These also affected many old industries, such as brewing, iron and steel where research was able to improve both processes and products (Broadberry et al., 2008).

The essay’s aggregate findings can be seen as complementary to understanding these regional and sectoral industrial developments. As previously noted, Klein and Crafts (2012) show these market access tendencies were reinforced at the regional level and dwarfed the role of natural endowments in explaining the emergence of the US “manufacturing belt.” For Britain, while initial industry initially responded to factor endowments they were later reinforced by these strong market access effects (Crafts and Mulatu, 2006). The so-called “second industrial revolution” freed industry from the constraints of location around natural resource deposits (Mokyr, 1999). An interesting research question is whether, as expected, this made market access considerations more important?

Notwithstanding this structural interpretation, Redding (2010) notes that “it is difficult empirically to disentangle the effects of market access from other leading determinants of comparative economic development such as locational fundamentals or institutions.” In this regard, the use of panel data is a powerful tool. Of course, these findings for market access do not rule out the possibility that other factors contributed to industrial development.

Indeed, the market access story cannot on its own fully capture industrial development experience of all countries. For example, peripheral countries such as Austria and Italy had market access levels in excess of the Scandinavians in 1870, but did not replicate their success. Several of these countries appear to have exported, rather than imported, capital for much of this period. Similarly, the long-standing literature looking at domestic market size issues struggles to explain early industrial development in Britain compared to China (Lin, 2006).

As Williamson (2010) reminds us, understanding historical economic growth is not straightforward: “answers are as complex as any question dealing more generally with the causes of modern economic growth, and no doubt any answer should
include fundamentals like culture, geography, institutions and good government.” A key contribution of the essay is to provide a neat methodology to explore one of these: geography.

2.7 Conclusion

Baldwin (2007) notes that linking economic geography ideas to history is an old idea; “Kuznets, Myrdal, and Rostow gave geography and agglomeration forces centre stage in their theories, but they lacked tools to formalize the links.” The standard empirical methodology developed in the NEG literature has prompted a burst of research exploring the role of economic geography and provides a promising framework for historical research.

The paper makes contributions in two main areas: methodological and historical. The main historical contribution is showing quantitatively how economic geography can help to explain the core and periphery patterns of late nineteenth century industrial development. These findings are consistent across different samples, measures of industry, and robust to the inclusion of control variables. They are also robust to specifications that explore endogeniety and the spatial correlation in the data. The findings complement a much larger literature on regional industrial historical growth.

A second methodological contribution to the wider spatial literature is providing further evidence to support Combes’s (2008) view of the close link between the spatial structure of economic activity between countries and the measure of market access. As in the modern literature, these appear to better capture historical differences in cross-country industrial development than population density. The essay also provides further evidence showing the reasonable performance of the ad-hoc market potential measure.

While drawing causal conclusions from relatively small historical samples is hazardous, there are several reasons to believe the findings are more than spurious. This includes the structural nature of the model and consistency with several
themes in the historical literature on economic envelopment. Since both “own” and foreign elements make up market potential they appeal to both domestic and international factors in shaping industrial development. The findings do not come without puzzles and market access should be seen as a potential missing explanatory variable to explain modern economic growth, alongside fundamentals like culture, institutions and good government (Williamson, 2010).

The essay’s findings could also provide the basis for further research to shed light on the causes of uneven industrial development. Firstly, market access is increasingly linked to a range of outcomes other than trade in areas such as in human capital. Secondly, while included principally for econometric purposes, the persistence of spatial lag effects warrant further investigation. One possibility is that it might reflect “spillovers” between countries. Unfortunately, the large detailed sectoral and cross-country datasets that modern researchers have available to examine cross country differences in outcomes are not available historically. One interesting way to explore cross country differences further could be through greater use industry studies like Crafts and Wolf’s (2013) analysis of cotton in the nineteenth century.
Chapter 2 Appendix

List of countries

(Bairoch, 1982): Belgium, Denmark, France, Germany, Italy, Netherlands, Portugal, Finland, Spain, Sweden, Switzerland, Britain, Greece, Portugal, Japan, Australia, Canada, Brazil and the United States.

(Mitchell, 2007): Belgium, Denmark, France, Germany, Italy, Finland, Sweden, Britain, Greece, Japan, Australia, and the United States.

(Bénérix et al., 2012): Belgium, Denmark, France, Germany, Italy, Netherlands, Portugal, Finland, Spain, Sweden, Switzerland, Britain, Portugal, Japan, Australia, Canada, Brazil and the United States.

<table>
<thead>
<tr>
<th>Table 2.7: Data sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
</tr>
<tr>
<td>Industry as share of GDP</td>
</tr>
<tr>
<td>Industry per capita</td>
</tr>
<tr>
<td>Manufacturing growth rates</td>
</tr>
<tr>
<td>Distance</td>
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<tr>
<td>Country Size</td>
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<tr>
<td>Tariffs</td>
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<tr>
<td>GDP</td>
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<tr>
<td>Land-labour ratio</td>
</tr>
<tr>
<td>Coal</td>
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<tr>
<td>Ag tariff</td>
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<tr>
<td>Man tariff</td>
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<tr>
<td>Schooling</td>
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</table>
Table 2.8: Determinants of industry as a share of GDP (BR Mitchell), 1860-4 to 1910-14

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>lnMP(-1)</td>
<td>0.959***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.311)</td>
<td></td>
</tr>
<tr>
<td>lnMA(-1)</td>
<td></td>
<td>1.052***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.286)</td>
</tr>
<tr>
<td>lnFMP(-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnPOPD(-1)</td>
<td>-0.744**</td>
<td>-0.712**</td>
</tr>
<tr>
<td></td>
<td>(0.354)</td>
<td>(0.341)</td>
</tr>
<tr>
<td>lnLANDLAB</td>
<td>0.0921</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td>(0.190)</td>
<td>(0.177)</td>
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<tr>
<td>lnCOAL</td>
<td>0.0276***</td>
<td>0.0298**</td>
</tr>
<tr>
<td></td>
<td>(0.0153)</td>
<td>(0.0154)</td>
</tr>
<tr>
<td>lnSCHOOL</td>
<td>-0.137</td>
<td>-0.171*</td>
</tr>
<tr>
<td></td>
<td>(0.125)</td>
<td>(0.113)</td>
</tr>
<tr>
<td>lnMANTARIF</td>
<td>0.0649</td>
<td>0.209</td>
</tr>
<tr>
<td></td>
<td>(0.786)</td>
<td>(0.792)</td>
</tr>
<tr>
<td>lnAGTARIF</td>
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<td>-0.558</td>
</tr>
<tr>
<td></td>
<td>(0.535)</td>
<td>(0.550)</td>
</tr>
<tr>
<td>Observations</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>R squared</td>
<td>0.783</td>
<td>0.779</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors clustered at country level in parentheses. *** p<0.01, ** p<0.1, * p<0.5. Fixed effects and 5 year time dummies (not reported). All variables are in logarithms. Fixed effects and 5 year time dummies included. Control variables as described in the text. Sample is taken from BR Mitchell (2007).
Table 2.9: Manufacturing growth rates, 1870-1914

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
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<td>dlnMP</td>
<td>0.349***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.070)</td>
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<tr>
<td>dlnMA</td>
<td>0.372***</td>
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<tr>
<td></td>
<td>(0.078)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dlnFMA</td>
<td>0.153</td>
<td>0.114</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.100)</td>
<td>(0.071)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>171</td>
<td>171</td>
<td>171</td>
<td>171</td>
</tr>
<tr>
<td>R squared</td>
<td>0.337</td>
<td>0.339</td>
<td>0.246</td>
<td>0.254</td>
</tr>
</tbody>
</table>

Notes: Robust standard errors clustered at country level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables are in logarithms. 5 year time dummies included. First difference of all explanatory variables used. Sample is taken Bénétrix et al. (2012).

Figure 2.7: Wages, GDP and Industry
Figure 2.8: Correlation between different Industry measures
Chapter 3

Anthropometrics and occupations in nineteenth century Britain and Ireland: Some evidence from the East India Company army

3.1 Introduction

It has been recognized since Roman scholars that taller adults tend to hold jobs of higher status (Schick and Steckel, 2010). Early statistical analysis of this link dates back at least a century to Gowin’s (1915) survey showing differences in the heights of US executives and average men. Recently, attempts have been made to go beyond correlation and better understand the mechanisms behind the height-labour market nexus. Research shows that physical growth and skills development share many inputs such as health, nutrition and care in early life (Böckerman and Vainiomäki, 2013).

An early distinction in the mainstream literature emerged between developed countries, where the intelligence related benefits of height are emphasized, and in developing countries, where the focus is on physical abilities (Vogl, 2014) Notwithstanding Margo and Steckel’s (1982) classic work linking antebellum slave prices
to stature, much less is known quantitatively about the mechanisms behind the links between stature and labour market outcomes. The lack of large and representative historical datasets, containing stature, wages and occupations, are an obvious barrier to quantitative analysis. This leaves a gap in the literature as historical differences in heights across social groups were often much larger than today. Historical analysis can also straddle the modern literature’s dividing line between economies intensive in manual labour and those in skilled labour.

Motivated by this, the essay re-examines the nineteenth century recruitment records of 30,000 British and Irish born recruits of the East India Company (EIC) army assembled by Mokyr and Ó Gráda (1996). In their pioneering analysis on health and height, the authors note that taller recruits from both islands were drawn from the more literate occupations of the day. This essay extends their analysis by using the latest econometric techniques to rigorously assess two key questions: first, was height linked to recruits’ previous occupations? and if so what types of occupations was it linked to?

While most historical military and convict records are difficult to analyze because they are not representative of the population at large, the EIC records contain an unusually large number of previous occupations. While previous labourers account for a large bulk of recruits, the records also contain previous surgeons, architects and teachers, and allows the essay to explore the links between stature across a range of occupational groupings. The answers can shed light on the relative roles of strength and intelligence in explaining historical labour market outcomes. While not a random sample of the nineteenth century United Kingdom labour market, the records do allow for an analysis of ethnically homogeneous and geographically concentrated groups over a 30-year period from a single data source.

The first stage of the empirical analysis is the coding of 30,000 occupations by skill level using the Historical International Standard Classification of Occupations (HISCO) coding scheme (Van Leeuwen and Maas, 2011). A multinomial logit model shows that taller recruits were around 30% more likely to have previously held sedentary non-manual occupations, rather than physically demanding
manual occupations. This pattern is similar across British and Irish born recruits, and urban and rural born recruits. The findings are not affected by major historical events, including the Irish famine, and are robust to controls for the economic cycle, birth cohort effects and the inclusion of a simple “age heaping” variable as a proxy for human capital.

These quantitative findings add to the generality of Deaton’s (1997) claim that the height-labour market nexus is historically reliable. The essay points to more similarities between modern and historical labour markets than one might have expected. Even for Britain, the most advanced country of the day, a vast amount of “wheeling, dragging, hoisting, carrying, lifting, digging, tunneling, draining, trenching, hedging, embanking, blasting, breaking, scouring, sawing, felling, reaping, mowing, picking, sifting and threshing was done by sheer muscular effort, day in, day out” (Harrison, 1971).

While modern scholars have access to detailed microeconomic and longitudinal surveys to separate out causation and correlation, there is a limit to what can be gleaned from recruitment records. The essay documents how two important, and related, themes in the literature can help to shed light on the findings.

Firstly, the modern research showing that nutritional status, height and childhood are rewarded in the labour market through traits such as cognitive skills, confidence, intelligence, social skills as well as physical strength (Currie, 2008). And second, the well-established findings from the biological standard of living literature showing how the wealthier are better fed and likely to be taller. They have the potential to experience superior physical growth and cognitive development and end up in higher status (and paying) occupations.

There are reasons to believe that these profound effects of early-life conditions on labor market outcomes were of equal, if not greater, importance in understanding the historical entry into occupations. Firstly, historical differences in heights between social groups were large historically compared to today. Secondly, class, parental income and background were major determinants of access to human
capital in nineteenth century Britain, such as through apprenticeships. One implication is that the modern approach of “sorting” to gauge the returns to height may simply be capturing this correlation in historical data.

Understanding how stature was rewarded historically in the labour market is, however, of more fundamental interest than simply replicating modern studies. Although no attempt is made to substantiate these links, these and other recent findings have the potential to shed new insights on the role of human capital and nutrition in economic development (Kelly et al., 2013). These share many classic ideas of Fogel (1994) on the role of nutrition, but extend his ideas in one crucial aspect by focusing on more general skill development than simply physical strength. The essay also contributes to a wider historical literature showing how height, as a marker for early life conditions, can be used as an “explanatory variable” to think about outcomes in later adult. These go beyond the labour market and include outcomes such as literacy, migration, reduced criminal tendencies and better marriage prospects (Humphries and Leunig, 2009).

The essay proceeds in four main sections. Section 3.2 sets out a review of the related literature. Section 3.3 contains a brief background on the EIC army recruits, focusing on their representatives in the nineteenth century labour market. This section also documents the HISCLASS (1990) classification of recruits’ previous occupations that underlies the analysis. Section 3.4 sets out the econometric analysis of recruits’ previous occupations and the associated robustness checks. These results are then discussed in section 3.5.

### 3.2 Literature review

In the earliest attempt to quantify the height labour market nexus, Gowin (1915) compared the heights of men of differing status in the same profession. He reported that bishops were taller on average than preachers in small towns, and sales managers were taller than salesmen. Similar results were reported for lawyers, teachers and rail road employees. Data from the antebellum American South shows that height and weight were positively associated with slave value, suggesting that better fed, healthier slaves were more productive (Margo and Steckel, 1982).
Recently, economists, with increasing access to detailed datasets, have sought to explore the underlying mechanisms behind these links rather than simply establish correlation. At least four theories have been put forward to explain these links, none of which should be seen as mutually exclusive. Height is increasingly being seen as one measure of human capital investment that are likely to be correlated with many others (Böckerman and Vainiomäki, 2013).

A predominant view for developing countries is the labour market returns to stature derive from the physical advantages of being taller and the productivity advantage in economies that rely on manual labour (Thomas and Strauss, 1997). Anthropometric measures such as body height are strongly correlated with muscular strength (Sills and Everett, 1953). The term “strength” encompasses physical health, robustness, and endurance, and predicts that taller people should have a productivity advantage in physically demanding jobs.\(^1\) Schultz (2002) concludes that an additional centimetre of adult male height is associated with a higher wage of 1.5% in Ghana and 1.4% in Brazil. Using a uniquely constructed dataset from Tanzania, Bodenhorn and Price (2009) suggests that these links have a biological foundation, whereby the energy requirements and metabolic costs associated with work effort are inversely related to stature.

In modern developed economies, where fewer jobs are physically demanding, alternative explanations have been sought to explain the labour market returns to height. Persico et al. (2004) suggest that boys who are taller during adolescence are more likely to participate in social activities that build productive human capital and these experiences are responsible for the higher earnings observed for taller men. Linked to this, Judge and Cable (2004) suggest a link between height and self-esteem, with implications for how tall individuals are perceived and evaluated by customers or employers.

\(^{1}\)Baten et al. (2013) provide an excellent literature review of the links between nutrition, cognition, educational attainment and labour market outcomes. This includes the large literature on findings from natural experiments.
These, and similar arguments, have been challenged in the influential work of Case and Paxson (2008), who argue that the height premium in earnings largely reflect the positive association between height and cognitive ability. Medical studies show that both cognitive ability and height are driven by the same endowment, and as with physical development, poor nutrition and environmental insults during the developmental years impair cognitive development. When Case and Paxson (2008) include measures of cognitive ability in childhood wage regressions, the effect of height is reduced. They also show a tendency for taller workers to “sort” into high paying (and socio economic status) occupation.

In a sense, Persico et al. (2004) type explanations see height advantages reflecting “nurture,” while in Case and Paxson (2008) it is from “nature.” One implication is that if height advantages arise from nature then it should have prevailed historically. Several papers have recently challenged these simple developed and developing country, and brains and brawn dichotomies. In developing economies, returns to cognitive capacity may still exist through entrepreneurship or general problem-solving skills (Vogl, 2014). Lundborg et al. (2009) using Swedish data show that physical capacity explains a much higher proportion of the link between height and earnings than cognitive and non-cognitive abilities, reflecting that taller people are simply healthier.

Without arguing that taller individuals have greater cognitive or social skills, a fourth explanation focuses on how discrimination might explain the preferences for particular workers in occupations (Loh, 1993). These ideas have links to evolutionary theory and social psychology, and can explain preferences for particular workers in certain occupations. A related literature emphasises the link between height and authority (Lindqvist, 2012), which also leads to discrimination against shorter people in the labour market.

Since the 1970s height has become an increasingly valuable metric for historians, driven partly by the large availability of datasets. The underlying biology of stature and the relative importance of genes and the environment are widely understood by economists (Eveleth and Tanner, 1990). Until now, however, an-
thropic history has tended to focus on trying to explain height as a “dependent variable,” rather than as a “independent variable” capable of explaining later adult outcomes (Humphries and Leunig, 2009).

This methodological switch in how height is viewed by historians reflects its several advantages as an explanatory variable. Firstly, it is a measure of net nutritional status in childhood, including the fetal period, and is a good proxy for early life conditions. In large populations, the gene pool stays approximately constant over time and changes in average heights primarily reflect the influence of environmental factors. Secondly, unlike other measures such as schooling, adult stature is largely pre-determined before the age of five and can be treated as exogenous prior to labour market entry. Thirdly, height is also linked to adult health outcomes, including life expectancy (Steckel, 2009).

In addition to these attractive features of height as an explanatory variable, there are other more fundamental reasons why economic historians might be interested in exploring these issues further. Steckel (2009) note that “is assumed that all populations have equal potential which will be fulfilled under the conditions of optimal nutritional status. Poorer than optimal nutritional status will lead to wasting and shrinking, and to diminished cognitive ability in infants and children. This will affect the relative productivity of these populations.”

Stature can therefore be linked to both growth and productivity. Fogel (1994) discussed the contribution of better nutrition to higher productivity over the last 200 years. Highlighting improved life expectancy, as well as greater resilience and strength of humans today, he concluded that 20-30 percent of total output growth could be attributed to improved food intake.

These ideas have been widely recognised in the development literature, where there is substantial evidence that poor nutrition in early childhood has a negative effect on growth through pathways such as cognitive ability (Hanson, 2005). Recently, several important papers have extended these issues historically, going beyond the simple physical strength interpretation.
Kelly et al. (2013) note the historical productivity advantages of taller English workers, compared to their French counterparts, by focusing on what Heckman (2007) calls “human capability.” This involves cognitive skills, non-cognitive skills and health, all of which are highly correlated to height. In a similar vein, Baten et al. (2013) show how malnutrition in the past may have led to poor labour market outcomes by curtailing cognitive development. They show that those affected by the food crisis of the Napoleonic War years were more likely to be shorter and end up in professions requiring lower cognitive skill and wages.\(^2\)

Linked to these ideas, a small but growing literature uses stature to understand a range of historical adult outcomes. While these papers are primarily empirical, they appeal to ideas of stature as a marker for early life conditions. In an important methodological contribution, Humphries and Leunig (2009) explore the geographical mobility of mid-nineteenth century British sailors. Among those born outside London, they found the taller and literate were more likely to migrate to London, who they saw as men with “more choices in life.”

Lantzsch and Schuster (2009) assess socio-economic status and physical stature among nineteenth century Bavarian military conscripts, and show significant height differences between the occupational groups of the conscripts even after controlling for the parents’ occupations. In a similar analysis for nineteenth century Swiss army recruits, Schoch et al. (2009) concludes that “social-class affiliation was the most important determinant of differences in the biological standard of living [measured by height],” with the influence of class and regional disparities remaining constant.

Height is also linked to range of other, perhaps less obvious, historical adult outcomes. Bodenhorn and Price (2009) assess criminal tendencies in the nineteenth century US. Consistent with the view of “height as a source of labour market disadvantage,” they find that criminals were shorter than the average American.

\(^2\)Several papers such as Dalgaard and Strulik (2012) go much further and explicitly link the timing of the fertility transition to stature.
They go on to explain how a discriminatory preference for different heights among employees created a mismatch between individuals and jobs that led to crime opportunities. Manfredini et al. (2010) examine the role of height in the process of mate selection in two Italian populations at the turn of the twentieth century. They report “differential effect of tallness by population in the process of mate choice,” which they also explain in a labour market context.

### 3.3 The EIC army records

The East India Company was established as a trading monopoly in 1600 and by the mid-eighteenth century was Britain’s imperial arm in Asia. In addition to its large Sepoy (native) battalion, it was entitled to raise European troops to serve in India. Although a private army of commercial organization, by the early nineteenth century “John Company” was over two hundred thousand strong and larger than most European state armies (Reid, 2009).

The EIC had recruitment offices in London, Liverpool, Dublin, Cork and Newry, where data was systematically and carefully collected on recruits’ ages, height, place of birth and their previous occupation. In their pioneering study, Mokyr and Ó Gráda (1996) use these records to study the health and height of recruits in the nineteenth century. However, such is the unusually large spread of recruits’ previous occupations, the records also provide a unique insight into the nineteenth century labour market of the United Kingdom.

While labourer is the most common previous occupation, accounting for about one-third of British and one-half of the Irish born, recruits also included former surgeons, doctors, architects and even priests. To make the large number of oc-

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3. The East India Company was founded by royal charter granted in 1600 and was originally named “The Governor and Company of Merchants of London Trading in the East Indies.” After merging in 1709 with the Levant Company it became “The United Company of Merchants of England trading to the East Indies.” From the passage of the Charter Act of 1833 it became referred to as the East India Company in most parliamentary documents and debates (Talbot, 2013).

4. The records are located in the archives of the East India Company, East India Library, London. They were drawn from files L/MIL/9/29/L/MIL/9/46.
ocupations manageable for analysis, each occupation is classified by its skill level using the Historical International Standard Classification of Occupations (HISCO) coding scheme derived from HISCLASS (Van Leeuwen and Maas, 2011). This is based on the historical version of the International Labor Organizations 1968 International Standard Classification of Occupations (HISCO). The main dimensions of HISCLASS are the manual/non-manual division, the skill level, the degree of supervision and the economic sector.

While the original HISCLASS taxonomy comprises twelve social classes, for econometric purposes, and to avoid very few observations in some classes, each recruit is classed into one of four groupings: I. Manual, unskilled, II. Manual, low to medium skilled, III. Non-manual, low to medium skill and IV. Non-manual, high skilled. Table 3.3 sets these out in further detail. Figure 3.1 shows that the bulk of recruits, 85%, were previously in manual categories I and II. Around 15% of the recruits came from non-manual occupations III and IV, with the the highest socio economic status occupations (IV) containing just 2.5% of recruits. However, given the large dataset, this still gives valuable information on nearly 650 recruits in group IV.

The natural baseline for any comparison of recruits’ previous occupations is historical census data. There are limitations to such comparisons. First, no HISCO/HISCLASS breakdown is yet available for historical British or Irish censuses. Historical self-reporting of occupations also leads to well-known problems of reliability, especially among the young (Mokyr, 1983). For example, a farmer’s son could have been classed as a labourer until he inherited the farm; a carpenter’s apprentice as a servant and so on. Excluding recruits aged under 20 goes some way to mitigating this problem.®

® The HISCLASS scheme builds on two systems of occupational classifications: the HISCO and DOT. The HISCO is a historical extension of the ISCO made by the International Labour Organisation. HISCO includes more than 1,600 historical occupational titles that go back to the early 16th century (Van Leeuwen and Maas, 2011). The DOT system attaches skill-contents to a wide array of 20th century occupations.

®There is no data on those Irish-born who would have been migrants and not necessarily representative of the Irish-born as a whole due to “selective migration.” The age profile and the large amount of Dublin born recruits suggests large numbers were recruited in Ireland.
Figure 3.1: Structure of EIC recruits’ previous occupations

Notwithstanding these caveats, recruits’ occupations are compared to more manageable occupational groupings of the 1841 census. This includes Shaw-Taylor and Wrigley (2008) for England and Mokyr (1983) for Ireland. Both census data and recruits’ previous occupations show a much greater industrialised and urbanised Britain, and an agriculturally dominated Ireland. This goes some way in confirming the representatives of the recruits. Mokyr and Ó Gráda (1996) also assess the recruits’ occupations by the broad literacy levels. Again, they report a reasonably representative match with census data.

The spread of previous occupations are more representative than other nineteenth century groups examined in the literature, such as English and Irish con-
victs to Australia (Nicholas and Steckel, 1991) or the elites of the day (Floud et al., 1990). The recruits' mix of previous occupations show they were not just drawn from the lowest working classes. Both previous historical analysis and these occupational groupings suggest two main motivations for recruits joining the EIC.

Firstly, the data are consistent with a view of recruits as economically motivated men. These considerations were not trivial in a period characterised by sharp economic downswings (Broadberry and Leeuwen, 2010). While an extreme view of recruits might be “mercenary and tradesman obsessed with making money” (Reid, 2009), contemporary evidence also points more to the search for economic security. One Irish EIC recruit during the Famine noted that “a soldier’s rations in India are more than enough, and extras, like fowl, eggs, sweetmeats, and fruit are available and are not beyond he means of any soldier in India.”

Secondly, the data also fits a view of the EIC army as attracting men who were “down on their luck” or with something in their past they wished to escape. Heathcote (1974) likened the EIC recruits to the later French Foreign legion, where few questions were asked about their background: drink, petty crimes and family problems were possible reasons for joining up. Given such problems did not recognize social boundaries, this second factor helps to explain the small but steadily flow of previous surgeons, doctors and architects into the EIC. The proportion of recruits coming from category IV also shows strong cyclical patterns in Figure 3.2 and suggests that both factors might have been at work.

Another attractive feature of the data is the large geographical spread of recruits. While accounting for less than one-third of the population of the United Kingdom, Figure 3.2 shows the Irish-born supplied 45% of EIC recruits between 1830 and 1857, rising to 50% pre-famine. The over-representation of the Irish was

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7Corporal Maurice Moriarty of the East India Company in a letter to his family in Kerry. Reported in (Karsten, 1983), page 38.

8The records did not contain any further information about the roles than men filled on entry into the EIC. Given the large areas covered by the EIC, it is likely that many of them would have worked in areas of their previous expertise (Talbot, 2013).
consistent with the numbers of Irish born in the regular British army (Karsten, 1983). Urban areas were also over-represented in the EIC (55% of all recruits), and particularly those born in London and Dublin (10%). Those born in the early cradles of industrial development were generally under-represented (10%), possibly reflecting their alternative employment opportunities. The Scots and Ulster-born were also under-represented.®

As in all anthropometric datasets, there are selectivity issues with the EIC recruits (Bodenhorn et al., 2013). Although these are perhaps less obvious than prison, convict or regular military records they need to be borne in mind when interpreting the results. Mokyr and Ó Gráda (1996) note that because incomes

®Large towns were defined as places containing over 10,000 inhabitants in 1800. Industrial areas were defined as comprising Lancashire, the West Riding of Yorkshire, and Cheshire for Britain, and East Ulster for Ireland. Cities were selected based on DeVries (1984). A full description of all of the geographical definitions are in Table 3.5.
were lower in Ireland than England, the EIC tended to draw recruits from the wealthier Irish. Recruits were also younger than the population as a whole and women were excluded.\textsuperscript{10}

Another consideration is that minimum heights were imposed on EIC recruits, reflecting both supply and demand pressures facing the company for men. However, this essay’s interest in height is as “explanatory” and not “dependent” variable. As such, the imposition of minimum heights does not lead to the econometric biases that have been widely documented in the anthropometric literature (Wachter and Trussell, 1982). However, the imposition of minimum heights does have implications for interpreting the results as the recruits were drawn from the tallest sections of the population of both islands. The average height of British born recruits (excluding those under 20) was 67.6 inches; half an inch taller than

\textsuperscript{10}Although the modern literature shows that the link between height and labour market outcomes is more convincing for males (Case and Paxson, 2008).
the average of 67 inches for this period (Riley, 1994).\(^{11}\)

A second consideration with using any historical dataset is reliability. Historical information, such as military and convict records, was often "recorded with a level of detail far superior to modern censuses" (Nicholas and Nicholas, 1992). The attention to detail shown by some of the enumerators was clear in their supplementary comments in the records.\(^{12}\)

The problem of self-reporting of occupations is mitigated by the exclusion of those under 20. The "no questions asked" approach to recruitment suggests little reason for recruits to have provided systematically misleading information on their previous occupation. In their more detailed analysis of the records, Mokyr and Ó Gráda (1996) note isolated cases of stature misreporting, however there is no reason to think this was systematic. It is also encouraging that height differences among recruits mirror well established patterns in the literature that includes taller Irish and urban born recruits.\(^{13}\)

One area of concern is the reliability of recruits' reported ages. While most recruits were typically in their 20s, there was a notable spike (around one-third) in recruits reporting an age of exactly 20. This so-called "age heaping" is a common problem in historical demographic data, and has been ascribed to people's ignorance of their age and tendency to round off into whole numbers (A'Hearn et al., 2009). Even much later in the nineteenth century, the General Report for the 1891 census noted that "a very large proportion of persons, not improbably the greater number of adults, do not know their precise ages and only report it

\(^{11}\)While the use of a dependent variable from a truncated or non-normal distribution leads to bias, the same is not true for a truncated or non-normal independent variable.

\(^{12}\)Supplementary comments recorded on recruits were mainly related to physical defects and included "scar," "lost teeth," "mole," "stammers," "knock knee," and "looks old." One of the more interesting comments was whether a recruit was married. Unfortunately, this comments section appears to have been left to the discretion of the enumerators and comments made ranged from 2-10% of recruits in any particular year. Cross-tabs did not reveal a tendency for particular groups to attract comments.

\(^{13}\)Raw height comparisons across groups must be treated carefully without taking into account compositional effects such as age. Mokyr and Ó Gráda (1996) provide a thorough anthropometric analysis of the recruits.
The degree of age heaping is quantified by the Whipple index and averages 250 between 1830 and 1857. This is large and exceeds other comparable estimates for this period. Mokyr and Ó Gráda (1996) note the possibility of recruits exaggerating their ages where a limit of 20 was (or thought to be) in force. It is difficult to find contemporary evidence for this, although it is consistent with significantly reduced age heaping at other rounded ages of 25 and 30. Moreover, the records do contain a number of boys, including some as young as 14, and occasional comments from enumerators that some recruits "looked young." If there was an age limit, either formally or informally as in the regular British army, it was clearly not always enforced. Concerns about possible age misreporting from teenage recruits provides a further reason to exclude those aged under 20 from the final sample.

The final sample of recruits numbers just over 30,000. It excludes a small number born outside of the British Isles and those under 20. Table 3.1 shows summary statistics broken down by the four occupational categories. EIC recruits who had previously held the highest (lowest) skilled occupations were on average taller (shorter), older (younger), more likely to be British (Irish) born and to come from urban (rural) areas. The essay now turns to the multivariate modelling of recruits' previous occupations.

---

14 Quoted in Baten et al. (2013)

15 By eliminating recruits under 20, the sample has already been distorted compared to a random population.

16 The most commonly used indicator of age heaping is the Whipple index. This calculates the number of self-reported ages that are multiples of 5 relative to the number expected from a uniform population age distribution and is defined as \( W = \frac{100 \times \sum (n_{20} + n_{25} + n_{30} + n_{35})}{\frac{1}{5} \sum n_i} \). The index ranges between 100 (no tendency for ages ending in 0 and 5) and 500 (all people reporting ages ending in 0 or 5). At 100 it would imply that exactly 20% of the population report ages ending in multiples of 5.
Table 3.1: Summary statistics by occupation grouping

<table>
<thead>
<tr>
<th></th>
<th>Height inch</th>
<th>Age years</th>
<th>Irish Born</th>
<th>Capital Born</th>
<th>Urban Born</th>
<th>Industrial Born</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>67.56</td>
<td>21.58</td>
<td>59.3%</td>
<td>7.03%</td>
<td>32.0%</td>
<td>9.0%</td>
</tr>
<tr>
<td>II</td>
<td>67.54</td>
<td>22.01</td>
<td>30.7%</td>
<td>11.9%</td>
<td>48.1%</td>
<td>15.3%</td>
</tr>
<tr>
<td>III</td>
<td>68.11</td>
<td>22.27</td>
<td>33.7%</td>
<td>15.8%</td>
<td>47.1%</td>
<td>10.6%</td>
</tr>
<tr>
<td>IV</td>
<td>68.04</td>
<td>22.44</td>
<td>27.8%</td>
<td>13.3%</td>
<td>48.8%</td>
<td>12.7%</td>
</tr>
<tr>
<td>Av</td>
<td>67.63</td>
<td>21.85</td>
<td>44.6%</td>
<td>10.1%</td>
<td>40.4%</td>
<td>11.7%</td>
</tr>
</tbody>
</table>

3.4 Methodology and results

In order to analyse the role that stature might have played in explaining recruits' previous occupations, I follow Case and Paxson (2008) and the mainstream literature in estimating the following multinomial logit regression (MNL):

\[
\ln \frac{P_{ij}}{P_{io}} = \gamma_i \text{height}_i + X_i \Gamma_i
\]  

where \( P_{ij} \) is the probability of recruit \( i \) previously holding an occupation in category \( j \) relative to the reference occupation \( o \); height is in inches and \( X \) a vector of control variables. Recruits previously holding occupations in category I are chosen as the reference group as this is the largest grouping. Moreover, this group are likely to have different characteristics to the other three groupings given the large number of labourers.

Economists have been drawn to the MNL approach because it can be derived from a formal "sorting model" of occupational choice. The modern literature uses this height-based occupational sorting to assess the "returns to height" (Vogl, 2014). While the essay notes several reasons why this sorting approach might not be fully satisfactory in a historical setting, the MNL model remains a powerful empirical tool to answer two central research questions: first, was stature linked to previous occupation, and if so in what particular occupational groupings was it associated with?

The MNL model avoids the difficulty of comparing and ranking occupations.
It is sensible to assume that categories I (Unskilled, Manual) and IV (High skilled, Non-Manual) were at the lowest and the highest levels of the social class distribution respectively. However, it is less clear for the two intermediate groupings (II and III) as skilled manual occupations may have had a higher skills content, higher status or wages than lower skilled manual occupations.\footnote{An alternative possibility is to convert occupations into estimates of individual wages as in Williamson (1990). However, the lack of correspondence between occupational categories and the insufficient variation of imputed wage data makes this difficult. Even if detailed wage data did exist, determining whether certain manual occupations could be ranked higher or lower than non-manual occupations would require assessing non-wage components. Bleakley et al. (2013) benchmark nineteenth century occupations to those in 1950, but as the authors acknowledge this does have drawbacks.} The MNL also allows interpretation of the coefficients as intuitive Relative Risk Ratios (RRRs) that are the ratios of the probability of being in one outcome category over a reference category.\footnote{Other advantages of the MNL model are consistency with notions of random utility maximization, and the ease of estimating using standard maximum likelihood procedures.}

To ensure that the findings for stature do not reflect individual heterogeneity, a vector of control variables ($X$) is included in (3.1). Age of recruit is included to capture experience and a squared term to allow for non-linearities. The historical literature provides several rationales for including birthplace controls. While migration was increasingly important in this period, most notably for the Irish, Anderson (1985) shows that around half of the British population still lived less than 2 km from their birth place in 1851. Birthplace also captures the wider disease and diet environment in childhood, and also the strong regional patterns of literacy.\footnote{Baten et al. (2013) recently show that Poor Law coverage varied substantially across England, and had an important effect on early life chances.} Birthplace dummies equal to one are defined for the urban born, the Irish born, those born in capital cities and those in areas of early industrial development (Table 3.5).

The state of the labour market in "civvy street," and pay and conditions in the EIC army are obvious factors in determining the composition, and the quality, of recruits. This period saw several economic upturns and downturns that need to be controlled for so as not to distort any links between stature and occu-
pations (Broadberry and Leeuwen, 2010). These time dummies also capture any
effects of changes in the EIC’s minimum height requirements. As standard in the
literature, birth cohort dummies are included to capture any unobserved factors
common to cohorts born in the same period.

Several major historical events during this period could also distort any links
between stature and the mix of previous occupations. A dummy is included for
those recruited during the Irish famine (between 1845 and 1852). While this is
included primarily to capture the sharp drop in the number of (mostly manual)
Irish born recruits, in the view of Williamson (1986) it could also capture possible
wider labour market effects in the rest of the UK. A dummy variable is also in­
cluded to capture recruits born against the backdrop of food shortages during the
Napoleonic war years of 1803-1815. This cohort has been linked to poorer labour
market outcomes (Baten et al., 2013).

Table 3.2 shows the MNL results for the full sample. Time dummies are in­
cluded, but are not reported. Overall, the model performs well compared to
similar models using modern data (Howard and Prakash, 2012). The Wald test
of whether all coefficients in the model are simultaneously zero is easily rejected.
The model predicts over 50% of previous occupations correctly. Encouragingly,
tests also reject the null hypothesis that the four occupational categories could be
combined, suggesting that the groupings are not ad-hoc.

The results are unaffected by whether average 5 year time dummies are included or those
corresponding to changes in the EIC’s minimum height requirements.

The MNL model makes the assumption known as the independence of irrelevant alternatives
(iia). This means that adding or deleting alternatives (i.e. occupational categories) does not
affect the odds among the remaining alternatives. The Hausman test fails to reject IIA, however
the Small and Hsiao (1985) test is more mixed. These conflicting findings are not unusual,
and for this reason Long and Freese (2001) discourage formal testing for IIA. Instead, they
argue that MNL works best when the alternatives are dissimilar and not just substitutes for one
another. This is a reasonable assumption for occupations, and is further justified by the tests
of combining categories. As a robustness check, an ordered Probit model is also estimated with
categories ranked I to IV. Results in Table 3.8 show similar findings.

Table 3.9 shows the Likelihood Ratio test for combining categories. This is an important
test in terms of degrees of freedom, since if two occupational categories are indistinguishable
they can be combined and more efficient MNL estimates obtained.
Table 3.2: MNL model of EIC recruits’ previous occupations (RRRs)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>Height</td>
<td>1.017</td>
<td>1.219***</td>
<td>1.198***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.018)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>Irish born*Height</td>
<td>0.989</td>
<td>1.029</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>(0.0167)</td>
<td>(0.0236)</td>
<td>(0.053)</td>
</tr>
<tr>
<td>Age</td>
<td>1.681***</td>
<td>1.802***</td>
<td>3.3712***</td>
</tr>
<tr>
<td></td>
<td>(0.148)</td>
<td>(0.196)</td>
<td>(1.431)</td>
</tr>
<tr>
<td>Agesq</td>
<td>0.990***</td>
<td>0.989***</td>
<td>0.9777***</td>
</tr>
<tr>
<td></td>
<td>(0.116)</td>
<td>(0.002)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Irish born</td>
<td>0.693</td>
<td>0.054*</td>
<td>0.2467</td>
</tr>
<tr>
<td></td>
<td>(0.794)</td>
<td>(0.084)</td>
<td>(0.898)</td>
</tr>
<tr>
<td>Urban born</td>
<td>1.479***</td>
<td>1.3994***</td>
<td>1.2789***</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.0613)</td>
<td>(0.137)</td>
</tr>
<tr>
<td>Capital city born</td>
<td>1.275***</td>
<td>1.941***</td>
<td>1.536***</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
<td>(0.128)</td>
<td>(0.206)</td>
</tr>
<tr>
<td>Industrial born</td>
<td>1.575***</td>
<td>1.125*</td>
<td>1.278*</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
<td>(0.0728)</td>
<td>(0.161)</td>
</tr>
<tr>
<td>Post Famine recruit</td>
<td>1.103</td>
<td>1.072</td>
<td>1.195</td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.139)</td>
<td>(0.054)</td>
</tr>
<tr>
<td>1810-19 birth</td>
<td>0.989</td>
<td>1.012</td>
<td>0.685</td>
</tr>
<tr>
<td></td>
<td>(0.090)</td>
<td>(0.127)</td>
<td>(0.176)</td>
</tr>
<tr>
<td>1820-29 birth</td>
<td>0.935</td>
<td>1.198</td>
<td>0.6067</td>
</tr>
<tr>
<td></td>
<td>(0.110)</td>
<td>(0.127)</td>
<td>(0.1764)</td>
</tr>
<tr>
<td>1830-39 birth</td>
<td>0.9369</td>
<td>1.036</td>
<td>0.607</td>
</tr>
<tr>
<td></td>
<td>(0.136)</td>
<td>(0.199)</td>
<td>(0.260)</td>
</tr>
<tr>
<td>Nap war cohort</td>
<td>1.020</td>
<td>1.026*</td>
<td>0.837</td>
</tr>
<tr>
<td></td>
<td>(0.078)</td>
<td>(0.216)</td>
<td>(0.1933)</td>
</tr>
<tr>
<td>Observations</td>
<td>30054</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exponential form standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Reference group is category is 1. Time dummies included but more reported.
A standard deviation increase in height increases the probability of a recruit previously holding non-manual occupations (III or IV) relative to that of an unskilled manual (I) by around 30%. Stature has no ability to distinguish between recruits holding skilled or unskilled manual occupations. Interaction terms with height are also included for the Irish and Rural born recruits, who comprised the largest two sub-groups in the sample. A squared height term is also added to explore non-linear effects of height and possible diminishing returns to stature. In a further unreported extension, height is interacted with the time dummies to allow the effects to vary over the economic cycle. None of these extensions are found to be quantitatively significant.

Another interesting exercise is to compare the results for height to other variables. Age is positively linked to holding non-manual occupations, but there are diminishing returns to experience. Younger recruits are more likely to have been in low skilled manual occupations. Also significant are the controls for a recruit's place of birth. An urban born recruit was up to 50% more likely to have previously held non-manual occupations or skilled manual occupations, and this was further enhanced by strong capital city effects. Being London or Dublin born almost doubled the probability of previously holding medium skilled non-manual occupations (III). Also reflecting alternative occupational choices, recruits born in areas of early industrial development were less likely to have been in the unskilled manual occupations. The Irish born effects were large; this cohort were to 90% less likely to have been in non-manual or skilled manual occupation categories, although curiously these effects were not always statistically significant.23

The time dummies introduced to capture the effects of the economic cycle and changes in the minimum height requirements are all significant, although I do not attempt to interpret them. By contrast, the crude birth cohort dummies perform poorly in explaining previous occupations. Unlike Baten et al. (2013), I find no link between recruits born in the the food crisis of the Napoleonic war years and a

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23One possibility is that the birthplace effects reflect the choice of reference category, and the large numbers of agricultural laborers in the unskilled manual category (I). Changes in the base category continue to show birthplace effects across the groups.
tendency to end up in lower status jobs. There is a small sample size caveat to this cohort. Post Irish-famine recruits were more likely to have been in non-manual and skilled manual occupations, reflecting the sharp drop in Irish born recruits, but the numbers are not quantitatively large.

While of interest in themselves, the findings for these control variables do ask the fundamental question of whether pooling all recruits into a single MNL model over time is sensible? In particular, this pooling could mask birthplace or time effects that are not captured by adding a dummy variable. A series of MNL models are run for individual groups of recruits: the British and Irish born, the rural born, urban born, those born in capital cities and areas of early industrial activity. This flexible approach allows not just height, the essay’s main variable of interest, to vary but other coefficients across groups. The issue of pooling also potentially arises over time where the time dummy variable approach might not be adequate such as in picking up changes in the minimum height standards.

Table 3.6 in the appendix shows a similar pattern and magnitude for stature RRRs across these heterogeneous groups. Table 3.7 also shows similar pattern and magnitude of RRRs across the sub-periods 1830-39; 1840-1849 and 1850-57, and also when splitting the results between those recruited pre and post famine. These latter findings are important because they point to similar findings when different minimum height standards were in operation. In unreported analysis, separate models for different ages and birth cohorts show a similar pattern of findings.

3.5 Discussion of results

Figure 3.4 shows that taller recruits were much less likely to have been in physically demanding manual occupations of any description. This might seem surprising

---

24 One notable finding is the higher returns to stature among the urban Irish born, which is consistent with the EIC attracting the better-off Irish recruits. Full details of these models are available on request.

25 Note that the RRRs are the changes in the probability of being in a group relative to the reference group. The chart in Figure 3.4 reflects the small number in group IV but it does not undermine the significance of the RRR findings for this group.
as nineteenth century physical workloads were high by modern standards. Working hours were probably higher than ever before or since (Voth, 2003).

Bleakley et al. (2013) note that prior to widespread mechanization, physical labour was used to do a variety of things that would be done by machines, which they argue must have meant “brawn was of higher value relative to brains historically.” These echo the classic ideas of Fogel (1994) who argued that better fed and taller English workers were capable of more work than their French counterparts, based on their calorie intake. Mitch (1999) goes further and argues that Britain in the early nineteenth century was, if anything, “over educated.”

Figure 3.4: Probability of being in each occupational group

Instead, the results share more similarities with labour markets in modern
developed countries: taller recruits were more likely to have been in the most intellec
tually demanding and highest socio-economic status occupations of the day. Interestingly, the findings also share emerging ideas for modern developing coun
tries, where the reliance of the nineteenth century economy on manual labour does not bias taller individuals to strength-based occupations (Vogl, 2014).

At this point, modern researchers are able to go beyond correlation and seek to establish causation by adding variables such as family background, childhood IQ test scores and even physical strength measures, many of which are simply unavailable historically. While these approaches are not available to historians, several further avenues are available to understand these findings further. These links are consistent with two related themes that have been established in the modern and historical literature.

Firstly, stature as a marker of early childhood conditions is increasingly linked, both empirically and biologically, to cognitive and non-cognitive skills, social skills and not just physical strength (Vogl, 2014). These ideas challenge the simple dichotomies between “brains and brawn,” and developed and developing countries that characterised much of the earlier literature.

Secondly, and not unrelated, the biological standard of living literature has established that height is positively correlated to income and background more generally. Children from richer households consume better nutrients and have better access to health care, which has a positive effect on height in adulthood. They have the potential to experience superior physical growth and cognitive development, and the chance to enter higher status occupations (Currie, 2008).

These ideas are of potential historical importance in understanding the positive link between height and occupations for two reasons. Firstly, socio-economic differences in heights were large. Floud et al. (2011) showed that the large height differences between the prestigious Sandhurst recruits and the poorer boys in the London Marine society in the nineteenth century are of a magnitude no longer imaginable today: at age of 16 the height gap reached 22 cm.
Moreover, the extent that occupation was also linked to background points to another interpretation of the historical height-occupation correlation that arise from sorting models: tall sons of tall and wealthy fathers simply entered high status occupations. Again, there are reasons to expect this to have been important historically. Class and parental income were major determinants of access to human capital in nineteenth century Britain. While this is easy to understand for the elites of the day, this was also important in terms of access to apprenticeships for the working classes. Apprenticeships were often based on private contracts between parents and masters in the nineteenth century (Kelly et al., 2013). These themes are particularly relevant to Britain in the nineteenth century that has been viewed as a considerably more rigid system in which “family background play(ed) a much more significant role“ in determining future prospects compared to U.S” (Long and Ferriea, 2013).

Historical research outside Britain also points to similar findings. Using data on nineteenth century Bavarian military conscript, Lantzsch and Schuster (2009) find significant height differences between the occupational groups even after controlling for the parents’ occupations. In a similar vein, Schoch et al. (2009) concludes that “social-class affiliation was the most important determinant of differences in the biological standard of living (measured by height) for nineteenth century Swiss army recruits.

Both of these suggest that an omitted variable is likely to at work generating the links between recruits’ stature and previous occupations. The modern literature has directed much effort towards examining these issues. Case and Paxson (2008) show that the relationship between adult height and labour market outcomes disappear when controls for childhood cognitive test scores are included. Notwithstanding the richness of the EIC records documented in this essay, some additional information on the recruits would have been useful. ²⁶

²⁶ With this in mind, the tallest recruits in the sample were previous surgeons, who were over an inch taller than the average.

²⁷ Instruments have also been explored for possible feedback between stature and occupations, although this has been seen as more of a secondary problem (Carson, 2011). It fits the idea of
Firstly, a recruit's literacy was not recorded. Literacy is seen as a consumption good today, but during the early industrial revolution it was seen as an "investment good by the family," and an important marker for early life conditions and stock of human capital (Nicholas and Steckel, 1991). A second (and not unrelated) potential missing variable was father's occupation. While there is a limit to what more can be drawn from the EIC records, they do provide some alternative (and tentative) ways to explore the robustness of the findings.

The large degree of "age heaping" among the recruits provides the opportunity to use this as a proxy for numeracy, literacy and human capital (A’Hearn et al., 2009). This use of age heaping is not without its problems. The ability to recall age correctly could be indicative of "schooling, the bureaucratization of life, and changing cultural norms, rather than cognitive development" (Baten et al., 2013). However, none of these are likely to explain the high volatility in the Whipple index for recruits over a comparatively short historical period (Figure 3.5).

A dummy variable is created for each recruit if their age ended in 0 or 5, and is then included in the same specification as Table 3.2. Table 3.3 shows that the heaping variable has the expected sign, reducing the probability of previously holding occupation other than unskilled manual (I) by up to 20%. The findings echo those of Baten et al. (2013), who show individuals with heaped ages in the nineteenth century were more likely to "sort into occupations with limited intellectual requirements."

This inclusion of age heaping has no impact on the stature coefficient, and is counter to many findings in the modern literature where human capital controls typically reduce any height effects. One concern discussed in Section 2.3 is that the spike in recruits aged 20 reflects other factors, and a tendency for recruits to exaggerate their age where a limit was or thought to be in force. In unreported adult stature being largely pre-determined by age 2 or 3. Bleakley et al. (2013) also note that too many control variables can dilute the role of height as a marker for early childhood.

[28] Time dummies and birth cohorts are included. Neither are reported for space reasons.
Table 3.3: MNL model with the addition of age heaping (RRRs)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Height</td>
<td>Irish born*Height</td>
<td>Age</td>
</tr>
<tr>
<td></td>
<td>(1.016)</td>
<td>(0.989)</td>
<td>(1.351)****</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.0167)</td>
<td>(0.129)</td>
</tr>
<tr>
<td></td>
<td>1.219***</td>
<td>1.029</td>
<td>1.512***</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.0236)</td>
<td>(0.180)</td>
</tr>
<tr>
<td></td>
<td>1.989***</td>
<td>1.000</td>
<td>2.463**</td>
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<tr>
<td></td>
<td>(0.035)</td>
<td>(0.053)</td>
<td>(1.13)</td>
</tr>
<tr>
<td></td>
<td>1.198***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irish born</td>
<td>0.989***</td>
<td>0.977*</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.021)</td>
<td>(0.009)</td>
</tr>
<tr>
<td></td>
<td>0.989***</td>
<td>0.977*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heaping1</td>
<td>0.851***</td>
<td>0.804**</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.043)</td>
<td>(0.094)</td>
</tr>
<tr>
<td></td>
<td>0.868***</td>
<td>0.804**</td>
<td></td>
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<tr>
<td></td>
<td>(0.043)</td>
<td>(0.094)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irish born</td>
<td>0.801</td>
<td>0.288</td>
</tr>
<tr>
<td></td>
<td>(0.919)</td>
<td>(1.049)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.061*</td>
<td>0.288</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.096)</td>
<td>(1.049)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urban born</td>
<td>1.477***</td>
<td>1.521***</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.137)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.399***</td>
<td>1.521***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0613)</td>
<td>(0.137)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capital city born</td>
<td>1.277***</td>
<td>1.538***</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
<td>(0.206)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.943***</td>
<td>1.538***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.129)</td>
<td>(0.206)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial born</td>
<td>1.573***</td>
<td>1.278*</td>
</tr>
<tr>
<td></td>
<td>(0.069)</td>
<td>(0.161)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.124*</td>
<td>1.278*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.161)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post Famine recruit</td>
<td>1.109</td>
<td>1.185</td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.320)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.066*</td>
<td>1.185</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.131)</td>
<td>(0.320)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nap war cohort</td>
<td>1.053</td>
<td>0.859</td>
</tr>
<tr>
<td></td>
<td>(0.081)</td>
<td>(0.198)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.066*</td>
<td>0.859</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.131)</td>
<td>(0.198)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>30,054</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exponential form standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Reference category is I. Time dummies and birth cohorts included but neither reported. Heaping is a dummy variable if recruits age ended in 0 or 5.
regressions excluding recruits aged 20, there continues to be evidence of a negative
effect of age heaping on previous occupations (among those aged 25 and 30).

Another useful way to interpret the findings is the comparison between the
British born and Irish born recruits. Ireland has been seen as an impoverished
sophisticate\(^\text{a}\) and outlier in terms of both literacy and stature in the nineteenth
century. Neither were in line with levels of relative Irish economic prosperity
(Ó Gráda, 1995). Since not all of the Irish belonged to the ranks of the unskilled
labouring classes, Ireland offers a useful benchmark to judge the British born re­
results. With the exception of Ulster, Ireland was also unindustrialised and didn't
have the rigid social structures of England. Despite these differences, the Irish
and British born findings were similar, and if anything pointed to higher stature
returns among the Irish urban born.

Both of these robustness checks help to reinforce the role of height among the
recruits. However, thinking about height as one dimension of human capital that
captures very early investments suggests more fundamental implications. Steckel
(2009) argues that such ideas “could bring nutritional status and stature to the
fore in comprehending rates of return to schooling, socioeconomic inequality that
stems from cognitive deficits, and conceivably rates of technological change.” These
share many classic ideas of Fogel (1994), but extend these in one crucial aspect by
focusing on more general skill development and not just physical strength.

Economists have already begun thinking about how these ideas may shed light
on the role of human capital in economic development. Hanushek and Woess-
mann (2008) show that cognitive skill is a key determinant of economic growth
in developing countries. The essay shows that taller recruits were in occupations
where traits other than physical strength would have been important. Two recent
papers have arrived at similar findings. Baten et al. (2013) show how malnutrition
in the past may have led to poor labour market outcomes by curtailing cognitive
development. They show that those affected by the food crisis of the Napoleonic
War years were more likely to be shorter and end up in professions requiring lower
cognitive skill and wages. Kelly et al. (2013) note that nineteenth century taller
British workers had a higher endowment of competence." These authors note how some of these ideas appeal to classic works that emphasise the role of human capital in understanding modern economic growth. For Ben-Porath (1967) this includes workers adopting to technical change and for Galor and Weil (1999) the focus is on the quality of human capital.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.5.png}
\caption{Whipple index for recruits}
\end{figure}

3.6 Conclusion
Despite the universality of the height-occupation nexus, Vogl (2014) reminds us that its sources often differ widely by setting. The essay explores a nineteenth century setting where much less is known quantitatively about these links. While not a random sample of the population, the British and Irish born recruits in the East India Company army are a representative group of young working and lower middle class men in the nineteenth century. The size of the sample allows for
modern econometric approaches to be used to understand their previous occupations. The richness of the records also provide an insight into the relative roles of strength and intelligence in explaining historical labour market outcomes.

The essay establishes a robust and positive link between taller recruits and their tendency to have previously held non-manual occupations, even among the rural and Irish born. The findings suggest more similarities between modern developed and nineteenth century labour markets than one might have expected. As increasingly found for developing countries, the reliance of nineteenth century economies on manual labour did not bias recruits towards strength-based occupations.

The findings are consistent with modern research showing that nutritional status, height and childhood are rewarded in the labour market through traits such as cognitive skills, confidence, intelligence, social skills, as well as physical strength (Currie, 2008). Linked to this, the biological standard of living literature shows that the wealthier are better fed and likely to be taller. There are reasons to believe that these profound effects of early-life conditions on labour market outcomes were of equal, if not greater, significance in explaining entry into historical occupations. Differences in historical heights between social groups were often larger than today and background important in the accumulation of human capital.

One implication is that the modern approach of “sorting” to gauge the returns to height may simply be capturing this correlation in historical data. However, in the terminology of Humphries and Leunig (2009), the essay is a further example showing how historians can use height as an “explanatory variable” to explore a range of adult outcomes. These include literacy, migration, reduced criminal tendencies and better marriage prospects, and taken together suggest that these correlations are more than spurious. The essay also notes how these, and a series of recent papers, can potentially shed further light on the neglected role of human capital in the onset of modern economic growth that extend Fogel’s (1994) focus on physical capabilities.

There is, however, a limit to what more can be gleaned from the recruitment
records. Many of the variables that modern researchers are able to draw on to further understand these links are simply unavailable to historians. Several innovative ways to overcome the data shortcomings have been proposed and the essay explores one by using “age heaping” as a proxy for human capital. Another promising strand of future research might be to link recruits (at least for the British born) to census information on literacy, father's occupation and information on siblings. This could allow a further insight into the influence of genetic and environmental factors on historical labour market outcomes.
Appendix Chapter 3

<table>
<thead>
<tr>
<th>Occupational classification</th>
<th>Examples of EIC Occupations</th>
<th>HISCLASS Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unskilled Farm Workers [12]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farmers and Fishermen [8] Lower-Skilled Workers [9,10]</td>
</tr>
<tr>
<td>Variable</td>
<td>Label</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>Inches nearest quarter</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Years</td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>London or Dublin born =1</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>Born in a town of more than 10,000 in 1800 =1</td>
<td></td>
</tr>
<tr>
<td>Ind</td>
<td>Born in Lancashire, the West Riding of Yorkshire, Cheshire, or East Ulster =1</td>
<td></td>
</tr>
<tr>
<td>Irl</td>
<td>Born in island of Ireland =1</td>
<td></td>
</tr>
<tr>
<td>Ulster</td>
<td>Born in province of Ulster =1</td>
<td></td>
</tr>
<tr>
<td>Famine1</td>
<td>Recruited between 1847 and 1857</td>
<td></td>
</tr>
<tr>
<td>Famine2</td>
<td>Recruited between 1847 and 1852</td>
<td></td>
</tr>
<tr>
<td>Heaping1</td>
<td>An age ending in 0 or 5 = 1</td>
<td></td>
</tr>
<tr>
<td>Heaping2</td>
<td>Age given as 25, 30 or 35</td>
<td></td>
</tr>
<tr>
<td>Nap</td>
<td>Born during the Napoleonic wars 1796 to 1815 = 1</td>
<td></td>
</tr>
<tr>
<td>1810-19</td>
<td>Born in the decade 1810-1819 = 1</td>
<td></td>
</tr>
<tr>
<td>1820-29</td>
<td>Born in the decade 1820-1829 = 1</td>
<td></td>
</tr>
<tr>
<td>1830-39</td>
<td>Born in the decade 1830-1839 = 1</td>
<td></td>
</tr>
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</table>
### Table 3.6: RRRs for stature: Birthplace groups

<table>
<thead>
<tr>
<th>Group</th>
<th>II</th>
<th>III***</th>
<th>IV***</th>
</tr>
</thead>
<tbody>
<tr>
<td>British (all)</td>
<td>1.011</td>
<td>(0.012)</td>
<td>1.212***</td>
</tr>
<tr>
<td>British rural</td>
<td>1.052***</td>
<td>(0.0164)</td>
<td>1.232***</td>
</tr>
<tr>
<td>British urban</td>
<td>0.964</td>
<td>(0.0165)</td>
<td>1.183**</td>
</tr>
<tr>
<td>London</td>
<td>0.949</td>
<td>(0.038)</td>
<td>1.270***</td>
</tr>
<tr>
<td>Irish (all)</td>
<td>1.019</td>
<td>(0.013)</td>
<td>1.265***</td>
</tr>
<tr>
<td>Irish rural</td>
<td>1.000</td>
<td>(0.017)</td>
<td>1.306***</td>
</tr>
<tr>
<td>Irish urban</td>
<td>1.025</td>
<td>(0.024)</td>
<td>1.193***</td>
</tr>
<tr>
<td>Dublin</td>
<td>1.003</td>
<td>(0.048)</td>
<td>1.173***</td>
</tr>
<tr>
<td>Ulster</td>
<td>0.930**</td>
<td>(0.030)</td>
<td>1.319***</td>
</tr>
</tbody>
</table>

RRRs from MNL models run on individual groups. Exponential form standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Reference category is I.
<table>
<thead>
<tr>
<th>Period</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1830-39</td>
<td>1.067*</td>
<td>1.281***</td>
<td>1.296***</td>
</tr>
<tr>
<td></td>
<td>(0.032)</td>
<td>(0.047)</td>
<td>(0.097)</td>
</tr>
<tr>
<td>1840-49</td>
<td>1.023</td>
<td>1.231***</td>
<td>1.174**</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.0236)</td>
<td>(0.053)</td>
</tr>
<tr>
<td>1850-57</td>
<td>0.994***</td>
<td>1.163***</td>
<td>1.180***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.029)</td>
<td>(0.054)</td>
</tr>
<tr>
<td>post-famine</td>
<td>1.006***</td>
<td>1.188***</td>
<td>1.204***</td>
</tr>
<tr>
<td></td>
<td>(0.0146)</td>
<td>(0.023)</td>
<td>(0.044)</td>
</tr>
<tr>
<td>pre famine</td>
<td>1.038</td>
<td>1.269**</td>
<td>1.119**</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.0293)</td>
<td>(0.059)</td>
</tr>
</tbody>
</table>

RRR from MNL models run on these time periods. Exponential form standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Reference category is I.
Table 3.8: Ordered probit model of previous occupations

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full</td>
<td>British born</td>
<td>Irish born</td>
</tr>
<tr>
<td>Age</td>
<td>0.308***</td>
<td>0.319***</td>
<td>0.268***</td>
</tr>
<tr>
<td></td>
<td>(0.0443)</td>
<td>(0.0734)</td>
<td>(0.0545)</td>
</tr>
<tr>
<td>Height</td>
<td>0.0635***</td>
<td>0.0669***</td>
<td>0.0638***</td>
</tr>
<tr>
<td></td>
<td>(0.00529)</td>
<td>(0.00714)</td>
<td>(0.00565)</td>
</tr>
<tr>
<td>Agesquare</td>
<td>-0.00566***</td>
<td>-0.00569***</td>
<td>-0.00498***</td>
</tr>
<tr>
<td></td>
<td>(0.000944)</td>
<td>(0.00158)</td>
<td>(0.00116)</td>
</tr>
<tr>
<td>Irish*height</td>
<td>0.00630</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.00875)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irish born</td>
<td>-0.947</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.592)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital city born</td>
<td>0.224***</td>
<td>0.462***</td>
<td>0.0550</td>
</tr>
<tr>
<td></td>
<td>(0.0234)</td>
<td>(0.0382)</td>
<td>(0.0295)</td>
</tr>
<tr>
<td>Urban born</td>
<td>0.178***</td>
<td>0.208***</td>
<td>0.171***</td>
</tr>
<tr>
<td></td>
<td>(0.0149)</td>
<td>(0.0249)</td>
<td>(0.0193)</td>
</tr>
<tr>
<td>Industrial born</td>
<td>0.117***</td>
<td>0.408***</td>
<td>-0.0254</td>
</tr>
<tr>
<td></td>
<td>(0.0198)</td>
<td>(0.0331)</td>
<td>(0.0249)</td>
</tr>
<tr>
<td>Post famine recruit</td>
<td>0.0431</td>
<td>0.0194</td>
<td>0.0544</td>
</tr>
<tr>
<td></td>
<td>(0.0462)</td>
<td>(0.0801)</td>
<td>(0.0563)</td>
</tr>
<tr>
<td>Cohort</td>
<td>0.0148</td>
<td>0.0299</td>
<td>0.00827</td>
</tr>
<tr>
<td></td>
<td>(0.0364)</td>
<td>(0.0588)</td>
<td>(0.0461)</td>
</tr>
<tr>
<td>Observations</td>
<td>30,054</td>
<td>13,405</td>
<td>16,649</td>
</tr>
</tbody>
</table>

*** p < 0.01, ** p < 0.05, * p < 0.1. Time dummies and birth cohorts included but neither reported. Occupations ranked I to IV.

Table 3.9: Likelihood ratio test of combining categories

<table>
<thead>
<tr>
<th>Alternatives tested</th>
<th>chi2</th>
<th>df</th>
<th>P chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td>II- III</td>
<td>543.890</td>
<td>21</td>
<td>0.000</td>
</tr>
<tr>
<td>II- IV</td>
<td>103.469</td>
<td>21</td>
<td>0.000</td>
</tr>
<tr>
<td>II- I</td>
<td>3078.230</td>
<td>21</td>
<td>0.000</td>
</tr>
<tr>
<td>III- IV</td>
<td>40.786</td>
<td>21</td>
<td>0.006</td>
</tr>
<tr>
<td>III- I</td>
<td>1840.294</td>
<td>21</td>
<td>0.000</td>
</tr>
<tr>
<td>IV- I</td>
<td>482.902</td>
<td>21</td>
<td>0.000</td>
</tr>
</tbody>
</table>

*** p < 0.01, ** p < 0.05, * p < 0.1. P value that the groups can be combined.
Chapter 4

Irish financial markets 1913 to 1923

4.1 Introduction

In his assessment of Irish historiography, O’Day (1998) notes that the numerous studies of Irish history are influenced by the “authors’ personal predilection, purpose for writing, academic training and use of different research methods, and the circumstances at the time of writing.” This essay takes a fundamentally different approach to exploring events in the turbulent decade in Ireland between 1913 and 1923 by looking at the behavior of investors in Dublin.

The paper is motivated by the growing literature pioneered by Willard et al. (1996) that investigates the impact of historical political, institutional and military events on asset prices. Due to their forward looking characteristics, asset markets offer several potential advantages for historical analysis. Market actors have an incentive to carefully evaluate a prevailing situation because errors have monetary consequences. Historical prices cannot be subsequently altered or reinterpreted, unlike the views of historians or contemporaries (Frey and Kucher, 2000).

There are several reasons why studying financial markets in Dublin in this period are of interest. Firstly, the Dublin Daily Stock Exchange Listings are a rare example of a historical Irish economic dataset in a period characterised “by
a paucity of real data" (Hickson and Turner, 2005). With some exceptions, such as Hope and Lucey (2007), the stock records remain largely untapped by scholars. Secondly, Ireland provides a unique historical environment to explore conflict and political instability through financial markets because of the variety of domestic and international events. The period saw labour problems, the Great war, the Home Rule crisis, the War of Independence and the Civil War (Cottrell, 2006). And finally, while trading was suspended in late 1914 and minimum prices imposed on Government stocks during 1915, the Dublin market (like London) was largely free from regulation outside of this window.

In a first contribution, daily prices series for two guaranteed (or “Irish”) land stocks trading in Dublin are reconstructed between 1913 and 1923. These little known stocks were guaranteed by the UK Government to finance the transfer of land ownership from landlords to tenants in Ireland, and would assume a central role in the events surrounding the Anglo-Irish Trade War that began in 1932 (Dooley, 2004). Despite being among the most frequently traded assets in Ireland during this turbulent period, until recently no price series have been systematically collected for these stocks. Daily prices in Dublin are also collected for (British) 2.5% consols. These were not only the most traded assets in Dublin, but they provide a measure of long-term historical interest rates for the United Kingdom.

This essay employs a battery of familiar modern econometric tests to explore stock price movements between 1913 and 1923. The analysis focuses on prices and returns, on volatility and levels, and to a lesser degree London and Dublin prices. The methodologies range from a priori specification of historical events to purely data driven identification approaches. Conventional (and low power) Bai and Perron (2003) tests find no evidence of structural breaks in prices or returns between the different assets across this period, or between London and Dublin prices. As is typical with daily financial data, GARCH and more powerful tests of Barry and Hartigan (1993) do find short-term bursts of volatility and high probability of change points in prices and returns. However, with the exception of the period 1920 and 1921, it is difficult to assess these or pinpoint any specific events linked to explain these. Perhaps the essays’ most important finding is from a simple
cointegration approach that confirms the tendency for land stocks to move in line with, and be anchored by, the benchmark British consol.

The essay discusses several reasons for these findings with the aid of daily market commentaries such as those in the *Irish Times*. Previous scholars have noted the longstanding stability of British consols and other guaranteed stock in this period, reflecting the hegemonic power of Britain and preeminent position of the London financial market (Yoon, 2010). Given the continued British guarantee of land stocks after partition, the lack of a pronounced market reaction is not unexpected. While the daily market commentaries also confirm the picture of an often nervous Dublin market, they never actively speculated on default or other interruptions to debt servicing problems regarding these stocks.

Another possibility which cannot be discounted is that markets might have reacted through reduced trading or liquidity. While stocks mainly reflect the risk of government default linked to institutional crisis, equities may also capture reactions from commercial interests. Irish shares might also be less contaminated by wider British or international events of the day. Unfortunately, it is difficult to construct a high frequency Irish share index for this period because of infrequent trading of many shares.

In an exploratory analysis, the essay tracks the daily prices of nine shares trading in Dublin between 1913 and 1923 of strategic and wider economic importance. Shares were more volatile than the land stocks and showed strong sectoral patterns, particularly in the railways. Four of the six shares analysed show structural breaks, and three of these are between the end of 1919 and start of 1920 during the War of Independence. Separating out pure domestic events against the background of post-war austerity and deflation (Hickson and Turner, 2005) remains a challenge and should be the priority for future research.

The essay is not the first to investigate historical Irish financial markets, and complements the existing studies of historical Irish equity markets of Hickson and Turner (2005) and Grossman et al. (2013). Hope and Lucey (2007) stretch their
analysis back to the mid-nineteenth century for a handful of Dublin traded stocks and share prices. Events in Ireland are also mentioned in Brown et al.'s (2006) paper on historical British consol price movements. This essay is, however, the first to analyse this turbulent period of Irish history through econometric analysis of high frequency daily asset prices.

The essay is organised as follows. Section 4.2 provides a brief summary of the relevant literature. Section 4.3 describes the land stock data, and touches on the historical and institutional background of the assets. The results from the three econometric methodologies are briefly reported in Section 4.4. An exploratory analysis involving equities is set out in section 4.5. The paper finishes with some concluding remarks in Section 4.6.

4.2 Literature Review

In their groundbreaking analysis, Willard et al. (1996) search for "turning points" in the price of Greenbacks issued by the Union during the U.S. Civil War. Using a pure econometric procedure to identify structural breaks, they show some turning points coincide with events familiar from conventional historiography, while in others they do not. Weidenmier (2002) examines the price of Graybacks issued by the Confederacy and shows that investors shared similar views on Antietam and Gettysburg as turning points, but they had different opinions on other events.

The underlying rationale for this approach is based on economic theory predicting that sovereign bond prices are a good indicator of the political stability of a country or government in meeting their debt obligations. Wartime is a natural environment to explore these issues. Several studies apply this data driven approach to World War Two. Frey and Kucher (2000) show that assets on the Zurich stock exchange reflected many important historical events, including the German annexation of Austria. Waldenstrm and Frey (2008) show that domestic and foreign investors on the Stockholm Exchange reacted to war events, but foreign investors reacted stronger. Oosterlinck (2003) analyses the impact of military and political events on French bond prices between 1942 and 1944, and shows that
investor perceptions of Vichy France were affected by De Gaulle’s popularity, and not by specific military events.

While war is a clear example of an event that disturbs financial markets, this methodology also sheds light on a range of other historical events affecting institutional or political outcomes. Dasgupta and Ziblatt (2012) examine British consol yields during the Reform Acts of 1832, 1867, and 1884, and show investors were sensitive to political events. Burdekin (2006) finds structural breaks in Texan debt between 1845 and 1855 that were connected with actual legislation or rumors of pending annexation. Burdekin and Laney (2008) show similar findings for Hawaii. By contrast, Collet (2013) finds no evidence from pre-Italian bond movements to suggest that investors anticipated unification until the late 1860s.

Oosterlinck et al. (2013) note that this increasingly popular structural break approach risks “over-interpretation,” or seeking any contemporaneous event to match an econometrically derived structural break. This approach is also problematic when simultaneous events produce opposite effects. Another consideration is that debt repudiations were historically rare. Finally, research on modern and historical financial markets document the random walk (and non-predictability) behavior of many asset prices, along with their predictable time varying volatility (Bollerslev, 1986). These considerations motivate an alternative approach that links market sentiment to time varying asset price volatility. These approaches typically use \textit{a priori} identification of events in ARCH and GARCH frameworks to capture conditional volatility changes.

Brown et al. (2006) use a GARCH model to explore the monthly volatility of British consol returns between 1729 and 1959. They identify a decline in volatility from the end of the Napoleonic Wars in 1815 until 1914 of more than 50 per cent, but cannot explain this by news or macroeconomic variables. Instead, they show it reflects the underlying political stability of “Pax Britannia.” Interestingly, they find no structural breaks in consol prices over this period. Elmendorf et al. (1992) explore the link between “news” and British consol price variance. They select a set of major news events between 1870 and 1914, based solely on their significance.
as judged by historians. While they find evidence that news has some influence on consol price movements, this only explains a small fraction of their movements.

Voth (2011) uses a GARCH model to study the link between the stock market volatility and political uncertainty in inter-war Germany, which he proxies by anti-government demonstrations, riots and assassinations. He shows that the influence of political news is overstated; instead it was inflation that was responsible for most of the variability in inter-war German asset returns. Meulemann et al. (2013) reassess the greenback market during and after the American Civil War, using a volatility rather than the levels approach of Willard et al. (1996). They show that monetary policy makers were surprisingly able to credibly announce the resumption to gold half a year before it actually took place in 1879.

Several overarching historical themes emerge from this popular approach to financial market history. One is that major events may not have significant market effects if they are anticipated and factored into asset prices. Secondly, historical studies often identify reactions to rumours and expectations that, while failing to materialize, such as a bailout of Russian bondholders after the 1918 Soviet repudiation, were rational given the information available at the time. A third lesson is that reactions to political events are often intertwined with changes in financial policy and economic prospects (Brown et al., 2006).

These findings of mixed investor reactions of investors to historical episodes mirrors the lack of consensus on the drivers of historical sovereign risk. For North (1987), the key is institutional change and particularly those that limited the power of autocratic rulers or regimes. Bordo and Rockoff (1996) find that adherence to the gold standard worked as a good housekeeping “seal of approval” before 1914, because of the discipline governments had to follow when countries were on gold.

By contrast, others like Sussman and Yafeh (2002) find that wars were historically more important to investor expectations than institutional changes. Landon-Lane and Oosterlinck (2005) show that Russian bondholders adjusted their perception of risk significantly in response to news about the Great War. Other scholars
like Ferguson (2008) emphasise the importance of membership of the British Empire in determining the cost of capital, as well as the country history of default. Finally, for Flandreau and Zumer (2004), political and fiscal factors were more important than institutions or the gold standard.

4.3 Data overview: Government stocks

Government stocks were among the single most important assets traded in Dublin at the turn of the twentieth century. This is true whether measured quantitatively by their value, the frequency of trades or qualitatively by the attention in daily market commentaries such as those in the Irish Times.

Government stocks offer several advantages for historical analysis over ordinary company shares. First, they did not bear company or sector risk, and they were not subject to fads or so-called “survivorship” bias (Jorion and Goetzmann, 1999). Secondly, their longer time horizon means they were less affected by transient money market conditions and more by policy, institutional and regime change. Thirdly, transaction costs, particularly brokerage, were lower than ordinary shares. Finally, and most importantly, stocks were widely held and frequently traded (Mitchell et al., 2002).

Guaranteed (or “Irish”) land stocks were inextricably linked to the land question that dominated Irish politics from the mid-nineteenth century (Dooley, 2004). These stocks were created by a number of land acts passed between 1869 and 1909 to raise money for the Irish Land Purchase Fund that was responsible for advances to enable Irish tenants to buy land. Under these various Irish Land acts, landlords were paid in guaranteed land stocks, and had the option of selling these on the Stock Exchange if they needed cash, or retain the stock and receive a dividend on their stock (Wormell, 2012). The size of these land stocks were large: their

---

1 Thomas (1992) provides several examples, such as the “Bicycle Boom” in the late nineteenth century.
2 Land stocks were not redeemable for thirty years from the dates of the relevant acts. The Acts of 1891 and 1909 authorised stock to be issued to the vendors instead of cash. Other than those issued to vendors, stocks were sold either to the public or the Debt Commissioners. The
outstanding value has been put at around 40 percent of Irish GDP at the time of partition (Foley-Fisher and McLaughlin, 2014).

Under the Irish Land acts, a fixed annuity was payable by the tenant-purchaser until the whole of the advance had been repaid by means of the accumulated sinking fund. These funds were used to pay the twice yearly dividends payable in January and June, and also to retire some of the outstanding debt. While these bonds continued to have the legal guarantee of the British government, annuity repayment remained an obligation for the newly created Irish Free State (Foley-Fisher and McLaughlin, 2014). Payments running into several millions of pounds continued to be made by the fledgling Free State in the 1920s.\(^3\)

Thus, data on land stocks prices provide a novel, and potentially fresh insight into investors’ perspectives during this turbulent decade in Ireland. However, the extent that these Treasury backed land stocks were understood or seen by contemporaries, even among the most informed of the day, as “Irish assets” is less clear. Two factors, however, provide motivation for assessing their price movements between 1913 and 1923.\(^4\)

Firstly, the withholding of the land annuities by the Free State in 1932 was treated by Britain as a \textit{de facto} sovereign default. The British Government retaliated by imposing levies on Irish cattle exports which promoted the Anglo-Irish Economic War that lasted until 1938. As a result, land bonds issued by the Free State became virtually worthless after 1932. Secondly, Land stocks had a diverse ownership, spread among Government departments, most notably the Post Office, and the public across both islands (Wormell, 2012).

\(^3\)Foley-Fisher and McLaughlin (2014) note that the intention of the 1920 Government of Ireland Act was for land annuities to be “gifts” to the respective exchequers, North and South, and for land bond dividend and sinking fund payments to be made by the Imperial Government.

\(^4\)For example on Dec 18 August 1909, Mr. Patrick White MP asked in the House of Commons “Is the Guaranteed Land Stock an Irish investment?” Source: Historical Hansard
Daily prices are collected for the 2.75% and 3% land stocks between January 1913 and December 1923 from the *Dublin Daily Stock Exchange Listings*. While, neither daily trading volumes nor bid-ask spreads are reported in the records, it is possible to calculate from the *Daily Listings* the fraction of days on which trading took place. Trading in these land stocks took place on average around 45% of all days in this period (Figure 4.1).\(^5\). This was greater than most ordinary shares trading in Dublin and on par with the handful of railway and bank shares that dominated trading in the Dublin market.

\(^5\)Frequency of trading showed falls over this period. The introduction of war loans reduced the attractiveness of other government stocks. The average figure is also distorted by the imposition of minimum prices in 1915. (Michie, 2001)
days in the sample. Klovland (1994) notes that historically "the price of consols was the single most important asset price in the world economy." Since the national debts and public finances of Britain and Ireland were merged under the 1801 Act of Union, consol price movements in this period also provide a benchmark to assess land stock prices.  

Although London was the pre-eminent financial trading centre of the time, all of the price data are collected from Dublin. One reason is that the full suite of land stocks were not all trading in London at this time (Thomas, 1996). In reality, both markets had been closely integrated since the telephone connection was established in 1897 and meant that closing prices in Dublin should be reasonably close to those in London. (Thomas, 1996). Indeed, the correlation coefficient between average monthly London and Dublin consol prices across this period is 0.99 and the t-statistic for differences in means just 0.07.

Trading took place in Dublin from Monday to Fridays and included occasional Saturdays in 1913 and 1914. The market was closed on Bank and other public holidays. Like most historical financial price series, there are gaps in the Daily Listings of varying length. The stock exchange followed London and closed in August 1914 on the outbreak of the Great War. On the resumption of trading in 1915, the London Stock Exchange announced a list of recommended minimum prices for some 800 trustee securities to protect both the public and members from

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6 Under the 1888 conversion, consols could be called in at par after April 1923 and their yields reduced to 2.5% after 1903. Klovland (1994) concludes that redemption expectations in the years leading up to 1923 had negligible effects on consol prices. Although the prices of consols (and land stocks) were subject to the usual ex-dividend effects on the days when interest payments were made, since unlike share dividends these were unlikely to significantly change the trends in prices.

7 The prices are collected from the listings held in the National Archives in Dublin, DUB 77/3 series.

8 This compares monthly average consol prices in Dublin to those in London. London prices are taken from the NBER Macro history Database: http://www.nber.org/databases/macrohistory/contents/). A sample of land stock prices from London from the The Times are identical to those in Dublin. Further work on this would be useful but is unlikely to affect the essay's findings.

9 While brokers "continued to negotiate daily prices in the street...on the steps of the stock exchange no records of these exist" (Thomas, 1996).
price collapses from bad war news. The Dublin committee followed suit as mem-
bers felt tied by this resolution (Thomas, 1996).

The unpopular and binding minimum prices throughout 1915 effectively elimi-
nated an active market for all three stocks (Thomas, 1996). Once these were lifted
in December 1915, trading slowly resumed first for consols and then later for land
stocks. However, as Figure 4.1 shows trading never reached pre-war frequency lev-
els. Trading was further interrupted by domestic events that led to the closure of
the stock exchange and suspension of trading. There were no Daily Price Listings
published in late April to early May 1916 in the aftermath of the Easter rising, or
again in late June 1922 at the start of the Civil War.\textsuperscript{10}

Figure 4.2 shows a strong tendency for all three asset prices to move together
between 1913 and 1923, and this is confirmed by the correlation coefficients be-
tween the three assets that rarely dropped below 0.9 for any month in the period.
The largest cumulative daily price drops for all assets occurred in the last weeks
of July 1914. Consols and land stocks fell by around £5 in the week beginning
23 July 1914 and the two lands stocks by a similar magnitude. Towards the end
of the First World War, consols followed by land stocks make a brief attempt at
recovery. However, by December 1920 consols stood at just 44\% of par value, and
during this period land stocks also reached historical lows.

Brown et al. (2006) note the decline of consol prices may have reflected “postwar
social, political and economic pressures and the burgeoning Irish Crisis,” although
no attempt is made to quantitatively assess this. From historical lows, consols and
land stocks once again began to rise throughout 1922 and 1923, but this would
turn out to be a temporary rise in prices.

\textsuperscript{10}The records list these events as the “Sinn Fein’s rising” and “military events in the city”
respectively.
Figure 4.2: Daily price data: Consols and land stocks
The associated daily holding returns are calculated from 4.1 as the first difference of the logarithm of prices.

\[
R_t = 100[(P_t) - (P_{t-1})]
\]  

(4.1)

These daily returns are particularly useful as they are “less sticky than raw prices and better reflect how investor sentiment reacts to shocks or innovations affecting markets” (Oosterlinck et al., 2013). Daily returns in Figures 4.3 and 4.4 show typical features of financial markets: they average around zero and show volatility clustering and non-normality (Brown and Warner, 1985). There are clear periods where volatility in returns is high, such as in 1918 for consols and at times throughout 1920 for Land stocks.

Table 4.1 shows summary statistics for daily returns of each asset between 1916 and 1923, and in each case the Jarque-Bera test easily rejects the normality of the individual assets and their differences. There is evidence of excess kurtosis, or fat tails in the return distribution, and for one of the land stocks negative skewness, indicating that large decreases in returns were more frequent than increases.\(^{11}\)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>SK</th>
<th>Ku</th>
<th>JB</th>
</tr>
</thead>
<tbody>
<tr>
<td>rcon</td>
<td>0.008</td>
<td>0.599</td>
<td>-3.517</td>
<td>4.044</td>
<td>0.433</td>
<td>11.369</td>
<td>0.00</td>
</tr>
<tr>
<td>rland 2.75%</td>
<td>-0.0062</td>
<td>0.491</td>
<td>-5.676</td>
<td>4.467</td>
<td>-0.412</td>
<td>24.128</td>
<td>0.00</td>
</tr>
<tr>
<td>rland 3%</td>
<td>0.0147</td>
<td>0.515</td>
<td>-5.671</td>
<td>6.104</td>
<td>1.240</td>
<td>25.941</td>
<td>0.00</td>
</tr>
<tr>
<td>diff1 2.75%</td>
<td>-0.0120</td>
<td>0.727</td>
<td>-4.400</td>
<td>4.849</td>
<td>0.011</td>
<td>10.082</td>
<td>0.00</td>
</tr>
<tr>
<td>diff2 3%</td>
<td>0.0089</td>
<td>0.716</td>
<td>-4.441</td>
<td>4.217</td>
<td>9.822</td>
<td>25.941</td>
<td>0.00</td>
</tr>
</tbody>
</table>

This table reports sample statistics for the three daily returns. The sample period is 1/1/1916 to 31/12/1923 for consols. For land stocks the start is June 1916. Jarque-Bera is a test for normality based on the skewness (SK) and kurtosis (KU). Diff are the daily differences between land stocks and consol returns.

\(^{11}\)Both pre-estimation and post estimation tests detect conditional volatility up to lags of 10, or two trading weeks.
Figure 4.3: Daily returns: Land stocks

Figure 4.4: Daily returns: Consols
4.4 Empirical results

Three methodologies from the mainstream literature are used to assess price movements in this period. They focus on levels and volatility, and on prices and returns. The methodologies range from a priori specification of historical events to purely data driven identification approaches. In order to create a series for econometric analysis, the closing price from the previous day is rolled forward when trades did not take place. The larger gaps in the sample do pose problems for econometric analysis that rely on continuous samples. While interpolation can be used for small daily price gaps, the larger gaps from August 1914 until 1916 pose more conceptual (and econometric) problems.

The essay treats the pre-August 1914 and post January 1916 period as two samples, and all tests are carried out for both the sub samples 1913 to 1914 and then 1916-1923. Most of the interesting results are for the period 1916-1923.  

4.4.1 Structural break analysis

The logic of the structural break approach pioneered by Willard et al. (1996) is straightforward: if investors were reacting in significant ways to events in Ireland, then significant jumps in prices or returns should have occurred at critical points. The Bai and Perron (2003) method has become the workhorse of this literature to identify multiple structural breaks, and has been used in numerous economic history papers. The advantage of this approach is that the data is allowed to "speak for itself" without imposing any a priori specification of dates, such as those matching political developments (Waldenström and Frey, 2008).

The following general model is used:

\[ \text{alternative approach is to treat the series as continuous with dummy breaks included for the gaps. However it is unrealistic to assume that the outbreak of war and imposition of minimum prices in 1915 could be captured by a simple dummy variable, and this approach is not followed here. For a similar modern analysis using both structural break and volatility analysis on Greek debt and the EMU crisis, see Tamakoshi et al. (2012)} \]
where $y_t$ represents the observed, dependent variable, i.e. return, price, $z$ is the vector of covariates, $u_t$ is the disturbance at time $t$, $\delta_j$ is the corresponding vector of coefficients and the indices ($m = T_1, \ldots, T_m$) are the unknown break points. The algorithm uses the principle of dynamic programming, where the computation of estimates of the break points uses the global minimisers of the sum of squared residuals.

Firstly, I explore whether there is a structural break in the relationship between daily returns in consols and land stocks. Oosterlinck et al. (2013) argues that these are particularly useful in assessing investors reaction at short-term frequencies. Another advantage is that returns are stationary. I also look at the daily differential of consol and for the 2.75% and 3% land stocks returns. This is a crude way of attempting to strip out wider British and international events. I also explore for structural breaks in the asset prices themselves using simple AR(P) models of prices. Table 4.2 shows the Bai and Perron (2003) tests for zero versus one sequentially determined breaks.

\begin{table}[h]
\centering
\caption{Bai-Perron tests of 0 v 1 sequentially determined breaks}
\begin{tabular}{lcc}
\hline
F stat & \\
\hline
Day Returns consol & 4.011 & \\
Day Returns 2.75% land & 4.068 & \\
Day Return 3% land & 4.970 & \\
Consol - land 2.75% return & 1.874 & \\
Consol - land 2.3% return & 7.928 & \\
Land 3% price & 4.251 & \\
Land 2.75% price & 6.367 & \\
Consol price & 4.982 & \\
\hline
\end{tabular}
\end{table}

Break test options: Trimming 0.10, Max. breaks 5, Big. level 0.05

13] The relevant lag lengths are assessed using the BIC, AIC and SC criterion. Full details available on request.

14] The procedure requires specifying a maximum number of breaks, which is set equal to 5, and a minimum length of parameter stability, or “trimming percentage.” Bai and Perron’s (2003) advice is followed and this is varied between 10% and 15%.
There is no evidence of any breaks in daily holding returns in land stocks or consols, or their differentials. All of these tests are also carried out on weekly and monthly data as well. There is no evidence of any structural breaks in prices. I also carry test for differences in consols trading in London and Dublin and this also finds no structural break. As noted, the correlation between the two series was around 0.99 and so the structural break test is not surprising. Testing for breaks in prices is conceptually more difficult since there is the question of the stationary of the series.  

A potentially more pressing problem is that there is a low power issue with Bai and Perron (2003). Alternative Bayesian change point analysis of Barry and Hartigan (1993) have greater ability to detect short deviations. These tests show a much higher likelihood of change points in the data using the posterior probability. In some cases these breakpoints occur too frequently to sensibly assess or interpret. These break findings are not surprising given the stylized features of daily financial market data that typically show on average zero returns but considerable variation around this (Brown and Warner, 1985).

4.4.2 Volatility analysis

Another facet of investor reaction to historical events can be gauged through patterns of asset price volatility (Brown et al., 2006). While the three individual daily returns (and their differentials) cluster around zero each year, their volatility tells a different story. The standard deviation of returns for some months in 1920 and 1921 is more than three times those in 1913. This reflects the well-established feature of time varying volatility in financial time series that has proved useful to exploit historically (Meulemann et al., 2013).

In an a priori approach to explore historical events, political or other news or regime changes can be coded into simple dummy variable indicators and added as explanatory variables to standard GARCH models in (4.3). The estimated

\footnote{Note that the estimated models in all cases had very very high AR(1) coefficients. Tests reported in the Appendix overwhelmingly report unit roots in daily prices.}
parameter $d$ in the simple GARCH(1,1) model in 4.3 shows the extent that particular events, or regime changes, are associated with systematically higher or lower volatility. These models are expected to yield satisfactory results, regardless of whether or not Dublin financial markets were affected by turbulent events (Bollerslev, 1986). This approach can also be extended to add more events in a simple mean equation for returns.

$$\sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \beta_1 \sigma_{t-1}^2 + d_t$$  \hspace{1cm} (4.3)

The choice of events to include in this turbulent period for Dublin is large, and covers domestic events in both islands and also international events. As noted by Elmendorf et al. (1992), this approach potentially raises "observer bias in selecting news events." To mitigate potential subjectivity, two historical reference sources are used to select key events: Cannon (2009) and Connolly (2002). While this still involves some \textit{a priori} selection of historical events, those chosen by professional historians are likely to suffer from less subjectivity. The limited number of events are set out in Tables 4.6 and 4.7 in the Appendix for both islands are not contentious.\footnote{Other novel approaches to defining historical "news" include the size of newspaper headlines (Niederhoffer, 1971) and events listed in almanacs (Cutler et al., 1989).}

It is natural to explore whether the War of Independence and Civil War were associated with changing volatility. Also whether specific events triggering both their start and end, as acknowledged by historians, prompted market reactions. The period also saw several changes in British political administrations, and these are included to capture both wider investor sentiment and possible policy towards Ireland. The 1918 election has been seen as a watershed in the political landscape of both islands and is this included along with the 1918 armistice.\footnote{A question with using daily data is how far to allow news events to impact on price volatility (or means). The paper explores several possibilities, including just on the day, and also allowing for an event to have an impact for up to a full trading week after an event. The results are not affected by this choice.}

The choice of events to include is not wholly unconstrained. The periodic clo-

104
Table 4.3: GARCH(1,1) Daily consol and land stock spreads. 1916: 1923

<table>
<thead>
<tr>
<th></th>
<th>Con</th>
<th>Con-2.75% land</th>
<th>Con-3% land</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_1$</td>
<td>0.183*** (0.021)</td>
<td>0.161*** (0.0273)</td>
<td>0.229*** (0.0325)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.601*** (0.033)</td>
<td>0.503*** (0.0648)</td>
<td>0.3455*** (0.059)</td>
</tr>
<tr>
<td>WOI</td>
<td>0.015** (0.006)</td>
<td>0.041*** (0.0146)</td>
<td>0.05596*** (0.0162)</td>
</tr>
<tr>
<td>CW</td>
<td>0.002 (0.006)</td>
<td>-0.0413 (0.0238)</td>
<td>-0.024 (0.0169)</td>
</tr>
<tr>
<td>WOIST</td>
<td>0.120 (0.205)</td>
<td>0.063 (0.122)</td>
<td>0.1178 (0.1685)</td>
</tr>
<tr>
<td>WOIEND</td>
<td>0.229 (0.321)</td>
<td>0.737* (0.4031)</td>
<td>1.6258* (0.9038)</td>
</tr>
<tr>
<td>CWST</td>
<td>0.014 (0.025)</td>
<td>-0.00183 (0.0348)</td>
<td>0.0301 (0.061)</td>
</tr>
<tr>
<td>CWEND</td>
<td>0.348 (0.414)</td>
<td>0.196 (0.4857)</td>
<td>0.2079 (0.5740)</td>
</tr>
<tr>
<td>ARMIS</td>
<td>-0.0058 (0.017)</td>
<td>0.0356 (0.0938)</td>
<td>-0.00495 (0.2067)</td>
</tr>
<tr>
<td>1918ELEC</td>
<td>-0.003 (0.021)</td>
<td>-0.135*** (0.0361)</td>
<td>0.125 (0.1254)</td>
</tr>
<tr>
<td>EASTER</td>
<td>-0.022*** (0.0053)</td>
<td>0.444 (0.326)</td>
<td>0.0124 (0.070)</td>
</tr>
<tr>
<td>BONAR</td>
<td>-0.056 (0.053)</td>
<td>0.002</td>
<td>0.0053</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Time dummies for day of the week included, but not reported. A t-distribution, rather than a normal distribution, is employed throughout to account for the fat-tailed (kurtosis) innovations in the returns and spreads.
sure of the Dublin market means there is no data during the Easter rising in April 1916 or the start of the Civil War in late June 1922. A dummy variable is included for the week following the resumption of trading for both of these events. Another technical consideration is that the need to maximise the log likelihood places a limit on the number of explanatory variable that can be added to a GARCH model (Johnson, 2002).

Table 4.3 shows results from a GARCH (1,1) specification for daily consol returns (rcon) and for the 2.75% and 3% land stocks their differential with consols between 1916 and 1923. These differentials are a crude way in stripping out wider British or international events.\(^{18}\) Dummies for the day of the week are included in the estimation, but are not reported for space reasons. A t-distribution, rather than a normal distribution, is employed throughout to account for the fat-tailed (kurtosis) innovations in the returns (Bollerslev, 1986).

Each of the three assets, and for the land stocks their differences with consols, can be characterized as GARCH (1,1) processes. The ARCH (\(a_1\)) and GARCH (\(\beta_1\)) parameters are significant at the 1% level, but sum well below one showing a modest degree of persistence. The War of Independence between January 1919 and December 1921 is associated with an upsurge in volatility in the lands stocks relative to consols, but there is no corresponding increase during the Civil War. Figures 4.5 and 4.6 show relatively calm volatility in the differential throughout the war years but there is a noticeable jump in volatility during 1920 and 1921. Since consol prices mirrored the London market, this could be indicative of Dublin specific volatility. However, a further analysis of the land stocks trading in London would be needed to justify this conclusion.

Key events traditionally associated with the start and end of the War of Independence have limited impact, although there is a rise in volatility of land stocks relative to consols following the signing of the Anglo-Irish treaty. There was a

\(^{18}\)Results for 1913-1914 are available on request. The mean return equation is estimated with a constant only. As is typically found in the modern literature, none of the additional variables from Table 4.3 are significant in the mean return equation. HAC standard errors are used.
Figure 4.5: Conditional variance of daily return: 2.75% Land stock relative to consols

![Graph showing conditional variance of daily return for 2.75% Land stock relative to consols over the years 1916 to 1923.]

Figure 4.6: Conditional variance of daily return: 3% Land stock relative to consol

![Graph showing conditional variance of daily return for 3% Land stock relative to consol over the years 1916 to 1923.]

reduction in consol volatility in the week after the Easter rising, but note that land stocks had not resumed normal trading at this time. In line with Brown et al. (2006), daily volatility shows little change around political administrations, particularly in 1918, or following the 1918 armistice.  \(^{19}\)

### 4.4.3 Cointegration analysis

As guaranteed British stocks, Irish land stocks could have theoretically reflected factors common to the wider UK and Irish risk factors. While assessing the differences in land stock and consol returns (and prices) is useful in stripping out common macroeconomic fluctuations or other “news,” it does not fully capture their relative importance. Nor can it answer the obvious question of whether consols simply anchored the value of land stocks and left little room for Irish specific risk factors?

Cointegration has proved a useful tool in understanding these issues in a number of historical contexts. It can capture not just any equilibrium relationship between different assets, but also explore the extent that shocks in one asset can “explain” movements in other assets. A system-wise Johansen Cointegration test (Johansen, 1988) is used to analyse the presence of the long-run equilibrium relationship between consols and land stocks, using (4.4):

\[
\Delta P_t = v + \Pi P_{t-1} + \sum_{i=1}^{p-1} \Gamma \Delta P_{t-i} + \epsilon_t
\]  

(4.4)

Where \(\Delta\) is the first difference operator, \(P\) is a vector of endogenous variables [\(\text{LNCON}, \text{LNLAND1}, \text{LNLAND2}\)], the first element being the the log of the benchmark consol price (whose difference corresponds to the daily holding return), and the second and third elements being the daily return on the 2.75 and 3% land

\(^{19}\)As in Brown et al. (2006) a PREMIUM variable, defined as the percentage difference between the natural log of the bond price and one hundred, is explored to capture potential redemption effects, but these are not found to be significant. Box-Ljung statistics show no significant autocorrelation up to order 10 for standardized residuals and residuals squared. An identical EGARCH specification is also estimated that allows for shocks to volatility to differ depending on whether they were positive or negative. There is not much to choose between the models using the Bayesian Information Criterion (BIC).
stock respectively. It is a coefficient matrix which contains information about the long run relationship between variables in the vector.$^{20}$

Table 4.5 in the appendix shows that both the maximum eigenvalue and trace test find two cointegrating vectors between the three assets. Full details of the vector error correction model (VECM) are available on request. However, two supplementary statistics produced by the VECM are of particular interest in understanding the path of prices.

Firstly, the impulse response functions trace the direction of response to one standard deviation random shocks among the assets. Figure 4.7 shows these impulse response functions for the following two week trading period. They show that a shock in consol prices (LNCON) leads to a positive and significant effect on both the 2.75% and 3% land stock prices (LNLAND1, LNLAND2). There is no evidence of the reverse: namely land stock shocks having an impact on consol prices.

Secondly, the variance decomposition determines how much of the forecast error variance of each asset price can be “explained” by exogenous shocks to prices (including itself). In unreported analysis, the benchmark consol is shown to be the most exogenous of the three asset prices. Virtually all (99.8 per cent) of the variation in the consol price forecast error is explained by its own shocks. The corresponding figures are over 70 and 65% for the two land stocks. The variance decomposition shows that consol prices contribute non-trivial amounts to the land stock forecast errors. By contrast, shocks to each of the land stocks have little impact on the consol price forecast error.

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$^{20}$If the variables are cointegrated, the cointegrating rank, $r = \alpha \beta$, where $\alpha$ is the matrix of parameters denoting the speed of convergence to the long-run equilibrium and $\beta$ represents the matrix of parameters of the cointegrating vector.
Figure 4.7: Impulse response functions

Response of LNCON to Cholesky
One S.D. Innovations

Response of LNLAND1 to Cholesky
One S.D. Innovations

Response of LNLAND2 to Cholesky
One S.D. Innovations
4.5 Share prices: An exploratory analysis

4.5.1 Background

The focus on Government stocks in this essay is justified twofold: the need to use frequently traded assets in Dublin and the novelty of land stocks as a measure of market sentiment. While stocks mainly reflect the risk of government default as a consequence of institutional crisis, equities may also reflect potential losses of private firms or shareholders as a consequence of violent social conflict or political change (Battilossi and Houpt, 2009).

Analysing Irish equity markets as opposed to stocks in this period has two advantages. Firstly, and more importantly, they could be less “contaminated” by wider British or other world events than stocks. Indeed, Grossman et al. (2013) note that patterns of Irish equity prices in this historical period “mirrors those in Belgium more than the UK.” Secondly, shares were not subject to the introduction of minimum prices that stocks were during the war years.

Several existing papers already look at historical monthly Irish equity markets. Unfortunately, it is difficult to construct a high frequency stock market index for Dublin in this period because many shares were not trading daily. An alternative is to analyse frequently traded shares. This approach raises concerns as involves (extreme) elements of self-selection bias. However, this approach is not without precedent in the literature. As a proxy for Hawaiian commercial interests at the time of annexation, Burdekin and Laney (2008) study the daily share price of the strategically important Hawaiian Commercial and Sugar Company.

To the extent that the turbulent events affected commercial interests in Ireland, shares might better capture market reaction than Government stocks. The most frequently traded ordinary shares in Dublin in this period were in banking and rail. These sectors have the advantage of not only being regularly traded, but also of being of wider strategic importance to the Irish economy. Both sector’s were closely linked to the future health of the Irish economy, but on a more practical
level, their day-to-day activities were also exposed to events in this turbulent period. Illustrating the latter for railways, the *Irish Times* noted on the resumption of trading after the Easter rising:

“very heavy decreases are shown in home railway traffic as a result of the practical cessation of working for some days while military movements were being made to cope with the rebellion.”

(14 May 1916)

4.5.2 Analysis of share prices

Daily share prices are collected from the *Dublin Daily Stock Exchange Listings* between January 1913 to December 1923 for nine stocks. Three banks (Bank of Ireland, Hibernian, Ulster Bank), three railways (Great Southern and Western Railways, Great Northern Ireland Railways, Midland Great Western Railways), one tram (Dublin United Tramways), one drapery (Arnotts) and one bakery (Johnston Mooney and O’Brien). The latter two were dropped from the analysis because of the lack of trading. Ulster Bank ceased to appear in the Dublin *Listings* during 1918.

In the absence of liquidity data, the proportion of days each share was traded is also calculated in a similar fashion to stocks. The banks traded at a similar frequency to stocks at roughly once every two days. The rail stocks traded slightly more frequently and for one company, Great Southern and Western Railways, it occasionally reached the trading frequency of consols.

Figures 4.8 to 4.11 set out prices for the bank and rail stocks. Several features are notable from these graphs. Firstly, ordinary shares appear more variable than stocks and this is confirmed by the higher coefficient of variation for shares than stocks.\(^\text{21}\) Secondly, is the tendency for share prices in the same sectors to move

\(^{21}\) This represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another when the means are drastically
Figure 4.8: Bank of Ireland daily share prices

Figure 4.9: Hibernian Bank daily share prices
Figure 4.10: Great Southern and Western Railways, Great Northern Ireland Railways daily share prices

Figure 4.11: Midland Great Western Railways Daily share prices
together. The banks appear to go through several cycles, declining around 1920 but recovering at the end of the period to end 1923 higher than 1913. The three rail stocks decline throughout the period, sharply falling in 1920, although MGW does make a brief recovery at the end of the period. All three rails stocks end 1923 substantially lower than at the start of 1913.

Prices (and returns) can also be assessed around key events in the period, including the reopening after the Easter rising and also the outbreak of the Civil War. No significant price movements can be detected, and several shares actually rise in the weeks after the Easter rising and the Civil War. Prices around the times of the key events listed in Tables 4.6 and 4.7 also fail to show any systematic responses.

An initial battery of tests are carried out on these ordinary share prices focusing on returns and prices, and levels and volatility. For space reasons, only a flavour of the findings are given. Four of the six ordinary shares analysed (Great Southern and Western Railways, Great Northern Ireland Railways, Dublin United Tramways, Bank of Ireland) show conventional structural breaks over this period in contrast to the land stocks. Three of these shows break points at at similar times at the end of 1919 and start of 1920 (Great Northern Ireland Railways, Great Southern and Western Railways and Dublin Tramways) using the simple Bai and Perron (2003) test. This corresponds to the second year of the War of Independence. The Bank of Ireland show a structural break later in 1921.

Both pre-estimation and post estimation tests detect conditional volatility in returns and prices, which in some cases are up to two trading weeks. All of the shares show large swings in volatility from simple GARCH models. The swings are sometimes of a higher order magnitude than in stocks for some shares. As in Section 4.5, the Barry and Hartigan (1993) tests also continue to find evidence of frequent change points over short periods of time.

different from each other. The CVs were almost double the value for rail shares compared to land stocks. Banks also had higher CVs.
4.6 Discussion

The analysis begins by following the large cliometric literature that searches for structural breaks in asset prices or returns, by using the pure “data driven” methodology of Bai and Perron (2003). No structural breaks in daily consol or land stock prices or returns are found during this period. No breaks are found in London and Dublin consol price differentials. This is in contrast to swings in daily volatility, which like many high frequency financial assets can be modeled by a simple GARCH (1,1) process. More powerful Bayesian change point tests also point to the high probability of frequent change points in both returns and prices in this period. In order to understand these further, I supplement these econometric findings with contemporary market commentaries and political developments.

The short and longer-term behaviour of these assets might be seen as puzzling from a historical perspective. However, all three assets show familiar patterns from modern financial markets. Daily returns are on average zero return but show considerable variation around this (Brown and Warner, 1985). Conventional tests such as Bai and Perron (2003) are likely to struggle to capture much in this period. This short term volatility is likely to reflect changing expectations rather than fundamentals (Meulemann et al., 2013).

In their reviews of Irish financial markets, the Irish Times mirror some of these uncertainties. For example, 1914 was “a year without parallel.” By the 1916 review, the market was “flat on political anxiety.” However, it was not all negative and during 1918, with signs of progress on the Ulster question and the Great War, the Irish Times reported a market “upbeat on the wider situation improvements.” However, apart from the general period in the War of Independence, there is little in terms of specific events to link these sometimes erratic daily spikes to. Neither the Dublin (nor London) markets were at any time anticipating payment difficulties, let alone any default on these Irish land stocks.22

Other than normal market volatility, the absence of a more pronounced long-

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term market effect might also be linked to subsequent events in the 1920s. The newly created Free State was obligated for four principal sources of debt: Irish Republic Bond-Certificates (issued to fund the War of Independence); Land Bonds; a share of Imperial Debt; and new issuance (Foley-Fisher and McLaughlin, 2014). While the land annuities issue did not disappear in the 1920s, particularly in local politics (Dooley, 2004), the Irish Free State was continuing to pay annual annuities in the course of the 1920s.23

The default on land annuities did not take place until a decade after the Treaty. Although the Free State was released from its obligation to repay its share of Imperial Debt under the 1925 of Agreement Act, it remained obligated for land bond payments. Indeed, as set out in the 1926 Ultimate Financial Settlement (UFS):

"The Government of the Irish Free State undertake to pay to the British Government at agreed intervals the full amount of the annuities accruing due from time to time under the Irish Land Acts, 1891-1909, without any deduction whatsoever whether on account of Income Tax or otherwise."

(Text from the Ultimate Financial Settlement, 1926)

The Treasury had taken losses on the flotation of land stocks, and also in paying bonuses to landlords, and reiterated their public backing of land stocks at key times (Wormell, 2012). The relevant part of the UFS set out:

"The British Government accept liability for the provision out of monies provided by Parliament of the cost of the interest and sinking fund on bonus and excess stock under the above-mentioned Acts, subject to a contribution by the Irish Free State Government."

(Text from the Ultimate Financial Settlement, 1926)24

23 Annual payment details are set out in the accounts of the Irish Land Purchase Fund.
Against this background, the lack of a more pronounced market reaction in land stocks to events is not surprising. The most important econometric finding is the links between consols and Irish stocks. Since consols and land stocks had the same issuer, i.e. the British Government, the cointegration findings are not surprising. Neither given the size of the British capital market is the relative importance of consol prices in anchoring land stocks established in the impulse response functions in the VECM. Yoon (2010) reports a similar historical finding between consols and other Guaranteed British stocks, including rail stocks, Indian stocks and corporation stocks.

Notwithstanding daily market volatility, consols were remarkably stable historically, and this paper’s daily findings mirror those of Brown et al. (2006), who find no structural breaks in consol yields or prices over the entire 1729 to 1960 period (using the low power) Bai and Perron (2003) tests and monthly data. Brown et al. (2006) attribute this to the political and economic stability during the “Pax Britannica” period. Bordo et al. (2003) also note the roles of favorable prices and inflation shocks in regard to UK financial stability.

These findings share some general themes in the literature on stock price movements. While the relationship between different measures of “news” and volatility is well researched, news can typically only explain a small fraction of the movement in financial markets (Brown et al., 2006). Financial markets are generally seen to react to some, but by no means all, of the events emphasized by later historians. Interestingly from a historical perspective, it was that only the War of Independence and its conclusion that was associated with higher variability in daily returns in the GARCH model. By contrast, other specific events did not have an economically significant impact on volatility, and these included changes in prime ministers and even major events such as the 1918 armistice. These findings are consistent with a view of volatility as being dependent on the overall economic and political climate, rather than isolated events. Indeed, one of the criticisms of the conditional volatility approach is its “black box” nature that cannot capture macroeconomic factors (Voth, 2011).
Oosterlinck et al. (2013) describes this structural break approach to history as useful for examining “extreme events, critical to the outcomes of existential wars such as the US Civil War and World War II.” By contrast, this method may be less useful for examining market reaction to events of “middling” significance, such as battlefield or diplomatic events associated with wars of choice or civil disturbances.

Further insight into this period could come from other market reactions. One interesting area of research in the finance literature is the link between volatility and liquidity (Mike and Farmer, 2008), and one view sees them as driven by a common factor: namely uncertainty. Unfortunately, there are no detailed liquidity data for consols or land stocks in this period, however contemporary market commentaries can help to fill this gap. These point to a market where liquidity did at times dry up during key events, despite the large diverse ownership of all three assets. On the resumption of trading after the Easter rising, the Irish Times noted that

“Considering the recent course of disturbing events in Dublin and the provinces, it was remarkable how little prices of stock exchange securities suffered. Dealing in stocks was exceeding circumscribed.”

(May 9, 1916)

And in summing up the first full week after the resumption of trading, the Irish Times noted

“The Dublin stock exchange might as well have extended its enforced holiday during the past week, as dealing were exceedingly small each day, and on more than one occasion was literally at a standstill. Consols were mostly dull.”

(May 15, 1916)

As events progressed there was a similar pattern of findings for liquidity. Com-
menting on trading at the height of the war of independence in February 1920, The Irish Times noted,

"Sagging prices have been shown for Irish land[stocks] ... but with very little stock changing hands."

Of course, none of these explanations can rule out the possibility that investor reaction was directed towards other asset classes. British guaranteed stocks with their unique historical features might not be the best assets to explore in this period. It is unlikely that any econometric approach can remove wider British or international events influence from lands stocks. The daily share prices collected from the *Dublin Daily Stock Exchange Listings* between January 1913 to December 1923 might be a more promising source of information.

Interestingly, half of the stocks show conventional breaks around the end of 1919 and start of 1920. This was a period with several decisive developments in the War of Independence. This period saw the first text of the Home Rule Bill being introduced to the House of Commons in February 1920. It also coincided with the arrival of British recruits to help the RIC (the "Black and Tans") as the civil situation was deteriorating (Cottrell, 2006). Separating out pure domestic events against the background of post-war austerity and deflation (Hickson and Turner, 2005) in this period remains a challenge and should be a priority for future analysis. This is not straightforward. As Grossman et al. (2013) note, the "interwar period saw a number of boom-bust cycles, concurrent with war and other political events affecting Ireland, including its independence movement."

The price data offers several other challenges for further work. Interestingly, assets during the Civil War do not appear to show the same volatility (as consols) or structural breaks (for shares) as the War of Independence. This might be surprising given the destruction of the physical capital that this period saw (Coleman, 2013). In fact, the Civil War took place against rising consol and land stock prices, and also for many ordinary shares.
4.7 Conclusion

Instead of relying on the statements of politicians or views from historians, the essay explores Government stock prices in Dublin to gauge investor sentiment between 1913 and 1923. In one of the essay's main contributions, the daily prices of little known Irish land stocks are reconstructed and used as a novel approach to infer market sentiment in this turbulent period. This offers a potentially valuable alternative to a highly politicised historiography of the period. Supplemented by qualitative evidence in the form of daily market commentaries, the essay arrives at three main findings.

First, conventional tests find no evidence of structural breaks in this period. Although as is typical with daily financial data, GARCH and more powerful break tests do find frequent short-term bursts of volatility and high probabilities of change points in both prices and returns. However, it is difficult to isolate any specific events linked to higher volatility or change points. A simple cointegration approach shows a tendency for land stocks to move in line with benchmark British consols. Given the continued British guarantee of land stocks after partition and continuing payments by the Free State of annuities during the 1920s, these findings are perhaps not unexpected.

Second, the essay shows how ordinary Irish shares that might be less contaminated by wider British or international events of the day could provide a better insight into the commercial reactions. A handful of selected shares show much more volatility than land stocks, as well as strong sectoral patterns. Four of the six shares show conventional (but low power) structural breaks, with three of these occurring between the end of 1919 and start of 1920 during War of Independence.

Thirdly, the Dublin market is a useful case study showing some of the methodological issues of this increasingly popular “market approach” to history. For example, not having detailed liquidity data and the periodic suspension of markets during periods of crisis can hamper quantitative analysis. Historical analysis of daily data also has to take into account the stylized features of high-frequency
financial data. The essay also documents the low power of the Bai and Perron (2003) approach to structural breaks compared to alternative measures.
Appendix Chapter 4

Table 4.4: Unit root tests

<table>
<thead>
<tr>
<th></th>
<th>ADF</th>
<th>PP</th>
<th>DF-GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>lncon</td>
<td>-1.812</td>
<td>-1.723</td>
<td>-0.809</td>
</tr>
<tr>
<td>Δlncon</td>
<td>-24.664***</td>
<td>-42.524***</td>
<td>-2.638**</td>
</tr>
<tr>
<td>inland1</td>
<td>-1.575</td>
<td>-1.610</td>
<td>-1.064</td>
</tr>
<tr>
<td>Δinland1</td>
<td>-42.444***</td>
<td>-42.241***</td>
<td>-2.145**</td>
</tr>
<tr>
<td>inland2</td>
<td>-1.365</td>
<td>-1.4236</td>
<td>-1.125</td>
</tr>
<tr>
<td>Δinland2</td>
<td>-42.937***</td>
<td>-4.949***</td>
<td>-41.937***</td>
</tr>
</tbody>
</table>

Note: The asterisks *** denote the significance at the 1 per cent level. ADF is the augmented Dickey-Fuller test, PP is the Phillips-Perron test, and DF-GLS is the Dickey-Fuller Generalised Least Square test. In denotes a natural logarithm and is the first difference operator. The figures in parentheses indicate the optimal lag length for ADF and DF-GLS tests, and bandwidth for PP test. The optimal lag length are selected by Akaike information criterion (AIC).

Table 4.5: Johansen cointegration tests

<table>
<thead>
<tr>
<th></th>
<th>H0</th>
<th>H1</th>
<th>Critical values</th>
<th>(Pvalue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR(λtrace)</td>
<td></td>
<td></td>
<td>5 per cent</td>
<td></td>
</tr>
<tr>
<td>r=0</td>
<td>r≥1</td>
<td>78.034</td>
<td>29.797</td>
<td>0.000</td>
</tr>
<tr>
<td>r≤1</td>
<td>r≥2</td>
<td>17.145</td>
<td>15.495</td>
<td>0.028</td>
</tr>
<tr>
<td>r≤2</td>
<td>r≥3</td>
<td>1.811</td>
<td>3.841</td>
<td>0.1784</td>
</tr>
<tr>
<td>LR(λmax)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r=0</td>
<td>r≥1</td>
<td>60.888</td>
<td>21.131</td>
<td>0.000</td>
</tr>
<tr>
<td>r≤1</td>
<td>r≥2</td>
<td>15.333</td>
<td>14.264</td>
<td>0.0338</td>
</tr>
<tr>
<td>r≤2</td>
<td>r≥3</td>
<td>1.8111</td>
<td>3.841</td>
<td>0.1784</td>
</tr>
</tbody>
</table>

Note: *** and ** denote the significant level at the 1 and 5 per cent levels, respectively. The critical values are obtained from MacKinnon et al. (1999). The AIC statistic is used to select the optimal lag order. The selected lag order is five.
<table>
<thead>
<tr>
<th>Date</th>
<th>code</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 September 1914</td>
<td>*</td>
<td>Government of Ireland Act, offering Irish Home Rule, passed but application simultaneously postponed for the duration of World War I</td>
</tr>
<tr>
<td>20 March 1914</td>
<td>MUT</td>
<td>Curragh mutiny</td>
</tr>
<tr>
<td>24 April 1916</td>
<td>EASTER</td>
<td>Easter Rising: The Irish Republican Brotherhood led an action which seized key government buildings in Dublin, and issued the Proclamation of the Irish Republic.</td>
</tr>
<tr>
<td>14 December 1918</td>
<td>ELECTION</td>
<td>A General Election returns a majority for Sinn Fin in Ireland</td>
</tr>
<tr>
<td>11 September 1919</td>
<td>ILLE</td>
<td>British government declares the Dial illegal</td>
</tr>
<tr>
<td>21 January 1919</td>
<td>WOI</td>
<td>Irish War of Independence start: two members of the Royal Irish Constabulary killed in what is generally considered to be the first act of the War of Independence. The First Dil of the Irish Republic meets and issues a Declaration of Independence from the UK.</td>
</tr>
<tr>
<td>6 December 1921</td>
<td>WOI</td>
<td>Irish War of Independence - end: negotiations between the British government and representatives of the de facto Irish Republic conclude with the signing of the Anglo-Irish Treaty and the creation of the Irish Free State</td>
</tr>
<tr>
<td>28 June 1922</td>
<td>CW</td>
<td>Irish Civil War - start: Bombardment by Anti-Treaty forces occupying the Four Courts marks the start of the Irish Civil War</td>
</tr>
<tr>
<td>24 May 1923</td>
<td>CW</td>
<td>Irish Civil War - end: volunteers to dump arms - effectively ending the Civil War</td>
</tr>
</tbody>
</table>

Source: Connolly (2002)
Figure 4.12: Example of a BCP test on Land stock returns relative to consols

![Posterior Means and Probabilities of a Change](image)
<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st July 1916</td>
<td>SOMME</td>
<td>Battle of the Somme</td>
</tr>
<tr>
<td>6 December 1916</td>
<td>GEORGE</td>
<td>David Lloyd George becomes PM</td>
</tr>
<tr>
<td>11 November 1918</td>
<td>ARMIST</td>
<td>Armistice ending World War one</td>
</tr>
<tr>
<td>19-23 October 1922</td>
<td>BONAR</td>
<td>Lloyd George resigns. Andrew Bonar Law becomes new PM</td>
</tr>
<tr>
<td>22 May 1923</td>
<td>BALDWIN</td>
<td>Stanley Baldwin becomes Prime Minister.</td>
</tr>
</tbody>
</table>

Source: Cannon (2009)
Chapter 5

Conclusions

The thesis is motivated by the increasing success of economic history in exploring questions through novel datasets and modern econometric methodologies. As well as exploring specific historical questions, all three essays contribute to wider mainstream literatures and also highlight more general issues of working with historical data.

Using a panel of 19 countries between 1860-4 and 1910-14, essay one shows quantitatively that access to markets mattered for early industrial development. Cliometric interest in economic geography models has tended to focus on exploring the strong regional clustering patterns of early industrial activity. Market access is operationalised from the NEG literature as the distance-weighted sum of the market capacity of surrounding locations, taking into account their trade costs (Fujita and Venables, 1999). This helps to explain the core and periphery patterns of late nineteenth century industrial development. Also consistent with the modern spatial economics literature, I find little role for population density (Brakman et al., 2009). The results are robust to different samples, measures of industry, the inclusion of control variables and strategies for dealing with endogeneity.

Notwithstanding the small panel nature of the data, the findings have three advantages when it comes to interpretation. Firstly, they can be given a structural interpretation. Secondly, by explicitly incorporating endogeneity and spatial
dependence into the modeling, I allow for a more robust analysis of the spatial inter­
teraction between countries. Finally, the findings are consistent with familiar themes that emphasise the role of both domestic and external factors in understanding historical economic growth.

The essay’s findings also touch on two other geographical considerations when thinking about historical industrial development that warrant further research. While the original impetus of the market access approach was based on trade considerations, there are growing links between market access and migration, investment, foreign direct investment, human capital as well as industrial development. Secondly, while included principally for econometric purposes, the persistence of spatial correlation warrants further investigation. One possibility is that it could reflect “spillovers” between countries.

Despite the universality of the association between height and labour market outcomes, Vogl (2014) reminds us that its sources differ widely by setting. Essay two explores these links for nineteenth century Britain and Ireland using data on nineteenth century East India Company army recruits assembled by Mokyr and Ó Gráda (1996). Taller recruits were around 30% more likely to have been in non-manual occupations. These links are not driven by birthplace or age heterogeneity, and are not affected by major historical events such as the Irish famine. The findings suggest more similarities between modern and nineteenth century labour markets than previously thought.

The essay documents how two important strands of literature can help to shed light on the findings. Firstly, the modern research showing that nutritional status, height and childhood are rewarded in the labour market through traits such as cognitive skills, confidence, intelligence, social skills, and not just physical strength (Currie, 2008). And second, the findings from the biological standard of living literature showing how the better off are better fed and have better access to health care. They have the potential to experience superior physical growth and cognitive development. There are reasons to believe that these profound effects of early-life conditions on labour market outcomes were of equal, if not greater, significance in
explaining entry into historical occupations (Baten et al., 2013).

One implication is that the modern approach of “sorting” to gauge the returns to height may simply be capturing this correlation in historical data. More fundamentally, the essays’ findings are part of a growing literature that illustrates the profound effects of early-life conditions on labour market outcomes in both modern and historical settings. In the vein of Humphries and Leunig (2009), the paper is further evidence showing how historians can use height as an “explanatory” variable to explore a range of adult outcomes. The mechanisms explored in this essay are of potentially great interest in historical research. While no attempt is made to substantiate some of the wider implications, they do appeal to Steckel’s (2009) claim that they could “bring nutritional status and stature to the fore in comprehending rates of return to schooling, socio-economic inequality that stems from cognitive deficits, and conceivably rates of technological change.” The essay finishes by setting out an ambitious way that the analysis could be extended by linking recruits to census data.

Essay three presents an alternative approach to understand the turbulent decade in Irish history from 1913 to 1923 that relies purely on financial market reactions, rather than the views from historians. The first main contribution is collecting daily prices for consols and land stocks by hand from the Dublin Stock Exchange Daily listings for this decade. These land stocks were inextricably linked to the Land issue that dominated Irish politics from the mid-nineteenth century, and they would assume a central role in the events surrounding the Anglo-Irish Trade War that began in 1932.

A battery of econometric tests arrives at three conclusions. First, conventional tests find no evidence of structural breaks in prices or returns in this period. However, as is typical with daily financial data, GARCH and more powerful break tests do find frequent short-term bursts of volatility and high probabilities of change points in prices and returns. However, it is difficult to isolate any particular events linked to higher volatility or erratic change points. A simple cointegration approach shows a tendency for land stocks to move in line with benchmark British
consols. Given the continued British guarantee of land stocks after partition and continuing payments by the Free State of annuities during the 1920s, these findings are perhaps not unexpected.

The essay finishes by showing how ordinary Irish shares that might be less contaminated by wider British or international events of the day might provide a better insight into market reaction. A handful of selected shares show much more volatility than land stocks, as well as strong sectoral patterns. Four of the six shares show conventional (but low power) structural breaks, with three of these occurring between the end of 1919 and start of 1920 during the War of Independence. Separating out pure domestic events against the background of post-war austerity and deflation remains a challenge and should be the priority for future analysis.

All three essays can be seen as case studies in the use of historical datasets for quantitative analysis. The thesis shows that large historical datasets are available that allow for modern methodologies to be replicated. However, working with smaller datasets is not a barrier to historical analysis. The thesis shows the importance of evaluating datasets in terms of both reliability and representativeness. The thesis also shows how historians can overcome problems associated with data availability through proxy variables and drawing on more qualitative sources of information.
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145


