

Digging Deeper: Global Coal Prices and Industrial Growth, 1840-1960

by

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Short Abstract

This thesis investigates to what extent coal prices differed globally during the nineteenth and twentieth centuries, and whether those differences mattered for economic development. The backbone of my empirical investigation is a new dataset of annual coal prices spanning the years 1840 to 1960 for, on average, over 30 globally distributed ports. This dataset is complemented by pithead prices for all major coal-producing countries. My analysis includes all major steam coals and I eliminate quality differences by accounting for differences in their carbon content.

I construct my argument by examining two major drivers of differences in coal prices. First, I examine trade costs for Welsh steam coals, which were shipped to most regions of the world. Secondly, I estimate the effect of the spread of coal mining, for example to India, on local coal prices by initiating competition between coals from different origins. While trade costs declined most during the late nineteenth century, the spread of coal mining led to continued price convergence in the interwar period. And yet, global coal price differences remained significant, especially between producing and importing countries.

Arguably, my most interesting finding is on the effect of those coal price differences. More specifically, I calculate the ratio of coal prices to wages, and explore whether countries where this ratio was closer to the British ratio were in the best position to use the most advanced steam technology. My econometric results indeed show that countries with a low coal price/wage ratio experienced higher manufacturing output growth during the period 1870 to 1940. This finding of my thesis highlights one potential way in which different levels of coal prices may have contributed to varying degrees of technology adoption between countries and ultimately economic growth.

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1. Introduction

In 1865 Jevons published *The Coal Question*. It contained an alarming argument: Britain would run out of coal in less than 100 years if coal production would continue to increase at its long-run growth rate.¹ As we know, Jevons's prediction shared the fate of many other economic forecasts in that it was invalidated by changing trends. British coal production peaked in 1913, and to the present day Britain has sizeable coal deposits. The last British deep-coal mine closed in 2015, which puts the end of commercial viability of this type of coal mining 150 years after Jevons's publication. More recent research now tentatively estimates that 90% of total global coal production will be reached by 2070.² Only time will be able to tell. Yet Jevons's work remains valuable because of his conviction that the economic destiny of Britain was dependent upon the availability of her coal resources:

“[...] we cannot long maintain our present rate of increase of consumption; [...] the check to our progress must become perceptible within a century from the present time; that the cost of fuel must rise, perhaps within a lifetime, to a rate injurious to our commercial and manufacturing supremacy; and the conclusion is inevitable, that our present happy progressive condition is a thing of limited duration.”³

At the time of Jevons's publication, coal-run steam engines were the major provider of mechanic power in manufacturing industries such as textiles. On top of that, the iron and steel industries required coking coal as an important input as well as iron ore, which was also available in vicinity to British coal deposits. A consideration to save British coal resources was to levy export taxes on coal to favour production for domestic purposes.⁴

Jumping over half a century ahead, Britain faced coal scarcity in the reconstruction boom

¹ W. Jevons, *The Coal Question: An Inquiry Concerning the Progress of the Nation and the Probable Exhaustion of our Coal Mines*, (London, 1865)

² D. Rutledge, 'Estimating Long-Term World Coal Production with Logit and Probit Transforms', *International Journal of Coal Geology*, Vol. 85, No. 1, (2011)

³ W. Jevons, *The Coal Question. An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*, 2nd edn, (New York, 1906), p.245-46

⁴ For example, a Dr. Buckland suggested this at a hearing of the *Committee on the Coal Trade of 1830*, as referenced in W. Jevons, *The Coal Question: An Inquiry Concerning the Progress of the Nation and the Probable Exhaustion of our Coal Mines* (London, 1865), XVII.2

post-World War II. Interestingly, back then, it was believed that continuing coal exports was in the best interest of Britain. Coal exports to the continent and Argentina were maintained (at a lower level) since the British coal industry wanted to keep its supply streams steady, fearing that otherwise they would be eventually driven out of the market by other coal supplying countries.⁵

While the relationship between coal production and the British Industrial Revolution appears particularly striking, such dependencies can also be observed on a global level. Figure 1.1 gives the share of the leading coal-producing countries in global GDP for the four benchmark years 1850, 1900, 1950 and 2000, a period when industrial development spread over the world. Note that the countries are ranked in descending order according to coal production in each of the four benchmark years separately, so the countries underlying the groups change.

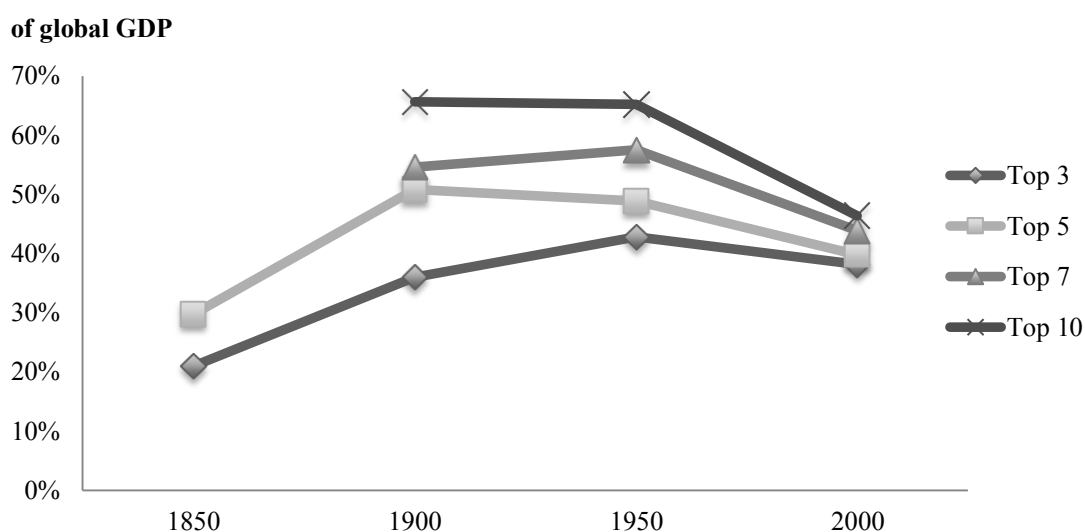


Figure 1.1: Share of top coal-producing countries in global GDP

Notes: Coal output volumes from Mitchell and GDP in 1990 Int. Geary-Khamis Dollar (GK\$) from Maddison.⁶ Brown coal output is not included, but anthracite for the USA. GDP 1950 for Germany is East plus West Germany. GDP 2000 for Russia refers to the USSR.

⁵ W. Ashworth, *The History of the British Coal Industry. 1946-1982: The Nationalized Industry*, (5 vols., Oxford, 1986), p.214-15

⁶ B. Mitchell, *International Historical Statistics: Africa, Asia & Oceania, 1750-2005*, 5th edn, (Basingstoke, 2007), B. Mitchell, *International Historical Statistics: Europe, 1750-2005*, 6th edn, (Basingstoke, 2007), B. Mitchell, *International Historical Statistics: The Americas 1750-2005*, 6th edn, (Basingstoke, 2007), A. Maddison, *Statistics on World Population, GDP and Per Capita GDP*, at <http://www.ggdc.net/MADDISON/oriindex.htm>, accessed 09 December 2012

The graph shows that there is a strong association between coal production and economic activity. The economic power of coal-producing countries increased from 1850 to reach a kind of plateau level in 1900 and 1950, showing a decrease when we hit the last benchmark year of 2000. Even then the top three producing countries accounted for 38% of global GDP. The back-of-the-envelope calculation underlying Figure 1.1 can be criticised in many ways – for instance, the sample underlying it. Additionally, these trends could be driven by the influence of certain countries such as the USA, which accounted for an overproportional share of both GDP and coal production. However, one should note the significant changes in the underlying order of countries: in 1850 the five largest coal-producing countries were Britain, the USA, Germany, France and Austria, where the first four had a similarly sized GDP of around 50mGK\$. In comparison, in 2000 the five major coal-producing countries were China, the USA, India, Australia and South Africa. So four-fifths of the sample have changed without damaging the strong correlation between coal production and GDP.

Since Jevons, economics and economic history have evolved as academic disciplines and a large body of research has been produced on the causes of economic growth, focusing on the Industrial Revolution in particular. No serious scholar would advocate mono-causal explanations in that coal was *the* determining driver of economic development, nor do I claim such a relation existed. The correlations explored in this introduction suggest that coal was a prerequisite, concomitant or consequence of economic growth. Rather, researchers now argue in favour of a multitude of factors in a “seamless web of historical change.”⁷ That said, out of the considerable number of potential explanations, scholars often lean towards certain factors they found particularly decisive such as the institutional framework protecting property rights (Acemoglu, Johnson and

⁷ A. Cameron and L. Neal, *A Concise Economic History of the World: From Paleolithic Times to Present*, 4th edn, (Oxford, 2003), p.164

Robinson; North and Thomas), trade and market integration (O'Rourke and Williamson), geography (Sachs) or the scientific advances of enlightenment (Mokyr).⁸ Other contenders are religion, human capital, and indeed coal as Pomeranz argues that North-Western Europe economically outperformed China since her coal deposits were in “the wrong place” – in other words, far away from the commercial and more densely populated areas along the coast.⁹ Other researchers have refuted the importance of certain factors, and Clark and Jacks, for example, postulate that coal mining expanded in response to increased demand, and thus only made a “negligible contribution to Industrial Revolution incomes.”¹⁰

Distinguishing between the relative importance of these factors is a constant and perhaps insurmountable challenge. Comparing the growth experiences of different countries can help to tease out the effect of different factors. The causality often also runs both ways. For instance, higher economic growth created better living standards allowing children to attend school rather than to work, which may have led to higher growth in the longer term. Economists refer to this problem as one of the causes of endogeneity, when in regression analyses the error term is correlated with the independent variable. And while there are some econometric solutions to such problems – for instance an instrumental variable approach – they are not always feasible, and require a deep understanding of the underlying causalities.

Coal is a prime example of the interdependencies between different determinants that could explain economic growth. In his investigation into the reasons for America's

⁸ D. Acemoglu, S. Johnson and J. Robinson, 'The Colonial Origins of Comparative Development: An Empirical Investigation', *National Bureau of Economic Research*, No. w7771, (2000), D. North and R. Thomas, *The Rise of the Western World: A New Economic History* (Cambridge, 1973), K. O'Rourke and J. Williamson, *Globalization and History: The Evolution of a Nineteenth-Century Atlantic Economy* (Cambridge, MA., 2001), J. Sachs and A. Warner, 'Natural Resource Abundance and Economic Growth', *National Bureau of Economic Research*, No. w5398, (1995), J. Mokyr, *The Enlightened Economy: An Economic History of Britain, 1700-1850* (New Haven, 2009)

⁹ K. Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World* (Princeton, N.J., 2000), p.66-68

¹⁰ G. Clark and D. Jacks, 'Coal and the Industrial Revolution, 1700-1869', *European Review of Economic History*, Vol. 11, No. 1, (2007), p.39

industrial success, Wright emphasises natural resource abundance, particularly coal and iron ore deposits, and crucially, the ability to exploit them.¹¹ Coal is thus not only a geological benefit, but requires the skills to locate and exploit it; or, to put it in Wright's words (emphasising the necessity of complementing factors), resource abundance was "historically rather than geologically determined."¹² Amongst a number of factors, he cites the formation of the United Geological Survey founded in 1879, succeeding a number of other services, as instrumental in generating knowledge about exploitable mining deposits and how to adapt technologies to the identified mining conditions.¹³ This is one specific example of the role of skills, which itself can be aggregated under the term "human capital." One can easily think of a range of further underlying factors. Once the coal deposits were located, access to finance in order to pay for the development and building of a costly supporting infrastructure such as railway lines was required. A stable institutional environment would have been favourable to limit the risk for such long-term investments. Trade links were essential in order to bring in advanced mining technology and experts to run it, or alternatively, conditions to develop such technology and training domestically. This is not to say that geology had no role to play. And clearly some world regions have been less fortunately endowed with coal deposits, such as Latin America, which had to import coal from Britain until after World War II. Still, the available coal deposits in Colombia were only mined on a large scale from the 1970s onwards. In 2000 Colombia was the tenth largest producer and its coals are now shipped to Britain.¹⁴

The underlying idea of this thesis is therefore not to prove, or disprove, the importance of coal for economic growth, but to initially create a sound (price) data base in order to start evaluating such claims empirically. I will carve out the ways in which coal

¹¹ G. Wright, 'The Origins of American Industrial Success, 1879-1940', *The American Economic Review*, Vol. 80, No. 4, (1990)

¹² *ibid.*, p.664

¹³ *ibid.*, p.664

¹⁴ B. Mitchell, *International Historical Statistics: The Americas 1750-2005*, 6th edn, (Basingstoke, 2007)

may have mattered, while always acknowledging further, deeper determinants. Coal is so prominent in industrial development that it deserves to be used as a case study. As such, three analytical chapters will evaluate it from different angles. The second chapter deals with trade cost developments of coal, and market integration as a driver of economic growth itself. The third chapter examines the expansion of coal mining to other countries such as South Africa and the effects of this development on price levels. This expansion is a result of technology spill-overs and foreign investments, modes of market integration themselves. The fourth chapter then considers the effect of the ratio of coal prices to wages on manufacturing output growth. This ratio describes technology that was based on a factor price ratio of low coal prices and high wages, and thus, the more similar the ratio to Britain, the easier it would have been for countries to use the most advanced technology. In this way, every analytical chapter examines coal in connection with specific underlying determinants of economic growth.

The focus on one specific commodity allows for an in-depth examination and thus for a long investigation period from 1840 to 1960 across very different states of the international economy and for a truly global sample of countries. The time boundaries are determined by the rise and fall of steam shipping, since the thesis exploits the abundant price data available in the shipping literature, which coincides with the declining relative importance of coal discussed in Section 1.3. The investigation periods of Chapter Three (1883-1938) and Chapter Four (1870-1940) are slightly shorter. Therefore, the core time periods of this thesis are the First Global Economy pre-World War I as well as the de-globalised interwar period. The country focus can be classified as global without significant caveats. Since Chapter Two focuses on the trade of Welsh coal, the included ports are confined to the vast network of countries importing Welsh coals. The main exceptions are Scandinavia and Russia, which imported coal from the North of Britain, and Australia and the USA with their own large domestic supplies. But then again, apart from

Russia, all those regions are included in Chapter Two and Three. Finally, the second chapter uses South Africa and India as two case studies that examine the development of domestic mining. The following sections will provide the wider historical context of the major developments in the two identified time periods of international trade and, more specifically, the development of mining and industry. References will be made where more detailed information can be found in the respective chapters.

1.2. The international economy during the nineteenth and twentieth centuries

The long nineteenth century extending up to World War I was a period of unprecedented integration of the world in terms of migration, trade and capital flows leading to the First Global Economy. When discussing my research I often felt that scholars assume that a globalised economy meant that global coal price differences had become negligible. While such an assumption may be premature, as will become apparent in the following, and as is also explained in detail in Section 2.2.3, the developments of the international economy are highly relevant and set the context for my investigation.

The expansion of global trade was fostered by a fortunate symbiosis of decreasing trade costs as well as relatively low barriers to trade. In the first half of the nineteenth century, improvements to roads and canal construction considerably reduced transportation costs in Europe, and slightly later by the construction of railway networks.¹⁵ Long-distance trade benefited dramatically from a number of improvements to shipping technology. The most notable technological development in this regard was the application of the steam engine to ships, which made them independent of wind energy, allowing for more direct

¹⁵ D. Jacks, 'Intra-and International Commodity Market Integration in the Atlantic Economy, 1800–1913', *Explorations in Economic History*, Vol. 42, No. 3, (2005)

and faster shipping routes (Section 2.3.1 offers a detailed account concerning changes in shipping technologies and their coal consumption). Due to her dominance in shipping, Britain was at the centre of global trade flows and, for example, the British Navy played a key role in ensuring an adequate infrastructure of coaling stations around the seas.¹⁶ British imperialism, and also that of France and Russia in particular, forced relatively free trade regimes upon their colonies. During the two Opium Wars 1839-42 and 1856-60, which followed a Chinese ban on importing opium, Britain forced China to open its ports and the Yangze river to international trade under minimal tariff protection.¹⁷ There were incidents of increasing protectionism, such as for grain in a number of European countries and the US after 1870, and also high tariff barriers of the US on manufacturing produce. Nevertheless, Estevadeordal concludes that for international trade “tariffs seemed to have played a minimal role before 1914, but they mattered more after 1914 when policies became more activist.”¹⁸

The Classic Gold Standard of a stable monetary system supported global trade flows and division of labour, where currencies were convertible with a fixed exchange rate into gold. Britain stood for the largest share of foreign investment and, as Clemens and Williamson show, most of it went to the New World.¹⁹ Those countries were land-abundant and resource-rich, but also labour-scarce, and investors seemed to have favoured countries with such resources over countries with cheap labour only. In this way, capital followed labour, which was itself moving relatively freely to the New World.

The pre-World War I period stands in stark contrast to the reversal of globalisation and the fragmentation of the world economy overshadowing the interwar period. Therefore

¹⁶ S. Gray, 'Black Diamonds: Coal, the Royal Navy, and British Imperial Coaling Stations, Circa 1870-1914' (University of Warwick Doctor of Philosophy in History, 2014)

¹⁷ R. Findlay and K. O'Rourke, *Power and Plenty: Trade, War, and the World Economy in the Second Millennium* (Oxford, 2007), p.388-89

¹⁸ A. Estevadeordal, B. Frantz and A. Taylor, 'The Rise and Fall of World Trade, 1870-1939', *The Quarterly Journal of Economics*, Vol. 118, No. 2, (2003), p.362

¹⁹ M. Clemens and J. Williamson, 'Where did British Foreign Capital Go? Fundamentals, Failures and the Lucas Paradox 1870-1913', *NBER Working Paper Series*, No. 8028, (2000)

my research period from 1840-1960 is unorthodox in that it extends over very different economic conditions; research papers in economic history often take 1913 as a convenient end year. World War I had distorted trade linkages and countries struggled with the readjustment from war economies to peace times. Nevertheless, a short and promising interlude started in the mid-1920s when international trade expanded and countries increasingly joined the Interwar Gold Standard. The Great Depression emerging in the US in 1929 brought this blossoming to an abrupt end: trade declined dramatically and tariff protection levels went up. Trade was increasingly carried out in trade blocs that had their currencies pegged to each other. The Sterling Area encompassed Britain and her colonial Empire, and countries in Scandinavia and Latin America that had close trading relationships with Britain. Thus Britain remained at the centre of a global trading network, though the days of British dominance over the global economy were over. The lack of leadership was indeed also one of the reasons for the lack of stability of the interwar period.

1.3. The “coal” context: mining, technology and the growth of industry

The Industrial Revolution started in Britain during the second half of the eighteenth century, and was characterised by steadily increasing productivity, particularly in the cotton, iron and steel sectors.²⁰ During the nineteenth century, industrial development spread to North-Western Europe and the USA. In 1850 circa 77% of global coal output was extracted in Britain, but the share declined to 34% in 1900 mainly due to the expansion of production in the US and Germany. Thus, the spread of industrial growth was at least initially correlated with the expansion of coal mining, in terms of timing but also

²⁰ C. Harley and N. Crafts, 'Simulating the Two View of the British Industrial Revolution', *The Journal of Economic History*, Vol. 60, No. 3, (2000)

geographically. Industrial clusters emerged in the vicinity of coal mining in the North-East of Britain, the Ruhr-District of Germany and in Wallonia/Belgium.

As Allen argues, those other early industrialisers had similar factor price ratios to Britain, which allowed for the adoption of British technology. This then allowed them to follow Britain's development path.²¹ When we look at other world regions the pattern becomes less clear. Coal mining expanded slowly geographically and, by 1900, coal production outside Europe and North America exceeded 5m tons per year in Japan, Australia and India when total global production was circa 607m (see Figure A1 for global production broken down by country from 1850 to 1950).²² Coupled with decreasing transportation costs, particularly of bulk commodities, this should have led to more similar factor ratios.

However, this did not generate industrial development elsewhere, or at least the process was less uniform in terms of timing and force. Initially, during the nineteenth century, manufactures were mainly exported to other world regions in return for raw materials. India deindustrialised until the late nineteenth century due to the decline of her cotton industry facing stiff competition from British, more capital-intensive, manufacturers.²³ However, it is also true that coal mining in India expanded and a successful metallurgical sector emerged around 1900.²⁴ Other countries showed less ambiguous and more favourable developments as Paloera, Amorochio and Musacchio argue in the case of Argentina:

“This early industrialization was an endogenous, private-sector-led process driven by the dynamism of the export economy. The industrial boom was tightly linked to the development of agriculture, which produced forward

²¹ R. Allen, *The British Industrial Revolution in Global Perspective* (Cambridge, 2009)

²² Mitchell, *International Historical Statistics: Africa, Asia & Oceania, 1750-2005*, Mitchell, *International Historical Statistics: Europe, 1750-2005*, Mitchell, *International Historical Statistics: The Americas 1750-2005*

²³ B. Gupta and T. Roy, 'From Artisanal Production to Machine Tools: Industrialization in India Over the Long Run', in K. O'Rourke and J. Williamson (ed.), *Industrialization in the Global Periphery*, Oxford, (forthcoming), p.1

²⁴ *ibid.*, p.15

and backward linkages, accelerating urbanization rates, and giving rise to a new consumer class that demanded manufactured goods.”²⁵

During the interwar period, mining expanded further to other world regions, such as China, while coal production peaked in Britain in 1913. Interrupted by curtailed supplies amid World War I, countries became more aware that domestic coal was important and growing protectionism perhaps added to that conviction.²⁶ Manufacturing, though, performed better and started in further world regions such as the Middle East. While a large gap between the core countries of Europe and the US, as opposed to the rest of the world, had opened up in terms of GDP per capita during the nineteenth century, industrial growth helped to reduce this gap during the interwar period.

Coal remained a vital source of energy throughout the twentieth century, though the relative importance as compared to other primary sources of energy, especially to oil, declined, as shown in Figure 1.2 below.

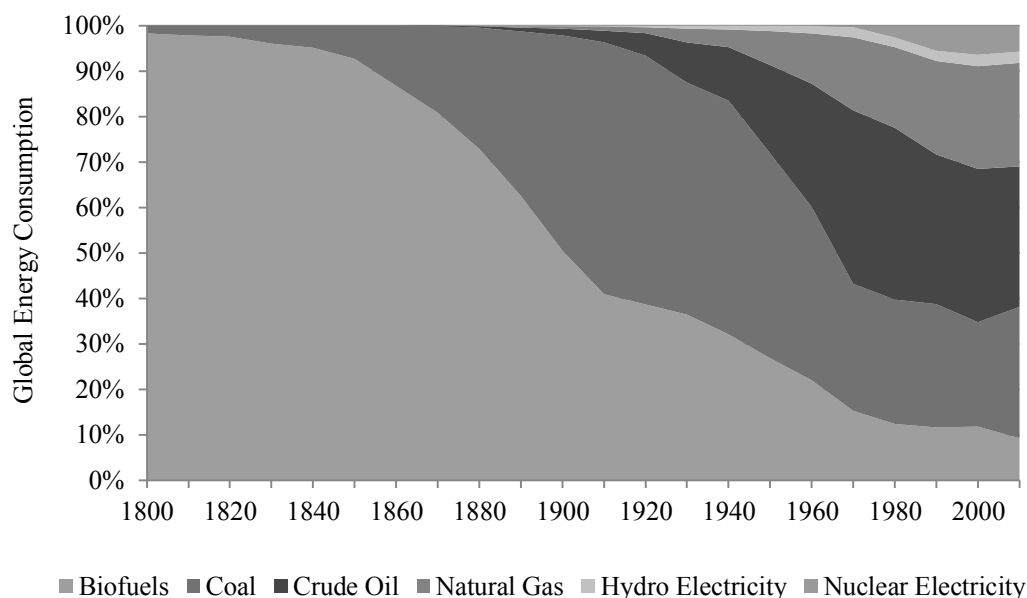


Figure 1.2: Share in global energy consumption by energy source, 1800-2008

Source: M. Roser. *Energy Production & Changing Energy Sources*, from <https://ourworldindata.org/energy-production-and-changing-energy-sources>, accessed 22 November 2016

²⁵ G. Paolera, X. Amoroch, et al., 'Industrial Growth in South America: Argentina, Brazil, Chile and Colombia, 1890-2010', in K. O'Rourke and J. Williamson (ed.), *The Industrialization of the Global Periphery*, Oxford, (forthcoming), p.5

²⁶ League of Nations, (1929), *The Problem of the Coal Industry*, p.9

Crude oil started gaining ground in global energy consumption from the early twentieth century onwards. This trend accelerated and becomes more obvious during the late interwar period, and especially post-World War II. At the time, the expansion came at the expense of coal. This trend of a relative decline is multifaceted in that it varied considerably with respect to world regions and groups of consumers. In Europe, for example, the shift away from coal was more radical and abrupt, and during the 1960s oil overtook coal in terms of importance.²⁷ In shipping, the conversion from coal to oil happened comparatively early, starting around World War I, and at a large scale too; its course and implications for the coal bunker market will be discussed in Section 2.3.1. Arguably, the crucial change was in the fact that strong alternative energy sources to coal arose, and in the context of economic development, access to coal became less relevant, a theme which will be picked up again in Chapter Four. In this way, the relative decline of coal justifies my investigation period that ends in 1960 (for coal price convergence in Chapter Two) and at the start of World War II (Chapters Three and Four).

As this introduction has tried to highlight, the growth of coal mining and economic development is tightly linked. However, this relationship became an increasingly blurry one over time, especially after the first wave of industrial expansion across Europe and the US, and the availability of alternative sources of energy. Due to the highlighted interdependencies between the trade environment, the development of industry and coal mining, this investigation provides nuanced results, and will certainly not be able to settle the debate on the importance of coal. Nevertheless, by examining precisely defined aspects in turn, I aim to gain some more clarity on the role of coal in global integration and development.

²⁷ The share of coal in primary energy production in Europe declined from over 80% in 1950 to less than 30% in 1970, when oil accounted for 60%. See R. Gentvilaite, A. Kander and P. Warde, 'The Role of Energy Quality in Shaping Long-Term Energy Intensity in Europe', *Energies*, Vol.8, No.1 p.141, Figure 6

1.4. Agenda

This thesis attempts to offer a holistic picture of how coal prices differed globally, what the main drivers of these differences were, and to what extent these price differences affected industrial development. In a way, the thesis hopes to demystify coal and its role in economic growth by bringing ample and carefully adjusted coal price data to the debate. It also bridges different bodies of literature in economic history, such as on market integration and the role of geography, and I hope that it proves fruitful for any scholar interested in the role of coal in global economic growth during the nineteenth and twentieth centuries.

Chapter Two examines global price convergence in coal over a 120 year-long period by using the market for Welsh bunker coal as a case study. Welsh coals were the preferred type for fuelling ships and were used all over the world. I have compiled a novel data set of prices for Welsh bunker coal, which thus allows for comparing a homogenous kind of coal across space and time. The data set consists of 2,616 annual price quotations from the period 1840-1960 with, on average, over 30 international ports per year. While market integration studies have shown price convergence during the long nineteenth century, and the limited available evidence hints at disintegration during the interwar period for a number of commodities, I argue that the trajectory for coal was different. Coal had a higher bulk-to-value ratio, and perhaps due to its importance as a vital energy carrier, tariff rates developed differently. Results indicate that international price gaps remained relatively stable in the mid-nineteenth century until they converged significantly from the 1880s onwards. The interruption of World War I was a dramatic one, but temporary since prices swiftly converged in the 1920s. However, during the interwar period prices did not converge beyond the pre-World War I level. Analyses also reveal that absolute price gaps

remained at high levels after World War II. These findings suggest that one should pursue a more commodity-specific view of market integration, in light of the significantly different patterns and a more continuous course of integration for commodities such as coal. As such, these findings show that trade had not harmonised global coal prices by the advent of World War I, and thus give the impetus for the following two chapters.

Chapter Three examines trends in global coal prices from 1883 to 1938 and the spread of coal mining as a potential determinant of global price convergence. I argue that this development was an important factor in global coal price differences since it brought mines closer to places of consumption. Furthermore, I argue that competition increased in a range of countries that did not start extracting their own coal, due to intensified competition between coals from different sources of supply. To this end, I have compared prices for different coals in a globally dispersed sample of 40 ports, where I have eliminated quality differences based on different levels of carbon content. My results confirm global convergence in coal prices during the entire period, including the interwar years when trade costs stagnated. The discovery and exploitation of domestic coal mining in further countries was key to this development. Coal prices declined by up to 50% at South African and Indian ports, where British coals were replaced by domestically produced coals. Over time, both South African and Indian coals established growing export networks, significantly reducing prices at foreign ports. Even though the gains from domestic mining were huge, the process of developing domestic mines and processing the coals adequately took years, even decades from the initial discovery until the takeover of the domestic market. This finding highlights that this mode of market integration is particularly dependent on investment, technology and skill as necessary conditions for benefitting from cheap coal next to the actual endowment.

The fourth chapter explores Allen's recent argument – that the ratio of coal prices to wages triggered the British Industrial Revolution – for a global set of countries.²⁸ According to Allen, high wages created incentives for research in labour-saving technology and steered technical progress towards the exploitation of comparatively cheap coal. Using my new coal price data set introduced in Chapter Two, and my approach of adjusting for quality differences in coals (Chapter Three), this fourth chapter investigates the relationship between coal price/wage ratios for 23 countries from 1870 to 1940 and manufacturing output growth (recently estimated by Bénétrix, O'Rourke and Williamson).²⁹ I then test whether countries with a similar factor-price ratio to Britain – high wages and low coal prices - had higher manufacturing output growth since they were able to adopt the most modern, mainly steam engine-based technology.

My results confirm that countries with a low coal/wage ratio had higher levels of GDP per capita, and also that the ratio is negatively correlated with manufacturing output growth. An increase of coal prices by 50% decreased manufacturing output growth by between 0.32% to 0.13% per annum. This is a lower bound estimate since the effect may have been even greater pre-1870 when steam engines were less efficient. In my fixed effects models, the level of the coal price/wage ratio refers to the first year of each decade, e.g. 1870 for 1870-79, in order to counter endogeneity concerns. The results are robust to controlling for decadal fixed effects, and other potential determinants such as trade openness, human capital development and institutional environment. In addition, it remains robust to various changes to the dataset, such as excluding the World War I-period. Those results increase our confidence that coal price/wage ratios were proximate determinants of industrial development, acknowledging that the level of coal prices is partially determined by infrastructure and technology.

²⁸ R. Allen, *The British Industrial Revolution in Global Perspective* (Cambridge, 2009)

²⁹ A Bénétrix, K. O'Rourke & J. Williamson, 'The Spread of Manufacturing to the Poor Periphery 1870-2007', *Open Economics Review*, Vol. 26, No. 1, (2015)

The final section of this thesis summarises the major findings of the three analytical chapters and relates them to each other. The extensive appendices aim to give maximum transparency on the sources and the data underlying the different analyses.

The thesis does not intend to settle the debate about the role of coal in the Industrial Revolution and beyond, since the process had so many facets. However, this thesis develops a large new data set with prices from the largest section of global coal markets. A novel aspect of this data set is the inclusion of a wide range of data from Latin America, South Africa and Asia. The elimination, or at least significant reduction, of coal quality differences by adjusting prices based on their respective carbon contents, is another way in which this thesis allows for more sound international comparisons.

By investigating both the development of price differences for traded coals, as well as the effect of new sources of coal supplies and stiffened competition, I believe that I have provided a nuanced account of how global coal prices developed. This also gave me a vast and representative data set of coal prices that includes port as well as pithead prices, the two major locations where industry tended to settle. Due to this in-depth approach, it indeed became apparent that coal is a unique commodity in terms of market integration, and it pays to consider other modes of integration such as the spread of mining to further countries. This approach allows me to firmly answer the first major question that coal prices were indeed considerably different until post-World War II. There was a trend, though, towards lower price differences from the nineteenth century continuing throughout the interwar period.

Whether coal price differences mattered for economic development can be approached and measured in various ways. I consider arguments that the coal price/wage may have shaped the ease of adopting the most advanced technology, thus contributing to industrial development. There are certainly also other ways to gauge the effect, for example, by actually conducting research on what type of technology was used in which

countries, and at what point in time. My results show that there was a small but robust effect of this ratio on manufacturing output growth; low coal prices relative to wages indeed seemed to have contributed to such growth.

2. A Different Trajectory of Price Convergence? Evidence from Bunker Coal Markets, 1840-1960

Abstract

This second chapter examines global price convergence in coal over a 120-year long period by using the market for Welsh bunker coal as a case study. Market integration studies have shown price convergence during the long-nineteenth century, and the limited available evidence hints at disintegration during the interwar period for a number of commodities. Due to the higher bulk-to-value ratio of coal, and the different development of tariff protection levels, integration patterns may have been very different in coal. I have compiled a novel data set of prices for Welsh bunker coal, the preferred type for fuelling ships, which allows for the comparison of a homogenous kind of coal across space and time. The data set consists of 2,616 annual price quotations from the period 1840-1960 with on average over 30 international ports per year. Results indicate that international price gaps remained relatively stable in the mid-nineteenth century until they converged significantly from the 1880s onwards. The interruption by World War I was dramatic but temporary since prices swiftly converged in the 1920s. However, during the interwar period prices did not converge beyond the pre-World War I levels. Analyses also reveal that absolute price gaps remained at high levels after World War II. These findings suggest that one should pursue a more commodity-specific view of market integration, in light of the significantly different patterns and more continuous course of integration for commodities such as coal. As such, these findings have implications for the debates on the harmonisation of global energy prices and the persistence of comparative geographic advantages.

2.1 Introduction

In recent years, a growing body of literature has developed around the concept of market integration, where a consensus on the course of market integration seems to be emerging: during the long nineteenth century, until World War I, markets integrated, thus forming the first truly global commodity market. World War I brought this development to an end and the interwar period could not sustain a turn-around towards integration; it took until after World War II for commodity prices to show convergence again. While this consensus may be true for a number of traded products and some commodities, if not a majority, I will argue that international price convergence in coal markets progressed differently. Due to coal's comparatively low value-to-bulk ratio, transportation costs have a much more pronounced effect on coal prices. The absolute height and development of tariff rates may also have been different than they were for grain, for example, since governments may have been reluctant to tax raw material imports, and transportation costs acted as natural tariff barriers. The global market for Welsh bunker coal provides a framework to study global price convergence over the period 1840-1960. It is a unique opportunity to compare a homogenous quality of coal on a global scale for over 100 years.

The remainder of this chapter is organised as follows. Section 2.2 reviews two strands of literature. Part 2.2.1 proceeds chronologically to survey research focusing specifically on market integration and the evolution of transportation costs.³⁰ Part 2.2.2 reviews the broader literature on the coal industries and industrial development since this literature contains international coal price comparisons. Section 2.3 outlines the evolution of the global bunker coal market, the tightly linked improvements in shipping technology and market competitiveness. Section 2.4 discusses the sources and extracted price data.

³⁰ Whilst dramatic political, economic and technological events shaped the environment in which commodities were traded, the following discussion will focus, due to space constraints, on research directly pertinent to market integration rather than the exogenous determinants.

Section 2.5 introduces the theoretical foundations and methodological approach. Section 2.6 presents the empirical results. Section 2.7 validates the results by linking them to the major determinants of market integration. Section 2.8 summarises the findings and outlines the remaining caveats of this chapter.

2.2. Historiography

2.2.1. Inter-market integration during the nineteenth and twentieth centuries

Due to high transportation costs, war and mercantilist trade restrictions, global trade before the nineteenth century was very likely confined to particular trade routes, geographical areas and mostly luxury products.³¹ With industrialisation and the end of the Napoleonic Wars, trade between European markets and the colonial offshoots expanded dramatically. Europeans imposed trade openness on their colonies and countries such as Japan were also forced to allow foreigners greater access to their economies in the second half of the nineteenth century. Technological advances in maritime transport, such as steam engines and steel hulls, and in overland transport – for instance, the development of railway and canal networks – combined to drive down transportation costs.³² These improvements culminated in a period of globally integrated markets from 1870 to 1913. Recent research emphasises the size of price convergence in the earlier nineteenth century: in a study of international wheat market integration over the last two centuries, Federico and Persson find that the largest improvements in grain market integration between the United States

³¹ R. Findlay and O'Rourke, *Power and Plenty: Trade, War, and the World Economy in the Second Millennium*, p.425-6, S. Özmucur and Ş. Pamuk, 'Did European Commodity Prices Converge during 1500-1800?', in T. Hatton, K. O'Rourke, et al. (ed.), *The New Comparative Economic History: Essays in Honor of Jeffrey G. Williamson*, Cambridge, Massachusetts, (2007)

³² The effects of maritime technology on transportation costs will be discussed in greater depth in a later section; one of the main sources is C. Harley, 'Ocean Freight Rates and Productivity, 1740-1913: The Primacy of Mechanical Invention Reaffirmed.', *Journal of Economic History*, No. 48, (1988)

and United Kingdom took place during the period from 1830 to 1870.³³ Jacks dates the establishment of an integrated international wheat market to 1835.³⁴ Both papers follow an established tradition in the field of market integration: investigating grain prices. The importance of grain for consumption and commerce, the demands it places on transportation, and the abundance of available price data, renders this commodity a suitable candidate for the study of market integration.³⁵

As a caveat, grain as a key foodstuff has often received considerable attention and special treatment in policy decisions. For instance, in the early 1880s, Germany introduced tariffs on grain imports whilst trade in non-ferrous metals and other commodities remained free. As identified by Klovland, grain price differences between Britain and Germany widened in consequence, whereas previously they had represented one of the most closely integrated markets.³⁶ In contrast, price gaps from the 1850s to early 1870s remained relatively stable in copper, lead, tin and zinc between Britain and Germany before prices converged through the end of the century.³⁷ O'Rourke and Williamson confirm this price convergence for industrial commodities between 1870 and 1913 in the Anglo-American trade, and Huber also finds declining price gaps for iron bars between Japan and England as well as Germany, already emerging in the period 1846-55.³⁸ Thus, the specific nature of

³³ G. Federico and K. Persson, 'Market Integration and Convergence in the World Wheat Market, 1800-2000', *The New Comparative Economic History: Essays in Honor of Jeffrey G. Williamson*, (2007)

³⁴ D. Jacks, 'Intra-and International Commodity Market Integration in the Atlantic Economy, 1800-1913', *Explorations in Economic History*, Vol. 42, No. 3, (2005), p. 399

³⁵ "In terms of 'transport suitability' it could be called an intermediate good. It has on the one hand a high bulk-to-value ratio, meaning that transportation costs and capacities are central to the extent of grain markets." Thus, grain is a good basis for inferences about the overall state of integration as some goods with lower bulk-to-value ratios are already integrated while others are still to come. From R. Studer, 'India and the Great Divergence: Assessing the Efficiency of Grain Markets in Eighteenth-and Nineteenth-Century India', *Journal of Economic History*, Vol. 68, No. 2, (2008), p.17

³⁶ J. Klovland, 'Commodity Market Integration 1850-1913: Evidence from Britain and Germany', *European Review of Economic History*, Vol. 9, No. 2, (2005)

³⁷ *ibid.*

³⁸ K. O'Rourke and J. Williamson, 'Late Nineteenth-Century Anglo-American Factor-Price Convergence: Were Heckscher and Ohlin Right?', *The Journal of Economic History*, Vol. 54, No. 04, (1994), J. Huber, 'Effect on Prices of Japan's Entry into World Commerce After 1858', *The Journal of Political Economy*, Vol. 793, (1971)

a commodity can lead to very different trends in price convergence, as shown here by grain vs. non-ferrous metals, given that tariff effects overrule changes in transportation costs.

Apart from the trend in integration, the absolute level of price convergence between coal and grain, in particular, can also differ considerably. Since market integration studies have so far hardly included traded coal prices, substantiating this claim is difficult using readily available evidence. The only comparison of traded coal prices is by Klovland who finds a price difference of 44.4% in 1875/77, 44.8% in 1901/03 and 29% in 1911/13 between English steam coal in North-East England and the import prices at Hamburg.³⁹ In contrast, the wheat price gap between Liverpool to Chicago was 57.6% in 1870, 17.8% in 1895 and 15.6% in 1913.⁴⁰ Thus, judged on the basis of percentage price gaps, wheat prices differences between Chicago and Liverpool were smaller than coal price differences between North-East England and Hamburg after 1895 or 1900, even though the shipping distance between New York and Liverpool alone is over eight times greater than that between Hull and Hamburg.⁴¹

World War I crippled trade and marked the end of the first international economy. After the exceptional years 1914-18, trade picked up again. However, the effect on market integration is unclear since this period has been studied only very rarely, potentially due to a spread in the use of indexes at that time and the consequent lack of ordinary price data. Therefore, I cannot point out to what extent the developments in market integration differed between agricultural and industrial commodities. In fact, Federico and Persson find that grain market integration was even higher in the early 1920s than in 1913, but subsequently deteriorated with fresh tariff rounds from the mid-1920s and the onset of the

³⁹ J. Klovland, 'Commodity Market Integration 1850–1913: Evidence from Britain and Germany', *European Review of Economic History*, Vol. 9, No. 2, (2005)

⁴⁰ K. O'Rourke and J. Williamson, *Globalization and History: The Evolution of a Nineteenth-Century Atlantic Economy*, p.43

⁴¹ While not stated explicitly in Klovland's source descriptions, I am assuming that the price for North East England refers to Hull, an important coal exporting harbour. The underlying shipping distances are 3,108 nautical miles (nm) New York – Liverpool and 383nm Hull to Hamburg calculated by using www.sea-distances.org.

Great Depression in 1929.⁴² By investigating a wider range of agricultural commodities and countries, with trade routes between all continents bar Australia, Hynes, Jacks and O'Rourke confirm a return to price convergence between 1922 and 1927.⁴³ However, they only find lower price gaps in Anglo-American wheat trade and Anglo-Indian cotton trade compared to the 1913-level; these are only two out of twenty cases. I found in my master's thesis that non-ferrous metal price gaps between the United Kingdom, Germany and United States reached, but rarely undercut, the price level of 1913 in the 1920s.⁴⁴

These improvements proved only a short interlude, however, as the next external shock, the Great Depression, tore the world economy apart. Barriers to trade were erected around the world, with import substitution policies implemented in Latin America and Germany for reasons of autarky, which diverted and reduced trade. This is reflected in diverging prices as documented by Hynes et al. They find price divergence for thirteen out of nineteen trade relationships between 1929 and 1933, and divergence for sixteen cases when expanding the observation period to 1939.⁴⁵ I also identified non-ferrous metal price divergence post-1929, but measured significant improvement from 1934 to 1939.⁴⁶ The underlying hypothesis is that there might have been some temporary price convergence prior to World War II.⁴⁷ However, given the very limited research, it appears that the argument of interwar market disintegration is, to a certain extent, grounded in inferences from the general trade literature, based on trade volume observations, and more research using price data has to be undertaken to raise our confidence in this interpretation.

⁴² G. Federico and K. Persson, 'Market Integration and Convergence in the World Wheat Market, 1800-2000', *The New Comparative Economic History: Essays in Honor of Jeffrey G. Williamson*, (2007), p.100

⁴³ W. Hynes, D. Jacks and K. O'Rourke, 'Commodity Market Disintegration in the Interwar Period', *European Review of Economic History*, Vol. 16, No. 2, (2012)

⁴⁴ A. Wegerich, 'Were Interwar Markets Integrated? Evidence from American, British and German Non-Ferrous Metals, 1913-39' (London School of Economics and Political Science Master's Thesis, 2010)

⁴⁵ W. Hynes, D. Jacks and K. O'Rourke, 'Commodity Market Disintegration in the Interwar Period', *European Review of Economic History*, Vol. 16, No. 2, (2012)

⁴⁶ A. Wegerich, 'Were Interwar Markets Integrated? Evidence from American, British and German Non-Ferrous Metals, 1913-39' (London School of Economics and Political Science Master's Thesis, 2010)

⁴⁷ With the advent of World War II, once again international trading relationships were disrupted and trade relocated towards the respective trading blocs. The effect on market integration will probably never be quantified since price data is either scarce or not meaningful since prices were often not determined by market forces but by the state.

The historiography on market integration post-World War II is even more scarce than for the previous periods and we must therefore rely on less specialised literature. Protectionist policies, relics of the Great Depression, were often still in place after the war, and, due to the condition of many states' finances, currencies were unconvertible. Over time North America, Western Europe and Japan embarked on liberalisation, thus re-establishing an international economic system. However, it has to be noted that this economic system was far from covering the majority of the world by any measure. By 1960, 80% of the world population still lived in closed economies.⁴⁸ These comprised the communist states, most prominently the Soviet Union and China, but also most developing, decolonised countries, which, by and large, embarked on state-led industrialisation.⁴⁹ Thus, in geographic terms, free trade mainly encompassed the Atlantic economies after World War II until the dissolution of the Soviet Union and subsequent revival of a more globalised economy. Unsurprisingly, over the period 1990 to 2000, Parsley and Wei find increasing market integration in retail prices ranging from frozen fish fingers to men's Burberry raincoats for a global sample of 83 cities, which is cited here due to the absence of research using wholesale price data.⁵⁰ It is indeed surprising that market integration methodology has so seldom been applied to the post-World War II period.

A rare exception, O'Rourke⁵¹ finds wide fluctuations in Anglo-American wheat price gaps, which remain above the 1913 level and do not follow any clear trend. Coefficients of Variations indicate deteriorating market integration in maize and wheat from a geographically more varied sample.⁵² This indicates that market integration was

⁴⁸ J. Sachs and A. Warner, 'Economic Reform and the Process of Global Integration', *Brookings Papers on Economic Activity*, Vol. 1995, No. 1, (1995), p.12

⁴⁹ *ibid.* p.12

⁵⁰ D. Parsley and S. Wei, 'Explaining the Border Effect: The Role of Exchange Rate Variability, Shipping Costs, and Geography', *NBER Working Paper No. 7836*, (2000)

⁵¹ K. O'Rourke, 'Causes of Globalization, 1790 to 2000', in H. Kierzkowski (ed.), *Europe and Globalization*, Basingstoke, (2002)

⁵² The data used for the complete period refers to Algeria, Australia, Belgium (only wheat), Congo (only maize), Greece, South Korea (only maize), Malawi, Pakistan, South Africa, Spain, Sri Lanka (only Maize),

perhaps even decreasing during the period from 1966 to 1994. O'Rourke complements these findings with data from the International Monetary Fund (IMF) on a wider range of commodities, which follow a rather random walk over the period 1948 to 1999. It is notable that the IMF data includes price gaps for tin, zinc and lead. In these non-ferrous metals, for three out of five trading relationships, the highest price gaps were observed in 1999.⁵³ O'Rourke is careful in the interpretation of these results and suggests that rather than taking the message of non-directional or even decreasing market integration at face value, "that we urgently need serious research on CMI [commodity market integration] during the twentieth century."⁵⁴

2.2.2. Price comparisons in the coal industries literature

A wide body of literature on the coal industry, and the implications for industrial development, should also be reviewed here since these studies often involve analyses and comparisons of coal prices even though market integration is not the core of the research as such. The literature can thus yield valuable insights on potential data sources and the methodologies of comparing coal prices. Already in 1865 Jevons acknowledged the importance of coal, as the source of cheap fuel, for British supremacy in industry and formulated the then provocative thesis that British coal mines would eventually "approach the limit of commercial possibility."⁵⁵ As already mentioned in the introduction of this thesis, Jevons believed that coals were to be mined from increasingly deeper and less easily accessible seams, which would raise prices before Britain would run out of coal in less than one hundred years. In his edition of Jevons's work, Flux compares values of coal

Switzerland (only Maize), Thailand (only wheat), Tunisia (only wheat), Turkey, Venezuela (only wheat).
From *ibid.* p.84

⁵³ *ibid.* p.69

⁵⁴ *ibid.* p.68

⁵⁵ W. Jevons, *The Coal Question. An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*, 2nd edn., (New York, 1906), p.78

produced between Belgium, France, Germany, Britain and the USA.⁵⁶ These comparisons lack information on the qualities of coal and where the price emanated from, thus already hinting at the problem of forming meaningful price comparisons in coal, which I will address in the following chapter by adjusting for quality based on differences in carbon content. Probably the most informative insight is that bituminous coal prices at Baltimore show the largest decline over the 50-year period up to 1901, which Flux attributes to declining inland transportation costs.

Jevons provides another example of the dramatic effect of transportation costs that comes close to the comparisons made in the analysis section of this chapter:

“The best coal is put on board at Newcastle for 9s. or 10s. per ton. Before it reaches France its value is increased by one-half [...]. In the ports of Brazil and Argentina, the value of Welsh coal is about the double of its cost when shipped, while in some remote parts of the world coal cannot be purchased for less than GBP 3 or GBP 3.10 per ton.”⁵⁷

That Britain could operate as a global supplier of coal over such distances was due to a lack of competition, since other coal mining areas were not well developed, or predominately served domestic markets. Jevons also stresses that coal was often used as ballast on the outward journey, and thus British coals could often benefit from particularly low freight rates. Overall, the British coal industries, especially, benefited from continuously increasing world consumption.

The US coal industry developed later than the British one, but gained force with the establishment of railways in the mid-nineteenth century and the mining of bituminous coal. Most famously Wright has argued that natural resources, mostly coal and iron ore, and the ability to exploit them lay at the heart of American industrial success.⁵⁸ In 1913, the USA was in the unique position of being the world’s leading producer in petroleum, copper, iron

⁵⁶ *ibid.*

⁵⁷ *ibid.*, p.209

⁵⁸ G. Wright, 'The Origins of American Industrial Success, 1879-1940', *The American Economic Review*, Vol. 80, No. 4, (1990)

ore and coal, amongst others.⁵⁹ The effect of proximity to natural resources on price levels seems to have persisted well into the twentieth century, which Wright illustrates with anecdotal evidence from the 1920s: “Ford UK faced steel input prices that were higher by 50 per cent or more than those paid by the parent company.”⁶⁰ Apart from this piece of evidence, Wright’s major claim is that U.S. manufacturing exports were very resource intensive, and this was even increasing between 1880 and 1920, which is, as Allen points out, based on an analysis of quantities rather than prices.⁶¹ It has to be said that Wright stressed the learning effect, and the ability to exploit resources early in comparison to other countries, and thus his argument is more complex than a direct relation between abundance of natural resources, low prices and industrial development. Still, in the context of this chapter Allen’s criticism and the question of price levels are indeed highly relevant. Allen finds that coal prices never substantially undercut British prices:

“Up until about 1880 British manufacturing districts had cheaper energy than Philadelphia or New York. This was true for both bituminous and anthracite sold in the region. After 1880, America’s energy situation improved. Bituminous coal dropped in price on the east coast and sold for a similar price to British coal.”⁶²

Allen reaches this conclusion by converting US and British bituminous coal prices into prices per British Thermal Unit (BTU). This approach, however, requires an assumption regarding the exact quality of the underlying coal and it is not entirely clear how this could be achieved since Allen uses the “UK average export price of coal” for the period 1840-1913.⁶³ At this stage, it may suffice to conclude that British-US coal price comparisons are a contested issue, and Welsh coal prices, in particular, will be discussed in greater detail in Section 2.4.1.

Germany was another major coal producer, and Fremdling has analysed

⁵⁹ *ibid.*, p.661

⁶⁰ *ibid.*, p.662

⁶¹ R. Allen, 'American Exceptionalism as a Problem in Global History', *The Journal of Economic History*, Vol. 74, No. 2, (2014)

⁶² *ibid.*, p.6

⁶³ *ibid.*, p.28

competition between British and German coal in the contested markets of Northern Germany, France and the Netherlands.⁶⁴ In Northern Germany, particularly Hamburg, British coal supplies dominated until the middle of the nineteenth century before declining overland transportation costs favoured German domestic coals, which in turn gained dominance by the 1880s. However, most of Fremdling's analysis is based on consumption quantities, and regarding prices for the nineteenth century, Fremdling admits that "on this point, however, I have not yet gathered quantitative evidence."⁶⁵ The available price data he presents, taken from Regul, for 1913 shows slightly lower prices for British than German coal in Hamburg, Bremen and Stettin.⁶⁶ Fremdling comes to the conclusion that

"after all indigenous coal resources did not in any case guarantee cheap supplies, for a successful cartelisation could rise [*sic*] the price well above competitive levels."⁶⁷

Even if one would collect German coal prices, the uncompetitive nature of the market may render price comparisons less meaningful since it might remain unclear to what extent published prices reflected the prices charged in actual transactions.

So far I have only discussed literature on coal prices of major coal-producing nations. However, coal prices also feature prominently in national histories of importing countries such as those in the Mediterranean and Latin America, especially in the context of industrial development. Taking the case of Italy, Bardini shows that neither imports nor substitution by other energy sources could eliminate Italy's lack of domestic coal deposits.⁶⁸ His comparison of price levels gives a price of 8.13 shillings at the pithead in Britain vs. 25.92 shillings for coal imported to Genoa in the period 1909-1911.⁶⁹ I assume

⁶⁴ R. Fremdling, *Anglo-German Rivalry on Coal Markets in France, the Netherlands and Germany, 1850-1913*, Research Memorandum GD-21, Gronningen, (1995)

⁶⁵ *ibid.*, p.20 (Footnote 123)

⁶⁶ R. Regul, 'Die Wettbewerbslage der Steinkohle', *Vierteljahreshefte zur Konjunkturforschung*, Sonderheft 34, Berlin, (1933)

⁶⁷ R. Fremdling, *Anglo-German Rivalry on Coal Markets in France, the Netherlands and Germany, 1850-1913*, Research Memorandum GD-21, Gronningen, (1995), p.21

⁶⁸ C. Bardini, 'Without Coal in the Age of Steam: A Factor-Endowment Explanation of the Italian Industrial Lag before World War I', *Journal of Economic History*, Vol. 57, No. 3, (1997)

⁶⁹ *ibid.*, p.636

that the price at Genoa refers to Welsh coal, a high-quality coal as explained in Section 2.4.3, whereas the composition of the British average is not clear. While there was certainly a difference in price levels, Bardini's quantification of a factor 3.2x should rather be seen as a rough estimation. Similarly, due to the lack of exact quality descriptions/adjustments his comparisons of the Genoa price with coal prices in Germany, France and United States only give an indication, that unsurprisingly, coal was most expensive in Italy. In consequence, more price data and more careful price comparisons seem to be warranted not only for Italy, but also for Latin American countries where recent research seems to focus on coal consumption rather than prices.⁷⁰

2.2.3. Contribution

Whilst market integration has been researched rather extensively, the preceding overview clearly illustrates that the literature is still patchy. On a time dimension, more research is needed particularly for the post-World War I period continuing into the post-World War II period. On a geographic dimension, it would be desirable to stretch the sample of countries beyond the Atlantic economy, as some more recent research has begun to do.⁷¹ On the selection of products or commodities, more research needs to be done on industrial commodities, most importantly iron ore and coal. This chapter aims to reduce all three identified gaps by studying price integration for Welsh coals on a global scale during the period 1840-1960. The next section will introduce this case study in much greater detail. A second lesson learnt from the literature review, and particularly from research on the coal industries, is that coal price data seems surprisingly scarce. In this light, all new coal price series, as incomplete as they may be, can be very useful in a wide range of research

⁷⁰ C. Yáñez, M. del Mar Rubio, J. Jofré, et al., 'El Consumo Apparente De Carbón Mineral En América Latina, 1841-2000. Una Historia De Progreso Y Frustración.', *Revista De Historia Industrial*, Vol. 53, (2013), R. Bertoni and C. Román, 'Auge Y Ocaso Del Carbón Mineral En Uruguay. Un Análisis Histórico Desde Fines Del Siglo XIX Hasta La Actualidad.', *Revista De Historia Económica*, Vol. 31, No. 03, (2013)

⁷¹ R. Studer, 'India and the Great Divergence: Assessing the Efficiency of Grain Markets in Eighteenth-and Nineteenth-Century India', *Journal of Economic History*, Vol. 68, No. 2

applications. Perhaps as a consequence of the lack of data, available price comparisons lack rigour in that they do not compare like-with-like; instead they often compare different kinds of coals and thus different qualities, or coal from different locations such as pithead versus port prices.

Another way of seeing why coal market integration may have followed a different trajectory to grain is a comparison of price levels between commodities. The following table presents prices for commodities with vastly different weight-to-value ratios [closely related to the aforementioned bulk-to-value ratio] such as wheat, the most widely studied commodity, coal and others.

	Wheat	Anthracite coal	Copper	Pig Iron
1850	47.03	3.58	485.01	20.48
1900	25.72	3.86	374.78	19.67
1950	81.94	13.87	485.01	49.51

in USD per metric t

Table 2.1: Wholesale prices in the United States for wheat, coal and copper

Notes: Price descriptions, Wheat: For 1850 Northern (Genesee) at New York, 1900 Wheat No.2 at Chicago, 1950 No. 2, hard winter, closing spot market price, carloads, f.o.b. track at Kansas City; Anthracite coal: 1850 Anthracite, Schuylkill white ash lump at Philadelphia by cargo, 1900 Pennsylvania Anthracite, Chestnut at New York Tidewater, 1950 Anthracite, Chestnut for Wholesale, Railroad, net in Pennsylvania; Copper: 1850 Copper Sheeting at New York, 1900 Lake Copper at New York, 1950 Copper, electrolytic, delivered, for Connecticut Valley; Pig Iron: 1850 and 1900 Pig Iron No. 1 Anthracite Foundry Pig Iron in Philadelphia, 1950 Eastern Pennsylvania. Sources: *Historical Statistics of the United States*⁷² (for US prices) and the National Bureau of Economic Research;⁷³ my own calculations.

The implication of different weight-to-value ratios is that the costs of transportation, which are dependent on weight and bulkiness, have a greater effect on final sale prices for high weight-to-value commodities. Solely based on the prices above, we would expect that if copper was to be exported from the USA, the price per ton in the importing country would be higher; however, the percentage increase in price would be much smaller as compared to the percentage increase in price for coal exported to this country. What Table 2.1 ignores is that coal is bulky, meaning that the same weight of coal takes up more cargo space than, for instance, copper. This drives up transportation costs

⁷² S. Carter, S. Gartner, et al., *Historical Statistics of the United States: Earliest Times to the Present*, Millennial Edition On Line edn, (Cambridge, 2006)

⁷³ National Bureau of Economic Research. 'Macrohstory: Chapter IV. Prices', accessed 13 December 2012

further, thus reinforcing the assumption that transportation costs drive coal prices proportionally more. Another major factor changing the course of market integration may have been protectionist policies. However, if a country lacked domestic coal production, substitution for other forms of energy was difficult, and thus less coal endowed countries had to rely on imported coal. Due to limited substitutability, tariff policies may not have been so readily applied as in the case of wheat.

Based on the assumed importance of transportation costs in determining coal prices, the hypothesis guiding this research is that market integration happened later in coal: absolute price differences between exporting and importing countries remained significant prior to World War I. Prices converged further during the interwar period and were not disrupted by the Great Depression and the rise of protectionist policies. The alternative hypothesis would state that coal does not deviate from the consensus established by other commodities and that coal markets were tightly integrated prior to World War I and disintegrated thereafter. Next to these hypotheses regarding relative price trends, this chapter seeks to answer further questions: How much more expensive were coals in importing countries as opposed to Britain? How did the Welsh coal trade develop over time with regards to the scope of the trading network and market structure? What were the determinants of relative price trends in the Welsh coal market?

2.3. The global bunker coal market

Examining the case study of the bunker coal market – that is, the coal consumed by steamships – is a suitable way of addressing the coal quality issue, while achieving a

global scope at the same time.⁷⁴ For starters, steamships on long, often inter-continental voyages had to refill their bunkers along the way. As a result, bunker coal price quotations are available for an extraordinary number of locations worldwide; a scale that is very difficult to reach for any other coal market. Secondly, given that the coals used for bunkers were intended for a single purpose – powering a ship’s steam engine – they often exhibited similar traits. Welsh steam coal, in particular, gained dominance in the market. It became the bunker coal of choice in the nineteenth and well into the twentieth century. Thus, a homogenous kind of coal can be compared in a market with the same organisational characteristics worldwide.

2.3.1. Shipping technology as the determinant of demand for bunker coal

From the late eighteenth century onwards, engineers were experimenting with the application of the steam engine to ships. These attempts were somewhat driven by the successful use of the steam engine as a source of converting coal to mechanical energy in industrial processes. But the major advantage that the steamship had over the sailing ship was independence from wind and tide, and consequently quicker journey times.⁷⁵ Arguably, since she sailed most of the distance, the first steamship crossing the Atlantic was the *SS Savannah* in 1819 from Savannah, Georgia to Liverpool.⁷⁶ In 1838, the first regular transatlantic service was started by the first purpose-built steamship *SS Great Western*. While this ship was still using side-wheeled paddles, technology changed rapidly with the development of screw-propellers and iron hulls; for example, by 1847 the *SS Great Britain* crossing the Atlantic already possessed these features. Some of these improvements, such as the use of iron body hulls, were also applied to sailing ships. From

⁷⁴ “A term applied to coal consumed by ocean steamers, tugs, ferryboats or other steam water craft. Also called bunkers.” From H. Hoar, *The Coal Industry of the World with Special Reference to International Trade in Coal* (Washington, 1930), p.317

⁷⁵ The abbreviation SS stands for steamship and often forms part of a ship’s name.

⁷⁶ A. Kirkaldy, *British Shipping. Its History, Organisation and Importance* (London, 1914), p.49-50

the 1870s up until the 1890s, steam tugs were attached to large bulk-carrying sailing ships, allowing them to be towed into ports. Rather than replacing sailing ships, then, steamships actually prolonged their lifetime. In this rather gradual move from sail to steam, tonnage of steamships in the British Merchant Navy finally surpassed sailing ships in the 1870s. Steamships were improved further with the replacement of iron by steel in ship construction and fuel-economising technologies such as the compound engine and the implementation of steam turbines in the 1900s.

Another major determinant of the efficiency of steamships is the suitability of the coal for fuelling the boiler. For this reason, the Royal Navy carried out trials comparing different Welsh and North Country coals between 1846 and 1875, which were used by the Navy. The length of the trial period, though it was discontinuous, might initially surprise. But it can perhaps be explained by the importance of the outcome of these trials for colliers and coal merchants. After rumours of poor quality of Welsh coals used during the Crimean War, the Navy was convinced, or successfully pressured, to retake trials.⁷⁷ The outcome of these trials had very important signalling effects since, according to Morris and Williams,

“Instead of holding their own trials the steamship companies and a host of home and foreign buyers now came to be guided, when making their purchases, by the results of those held by the Admiralty and, consequently, the inclusion of a coal in the ‘Admiralty Lists’ proved for inestimable value in extending its sales.”⁷⁸

The general result of these trials was that Welsh steam coals were preferable since they “combine a high calorific value with ability to generate heat quickly.”⁷⁹ More precisely, these steam coals, falling into a class between anthracite and bituminous coals

⁷⁷ “The demand for Welsh coal was so great during the Russian war that a good deal of mixture was used. Engineers slept on their engines. Drivers and stokers had high wages, and worked day and night, and one can scarcely wonder that with the large and incessant demand, the “mixture” became, as time went on, not quite so good as it should be. At the close of the war, Newcastle took advantage of the rumoured depreciation in the character of Welsh coal, and petitioned for trials at the hands of the Admiralty”. From C. Wilkins, *The South Wales Coal Trade and its Allied Industries. From the Earliest Days to the Present Time*. (Cardiff, 1888), p.367

⁷⁸ J. Morris and L. Williams, *The South Wales Coal Industry 1841-1875* (Cardiff, 1958), p.34

⁷⁹ F. North, *Coal and the Coalfields in Wales* (Cardiff, 1931), p.159-60

ranked by their volatile matter content, had a calorific value around 8,000 calories per ton.⁸⁰

Next to the quality argument Welsh steam was a preferred kind of coal due to its compactness: a ton of Welsh coal measures 42 cubic feet against up to 52 cubic feet for various other British qualities.⁸¹ Steamers could in consequence either carry significantly more cargo or go greater distances when using Welsh coal; this advantage may have even been more pronounced compared to other “new” international coals such as Indian. However, this supremacy diminished over time due to technological changes. Once engines became better, they were able to burn lower quality coal but also consumed less coal altogether. Therefore, the greater compactness, and thus saving of cargo space, became less decisive once the total required amount of bunker coal needed declined.

While shipping technology created the market for bunker coals, it also determined their demise with the move from coal to oil. After initial reservations, the Royal Navy under Winston Churchill, then First Lord of the Admiralty, spearheaded this technological advance. The first ships to be fired only by oil were commissioned in 1915.⁸² The decision seems surprising given the competitive advantage that the Royal Navy had with its access to large Welsh coal supplies. This was the coal preferred by all navies, complemented by its global network of coaling stations – something that will be discussed in further detail in the next part. An advantage of oil was that it twice the thermal content by weight unit. This reduced the space needed for bunkers. Particularly important for naval warfare were greater speed and the creation of less smoke, which created unwanted visibility and

⁸⁰ The only exceptions were made for some distant coaling stations: Due to the deterioration of Welsh coals during transport over long distances, it was advised to mix Welsh coal with bituminous coal; the latter was usually exported from the North: “In distant stations, on the other hand, the use of a mixture enabled Welsh small to be burned and counteracted the undoubted deterioration of Welch coal over time and in transit. Even when mixtures were used, however, orders were not necessarily lost to the South Wales coalfield because, while the bituminous coals were usually supplied from Newcastle, there was a growing tendency for the Monmouthshire coal-owners to gain a share in this trade.” Morris and Williams, *The South Wales Coal Industry 1841-1875* (Cardiff, 1958), p.41

⁸¹ A. Kirkaldy and A. Evans, *The History and Economics of Transport*, 5th edn, (London, 1931), p.380

⁸² The following account is based on E. Dahl, 'Naval Innovation: From Coal to Oil', *Joint Force Quarterly*, Vol. Winter 2000-2001, No. 27, (2001)

disturbed effective signalling.⁸³ These points outweighed the major downside of dependency on foreign oil, a potentially critical factor during war time. While passenger liners also converted rather quickly, coal still played a more significant role in the cost-sensitive freight segment, for which coal-fired ships were still built in the 1930s, and due to the relatively long life of ships they remained in service up until the early 1960s. In this way shipping technology sets the boundaries of this investigation from the 1830s to the 1960s.

2.3.2. The operation of the bunker coal market

Since steamships were required to refill their bunkers on their journeys, a network of coaling stations was a pre-condition for international steam shipping. The British Empire acted as the institutional framework, which allowed for the realisation of such an infrastructural development.⁸⁴ She held territories around the world and also dominated world commerce, including that of coal. From the mid-nineteenth century onwards coaling stations were set up for convenient service along the major shipping routes. These also provided repair services, water and victuals supplies. Initially, they were frequented by mail and passenger ships, which valued speed and keeping to a schedule over the cost of transportation. The more economical sailing ships supplied these stations. Coal was often shipped over great distances from Britain since production was geographically still very limited in the nineteenth century. In addition, British trade was based on the export of high-value manufactures and the import of bulk commodities such as a grain. On the home route, much more space was required than on the outward route. To fill this empty space, coal was exported from Britain that benefited from comparatively low freight rates.

⁸³ Furthermore, logistics of coal loading and supplying the engine were considerably more labour-intensive than for oil, in a time when navies were suffering severe labour-shortages.

⁸⁴ S. Grey, 'Black Diamonds: Coal, the Royal Navy, and British, Imperial Coaling Stations, Circa 1870-1914' (University of Warwick PhD Thesis, 2014)

Wales stood at the centre of this coal export trade. The South Welsh collieries directly entered into contracts with large customers such as the Royal Navy or delivered coal freight on board (f.o.b.) at ports such as Cardiff.⁸⁵ Since the colliers were reluctant to take on the risks of international trade, coal merchants at Cardiff and Liverpool, such as the Cory Brothers, acted as middlemen who often had agencies or their own coaling depots abroad.⁸⁶ These merchants often possessed several depots along certain trading routes, which allowed fleet operators to enter annual contracts for supply on specific routes or ports.⁸⁷

For instance, coaling depots were set up on the Canary Islands, benefiting as they did from their geographical position situated on the major trading routes from Europe to South America. According to Bosa,

“The Canary Island ports began to supply coal in 1838, following the Royal Decree 11 November of that year in which the Port of Santa Cruz was officially given the status of coal-supplying port, enjoying practically no custom tariffs [...].”⁸⁸

In 1904 all five coal merchant companies were of British origin, according to the British consul.⁸⁹ Coal was predominately supplied from Wales.⁹⁰ The situation on the Canary Islands re-emphasises that the global bunker coal market of the long nineteenth century up World War I was essentially a British affair from source to distribution.

With the development of coal mining beyond Britain and Europe gaining speed in the last two decades of the nineteenth century the market changed fundamentally and coals from a much wider variety of origins competed. Welsh steam coal remained the most

⁸⁵ R. Walters, 'The Economic and Business History of the South Wales Steam Coal Industry, 1840-1914' (University of Oxford DPhil, 1975), p.301

⁸⁶ *ibid.*, p.301-02

⁸⁷ Kirkaldy, *British Shipping. Its History, Organisation and Importance*, p.459-60

⁸⁸ M. Bosa, 'The Role of the Canary Islands in the Atlantic Coal Route from the End of the Nineteenth Century to the Beginning of the Twentieth Century: Corporate Strategies', *Commodities of the Empire Working Paper No.4*, (2008), p.8

⁸⁹ *Informes Consulares Británicos Sobre Canarias (1856-1914)*, ed. N. Quintana (Las Palmas, 1992), p.657

⁹⁰ M. Bosa, 'The Role of the Canary Islands in the Atlantic Coal Route from the End of the Nineteenth Century to the Beginning of the Twentieth Century: Corporate Strategies', *Commodities of the Empire Working Paper No.4*, (2008)

suitable, but frequently the cost advantage of foreign coals was substantial and, consequently, Welsh coal lost out to these new competitors. As explained in the previous Section 2.3.1, improving engines meant that ships carried less bunker coal, which made the higher quality/ greater compactness of Welsh coal a less decisive factor. Welsh coal only remained competitive in certain locations far away from other mining areas, like Latin America, and also with clients such as navies, that imposed particularly high standards of coal quality.⁹¹ In 1892, the London manager of a large shipping line, described his views on the optimal coal sourcing strategy as follows:

“...the most economical way of supplying our steamers with fuel is to fill up with Belgian coal outwards as far as Port Said, then with Welsh coal from Port Said to Singapore, where we fill up with Japanese coal and continue the voyage to the Eastern ports, fill up again with foreign coal for the homeward passage [...].”⁹²

However, the rise of oil soon became a much more dominant concern than competition within the coal market. Coaling depots adapted to the new fuel. For example, on the Canary Islands, Shell established the first liquid fuel company in 1922.⁹³ Despite this, the advent of oil marked the decline of the coaling station network from a representative of British naval supremacy to a mere network of petrol stations.

⁹¹ As an example of the increased competition for Welsh coal, one contemporary account in 1892, the London manager of a large shipping line described his optimal coal sourcing strategy as follows: “...the most economical way of supplying our steamers with fuel is to fill up with Belgian coal outwards as far as Port Said, then with Welsh coal from Port Said to Singapore, where we fill up with Japanese coal and continue the voyage to the Eastern ports, fill up again with foreign coal for the homeward passage [...].” Dalziel, W., *The Records of the South Wales Coalowners' Association* (Cardiff, 1895), p.100-102

⁹² *ibid.*, p.100-102

⁹³ M. Bosa, 'The Role of the Canary Islands in the Atlantic Coal Route from the End of the Nineteenth Century to the Beginning of the Twentieth Century: Corporate Strategies', *Commodities of the Empire Working Paper No.4*, (2008), p.13

2.3.3. Size and relevance of the bunker coal market

Following on from the qualitative description above, Figure 2.1 gives an impression of the approximate size of the world market for British bunker coals measured by quantity.⁹⁴



Figure 2.1: British foreign bunkers and coal exports, 1830-1960

Data sources: 1830-1913: R. Church⁹⁵; 1923-43: B. Supple⁹⁶; 1950-60: W. Ashworth⁹⁷

As shown in Figure 2.1, the British trade statistics distinguished between coals on ships sailing abroad by their purpose. The black bar labelled “foreign bunkers” includes all coals, which were stored on British and foreign-owned ships going abroad for their

⁹⁴ It would be desirable to determine the global size of the bunker coal market including coals from other origins. However, trade statistics vary between countries in that bunker coals are sometimes included in exports and not provided separately, which makes such an estimation difficult and imprecise. Clearly, British bunkers account for the majority of the market during the nineteenth century up to World War I.

⁹⁵ R. Church, *The History of the British Coal Industry. 1830-1913 Victorian Pre-Eminence* (3 vols., Oxford, 1986), p.19

⁹⁶ B. Supple, *The History of the British Coal Industry. 1913-46 the Political Economy of Decline* (4 vols., Oxford, 1987), p.8-9

⁹⁷ W. Ashworth, *The History of the British Coal Industry. 1946-1982: The Nationalized Industry*, (5 vols., Oxford, 1986), p.672-3 & p.42-3

consumption during the voyage.⁹⁸ The white bar labelled “exports” stands for coals, which were to be sold abroad. This classification meant that coals supplied to foreign coaling stations and subsequently used as bunker coal were included under “exports”, and in consequence the volume of “foreign bunkers” understates the size of the world market for British bunker coals.

Before I come back to this problem, I will focus on “foreign bunkers.”⁹⁹ The changes in volume of “foreign bunkers” reflect by-and-large advances in technology with increasing use of coal as a fuel in the latter half of the nineteenth century as well as the explosion in the volume of trade. From a mere 2.2 million tons in 1869, “foreign bunkers” increased roughly ten-fold to a maximum of 21 million tons in 1913. After World War I, volumes reached similar levels with 18.2 million tons again in 1923 before embarking on a long-run decline. However, the bunker coal market was still of considerable size in 1950 with a volume of 4.1 million tons.

As mentioned before, a share of the coal classified as “exports” was used as bunker coal loaded onto ships at foreign ports. According to a consular report, the volume of coal exports to foreign coaling stations was estimated at circa 10 million tons in 1905.¹⁰⁰ As a rough approximation, we can use the values given in Figure 2.1 for 1903, and redistribute the estimated 10 million tons from the category “exports” to “foreign bunkers.” This would give us a total export market for bunker coals of circa 30 million tons in 1903. To put it differently, bunker coals accounted for circa 40 per cent of all British coal exports. Therefore, the bunker coal market is not only a suitable instrument for mapping out global differences in coal prices, but represents the conditions in a major part of the global coal trade.

⁹⁸ There is a further, comparatively small-volume, category “coastal bunkers” for coals consumed on ships sailing on domestic routes.

⁹⁹ There is no mentioning, that the flag under which a ship operated played a role. Consequently, the export volumes under “foreign bunkers” also include bunker coals on British ships going to foreign ports, too. Based on R. Church, p.33-34

¹⁰⁰ Based on S. Palmer (1970), ‘The British Coal Export Trade, 1850-1913’, in D. Alexander (ed.), *Voyages and Trade Routes in the North Atlantic*, Newfoundland, (1970), p.337-8

2.3.4. Welsh bunker coals: A competitive market?

The dominance of Welsh bunker coals raises the question whether pricing strategies by the coal merchants of Welsh coal may have reflected this strong market position. By extension, the added value of this investigation over other market integration studies, for instance on grain, would not be of a commodity with different bulk-to-value ratios and different levels of protectionism, but between commodities in a competitive and a non-competitive market. While at first sight the idea of restricted competition in the market for Welsh bunker coals sounds sensible, this was not the case and the market can be regarded as competitive, at least by the standards of the nineteenth and first half of the twentieth century.

A major reason for the competitiveness in the Welsh bunker coal market was the competition between the independent Welsh collieries and two different trading regimes for exports. Such competition was limited in Germany, for example, where a successful cartel, the Rheinisch-Westfälisches Kohlen-Syndikat, was organised at the producer level and regulated production volumes as well as prices. This degree of coordination did not exist in Wales. For instance, the Royal Navy purchased Welsh coals from around 25 different colliers, which illustrates the level of competition at the colliery level.¹⁰¹ This was one of two typical sales processes. Other large customers such as steamship and railway companies also submitted tenders and purchased coal supplies directly from collieries.¹⁰² The other main sales process included coal merchants as middlemen buying coals at f.o.b. prices.¹⁰³ The advantage for the collieries was that merchants guaranteed to take an agreed amount of coal for a sustained period, as they benefited from their specialist knowledge on

¹⁰¹ W. Brown, 'The Royal Navy's Fuel Supplies, 1898-1939; the Transition from Coal to Oil.' (King's College London Ph.D., 2003), p.21

¹⁰² J. Morris and L. Williams, *The South Wales Coal Industry 1841-1875* (Cardiff, 1958), p.34

¹⁰³ *ibid.*, p.156

freight rate developments and foreign markets. Still, the larger share of Welsh coal output was probably traded directly between collieries and major customers.¹⁰⁴

Given that a coal consumer decided not to purchase directly from a colliery, and was perhaps a smaller customer, this did not mean that a shipping company was at the mercy of a particular coal merchant, since it could decide between three main options. Some shippers engaged in long-term contracts – over a year or longer – with coal merchants, and there were a number of them that owned multiple coaling depots. Alternatively, the shipper could instruct its captain to buy coal on spot at a coaling depot the ship passed. My price data sources state such prices, which confirms that shippers could make informed decisions based on good information on the prevailing prices at coal depots around the world. And finally, a shipper could also decide to take on much more coal in Britain at the expense of some cargo for the outgoing voyage if prices along the way were deemed less attractive.

Given the purchasing options for shippers, especially larger ones, it appears that the most effective, and perhaps only feasible way to curtail competition, would have been an agreement between the Welsh, or in the best case, all British collieries. Morris and Williamson explain why this could never have worked:

“The obstacles to a more rigid control were formidable. The existence of the other British coalfields, particularly that of Northumberland and Durham in the most important market for steam coals, greatly restricted the range within which the Welsh producers could act alone. There could, moreover, be no effective price control without a restriction of output, but in a rapidly developing coalfield where many producers were still in the expansionary stage, it would have been difficult to secure agreement for a quota system.”¹⁰⁵

While their book covers the period from 1841 to 1875, their conclusion still applies to the remaining years of the nineteenth century and the interwar period, even though conditions changed over time. From the later nineteenth century onwards, Welsh coal

¹⁰⁴ *ibid.*, p.168

¹⁰⁵ *ibid.*, p.176

faced increasing competition from emerging coal-producing countries. Chapter Three deals in detail with the effects of such competition by, amongst others, German, Indian and South African coal. During the 1920s and 1930s, sluggish global demand added pressure on the Welsh coal industry, and Welsh coal had certainly lost its grip on the market that triggered that initial speculation about non-competitive market conditions. Interestingly, however, cartels were seen as a way to deal with heightened competition and sluggish demand. Such agreements were put in place on a voluntary basis from 1927-28 and then compulsory from 1930, but as Supple argues, these attempts of control were (once again) largely unsuccessful since “owners in the export fields were hindered in their overseas sales by minimum price regulations, and in their access to inland markets by quotas after 1934.”¹⁰⁶

There is, though, some evidence that small-scale collusion between coaling stations in certain locations existed. This may then have affected the comparatively small group of shippers that bought bunker coals on spot. The Canary Islands serve as a good example since they are geographically isolated and the coal market there has been well studied. As already stated in the Section 2.3.2, all five coal handling businesses were owned by British companies.¹⁰⁷ Next to the great similarities in their business operations, this cultural affinity may have increased the probability of negotiating price agreements. One should note, though, that this cultural affinity can also be conducive to market integration as Schulze and Wolf show based on the Austrian-Hungarian experience. They find that grain price differentials between locations with similar ethno-linguistic composition in the Austrian-Hungarian Empire of the late nineteenth century were smaller as opposed to differently composed populations.¹⁰⁸

¹⁰⁶ B. Supple, *The History of the British Coal Industry. 1913-46 the Political Economy of Decline* (4 vols., Oxford, 1987), p. 287-88

¹⁰⁷ *Informes Consulares Británicos Sobre Canarias (1856-1914)*, ed. N. Quintana (Las Palmas, 1992), p.657

¹⁰⁸ M. Schulze and N. Wolf, 'On the Origins of Border Effects: Insights from the Habsburg Empire', *Journal of Economic Geography*, Vol. 9, No. 1, (2009)

Bolsa undertook an in-depth study of the development of coaling stations on the Canary Islands, arguing that

“it can be deduced that during the last third of the nineteenth century and the first quarter of the twentieth, coal companies adopted several strategies involving the formation of trade cartels, drawn up collectively to distribute market share[...].”¹⁰⁹

Firms that sold more coals on the Atlantic islands as determined by their quota would contribute to a fund, which was given to the other firms staying below their quotas.¹¹⁰ My examination of the records of the coal merchant business Wilson, Sons & Company Limited (Wilson) also includes some limited evidence on collusive agreements. A note in the board documentation of Wilson describes collusive action with another coal trading house:

"It was also reported that the Company had agreed with Cory Bros & Co. to quote to the Rubathuno & Veloce Co. for Rio only, they (C. B. & Co) quoting for Montevideo only.”¹¹¹

Those incidents of uncompetitive behaviour were due to their geographic as well as temporal limitations and were most likely very restricted. Another way to give further evidence to this claim is to see how profitable coal merchants business actually were. Johns uses in his book on British trading companies post-tax returns on net capital employed (ROCE) as a measurement of profitability.¹¹² Due to data availability and the size of the business, Johns also included Wilson in his analysis of eight merchant businesses during the twenty-year period up to World War I.

¹⁰⁹ M. Bosa, 'The Role of the Canary Islands in the Atlantic Coal Route from the End of the Nineteenth Century to the Beginning of the Twentieth Century: Corporate Strategies', *Commodities of the Empire Working Paper No.4*, (2008), p. 16

¹¹⁰ *ibid.*, p.16

¹¹¹ 'Wilson, Sons & Company Limited. Minutes of Board and Annual General Meetings. 1877-1891', London Metropolitan Archives, CLC/B/225/MS20186/001, 1887 (note 1,109)

¹¹² G. Jones, *Merchants to Multinationals: British Trading Companies in the Nineteenth and Twentieth Centuries* (Oxford, 2000)

	Borneo Company	Swire's	Dodwells	H&C	Finlays	Brazilian Warrant	Wilson, Sons	Niger Co.	Avg.
1895-1900	9.4	8.7					10	10	9.5
1901-1908	18	5.4	10				12.5	9.5	11.1
1909-1914	14.9	7.2	-1.3	15	11.3 ^a	10.8 ^b	13.1	8	9.8
Std. Dev.	5.1	4.5	14.4	5.5	2.3	3.4	4.9	4.3	

Table 2.2: Average Post-Tax Return on net capital employed (in %) of British trading companies, 1895-1914¹¹³

Notes: (a) 1910, 1911, 1913 and 1914 only (b) 1910-1914 only (c) Standard Deviation is calculated for the annual figures that exist.

The ROCE-ratios for Wilson reach 10.0% in 1895-1900 and 13.1% during 1909-1914, and thus are similar in size to the average ratios across all available merchants. Since the other merchants were active in different trades such as tea (Dodwells) or teak production and gold exploitation (Borneo Company), coal trading did not seem to have been structurally different in terms of profitability. The take-over of Wilson's long-term supplier of Welsh bunker coals in 1908 did not seem to have influenced the profitability significantly. Jones describes the common performance as of "considerable prosperity;" the fact that he did not analyse differences between the sample firms more closely indicates that he did not view them as operating in structurally different markets. Jones rather highlights that the post-tax returns of his selected group, assumed to be representative of large merchant businesses, were higher than pre-tax ROCE in British industry.¹¹⁴

It became apparent that the structure of the Welsh coal industry, with its large number of independent collieries and coal merchants, did not lend itself to easy cartelisation. Also, over time Welsh coal was exposed to larger macroeconomic pressures, such as competition by coals from other origins, and sluggish world demand. There is some evidence hinting towards agreements that were limited in a geographical sense, to a specific time period and/or individual contracts. The coal merchant Wilson did not seem to

¹¹³ *ibid.*, p.82 (Table 3.3)

¹¹⁴ *ibid.*, p.82

have been more profitable than other coal businesses. Therefore, this section can reassure us that indeed the major differences of coal, as compared to other commodities that have been studied, is a different bulk-to-value ratio and different developments in tariff protection.

2.4. Data & Sources

This chapter relies on a novel data set of Welsh coal prices retrieved from printed primary, and partially archival, sources. Prices from most of the sources have never been studied systematically.¹¹⁵ The dataset consists of 2,616 annual price quotations of Welsh coal for the period 1840 to 1960. The sources also yield a further +3,000 prices for other types of coal, such as North Country or Bengal steam coal, which will, however, be excluded from this chapter to ensure that a homogenous kind of coal is compared. Since those additional quotations will be used in the subsequent two chapters, the following description of sources is relevant to all three analytical chapters. Prices are usually classified as f.o.b. at the coaling station or harbour. Thus, they include all costs associated with shipping the coal from a Welsh port, most likely Cardiff, to the respective coaling station, plus the costs occurring at the coaling station and for loading the coal onto the buyer's ship. The prices have been collected from a wide range of sources. These include reports by the Royal Navy to the House of Commons and the US Office of Naval Intelligence, business records of the coal merchant business Wilson, and British consular and commercial reports. The dataset contains prices from all continents bar Australia, where domestically mined coal was already used for bunkering in the 1860s. Due to the shrinking size of the Welsh coal trade network, the geographical reach decreases particularly after the 1920s, with Southern

¹¹⁵ References to individual prices from the *Royal Commission on Coal Supplies* as well as *Kirkaldy* can be found in the literature.

Europe, North Africa and South American remaining as core import markets. The novelty of the dataset and the number of sources involved demands a more thorough discussion that will proceed in a chronological fashion.

2.4.1. Welsh coal prices

Before we dive into the global comparisons, a discussion of the Welsh coal price at Cardiff seems warranted since it serves as a reference price in the following analyses. Annual prices for the period 1840 to 1888 referring to colliery screened steam coal, f.o.b., Cardiff have been taken from Walter's doctoral thesis *The Economic and Business History of South Wales Steam Coal Industry, 1840-1914*.¹¹⁶ Since his price series ends in 1913, his data have to be linked to other sources in order to cover the complete period up to 1960. I decided to link the price series at the earliest year possible since Sutherland's *South Wales Coal and Freight Market Review*, containing prices spanning the years 1889-1893, offers a more precise price description:

“these prices have been most carefully ascertained by averaging the current prices over a whole year from actual sales made at the current market price (not contracts) of first-class South Wales Steam Coals.”¹¹⁷

In addition, Sutherland's price description as well as the sheer size of the prices fits neatly with the successive source *South Wales Coal Annual* (see Figure A2 for Walters and my combined price series). Though the change in source from 1888 to 1889 has some effect on the absolute price level, the identification of the overall trend of price convergence seems not be obstructed as shown by the development of the Genoa-Cardiff percentage price gap using both sources (see Figure A4 and A5).¹¹⁸ *South Wales Coal Annual* is used for the

¹¹⁶ R. Walters, 'The Economic and Business History of the South Wales Steam Coal Industry, 1840-1914' (University of Oxford DPhil, 1975)

¹¹⁷ R. Sutherland, *South Wales Coal and Freight Market Review* (Cardiff, 1894), p.5

¹¹⁸ For the year 1889, Sutherland's price is 32.5% higher than that of Walters. Similarly, the price from the *South Wales Coal Annual*, becoming available in 1897, is 21.3% per cent higher in that year as compared to Walters's price. Inevitably, linking Walters price data to the later series will be noticeable. The reason for the

period 1897 to 1937 referring to annual averages of “Steam Coal Large F.O.B. Cardiff”.¹¹⁹ Rather than annual averages, prices refer to the first half of January from 1920 onwards. From 1949, prices have been taken for Best Admiralty Coal, f.o.b. Cardiff from the *United Nations Annual Yearbook* referring to January 1st of each year.¹²⁰ Figure A2 and A3 plot the complete price series and one should note that nominal prices remained remarkably stable for the period 1840 to mid-1890s with a lower bound of 0.40 GBP/t. Again, from 1924 to 1941, the price level moved little, approaching a minimum level of around 1.00GBP. Wide price fluctuations, we are bound to see at the importing harbours, thus seem to be caused by transportation and other costs rather than changes in the Welsh export price.

2.4.2. Data sources, 1840-1870

The previous account of the evolution of steam shipping has already hinted at the important role played by the Royal Navy, and specifically her coal trials. Indeed, the earliest quotation for bunker coals I could find were prices paid by the Royal Navy. These prices are given in five returns to the House of Commons dating from 1840, 1845, 1860, 1870 and 1871.¹²¹ In total, these returns give 387 prices for the three five-year periods

observed price differences might be that the later coal prices are for large coals only, whereas Walters’s sources are not as specific and might represent a wider variety of coal qualities and thus prices.

¹¹⁹ The last price quotation is referring to the second half of December 1936, which is used as a proxy for the price of January 1937.

¹²⁰ Gaps in the series from 1915-18 and 1839-48 have been closed by applying the relative change per year of the highly correlated *British Average coal export price (f.o.b.)* series by Sauerbeck. From A. Sauerbeck, ‘Prices of Commodities and the Precious Metals’, *Journal of the Statistical Society of London*, (1886). This price series will be discussed in greater detail in the next section.

¹²¹ British Parliamentary Papers, 1840, [221], *Coals. A Return of the Prices Paid by Government, for Coals at the Ports of Southampton, Portsmouth, Devonport and Falmouth, Respectively, during the Years 1837, 1838 and 1839--(so Far as Relates to the Naval Department)*, British Parliamentary Papers, 1845, [600], *Coal, &c. (Navy). Warlick's Patent Fuel. Returns Relative to the Contractors for the Supply of Coals to Her Majesty's Naval Establishments at Home and Abroad; and of Reports Respecting the Comparative Qualities and Efficiency of Grant's and Warlick's Patent Fuel*, British Parliamentary Papers, 1860, [363] *Coals (Navy). Return Showing the Quantities of Steam Coals Annually Purchased for the use of Her Majesty's Navy and Supplied to the several Depôts Abroad, in each of the Years 1855, 1856, 1857, 1858, and 1859; &c*, British Parliamentary Papers, 1870, [346], *Navy. Return Showing the Amount of Coal in Store at the several Home and Foreign Depots on the 31st Day of January in each Year since 1867 Inclusive, and the Average Price Paid Per Ton; Together with an Abstract from Reports on the Qualities of the Coals, and the Saving Effectuated*

1840-44, 1855-59 and 1866-70 referring to 75 different ports.¹²² As well as the coaling station of the purchase, the returns provide further information on the coal supplies such as the origin (thus quality) and how they were obtained. Coal prices for the period 1866-70 predominately relate to Welsh coals, or at least mixtures thereof. The return in 1845 lists 31 types of Welsh coal, and from the North East and Scotland only one each. However, since at the time the Royal Navy regarded them as equally suitable, we can assume that they were quite homogenous. While a few prices for the period 1840-44 include the delivery on board of the ships, the vast majority prices seem to apply to coal off-loaded at the naval docks.¹²³

As described previously, coal suppliers to the Navy were recorded on the ‘Admiralty’s list’ which was perceived as signalling quality by the market. Due to this gain in prestige, as well as the probably significant size of orders, the Navy may have received favourable terms. According to its business records, the coal merchant Wilson supplied Welsh bunker coal to the Navy as well as commercial shipping lines and thus allows me to quantitatively test this possibility. As one example, on 12 October 1882

“the Admiralty contract for Rio has been renewed [...] 42/6 Cardiff or Tyne coal. Engagement to last one year certain and to be terminable thereafter by 3 month [*sic*] notice [...]”¹²⁴

The next contract signed by Wilson at Rio was on 5 December 1882 with Rocco Piaggio & Son, Genoa, for the year 1883 at 42/6 s.d, and thus precisely for the same

Last Year by the New Method of Purchasing Direct, British Parliamentary Papers, 1871, [20], *Navy (Coals in Store). Statement of the Stocks of Coals at the various Home and Foreign Stations for the Years Ended 31st January 1869, 31st January 1870, and 31st January 1871*

¹²² The interest of the House of Commons may be explained by the novelty of coal as the fuel, and perhaps the related question on the outcome of the trials and consequently from which region in Britain coals will be purchased, but also the costs associated with the change from wind to coal. The initial motivations may also explain the cessation of these returns in the early 1870s when coal fuelling had become an unquestioned and integral part of Navy operations.

¹²³ This small difference in the specification of the prices does not constitute an issue since (1) the costs of loading coal onto the ship only comprise a small share of the total trade costs especially in the mid-19th century when transportation costs were extremely high and (2) there does not seem to be a systematic bias in that delivery on board prices are given for certain regions or years.

¹²⁴ Wilson, Sons & Company Limited, 'Wilson, Sons & Company Limited. Minutes of Board and Annual General Meetings. 1877-1891', Note 519 and 541

price.¹²⁵ In 1888 the Admiralty also paid exactly the same price as other customers, whereas in 1885 the prices paid by commercial shipping lines deviate slightly in both directions. In consequence, the prices collected and paid by the Navy appear to give a fair picture of prices paid at coaling stations.

2.4.3. Data sources, 1871-1906

Shipping magazines such as *Mitchell's Maritime Register* or the *Shipping and Mercantile Gazette* contain a paucity of freight rates data used by, amongst others, Harley and Klovland.¹²⁶ Unfortunately, to my knowledge, systematic reporting of bunker coal prices only started in 1900 by the *Coal Merchant and Shipper*, and thus a number of sources will be combined for the period 1870-1900.

As a major contributing source and also as an exception to the predominance of British sources, prices were taken from the publication *Coaling, Docking, and Repair Facilities of the Ports of the World* (in short *Ports of the World*) issued by the American Office of Naval Intelligence (ONI). In total, five editions were issued reporting prices for the period 1883 to 1908. The ONI provided intelligence reporting to the Secretary of the Navy and by the 1880s naval officers seem to have been employed on all navy vessels providing first-hand information to the head office in Washington.¹²⁷ In addition to the self-collected information, *Ports of the World* draws from publically available sources such as official and commercial publications.¹²⁸

¹²⁵ *ibid.*, note 541

¹²⁶ C. Harley, 'Ocean Freight Rates and Productivity, 1740-1913: The Primacy of Mechanical Invention Reaffirmed', *Journal of Economic History*, No. 48, (1988), J. Klovland, 'A Repeat Sailings Index of Ocean Freight Rates for the 1850s', *Working Paper*, (2006)

¹²⁷ S. Stein, *From Torpedoes to Aviation: Washington Irving Chambers and Technological Innovation in the New Navy, 1876-1913* (Tuscaloosa, Ala., 2007), p.64

¹²⁸ Office of Naval Intelligence, *Coaling, Docking, and Repairing Facilities of the World, with Analyses of Different Kinds of Coal*, 2nd edn, (Washington, 1888), p.2-3

Every edition of *Ports of the World* contains, amongst other information, details on coals available at a vast number of international ports.¹²⁹ Since even very small ports are included, but prices are only rarely stated for multiple years at the same coaling station, it appears that the authors were mainly concerned with a vast geographic coverage and focused on time-independent port features, such as listing the next coaling stations *en route*, rather than time-dependent pieces of information such as coal prices. For each port the reporting date (e.g. August 1883), the kind of coal on hand (e.g. Scotch) and the cost per ton are stated. Frequently the price is specified more precisely such as f.o.b., and charges for additional services such as lighterage and stowing are also occasionally stated separately. Exploiting this level of detail, I was able to create a lower-bound price series, usually referring to the f.o.b. price, and an upper-bound price series for stowed coal in bunkers of the purchasing ship.¹³⁰ If both quotations are available for a port, I use the lower-bound price in my analysis since it fits most closely with the descriptions of the other sources. In total, prices for 299 ports during the years 1883-88 were extracted from the second edition yielding 163 Welsh quotations, and a further 246 Welsh prices relating to the period 1889-1899 from the fourth edition.¹³¹

The coal merchant business Wilson, alluded to in the previous paragraph, was founded in Bahia, Brazil in 1837 and subsequently grew rapidly throughout South America. The business was concerned with “coaling, stevedoring, lighterage, towage, ship repairs and general trading.”¹³² The records used here are available at the London

¹²⁹ It also contains information on Lake ports as well as St. Lawrence River ports. Since my sample only contains sea ports, coals from these coaling stations have not been included.

¹³⁰ Price classifications for the lower-bound price series: no information, f.o.b., delivered, alongside, on board and at pile. For the upper-bound price series: stowed, stowing and delivery, in bunkers, incl. lighterage, lighterage and stowing, stowed if alongside wharf.

¹³¹ Office of Naval Intelligence, *Coaling, Docking and Repairing Facilities of the Ports of the World, with Analyses of Different Kinds of Coal*, 4th edn, (Washington, 1900)

Not all potentially available prices were extracted from the source. For example, Welsh anthracite quotations are excluded. Also, when the price description was unclear or contradictory the quotation was ignored.

¹³² *London Metropolitan Archives*, 'Wilson, Sons and Company Limited', at http://search.lma.gov.uk/scripts/mwimain.dll/576/8/1/1950694?RECORD&DATABASE=LMA_DESCRIPT ION&URLMARKER=STARTREQUEST, accessed 04 March 2014

to be shipping companies from European countries such as Britain, Italy and Germany. Shipping companies were often supplied by a number of Wilson's coaling depots.¹³⁵

In 1901 the Royal Commission of Coal Supplies was set up to investigate, amongst other aspects of coal supply, "the effect of exports of coal on British consumers and the Royal Navy" (Part D) and the "Maintenance under existing conditions of the competitive power of our Coal Mining industry with the coal fields of other countries" (Part E).¹³⁶ In addition to interviews with experts in the field, the Royal Commission sent out a request to British consuls to answer several questions, and the responses are included in Part XIII Replies. In the light of this research, their responses to the fourth question are the most relevant:

"State the highest and lowest prices obtained for British coal delivered into railway trucks alongside vessels in each of the last ten years, and at what prices other coals were sold under similar circumstances during the same period. (In answering this question please state the particular kinds of coal referred to.)"¹³⁷

The question is very precise, which is helpful in that prices stated by different consuls should be comparable. In addition, this definition comes very close to the price of bunker coal since it also involves port charges, discharging and loading coal onto another carrier, and some consuls already recognised this similarity.¹³⁸ In their replies, consuls usually gave prices for the 10-year period 1894 to 1903 and 290 quotations for coal were gathered that I could confidently categorise as Welsh. The exact descriptions varied between "Cardiff" for Piraeus, "South Wales Bunker Coal" for Recife or "British men-of-war" for Nagasaki; in the latter case the dominant position of Welsh steam coal as the preferred fuel of the Royal Navy justifies my classification. Once again prices refer to a very global

¹³⁵ While the majority of customers seemed to have been shipping companies, Wilson also supplied Welsh coal from the coaling station at Recife to the railway company Recife & San Francisco Railway.

¹³⁶ British Parliamentary Papers, 1905, [Cd. 2253,] *Royal Commission on Coal Supplies. Final Report of the Royal Commission on Coal Supplies. Part I. General Report*, p.2

¹³⁷ British Parliamentary Papers, 1905, [Cd. 2365], *Royal Commission on Coal Supplies. Final Report of the Royal Commission on Coal Supplies. Part XIII. Replies of H.M. Consular Officers in Answer to a Series of Questions upon the Maintenance of the British Coal Trade in Foreign Countries, Part III*

¹³⁸ The consul at Recife makes the same argument and therefore provides the price for Welsh bunker coal at Cardiff. *Ibid.*, p.158

sample with the closest port St. Malo, 310 nautical miles (nm) away from Cardiff and the furthest away Chemulpo, 13,942 nm away.

As the final source for this period, bunker coal prices were collected from the weekly trade journal *Coal Merchant and Shipper* whose editors claim in their mission statement of the first issue: “There is not in existence a single one that deals with the commercial side of the coal trade pure and simple.”¹³⁹ There might be some merit in this claim since I was not able to find any systematic reporting of bunker coal prices prior to the *Coal Merchant and Shipper* starting in September 1900. Bunker coal prices are reported in the sections *Current prices abroad* for foreign harbours, where a circular issued by Messrs. Harrisons of London, a coal trading and shipping business, is stated as the underlying source. *Current prices abroad* appears in the years 1900 to 1906, and from 1920 again. Each table states the harbour, price in GBP or a foreign currency, and the weight unit. All prices have been converted to GBP per long ton of 20cwt. It also states the quality, with Welsh accounting for slightly less than 50% of all quotations.¹⁴⁰ Post-World War I the price quotation is enhanced by giving a specification of the delivery price such as f.o.b. The minimum number of ports is 49 (18 Welsh quotations) in October 1920, increasing to 102 (43 Welsh quotations) in February 1922. Per available year, one issue of *Current prices abroad* was chosen, which in total yield 323 prices for Welsh coal during the period 1900-06 and 1920-23.

2.4.4. Data sources, from 1912

Kirkaldy’s *British shipping: its history, organisation and importance* published in 1914 contains a section on bunker coal prices taken from actual contracts in 1912. It lists prices for 132 ports including 47 quotations for Welsh coal. Due to the high number of Welsh

¹³⁹ *The Coal Merchant and Shipper*, Nol. 1, No. 1, (1900), p.13

¹⁴⁰ This estimation is based on the issues of February 1901 and February 1922 with a share of 48% and 41% respectively.

quotations, the sample gives a global coverage including ports such as Buenos Aires, Singapore, Mauritius and Bilbao. In addition, information on conditions of supply is given, in the vast majority of cases f.o.b.; currency and weights were adjusted again to GBP per long ton. The successive five editions were published under the title *The History and Economics of Transport* of which the last edition contains bunker coal prices for the years 1913, 1916, 1917, 1920, 1924, 1925 and 1930. In total 171 Welsh prices were extracted for the respective years. For the years 1916, 1917 and 1920 Kirkaldy gives two prices for some ports distinguishing between current and contract prices. I only included the contract prices, the majority of all prices, but the distinction between these prices will be discussed at the end of this section.

A final valuable source of price data is *Fairplay*, a leading British shipping magazine first published in 1883. I have taken the price data from *Fairplay's Annual Summary of British Shipping Finance* covering the period 1923 to 1960. These statistics yield in total 3,405 price quotations. Again, the data covers a truly global sample of ports from all continents grouped according to the regions West Islands (e.g. Tenerife) Australia (e.g. Albany), the Continent (e.g. Amsterdam), the Mediterranean (e.g. Malta), Eastern (e.g. Karachi), North American (e.g. Baltimore), Gulf & West Indies (e.g. Havana) and South America (e.g. Bahia). On average, price quotations are given for around 100 ports in the interwar period and around 60 in the period following World War II. The price quotations are always as of 1 January and mostly given in GBP.¹⁴¹ The price quotations also state the 'delivery form'. In the majority of cases it is 'f.o.b. trimmed' which means that the price includes stowing the coal into the ship's holds from dockside. As previously, prices quotations are accompanied by quality descriptions, in total 60, such as Welsh Best Natal or Westphalian. However, towards the end of this period, the quality descriptions become less specific often only saying "British" and post-World War II "bunker". Price

¹⁴¹ The price in other currencies, in total 13, have been converted using the exchange rate of December 31st of the previous year provided by Global Financial Database.

differentials between different qualities were narrowing over time, indicating that specific quality descriptions became superfluous.¹⁴² The total number of coal prices from 1923 to 1960 classified as Welsh from this source is 947 quotations.

2.4.5. Final dataset

Prices for Welsh coal from all sources have been linked to form continuous price series in one data set. Sources overlap for a number of years, and if prices were reported in both sources for the same port, the more precisely defined quotation was preferred.¹⁴³ The final dataset comprises 2,616 prices; due to the described adjustments, a slightly smaller number is used than the total potentially available data from all sources.

It also includes a small number of price quotations from a variety of sources that will be reviewed briefly. Amongst them are 22 observations I found scattered over a number of coal trade magazines as well as consular reports. In addition, I found a series of Cardiff coal prices at Genoa in the statistical volume *Dinamica die prezzi delle merci in Italia dal 1870 al 1929*.¹⁴⁴ Average prices of Powell's Duffryn, a type of Welsh coal, at Bombay for the period 1899 to 1917 were taken from *Note on the Production and Consumption of Coal in India up to the Year 1910* and *Report on the Production and Consumption of Coal in India 1920*.¹⁴⁵ The underlying sources are again trade reports.¹⁴⁶

¹⁴² If a harbour previously received “Welsh” coal, prices for “British” or “bunker” at that port are assumed to be for Welsh coal, and thus included.

¹⁴³ For instance, prices for the period 1900 to 1903 are available from *The Coal Merchant and Shipper* and *Royal Commission*. Prices from both sources were combined where complementary; if two prices were available for the same port, the price by *The Coal Merchant and Shipper* was preferred. The reason is that the source seems more reliable since its price quotations are more clearly specified, and not compiled by consuls, but by a coal merchant and thus an expert in the field.

¹⁴⁴ The prices refer to the ports Alexandria, Algiers, Constantinople, Havana, Marseilles, New Guinea, Nice, Odessa, Olehleh, Pelotas, Piraeus, Port Said and Salonica.

¹⁴⁵ Commercial Intelligence Department India, *Note on the Production and Consumption of Coal in India Up to the Year 1910* (Calcutta, 1911), p.30, Department of Statistics India, *Report of the Production and Consumption of Coal in India 1920* (Calcutta, 1922), p.23

¹⁴⁶ Up to 1915, Bombay Market Report and Trade Journal and then Current Quotations of the Bombay Chamber of Commerce are stated as the underlying sources.

In addition, specialised sources yielded additional price quotations for Hong Kong, Shanghai and Bombay. I have found the price data for Shanghai and Hong Kong in the Jardine Matheson Archive held at the University of Cambridge.¹⁴⁷ Jardine, Matheson & Company was a trading company founded in 1832 at Canton that was initially heavily involved in the Opium trade.¹⁴⁸ It later shifted activities and acted as an import/export agent as well as a financial services provider, but the focus on the Far East remained. Their archive contains trade circulars, which were also the underlying sources of, for instance, the 'Current Market Reports' of the *Coal Merchant and Shipper*. While this archive offers a wealth of unique material, consisting of over 80 boxes of documents, it is insufficiently complete for this kind of study, since a lot of price currents are only available for a single year, or very few years. Most of them relate to China, Japan and India from the 1860s to 1880s. The price series that I was able to construct for Hong Kong spans the years 1879-1886, 1888-89 and 1891-1893 taken from the *Fortnightly Price Current and Market Report* published by the Hong Kong General Chamber of Commerce. Prices are given for Welsh coal, until 1883 and afterwards referring to Cardiff – in Tals per ton. Usually around five other types of coal are cited next to Welsh such as Takasima, Chikuzen (both Japanese), Keelung (Taiwanese), English and Australian. Which issues survived varies per year, but I usually took the prices of January. The set-up of the price circulars for Shanghai is very similar and I have collected the prices from 1866-1871 from the *John Thorne & Co.'s Shanghai Coal Market Report* for 1871, for 1872-73 from *Price Current and Market Report published under the direction of the Shanghai General Chamber of Commerce*, and for 1875 from *E. W. Rice's Shanghai Coal Market Report*. The prices from 1876-78 and 1882-1908 actually originate from the North China Herald of Shanghai, the principal

¹⁴⁷ Janus, 'Jardine Matheson Archive', at

<https://janus.lib.cam.ac.uk/db/node.xsp?id=EAD/GBR/0012/MS%20JM>, accessed 12 May 2016

¹⁴⁸ 'Jardine, Matheson & Company: Records and Papers. Fortnightly Price Current and Market Report', Cambridge University Library, Department of Manuscripts and University Archives, MS JM/G71

English-speaking newspaper published in China, which is accessible online.¹⁴⁹ Prices refer to “Cargo quotations” often for “Cardiff, ex ship to arrive.” The following Table 2.3 gives a concise summary of the sources reporting import prices.

Source	Time period	# of Ports	# of Quot.	Date	Type of price
Fairplay	1923-1960	130	947	1st January	f.a.s., f.o.b., f.o.b. trimmed // current*
Kirkaldy	1913, 1916-17, 1920, 1924-25, 1930	120	171	Contract prices from some point within the year	f.o.b., f.o.b. trimmed (1912) // Contract, Current available for 1916-17 & 1920
Coal Merchant & Shipper	1900-1906, 1920-1922	61	323	Particular month within year (e.g. Oct 1900)	Post-WWI: f.o.b., f.o.b. and trimmed // current
Royal Commission of Coal Supplies	1894-1906	32	290	Annual price; often average of Year High and Year Low	"delivered into railway trucks alongside vessels" // current*
Office of Naval Intelligence	1882-1899	212	409	Particular month	current, very small no. of contract prices
Genoa Price Series	1870-1914	1	45	Average of 12 monthly quotations	on railway wagon// current*
Wilson & Co. Coal Merchants	1881-1892	11	38	Particular month; aggregated into annual quot.	unclear, sometimes a.s., sometimes f.o.b. // contract
Consular reports, coal journals	1873-94	13	22	Mostly annual average prices	various // current*
Navy Records	1840-44, 1855-59, 1866-70	75	387	Price for delivery within the year (in very few cases average taken in case two or more deliveries made)	f.o.b. or at coaling depot // Contract price for one delivery
North China Herald	1876-78 & 1882-1908	1	30	Day in June	ex ship to arrive // current*
Price currents, Jardine Matheson Archive	1866-1893 (see text for missing years)	2	17	Price at start of the year (usually particular date within January)	not stated // current
Indian coal statistics	1899-1917	1	19	Annual average	not stated or ex bunker // not stated

Table 2.3: Overview sources for price data

Note: * Assumption based on other information given by the source.

¹⁴⁹ Brill, 'The North China Herald Online', at <http://primarysources.brillonline.com/browse/north-china-herald-online>, accessed 08 October 2015

Table 2.3 might trigger questions regarding the comparability of the prices originating from different sources, and the two most pressing concerns will be addressed here: seasonality of the price data and the differences between contract and current prices. Comparing monthly prices with annual averages, or prices from different months, may be problematic in that changes do not reflect fundamental changes in price levels but seasonal patterns. For instance, prices might always be higher prior to the winter months when demand for coals increases. Due to its completeness, the Genoa price series allows for an examination of potentially inherent seasonality in the data, and also whether this changes over time. Analysing seasonality by decade does not indicate seasonality of any sort during the four decades from 1870 to 1910.¹⁵⁰ The only significant monthly effects identified in the two final decades, seem to reflect inflationary effects during the World War I period (lower prices at the beginning of the year) and deflationary pressures in the post-war period (higher prices at the beginning of the year), and thus concerns relating to seasonality can be rejected.

Remaining questions might relate to two elements of the price specifications. First, some sources report current prices, which seem to be spot prices, as supposed to contract prices which often include arrangements to supply a ship with coal multiple times during a period of a few months or years. Differences might arise between spot and contract prices if buyers expect increasing prices and are prepared to pay a premium to secure a certain fixed price for the future. However, sources do not note a significant difference between current and contract prices. The only exception is Kirkaldy which gives current and contract prices mostly referring to 1916 and 1917. The fact that two prices for one port are often reported and that they deviate significantly indicates that during World War I the current/contract distinction mattered. The relatively small number of current prices in these specific years have been excluded to achieve consistency within the cross-port

¹⁵⁰ J. Klovland, 'A Repeat Sailings Index of Ocean Freight Rates for the 1850s', *Working Paper*, (2006)

comparisons during this particular period; for the vast majority of years there is no evidence that comparing both kind of prices will bias the results.

2.5. Theoretical foundation and methodological approach

This investigation will rely on the most widely applied theoretical concept in the field of market integration: The classical “Law of One Price” (LOOP). The LOOP, advocated by Cournot, states that homogenous products should sell for the same price in two markets. Temporary price differentials are eliminated by arbitrage transactions and prices converge to a long-run equilibrium level.¹⁵¹ This model rests on the assumptions that markets are perfectly efficient and no transaction costs apply. In reality, deviations from LOOP occur, and are usually understood to reflect trade costs, as argued by Engel and Rogers or, more recently, by Schulze and Wolf.¹⁵² The size and the change of those deviations is what this chapter seeks to identify. Over time, market integration should show declining trade costs and absolute price convergence.

In the following analysis, trade costs constitute the difference between the export price at Cardiff, measured as f.o.b. per ton, and the sales price of such coal at the foreign ports, also usually quoted as f.o.b. per ton. The major components of those trade costs are freight rates from Cardiff to the importing port, applicable tariffs and port charges at the

¹⁵¹ The term arbitrage, implying a risk-less return, is widely used in the literature and A. Coleman justifies the usage of the term arbitrage in the context of gold shipments: “Although the transaction was potentially risky, as the London gold price could change within the bid-ask spread by the time a gold shipment arrived, in practice there was little risk as the Bank of England purchased most of the gold exported to London at a price that was announced in advance.” From A. Coleman, 'The Pitfalls of Estimating Transaction Costs from Price Data: Evidence from Trans-Atlantic Gold Point Arbitrage, 1886-1905', *Explorations in Economic History*, (2007), Vol. 44, No. 3, p.392. Depending on the commodities and time, risk could be reduced by hedging transactions on futures exchanges. However, it is unclear to what extent this facility was open to all considered commodities during the whole time period. Hence, the term ‘profitable opportunities’ than arbitrage would probably be more precise.

¹⁵² C. Engel and J. Rogers, J., 'How Wide Is the Border?', *American Economic Review*, Vol. 86, No. 5, (1996), M. Schulze and N. Wolf, 'On the Origins of Border Effects: Insights from the Habsburg Empire', *Journal of Economic Geography*, Vol. 9, No. 1, (2009)

importing port, as well as costs for offloading the coal at the port of destination and then unloading it on a purchaser's ship.¹⁵³ These are all costs a coal merchant selling coal at a foreign depot/port would have to cover. The list of potential cost items is longer (see Anderson and van Wincoop on the discussion of trade costs), however, those are the cost components that are individually presented in *South Welsh Coal Annual*, which is the most comprehensive source on the Welsh coal trade - leading me to believe that they are the most crucial.¹⁵⁴

In what follows, two major descriptive statistics will be introduced. These two descriptive statistics are the percentage price gap between the exporting and importing ports, and the Coefficient of Variation (CoV), the standard deviation divided by its mean, as a measure of price dispersion.

Integration implies declining percentage price gaps between the start and end price of a transaction, a simple measure of market integration already used by Federico and Hynes et al, amongst others.¹⁵⁵ Annual price gaps are calculated according to the following formula:

$$\text{Annual Percentage Price Gaps: } \frac{Price_{Port_{i,j}} - Price_{Cardiff_i}}{Price_{Cardiff_i}}$$

where $Price_{Port}$ refers to the price charged at the importing (in the majority of cases foreign) port and $Price_{Cardiff}$ denotes the price charged for the type of coal at Cardiff, the major coal exporting port in Wales. The smaller the price gap, the better integrated the markets or at least the lower are trade costs. The appeal of percentage price gaps stems

¹⁵³ To reiterate: the price quotation at the importing port is usually quoted as f.o.b. as well, which means that the quoted price per ton of coal includes the costs for loading the coal into the bunkers of the purchaser's ship.

¹⁵⁴ While Anderson and van Wincoop give very valuable and more thorough information on the composition of trade costs, the reader should be aware that some costs do not apply to this particular case study, most notably local distribution costs: J. Anderson and E. van Wincoop, 'Trade Costs', *Journal of Economic Literature*, Vol. 42, No. 3 (2004). I use the following two issues of the *South Wales Coal Annual* for tariff data, but it also contains some information on the other mentioned costs blocks: Davies and C. Hailey, *The South Wales Coal Annual for 1912* (Cardiff, 1912), A. Barnett and T. Beynon, *The South Wales Coal Annual for 1932* (Cardiff, 1932)

¹⁵⁵ G. Federico, 'The First European Grain Invasion: A Study on the Integration of the European Market 1750-1870', *EUI Working Paper*, (2008), W. Hynes, D. Jacks and K. O'Rourke, 'Commodity Market Disintegration in the Interwar Period', *European Review of Economic History*, Vol. 16, No. 2, (2012)

from the simple quantification of integration levels in percentages, and comparability across time and with other research papers in the field. A further advantage is that the prices are thus deflated by the coal price at Cardiff, and consequently inflation should not skew the comparisons over time. Deflating trade costs by the commodities' price follows an established practice in the field favoured by trade economist such as Hummels, and later applied by Williamson and Mohammed, and once again by Hynes et al.¹⁵⁶ It seems superior to other available options such as GDP deflators including non-tradables. Percentage price gaps are used for the graphical inspection of price trends (Section 2.6.1) of individual ports as well as in the econometric analyses. This allows for making statements on how the price gaps were behaving in the sample as a whole (Section 2.7). More specifically, I regress the percentage price gaps of Welsh coal between individual ports vis-à-vis Cardiff on year dummies and controls, which allows me to say something about average price gap trends over time.

The CoV is a simple and intuitive measure and frequently used in the market integration literature, for instance by Federico, Schulze and Wolf, as well as Studer.¹⁵⁷ The measure is robust to data errors, and given that they are randomly distributed, the upward and downward effects should cancel each other out.¹⁵⁸ The CoV is calculated across a global sample of ports with annual price data according to the following formula

$$CoV = \frac{\theta_t}{\mu_t}$$

where θ_t is the standard deviation and μ_t is the annual coal price average across all ports in year t . The underlying reasoning is that with increasing price convergence the deviations around the mean decrease, leading to a lower CoV. The trend of price convergence can be

¹⁵⁶ D. Hummels, 'Have International Transportation Costs Declined?', *University of Chicago*, (1999), S. Mohammed and J. Williamson, 'Freight Rates and Productivity Gains in British Tramp Shipping 1869–1950', *Explorations in Economic History*, Vol. 41, No. 2, (2004), Hynes, Jacks, et al., 'Commodity Market Disintegration in the Interwar Period'

¹⁵⁷ G. Federico, 'When did European Markets Integrate?', *European Review of Economic History*, Vol. 15, No. 1, (2011), M. Schulze and N. Wolf, 'On the Origins of Border Effects: Insights from the Habsburg Empire', *Journal of Economic Geography*, Vol. 9, No. 1, (2009), R. Studer, 'India and the Great Divergence: Assessing the Efficiency of Grain Markets in Eighteenth-and Nineteenth-Century India', *Journal of Economic History*, Vol. 68, No. 2, (2008)

¹⁵⁸ G. Federico, 'The First European Grain Invasion: A Study on the Integration of the European Market 1750–1870', *EUI Working Paper*, (2008), M. Schulze and N. Wolf, 'On the Origins of Border Effects: Insights from the Habsburg Empire', *Journal of Economic Geography*, Vol. 9, No. 1, (2009)

determined by chaining the CoV-coefficients for various years into a time-series. Since my price data sample is imbalanced, this means that coal prices are not available for every port in every year. As such, calculating CoV is difficult, as it should not be influenced by changes in the sample composition. Therefore, the CoV is applied more extensively in Chapter Three (Section 3.5), where a balanced sample is achieved much more easily due to the better data coverage in the twentieth century, than in Chapter Two (Section 2.6.2).

2.6. Time-series analysis of selected ports

2.6.1. Percentage price gaps. Figure 2.3: %-price gap Cardiff to 24 individual ports, 1840-1913

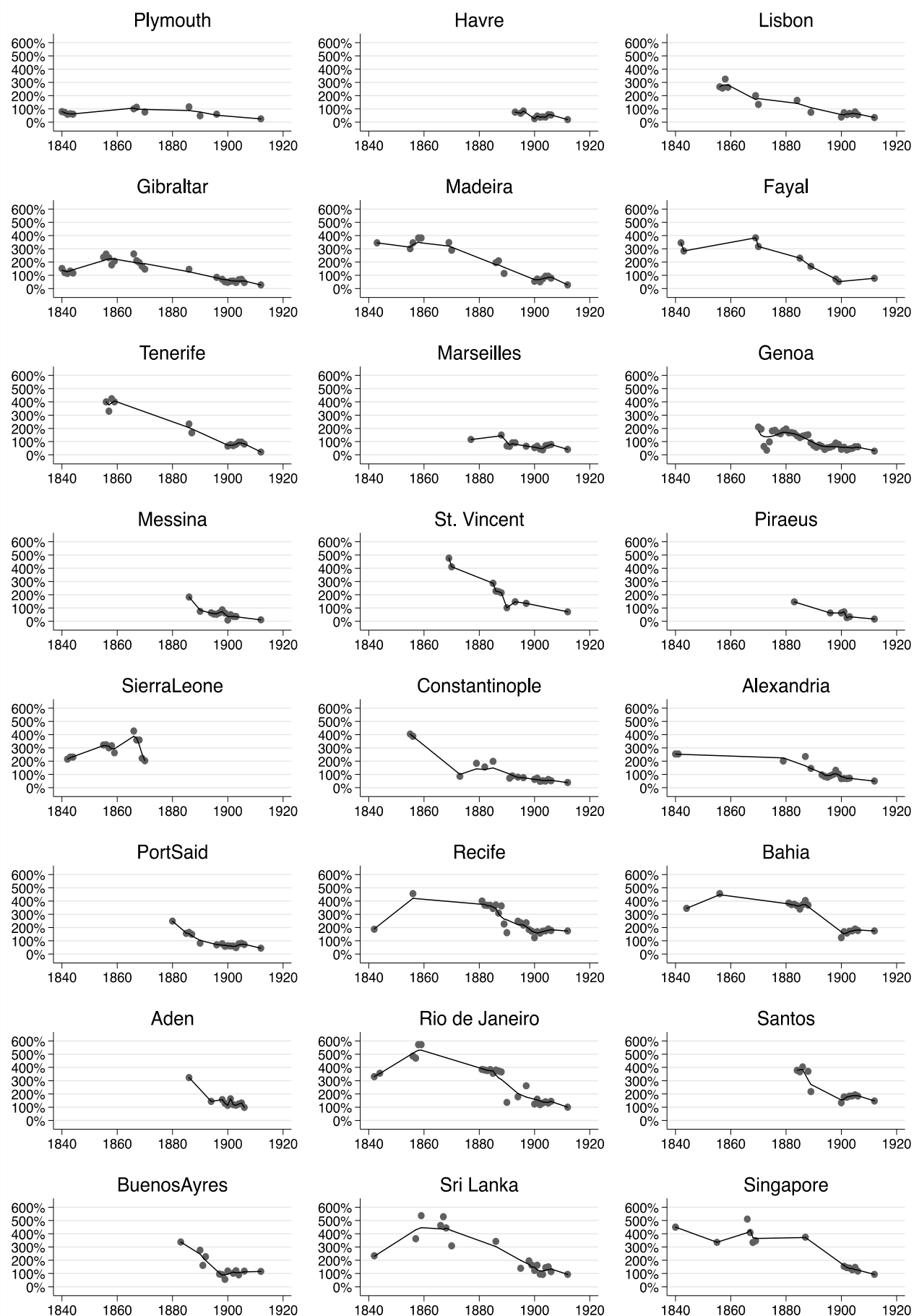


Figure 2.3 presents price trends at 24 ports sorted by increasing distance from Cardiff during the period from 1840 to 1913. The minimum distance is 214nm to Plymouth and the maximum distance is given as 8,165nm to Singapore. This sample of ports includes a wide range of distances and in consequence ports from all major importing regions: the European Atlantic coast, the Eastern Latin American coast, the Mediterranean, the North African coast and ports in the Pacific Ocean. The black line improves the visibility of trends in the price series using locally weighted regressions of the percentage price gaps on all available years.¹⁵⁹ The main observation is that percentage price gaps increase with distance, which seems to override region- or port-specific factors. The major relative price trends affecting all ports will be discussed below in chronological order.

During the period from 1840 to 1870, percentage price gaps fluctuated widely and no trend towards price convergence can be identified. For instance, at Gibraltar the average price gap was 126% 1840-45, it reached 223% 1855-59 and it declined again to 196% in the years 1866-70. In the years 1855-56 at the time of the Crimean War Welsh coal prices were four times higher at Constantinople than at Cardiff. Similar patterns characterised by high volatility also apply to more distant ports such as Singapore, Sri Lanka, Recife and Madeira. Even from one year to another the size of the price gaps changed considerably. For instance, at Sri Lanka the price gap increased from 463% in 1866 to 528% in the next year before it declined rapidly again to 308% in 1869.¹⁶⁰

From the 1880s a sustained trend in price convergence emerges which continued until the start of the twentieth century. At Genoa the price gap fell from 168% in 1882 to 41% in 1894, and reaching the smallest price gap with 29% in 1912. At Gibraltar the price gap decreased by 41% in the period from 1886 to 1896, and it continued to stay below 70% until World War I, reaching a minimum of 27% in 1912. A similar trend can be observed for Constantinople after 1885 and Alexandria after 1887. At Sri Lanka the price gap declined from 343% in 1886 to 139% in 1895. At Singapore the price gap shrank by a

¹⁵⁹ I used a lowess smoother with a bandwidth 0.4. For more information on the smoothing process, see <http://www.stata.com/manuals13/rlowess.pdf>.

¹⁶⁰ The price series for Sri Lanka refers to Trincomalee for the years 1840-70 and Colombo thereafter.

similar margin from 347% in 1887 to 154% in 1901 (no prices for the 1890s are available). The almost complete price series for Recife of the 1880s shows a dramatic fall from 363% in 1888 to 160% in 1890; then the price gaps were higher again in 1894 with 248% before it reached a minimum of 174% in 1912. While price convergence may thus have started earlier at Mediterranean compared to Latin American locations, all ports joined this trend by the late 1880s. Nonetheless, percentage price differences remained substantial at the height of the first global economy pre-World War.

Figure 2.4: %-price gap Cardiff to 24 individual ports, 1901-1960

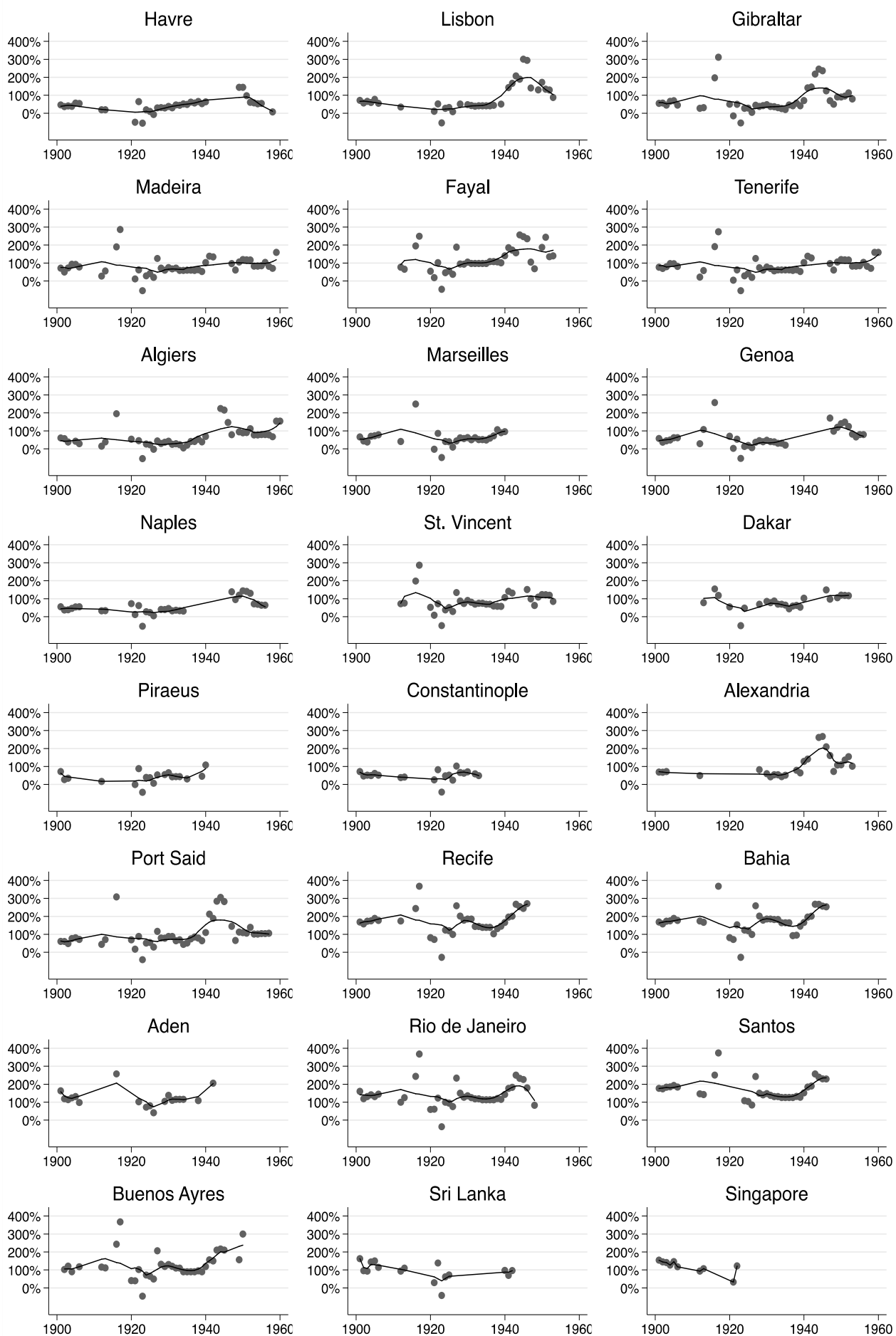


Figure 2.4 allows to compare the state of price convergence across the following three eras: pre-World War I; the interwar period; and post-World War II.¹⁶¹ The data frequency post-World War II is higher and price series more continuous. The sample of ports has been slightly adjusted as compared to Figure 2.3; the ports Plymouth, Messina and Sierra Leone dropped out and were replaced by Algiers, Naples and Dakar. The graphs also indicate a decline in the scope of the Welsh coal trading network as quotations end for Singapore and Sri Lanka during the 1920s (though they reappear at Sri Lanka temporarily around 1940), and Constantinople in the 1930s. The following chapter deals in detail with competition between Welsh and emerging domestic coals in South Africa and India.

Unsurprisingly, World War I and the disruption of supply lines led to shortages and price divergence: between 1913 and 1917 the coal price gap at Gibraltar increased ten-fold, five-fold at Madeira and more than doubled at Recife. By 1920 price gaps were already similar to the pre-World War I level, and prices converged towards the Cardiff price until the mid-1920, but the integration process appears to have been rather messy, with wide deviations from this general trend. This high level of price convergence was briefly disrupted in 1927; a significant increase in price gaps is recognisable, for instance, in the graphs of Fayal, Buenos Aires and Rio de Janeiro, which was most likely the result of the strike at the Welsh mines during 1926.¹⁶²

Although after 1927 prices converged further, reaching a stable level from the later 1920s until the late 1930s, price gaps at most ports did not decline beyond the pre-World War I level. The price gaps to Constantinople fluctuated around the pre-World War I level of circa 50%, and price convergence levels similar to pre-World War I were reached at the other three medium-range locations Alexandria, Genoa and Gibraltar. At Recife price gaps

¹⁶¹ Again, the black line indicates the trend over time using a lowess smoother, with bandwidth 0.4. The price gap for Port Said in 1917 of 519% is not shown on the graph due to the scaling of the y-axis which was set in order to allow for an easy identification of price trends.

¹⁶² The strike ended on December 1, 1926 and prices at Cardiff had already approached the pre-strike level by January 1, 1927. The prices abroad were still higher in January 1927 since they most likely reflected the disruption of supply during most of 1926. There was a time lag until new shipments reached the foreign ports, driving down prices to the pre-strike level.

were in most interwar years lower than before World War I and reached historical lows of 71% (1921) and 103% (1937). Thus, a small number of ports, also including Santos and Sri Lanka, were exceptions, in that price gaps seem to have declined further than pre-World War I. At all ports the size of price gaps was more constant in the late 1920s to late 1930s, than before World War I. This could indicate that the effect of freight rates became less detrimental for import prices, and thus the more stable components such as the costs at the delivery harbour and the price at Cardiff accounted for a greater share of the final price.

During World War II price gaps began widening mostly in 1940 and 1941, as shown by the graphs of Lisbon, Port Said and Gibraltar. Subsequently, prices diverged to a similar extent as observed during World War I at Gibraltar with a maximum of 245% in 1944 and 656% for Genoa in 1945. Price gaps continued to be very large after World War II and reached all-time maximum values of 1,090% at Alexandria and 950% at Genoa in 1952. Gibraltar and Madeira also showed higher prices in 1952, but they both stayed below the maximum prices experienced during World War II. This discrepancy is striking since prices had so far developed relatively uniformly across ports. Perhaps broader changes in market structure may explain these developments: strong demand during the reconstruction boom coincided with the nationalisation of the British coal industry in 1949 and the subsequent regulation of coal supplies including exports.

2.6.2. CoV-Calculation

Exploiting my Welsh coal price data set with the CoV is difficult. In part, this is because the sample changes due to the combination of sources used. But it is especially down to the fact that the Welsh coal trading network is shrinking. The latter factor introduces a bias in the sample, as more and more ports from the same world regions remain (for example, the Mediterranean and Latin America), while ports from other regions leave the sample, so the

variation in prices is bound to decrease. Therefore, calculating the CoV across all available price quotations – a highly unbalanced sample – could produce potentially misleading results. Nevertheless, the CoV will be calculated here as it acts as an important bridge to the results of the following chapter (where a balanced sample is achieved much more easily due to the better data coverage in the twentieth century). To mitigate a sample bias, I calculate the CoV for a sub-set of ports, where Welsh coal prices are available for each of the chosen benchmark years 1886, 1900, 1908, 1912, 1924 and 1932.

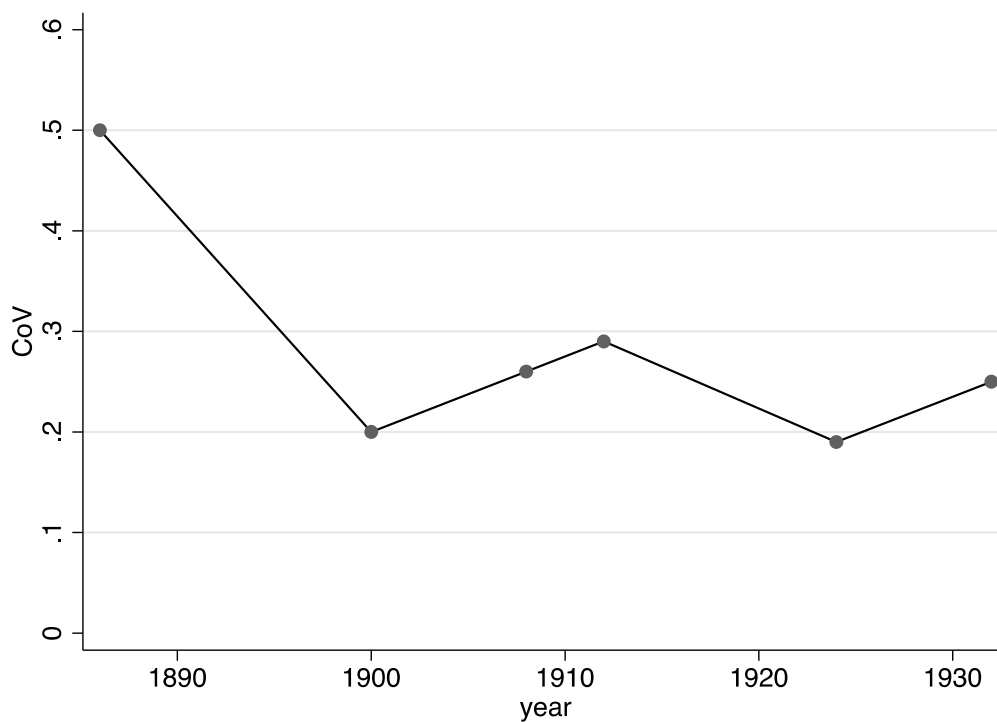


Figure 2.5: CoV across sixteen ports importing Welsh bunker coal, 1886-1932

Note: The ports in the sample are Barcelona, Bilbao, Alexandria, Buenos Aires, Piraeus, Lisbon, Marseilles, Gibraltar, Genoa, Santos, Rosario, Rio de Janeiro, Recife, Montevideo, Bahia, Port Said

The CoV more than halves from 1886 to 1900 from 0.5 to 0.2, which also marks the lowest level CoV across all benchmark years until 1924. After 1900, no clear trend is discernable: the CoV increases to 1912, reaching a value of 0.29 before it falls to a low of 0.19 in 1924. It then increases once again, reaching 0.25 in 1932. The observed trend

broadly aligns itself with the previous findings on price convergence with significant price convergence until the early twentieth century, and no further price convergence during the interwar period.

2.7 Econometric trend

2.7.1 Model specification

The graphical and descriptive analyses above reveal new insights, even though stark fluctuations in the coal prices coupled with discontinuities in the price series make it difficult to clearly identify long-run trends, particularly during the nineteenth century. As a solution, the following OLS panel regressions extract an econometric trend by combining the percentage price gaps for all ports and years in the dependent variable. Year dummy variables serve as the main explanatory variables, whose coefficients should thus aggregate the state of price convergence in a single indicator per year, which then can be compared over time. Once again, the use of percentage price differences between Cardiff and the respective importing ports as the dependent variables removes potential inflationary effects.

The time trend should not be diluted by changes in the composition of the sample in that prices are not available for the same ports every year. Model 1 therefore contains port dummy variables, which capture any port-specific effects. Between ports costs for coal handling, port dues and potential tariff payments may have differed. Model 2 uses shipping distances from Cardiff to the respective ports as a control since the previous descriptive analysis showed that percentage prices gaps increase with distance (in 1912 shipping distances explained 78% in the variation of price gaps as illustrated by Figure A6).¹⁶³

¹⁶³ One could argue that this does not only capture transportation costs but also changes in tariffs: the shorter the distance from Britain, the more countries would likely protect their market. However, following this line

Thus, shipping distances are a well-suited control to remove the effects of changes in the sample from year to year, for instance, a comparatively high number of distant ports in one year. If both models show a similar time trend, this should raise our confidence that they accurately describe the long-term trend in price convergence. In the following OLS regressions the constant has been excluded since the fitted values should go through the origin. This means, i.e. at Cardiff, that the percentage price gap should equal 0%.¹⁶⁴ Standard errors are always clustered at the port-level. The exact specifications of the OLS regressions are as follows.

Model 1: Year dummies and port-fixed effects

$$\frac{PricePort_{i,j} - PriceCardiff_j}{PriceCardiff_j} = Y1840_i + Y1841_i + Y1842_i + \dots + Y1960_i + Aden_j + Agrigento_j + Alexandria_j + \dots + Zea_j + \epsilon_{i,j}$$

where j denotes the port, i the year of the observation and $\epsilon_{i,j}$ the disturbance term.

1. $PricePort_{i,j}$ is the price in GBP per long ton at port i in year j .
2. $PriceCardiff_j$ is the price at Cardiff in GBP per long ton at year j .
3. $Y1840_{i,j}$ is the dummy variable equal to one if the year of observation is 1840. It is zero for all other years. Year dummies are included for each year within following periods 1840-45, 1855-59, 1866-70, 1882-1906, 1912-13, 1916-17 and 1920-60.
4. The dummy variable $Aden_{i,j}$ has the value one if $PricePort_{i,j}$ refers to Aden for year j . It equals zero for all other ports. Such a dummy variable is included for every port contained in the dataset.

of argument rather than the shipping distance from Cardiff, the distance to the closest source of high-quality coal supply should determine tariff barriers. This is not necessarily Britain, since the USA and Germany supplied high quality bituminous coals already in the late nineteenth century, and South Africa and other countries started exporting such coals in the early twentieth century.

¹⁶⁴ Running the OLS-models, including a constant, yields the same results, and adding the constant to each year dummy coefficient generates the same graph as shown in Figure 2.5.

Model 2: Year dummies and shipping distances

$$\begin{aligned} & \frac{PricePort_{i,j} - PriceCardiff_j}{PriceCardiff_j} \\ &= Y1840_i + Y1841_i + Y1842_i + \dots + Y1959_i + Y1960_i + distance_{i,j} \\ &+ \epsilon_{i,j} \end{aligned}$$

where again j denotes the port, i the year of the observation and $\epsilon_{i,j}$ the disturbance term.

The explanatory variable, which has not been introduced in Model 1, is defined here:

$distance_{i,j}$ is the shipping distance denominated in '000nm from Cardiff to port j in year i .

The shipping distances are adjusted to reflect the significant reductions in trip lengths through the Suez Canal. For instance, the shipping distance to Bombay decreased from 10,410nm to 6,150nm after the Suez Cana opening.¹⁶⁵ Therefore, two sets of shipping distance constitute this variable: 1. 1840 to 1869 shipping distances going around Cape Horn and the Cape of Good Hope, 2. 1870 to 1914 including the new shorter routes through the Suez Canal to the Pacific Ocean replacing the routes around the Cape of Good Hope.

Since the price data have been discussed in the previous section, it will suffice to describe the nature of the shipping distance data here: the distances have been taken from the contemporary source *Reed's Tables of distances between ports in all parts of the world and other useful tables* of 1882; for ports not included in this source distances were calculated using sea-distances.com.¹⁶⁶ A cross-check between distances taken from both

¹⁶⁵ The Panama Canal, opening in August 1914, also significantly reduced shipping distances on certain routes, such as from Cardiff to Callao by 3,922nm. While Welsh coal was exported to Chile and other ports on the Western Latin American coast, my last Welsh price quotations for this region refer to 1912, and thus Welsh coal seemed not to have been shipped through the Panama Canal in significant amounts.

¹⁶⁶ T. Reed, *Reed's Tables of Distances between Ports in all Parts of the World and Other Useful Information* (Sunderland, 1882), *Sea Distances*, at <http://sea-distances.com>, accessed 03 November 2013

sources for the same ports confirms that both methods yield highly similar distances deviating in a range of +/-1%.¹⁶⁷

2.7.2 Estimation results

Both models explain a high share of the variation in percentage prices gaps over time; the R-squared of Model 1 is 0.93 and 0.88 of Model 2. In Model 1 the time-fixed effects of 1856, 1858, 1859 and 1866 are significant at the 5%-level, 1867, 1868 and 1917 at the 10% level. In contrast, in Model 2 the vast majority of year dummies from 1841 to 1890 and after 1921 are significant at the 1% level; during the remaining period, some year dummies are significant. In Model 1 some of the port-fixed effects are significant. This lack of significance, particularly in Model 1, can be explained by the relatively small number of price observations per port. Running the regression of Model 1 on a reduced sample of 1,448 observations, this includes all ports with at least 20 observations, results in highly significant port dummies and a much higher number of significant year dummies. In Model 2 the highly significant *distance* coefficient shows that an increase of the shipping distance by 1,000nm raises the price gap by 23.5 percentage points.

¹⁶⁷ The great similarity in distances from both sources strongly suggests that the distances from *Reed's Tables* refer to steamship distances. Sailing distances were often quite different and longer, since sailing ships would take longer routes in order to benefit from currents and winds. Coal was still frequently transported on sailing ships until the 1870s, and therefore the true shipping distances pre-1870 may well have been larger than the distances used.

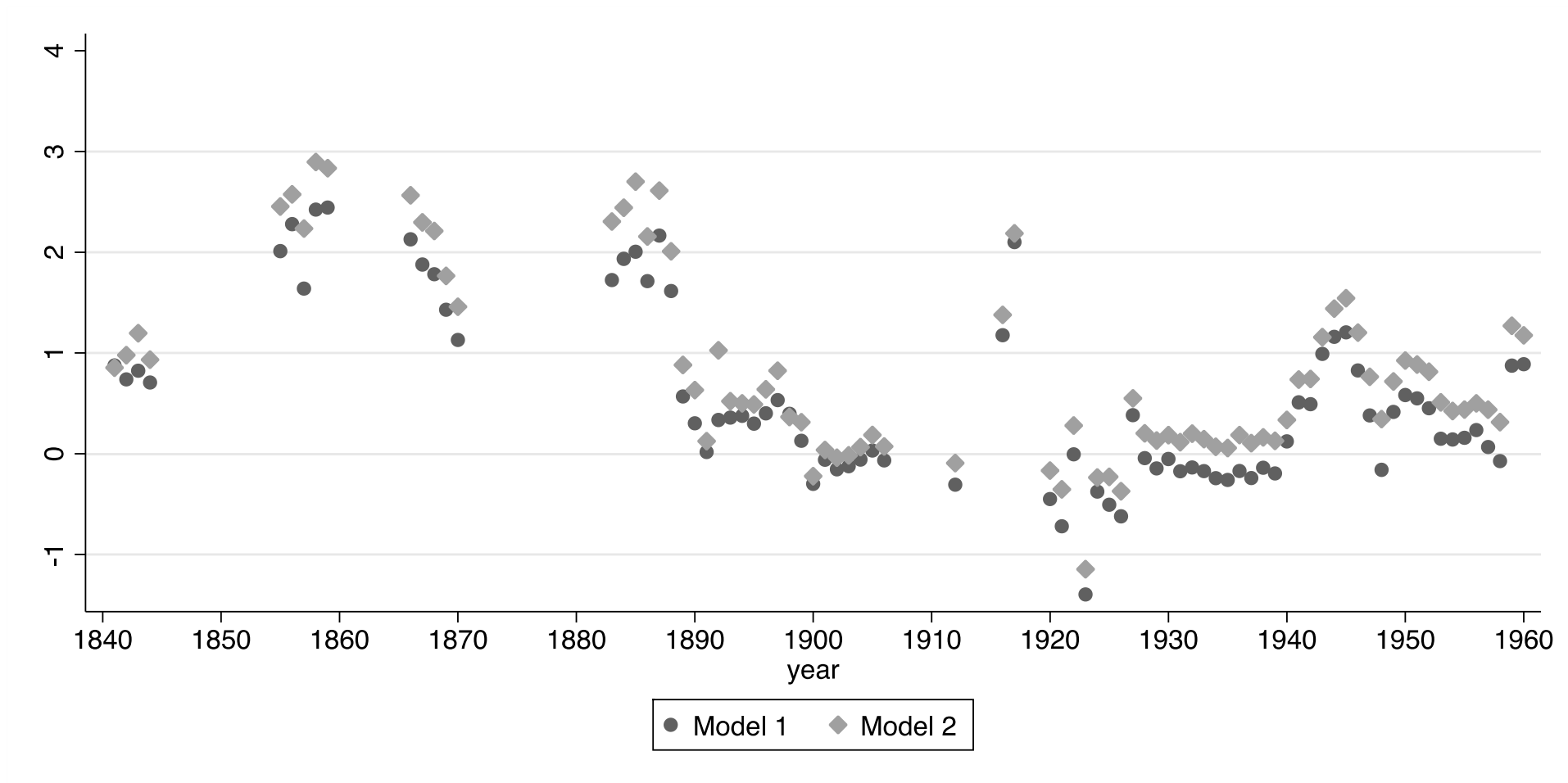


Figure 2.6: Year dummy coefficients of Model 1 and Model 2, 1841-1960

The time trend of Model 1 and Model 2, the focus of the exercise, is shown above in Figure 2.6. The size as well as the trend of the year dummies are remarkably similar in both models.¹⁶⁸ From 1840 until the late 1880s, coefficients fluctuate in a corridor between the values 1 and 3. No trend towards price convergence is discernable. It is remarkable that coefficients more than halve within a 5-year period, such as in the late 1860s. From 1888 onwards, the year fixed effects decline dramatically until the 1890s. Then they increase slightly again before they fall to a minimum in 1900 that is reached again in 1912. As already seen in the previous graphical analyses, World War I caused price divergence: the 1917-dummy reaches values above 2 in both models, a price convergence level only experienced prior to 1886. While price data for the immediate interwar period are missing, prices seemed to have integrated fairly swiftly. Based on Model 2, in 1923, prices were even lower at some Mediterranean ports than in Cardiff, which is puzzling but might indicate that there was oversupply at certain ports and reflect an unsteady re-integration process. While during the years 1924-26 coefficients were briefly lower than in 1912, the essential finding is a flat trend in price convergence from pre-World War I into the interwar period; for coal, there was no disintegration as identified for agricultural commodities by Hynes et al.¹⁶⁹

Apart from the hike in 1927, most probably caused by the strike in Welsh mines, coefficients, and thus price gaps, continued to decline from 1937.¹⁷⁰ While values for

¹⁶⁸ Given that both models show very similar results, the fact that I used only steam shipping distances in Model 2, and not those of sailing ships, which often transported coal until the 1870s, does not appear to affect my findings in a significant way. Nevertheless, I have re-run Model 2 using up to 40% longer distances pre-1870 to examine what the potential effect of using sailing distances might be. These tests indicate that the time trend coefficients would be slightly lower pre-1870 and slightly higher thereafter. The coefficient on *distance* would decrease. The trend towards price convergence would be slightly less dramatic, though the effect of using sailing distances appears to be very limited.

¹⁶⁹ W. Hynes, D. Jacks and K. O'Rourke, 'Commodity Market Disintegration in the Interwar Period', *European Review of Economic History*, Vol. 16, No. 2, (2012)

¹⁷⁰ During the seven month-strike in 1926, coal exports were at times forbidden since the available coals were needed to keep the domestic economy running. Next to such direct government interventions, which might explain a smaller increase in prices at home as opposed to abroad, it appears unlikely that sellers preferred British over foreign buyers since Wales was heavily dependent on the export trade and fostering reliable supply relationships. Thus, the Cardiff price variable might also simply pick up that when prices increased at

1937 are approaching the 1913-level, coefficients are, on average, slightly higher than in the first years of the twentieth century before World War I. From 1940 coefficients increase to circa 1 (Model 1) and 1.2 (Model 2) during the years 1943-46. The developments post-World War II are reminiscent of the post-World War I period, particularly of 1923, since the coefficient plunges to -0.193 (Model 1) and 0.173 (Model 2) in 1948, before increasing substantially again. A rather stable level persisted from 1953 to 1957, though at a significantly higher level as experienced in the stable interwar period of the 1930s. The early 1950s and especially 1959 to 1960 show maximum values with coefficients reaching records levels of 0.853 (Model 1) in 1960 and 1.27 (Model 2) in 1959. While acknowledging that only a rather short period of years post-World War II is covered, and given that the sample size is comparatively small, the evidence nevertheless strongly suggests that coal prices did not reach the levels of price convergence achieved during the interwar or pre-World War I periods again.

2.8 Freight rates and tariffs as determinants of price convergence

A comparison with the development of both potential and major cost drivers of coal prices – freight rates and tariff barriers – will serve as a plausibility check to my findings on price convergence. I do not attempt to give a rigorous econometric explanation, since it appears infeasible to construct precise control variables for freight and tariff rate developments due to the vast size of my data set. Such efforts are also inconsistent with the main purpose of this chapter, which looks to examine the level and trend of price convergence rather than its causes.¹⁷¹ However, what I can do here is compare my findings to available freight indexes

Cardiff such as during the wars, also shipping and insurance costs were rising, driving a greater wedge between the export and import prices, though this remains speculation at this stage.

¹⁷¹ My data set contains coal prices for 253 ports and 99 countries during the period 1840 to 1960, and finding all relevant freight rates appears as an infeasible task. By comparison, Jacks and Pendakur's publication, which focuses on maritime trade costs exclusively and uses the largest freight rate data set of which I am

and tariff rates that I have collected for critical benchmark years, and investigate whether these align with my findings (a very similar approach is also taken by Hynes et al. in ‘Commodity Market Disintegration in the Interwar Period’).¹⁷²

Harley investigated the relationship between British coal exports and outward coal freight rates from 1838 to 1913 by constructing a coal freight index, as displayed in Figure A7 of the Appendix. Harley’s index is based on routes to eight geographic regions, of which four shipping routes from Wales are included in my dataset and displayed in Figure 2.6 further below.¹⁷³ Since Harley’s index is using outward coal freights with some overlaps in terms of routes with my percentage coal price gaps, the trends in his index should correlate with my findings of price convergence.¹⁷⁴ Harley summarises the evolution of freights as follows:

“The general level of freights was essentially without trend until the mid-1860s. Then rates declined rapidly until the early 1890s as metal and steam technology was introduced in the industry. By the 1890s the average freight on coal had fallen to only about 45% of the level in the middle third of the century.”¹⁷⁵

Regarding Harley’s first point, my data analysis too does not indicate any trend in price convergence during the middle of the nineteenth century. Further support comes from recent research by Klovland who shows monthly freight rate movements 1848-1861 including a specific index for outward coal freight rates.¹⁷⁶ It confirms a boom in freight rates during the years 1853-54, which continues until 1856 on shipping routes affected by

aware, comprises freight rates from Britain to only 21 countries during the period 1870-1913, relating to 40 different commodities. D. Jacks and K. Pendakur, ‘Global Trade and the Maritime Transport Revolution’ *Review of Economics and Statistics*, Vol. 92, No. 4, (2010)

¹⁷² W. Hynes, D. Jacks and K. O'Rourke, ‘Commodity Market Disintegration in the Interwar Period’, *European Review of Economic History*, Vol. 16, No. 2, (2012)

¹⁷³ Harley’s data contain routes from Newcastle (England) to London, Hamburg or Le Havre and to Danzig. The routes from Welsh ports go to Bordeaux, Genoa, Colombo, River Plate and Chilean ports, where the latter are not contained in my dataset.

¹⁷⁴ While Harley uses a different inflation, the British GNP price deflator, and I deflate the price differences by the price at Cardiff, this should not have a significant impact on the comparability of the results in the low-inflation environment of the nineteenth century.

¹⁷⁵ C. Harley, ‘Coal Exports and British Shipping, 1850–1913’, *Explorations in Economic History*, Vol. 26, No. 3, (1989), p.315

¹⁷⁶ J. Klovland, ‘A Repeat Sailings Index of Ocean Freight Rates for the 1850s’, *Working Paper*, (2006)

the Crimean War such as Constantinople. Freight rates often doubled within the single year 1853, highlighting the great volatility in coal freight rates. Overall the British freight markets appeared very well-integrated and the wide fluctuations were remarkably synchronised, in that they affected the majority of shipping routes at very similar times. Again, this aligns itself well with my findings that changes in price convergence happened at a very similar time across my global set of ports.

Touching on Harley's second point, my findings suggest that price convergence started during the 1880s and continued during the 1890s, rather than from the late 1860s to the early 1890s as suggested by Harley. One thing to consider is that freight rates only constitute one major driver of percentage price gaps; other smaller determinants such as port charges, on- and off-loading costs may have developed very differently, especially since they may not have benefited as much from technological progress. Another way of explaining the difference in timing is a visual examination of the individual freight rates that constitute Harley's index. Figure 2.7 shows Harley's coal freight rates from Wales to the port of Genoa, Bordeaux, Colombo and the River Plate (the major ports are Buenos Aires and Montevideo), which are included in my dataset.

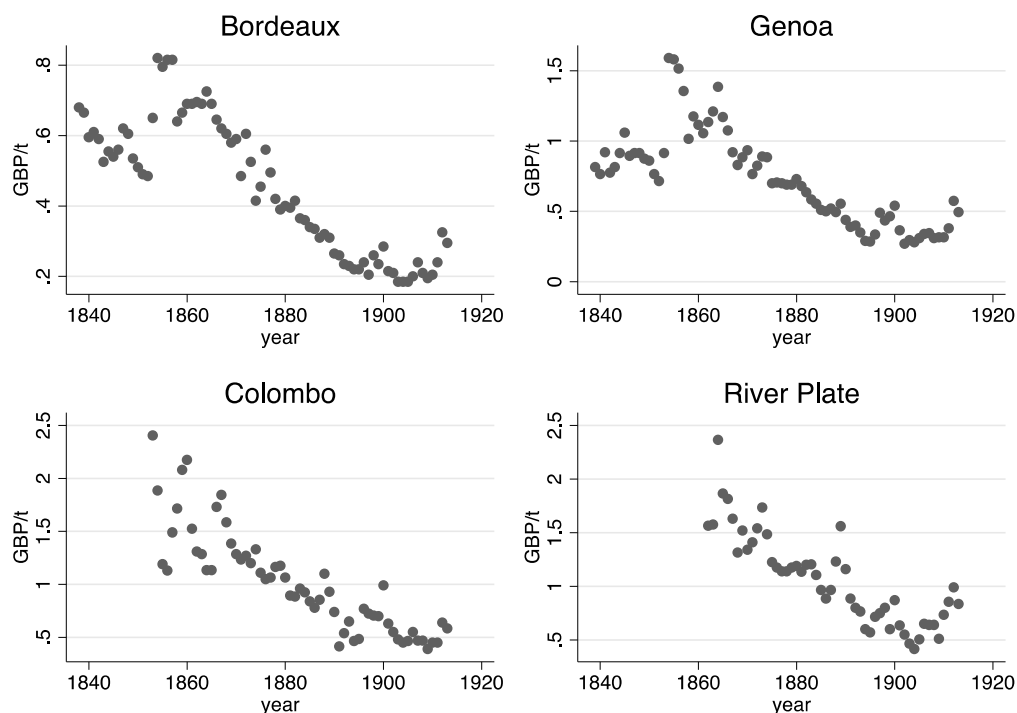


Figure 2.7: Freight rates 1838-1913 in GBP/t from Wales to Bordeaux, Genoa, Colombo and River Plate ports

Source: C. Harley (1989), 'Coal Exports and British Shipping, 1850-1913'¹⁷⁷

All four series show dramatic volatility in freight rates, in particular of the years up to the late 1870s. The two graphs of Genoa and Bordeaux go back further to 1838 and confirm that the minimum level of freights of the 1840s and early 1850s were only reached again during the 1870s. This lack of price convergence accords well with my findings. The similarities therefore confirm that my results are sensible, and that price gaps were most probably to a significant extent composed of, and driven by, freight rate developments. Identifying the start and end points of the decline in freight rates, and by extension coal price convergence, depends on when the freight rates start – from the 1860s or before – as well as other factors, such as the completeness of the series, and the selection of ports. Therefore, the trend for the second half of the nineteenth century might perhaps not be as clear as Harley's index suggests.

¹⁷⁷ C. Harley, 'Coal Exports and British Shipping, 1850–1913', *Explorations in Economic History*, Vol. 26, No. 3, (1989), Appendix Table 3, p.334-36

For the post-1913 period, comparisons with freight indexes are not as straightforward. Mohammed and Williamson developed a global freight index covering the interwar period, and by linking it to Hummel's index, they extended it to 1997.¹⁷⁸ Both indexes use freights of tramp shipping which transported low value bulk commodities.¹⁷⁹ These include coal but also other commodities, such as timber and grain, with considerably different stowage factors. In the remainder of this section, I will refer to Mohammed and Williamson's index as including Hummel's contribution. Their nominal global index reaches pre-World War I levels in the early 1930s, showing a slight increase towards the end of the decade. The same index deflated by commodity prices shows a more abrupt decline to pre-World War I levels already in the 1920s. While different in the course of freight rate developments, the real as well as the nominal index confirm a return to the level of freight rates experienced pre-World War I at some stage during the interwar years. This observation fits well with my finding that prices did not diverge in the interwar period as argued by Hynes et al.¹⁸⁰

For the post World War II-period, their nominal index shows a smaller hike in the earlier 1950s, and a more pronounced hike reaches the level of World War II in the later 1950s. When deflated by commodity prices, even the second and larger hike only reaches up to the freight rate level of the interwar period, but for the rest the freight level is significantly lower. My results show much larger price divergence post-World War II which might thus be explained by the choice of the deflator, or perhaps that freight rate developments became a less important driver of coal price differences. Next to those issues surrounding the deflator, the overall structure of the British coal export trade changed after

¹⁷⁸ S. Mohammed and J. Williamson, 'Freight Rates and Productivity Gains in British Tramp Shipping 1869–1950', *Explorations in Economic History*, Vol. 41, No. 2, (2004)

¹⁷⁹ *ibid.*, p.173

¹⁸⁰ W. Hynes, D. Jacks and K. O'Rourke, 'Commodity Market Disintegration in the Interwar Period', *European Review of Economic History*, Vol. 16, No. 2, (2012)

the nationalisation of the coal industry in 1949, which I will discuss in more detail in the final paragraph of this section.

If indeed the decline of freight rates contributed to price convergence for Welsh bunker coal prices, I can also use Model 2 to test this assumption. Such a development should mean that distance also mattered less over time. I therefore created an interaction term of distance times a year dummy for all years post-WWI in Model 2. The interaction term coefficient is -0.18 (as opposed to 0.28 on distance) and is significant at the 1%-level. For the reduced sample, with at least twenty observations per port, the interaction coefficient is -0.11 and 0.21 on distance, both highly significant. This confirms that indeed distance, and by extension freight rates, were less important post-World War I, which unites the previous discussion of freight rate developments with my empirical results.

Since the subject is picked up by Harley as well as Mohammed and Williamson, the issue of joint-production shall be briefly discussed. It refers to the level of freight rates being dependent on demand on both the homeward and the outward routes, as well as the specific characteristics of the cargo:

“This jointness arose because of the disparity between bulk and weight of different commodities and the limitations of navigational technology in this period that required buoyancy to be filled.”¹⁸¹

In consequence, outward coal freights may be artificially low only covering the marginal cost of the outward trip, since the demand on the homeward trip is so strong, and Klovland claims “it is well known that the average of coal freights to the various ports of coal were not a linear function of distance.”¹⁸² This jointness of production is a problem for Harley, as well as Mohammed and Williamson, in estimating total factor productivity, but not in the case of studying price convergence. If lower freight rates resulted in lower prices for bunker coal, and this also depends on other costs at the destination port, it

¹⁸¹ S. Mohammed and J. Williamson, 'Freight Rates and Productivity Gains in British Tramp Shipping 1869–1950', *Explorations in Economic History*, Vol. 41, No. 2, (2004), p.191

¹⁸² J. Klovland, 'A Repeat Sailings Index of Ocean Freight Rates for the 1850s', *Working Paper*, (2006), p.15

reflects the true price for which coal is available even though it might be lower than what might be expected. However, in the price dataset only very few prices such as Buenos Aires in 1892 clearly show lower prices as expected given the distance. In addition, the explanatory power of my regression Model 1, only using the distance interaction term with an adjusted R^2 's of 0.78, indicates that perhaps the overall significance of joint-production becomes less important when analysing such a large sample of trading relationships which also extends beyond World War I.

Tariff rates can be a forceful determinant of relative price trends. Hynes et al. attribute their results of market disintegration post-1929 to raising tariff rates.¹⁸³ Can different tariff rate developments in coal, as opposed to the range of agricultural commodities investigated by them, explain the contradiction to my findings? The following table contains import duties on coal from 23 countries from all geographic regions contained in my dataset. The years 1912 and 1932 were chosen on the assumption that, if tariff changes could explain different integration levels between the intermediate pre-World War I period as opposed to the interwar period, these two years should be representative of each era, and in particular, any move towards protectionism should have manifested itself by 1932.

¹⁸³ W. Hynes, D. Jacks and K. O'Rourke, 'Commodity Market Disintegration in the Interwar Period', *European Review of Economic History*, Vol. 16, No. 2, (2012)

	1912	1932
Algeria	4.72%	n/a
Argentina	0.00%	0.00%
Azores/ Portugal	5.04%	n/a
Brazil	0.00%	5.00%
Canary Islands/ Spain	0.00%	n/a
Egypt	0.62%	5.64%
France	3.84%	1.68%
Gibraltar	0.00%	n/a
Greece	0.00%	8.74%
Italy	0.00%	2.60%
Madeira/ Portugal	6.79%	4.82%
Malta	0.00%	n/a
Mauritius	3.55%	n/a
Morocco	10.00%	n/a
Portugal	6.44%	5.98%
Saint Vincent	0.00%	n/a
Senegal	0.00%	n/a
Singapore	0.00%	n/a
Spain	11.30%	10.06%
Sri Lanka	0.00%	n/a
Turkey	11.00%	25.59%
Uruguay	6.22%	n/a
Yemen	0.00%	n/a
Average	4.00%	7.01%

Table 2.4: Tariffs rates for coal in 1912 and 1932

Sources: *South Wales Coal Annual for 1912* and *South Wales Coal Annual for 1932*.¹⁸⁴

Notes: Averages composed of Argentina, Brazil, Egypt, France, Italy, Madeira/Portugal, Portugal, Spain, Greece and Turkey; the Spanish tariff is the average of a reduced duty in accordance with the United Kingdom-Spanish Convention applying to an import volume of 750,000t of British coal annually, and the normal rate; the Turkish tariff 1932 is for “mineral fuel: pit coal, lignite, peat and briquettes.” There is also a tariff rate of 72% for “anthracite in lumps, (mixtures are considered as “lump”), which could be applicable since bunker coals are usually mixtures. However, Welsh steam coal is a high quality bituminous and not an anthracite coal.

In 1912, the tariff classification usually referred to all types of coal such as “coal and coke” or “coal, coke and patent fuel”. A significant exception was Egypt, which had the category “for coal entering Egypt in transit at 1% ad valorem on a value of 0.82GBPE per ton South Welsh coal”, which in turn is expressed in percentage terms in the table above. This is the only country in 1912 reporting a distinction between tariff rates for “coal

¹⁸⁴ J. Davies and C. Hailey, *The South Wales Coal Annual for 1912* (Cardiff, 1912), p.294-302, A. Barnett and T. Beynon, *The South Wales Coal Annual for 1932* (Cardiff, 1932), p.290-97

in transit” and coal for consumption. There is thus only limited evidence that coaling stations were systematically treated differently; above all, tariff rates did not seem to have played a prominent role in shaping market integration. Twelve countries did not impose any tariffs, whereas eleven countries did impose tariffs. These were expressed as fixed money values, apart from Turkey, Morocco and Uruguay, which charged ad valorem tariffs. The imposed tariffs were rather small around 5%, which might indicate that they were not intended to shield off the domestic market but rather seen as a source of revenue. Higher tariffs of at least 10% applied in Morocco, Turkey and Spain. The latter two possessed their own coal mines, which could indicate that they were supposed to protect domestic production. The average tariff of 4% calculated for the number of countries present in both sample years, however, makes it clear that tariffs were very low, especially set into relation to the dramatic declines in freight rates.

Up to 1932, tariff rates increased moderately to 7.0%, a still relatively low level. For five jurisdictions tariff rates increased; it remained free in Argentina and decreased in four countries. The outlier, and thus a driver of the increase in the calculated average tariff rate, is Turkey with a tariff rate increasing from 11.0% to 25.6%. My price data series for Constantinople, shown in Figure 2.4, ends in 1933 which indicates that Welsh coal may have exited the market in response to heightened tariff barriers. While the overall increases are moderate, the more detailed specification of the tariffs, including surtaxes, indicates that tariff policy became more active. The tariff in Egypt was specified as 50 milliemes per 1,000 kg on which a 10% surtax of the duties imposed was added totalling a tariff rate of 5.6%. Apart from these surtaxes, all base duties in 1932 were specific, and not ad valorem. During the Great Depression, specific tariffs often amplified the decline in trade volumes. For example, the lead price at New York fell by 54% from 1929 to 1932, which caused the

specific tariff rate to increase from 43% to 91% as a share of the sales price.¹⁸⁵ In contrast, the Welsh coal price at Cardiff remained constant slightly below 1GBP/t between 1929 and 1932 (Figure A3). The proliferation of duties, comparing 1912 to 1932, nurtures the impression that tariff policies were carried out more actively, perhaps also to deal with the depreciation and volatility of currencies. But overall tariffs remained at relatively low levels. One can only speculate whether importing countries were cautious to keep coal prices rather low and therefore refrained from greater tariff rates, or whether the stability of the coal price helped, in that it did not trigger specific tariffs to increase to higher and perhaps unintended levels, as illustrated by the American lead price.

Apart from investigating protectionism of the importing countries, it seems warranted to turn, though relatively briefly, to the competitive situation in the British market. Apart from a coal export tax from 1901-1906, the British coal trade appeared to be free from government intervention since the mid-nineteenth century. This changed with the nationalisation of the British coal industry in 1949. Until the late 1950s coal supplies were controlled and specific volumes assigned to industry and households, and the amount available for export was also stipulated. In this period domestic demand frequently came close to domestic supply, but perhaps contrary to what one might believe, Britain was keen to continue exporting since, as Ashworth notes, “they wanted the revenue, and they believed that in the long run they would be able to supply an export market reliably and they needed to preserve it until then.”¹⁸⁶ An export price was determined which exceeded the home market price by around 1 GBP in the late 1940s and early 1950s, and slightly more thereafter.¹⁸⁷ The distinction between a home and export price, however, cannot explain price divergence between the export price and import prices abroad. Perhaps the

¹⁸⁵ The original prices are taken from Yearbook of the American Bureau of Metal Statistics 1933. For more details on prices and tariff rates, please consult my master’s thesis ‘Were Interwar Markets Integrated? Evidence from American, British and German Non-ferrous Metals, 1913-1939’.

¹⁸⁶ W. Ashworth, *The History of the British Coal Industry. 1946-1982: The Nationalized Industry*, (5 vols., Oxford, 1986), p.214

¹⁸⁷ *ibid.*, p.215

reduced global market share of British coals lies at the heart of this since Ashworth also states, “The NCB [National Coal Board], in general, followed a policy of pricing exports commercially, but chose to follow rather than lead the market.”¹⁸⁸ British coal traders may have moved from being price setters to price takers. Therefore, prices for British coals abroad may have reflected less the British export price plus freight rates and other costs, but rather responded to market conditions and the prices charged by competing coals. The following third chapter on the emergence of new coal supplying nations, and consequently a changed competitive landscape, examines the effects on price levels of heightened competition.

2.9 Conclusion

The global market for Welsh bunker coal indeed followed a different trajectory of market integration. Prices did not converge in the period 1840 to 1870, before they joined the common trend of dramatically falling trade costs from the 1880s until the early twentieth century. Also the volatility of the percentage price differences and thus import prices declined markedly. Nevertheless, even in this period of comparatively high market integration, price gaps exceeded 20% at Mediterranean ports. Prices certainly had not integrated to a degree that import dependence did not matter anymore. During the interwar period prices converged swiftly again but, with a few exceptions, not beyond the level experienced pre-World War I. In the light of the adverse effects of the Great Depression on trade, staying at a similar level of market integration as during the first global economy appears remarkable. The increases in coal tariffs were only minor, and clearly insufficient to overrule the effect of other more stable elements constituting trade costs, such as freight

¹⁸⁸ *ibid.*, p.214-15

rates. The available evidence until 1960 indicates that the state of market integration post-World War II was actually worse than during the interwar as well as the later pre-World War I period.

Some caveats need to be stressed. The included prices refer to ports and thus establish a lower bound in terms of price differences. Importing countries faced significantly higher coal prices at places of consumption, given that industry was not always directly located at the port. Conversely, in Britain, coal was available closer to the pitheads at lower costs than at the Welsh ports. Including prices at various stages of the supply chain, pithead and places of consumption, should give a more accurate picture of the level of industrial input prices in various countries and global price variation more generally; these prices should also capture trends in overland transportation costs. Finally, this chapter focused on a British trading network, which was still dominant but shrinking over time. Investigating price convergence, including prices from other coaling areas, would lead to a more comprehensive understanding of the relative price trends in coal on a truly global level.

3. A Second Force in Coal Price Convergence: the Spread of Coal Mining and Competition in the World Bunker Coal Market, 1883-1938

Abstract

I examine trends in global coal prices during the late nineteenth century until the late interwar period and the spread of coal mining as a potential determinant of global coal price convergence. This chapter does not rely on the traditional approach to market integration of studying price differences of a commodity traded between the importing and exporting location. Instead, I compare the prices of bunker coals at a vast and globally dispersed sample of 40 ports. In order to compare like-with-like, the prices are adjusted based on their different levels of carbon content. The results confirm global convergence in coal prices during the complete period, including the interwar years when trade costs stagnated. The discovery and exploitation of domestic coal mining in further countries was key to this development. Coal prices declined by up to 50% at South African and Indian ports, where domestically produced coals replaced British coal. Over time, coals from both newcomers established growing export networks. Increased competition led to declining prices at other ports. Even though the gains from domestic mining were huge, the process of developing domestic mines and processing the coals adequately took years, even decades, from the initial discovery until the takeover of the domestic market. This finding highlights the importance of investment, technology and skills as necessary conditions for benefitting from cheap coal next to the actual endowment.

3.1. Introduction

Even though decreasing transportation costs significantly reduced coal price differences between Wales and importers of her coal, particularly from the mid-1880s to the early twentieth century, prices for imported coal remained significantly above the price at the Welsh ports of departure as shown in the previous chapter. In consequence, trade did not seem to have been able to eliminate locational disadvantages, in that coal-importing countries faced higher prices vis-à-vis coal-producing countries such as Britain.

The global dominance of British coal and thus the representativeness of its prices diminished, however, particularly in the twentieth century. Global bunker coal price differences became less a function of British export prices plus transportation costs, and were instead increasingly determined by a greater number of supplying countries and a more complex web of trading relationships. The declining geographical scope of the British coal trade, or alternatively, the rise of new sources of supply, is tightly linked to the spread of coal mining. Mines were opened in proximity to places of consumption that were previously supplied by British mines. This raises the question of what the relationship between changing supply conditions and global price differences was. More specifically we want to know: how did relative coal prices develop in the late nineteenth century until World War II at a global level? How did coal prices in a country react to the replacement of imported coal by domestically mined coal? And what was the effect on prices in other countries that benefited from increased competition between coals from different sources?

The remainder of this paper is organised as follows. Section 3.2 will first review the literature on international coal prices comparisons. Section 3.3 develops a theoretical framework. Section 3.4 introduces the price data set and how coal price data are manipulated in order to minimise quality differences. Section 3.5 offers a macro view on global trends in coal prices without distinguishing between the underlying forces towards convergence. Section 3.6 is the main analytical part and subdivided into five individual sub-sections. 3.6.1 estimates the short-run effect on prices once British coal has to compete against another coal suppliers. Sub-section 3.6.2 investigates in detail the underlying process of how domestic coal mining emerged in India and drove out British coals, and 3.6.3 does the same kind of case study for South Africa. 3.6.4 compares coal price at the pithead of Wales, South Africa, India and other major coal producers. In sub-section 3.6.5, a Difference-in-Difference (DID) technique is used as a way of estimating the long-run

impact on prices of the replacement of imported coal by domestic output. Section 3.7 ties together the different qualitative pieces of evidence and quantitative results and concludes.

3.2. Literature review: the persistence of geographical advantages

In his famous paper “The Origins of American Industrial Success, 1879-1940” Wright establishes a connection between the expansion of mining outside the US and a declining resource intensity of US exports. More precisely, Wright finds that the resource intensity of US manufacturing exports increased between the 1880s and 1920s, exceeding the resource intensity of its imports. This relationship began to reverse in the 1920s and by 1940 the resource intensity of manufactured imports and exports was nearly at par.¹⁸⁹ This might mark the time when the US lost its price advantage in natural resources.

Wright brings forward two probable explanations for this development: through increased global market integration – declining trade costs – proximity to natural resources mattered less, or alternatively, the discovery and development of natural resources in other world regions reduced the comparative advantage of the US. Manifold pieces of research have shown that commodity prices converged significantly during the late nineteenth century until World War I (see, for example, O’Rourke and Williamson).¹⁹⁰ However, this body of research is predominately focused on agricultural commodities that have higher bulk-to-value ratios than coal. Klovland’s findings on British-German coal price differences and my findings in the previous chapter on international price gaps for Welsh bunker coals show that substantial price differences remained even after World War II.¹⁹¹

¹⁸⁹ G. Wright, 'The Origins of American Industrial Success, 1879-1940', *The American Economic Review*, Vol. 80, No. 4, (1990), p.658f.

¹⁹⁰ K. O'Rourke and J. Williamson, 'Late Nineteenth-Century Anglo-American Factor-Price Convergence: Were Heckscher and Ohlin Right?', *The Journal of Economic History*, Vol. 54, No. 4, (1994)

¹⁹¹ J. Klovland, 'Commodity Market Integration 1850–1913: Evidence from Britain and Germany', *European Review of Economic History*, Vol. 9, No.2, (2005)

Thus Wright's former argument of market integration does not seem convincing in the context of coal markets (and most likely other bulky commodities, such as iron ore).¹⁹² If we were to see convergence in global coal prices, it ought to be dependent on the discovery and exploitation of new sources of supply, and in consequence increasing competition in coal markets.

In 1913 the US was the world's leading producer in a number of natural resources including iron ore, coal and copper.¹⁹³ From the 1920s onwards the US started importing natural resources on a large scale and became a net importer for a number of commodities. Based on Wright's evidence this shift coincides with a change in distribution of global natural resource reserves. Comparing reserves as estimated in 1910 with 1955 for iron ore (and a similar exercise for petroleum for a later period shows the same result), Wright finds that iron ore reserves only grew relatively little in the cases of the US and Europe. In contrast, proven reserves in Asia increased from next to nothing to the first spot in the ranking of reserves, followed by South America replacing the US in the third spot. American richness in resources was thus rather "historically" determined by the ability to discover and exploit resources comparatively early rather than actual natural differences with other regions.

Wright's analysis of changing resource reserves offers only indirect evidence of supposedly reducing price differences, and rigorous price comparisons for natural resources, in particular coal, are surprisingly scarce.¹⁹⁴ As perhaps one of the first attempts toward addressing this question, as mentioned in the literature review in Section 2.2.2, Flux compares values of coal produced between countries. He finds that costs for US coal at Baltimore fell considerably relative to several European producers in the 50 year period

¹⁹² *ibid.*

¹⁹³ G. Wright, 'The Origins of American Industrial Success, 1879-1940', *The American Economic Review*, Vol. 80, No. 4, (1990), p.661

¹⁹⁴ Though Wright's analysis is based on traded quantities rather than prices, he sees a strong correlation between prices and import behaviour: "Without conducting extensive global cost comparisons, it is evident that a country for whom resource prices are determined at the margin by imports is not going to have a major locational advantage in resource costs over its industrial rivals." *ibid.*, p.663

up to 1901.¹⁹⁵ However, his comparisons have shortcomings in that he does not disclose what type of price data he uses, and that he fails to control for differences in coal quality.

In his recent contribution on the reasons for US industrial success, Allen finds that bituminous as well as anthracite coal prices were higher in the US until 1880 before prices at the East coast converged to the British coal price level, and eventually even undercut it.¹⁹⁶ Allen reaches this conclusion by converting US and British bituminous coal prices into prices per British Thermal Unit (BTU). Those conversions, however, require knowledge on the exact qualities of the underlying coals and it is not entirely clear how this could be achieved since Allen uses the “UK average export price of coal” for the period 1840-1913.¹⁹⁷ Despite the highlighted shortcomings, Flux’s (from the mid-nineteenth century) and Allen’s (after 1880) findings of declining US coal prices relative to Britain fit with Wright’s story of increasing resource intensity of US exports post-1880.

Regarding Europe, Fremdling examines the competition between British and German coal in the Northern German, French and Dutch markets although his analyses are mostly based on consumed quantities.¹⁹⁸ The available price information indicates that low distances to mines do not necessarily indicate low prices and depend on the level of competition between coals. In Northern Germany, British coals were often cheaper than Westphalian coals since “after all indigenous coal resources did not in any case guarantee cheap supplies, for a successful cartelisation could rise the price well above competitive levels.”¹⁹⁹

Allen, Flux and Fremdling give some evidence on relative coal price trends, particularly of American versus British coals, but overall the literature review has only

¹⁹⁵ W. Jevons, *The Coal Question. An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*, 2nd edn., (New York, 1906)

¹⁹⁶ R. Allen, 'American Exceptionalism as a Problem in Global History', *The Journal of Economic History*, Vol. 74, No. 2, (2014), p.318

¹⁹⁷ *ibid.*, p.28

¹⁹⁸ R. Fremdling, *Anglo-German Rivalry on Coal Markets in France, the Netherlands and Germany, 1850-1913*, Research Memorandum GD-21 vols., Gronningen, (1995)

¹⁹⁹ *ibid.*, p.21

highlighted how little is known about global trends in relative coal prices. We do not know when international coal price differences disappeared, nor do we know precisely what was responsible for this change. It also appears that more could be achieved in reducing the effect of coal quality differences for the interpretation of trends in relative prices.

Although not relying on price evidence, Wright has convincingly established a correlation between the declining reliance of the US industry on (domestic) natural resources and the rise of mining in other world regions during the first half of the twentieth century. Wright does not view the geologic endowments with natural resources as the US advantage: if only natural resource endowments would have mattered, Europe would have been in an even better position than the US since European iron and coal output exceeded US output by 30% to 50% during the years 1910-1913.²⁰⁰ Rather, the large and integrated US domestic market encouraged investments in infrastructure and also played a role in facilitating discoveries itself since national agencies such as the United States Geological Survey were instrumental in fostering knowledge about mining and exploration possibilities.²⁰¹

In Wright's more recent publication, together with David, the argument is developed further that natural resource endowments are endogenous and "socially constructed" rather than geologically determined.²⁰² According to both authors, the international spread of mining knowledge determined the discovery and geographical distribution of known natural resource deposits, and thus the speed and scope of these knowledge spill-overs may drive the relative price changes in coal this paper seeks to measure.²⁰³

²⁰⁰ G. Wright, 'The Origins of American Industrial Success, 1879-1940', *The American Economic Review*, Vol. 80, No. 4, (1990) p.664

²⁰¹ However, why such institutions can only thrive in larger markets is not entirely clear, and it might be the case that the level of education rather than any market size effects were more important for the comparatively early and thorough discovery of America's natural resource base.

²⁰² P. David and G. Wright, 'Increasing Returns and the Genesis of American Resource Abundance', *Institutional and Corporate Change*, Vol. 6, No. 2, (1997)

²⁰³ *ibid.*, p.241

This chapter seeks to close the gaps in the literature by empirically investigating the effects of trade cost declines as well as the expansion of coal mining on global price differences. For this reason, a large and new data set of bunker coal and pithead prices has been used that may also prove fruitful for future research. In addition, coal prices are adjusted based on their different carbon content, which marks an improvement over the (limited) available literature that often did not compare like with like. The two case studies of South Africa and India examine the development of domestic coal mining in detail following Wright's suggestions that the ability to exploit resources mattered as much as their existence.

3.3. Methodology: theoretical foundations

In his 1933 work, Regul establishes the conceptual foundations of this chapter by examining so-called *Frachtgrenzen*, i.e. freight borders, in the case of Germany and surrounding markets for hard coal.²⁰⁴ By adding railway freight rates to the pit prices, most frequently for Ruhr coals, he determines areas covered by a monopoly of Ruhr coal up to the freight borders where they match the price for coals from another source. While there are reasons speaking against clearly divided geographical markets, which will be discussed later, Regul's concept provides a helpful framework to think about price setting and competition in this market. Figure 3.1 should be interpreted as an analogy since it shows what price setting would look like in a competitive market, if an additional supplier of a homogenous kind of coal entered the market. We would expect a similar effect, though, if a market changes from a monopoly to a duopoly.

²⁰⁴ R. Regul, 'Die Wettbewerbslage der Steinkohle', *Vierteljahreshefte zur Konjunkturforschung*, Sonderheft 34, Berlin, (1933)

It illustrates that the emergence of new coal supplies may have affected prices by increasing competition and the substitution of the originally supplied coal by a new and cheaper coal. Note that Figure 3.1 is different from textbook graphs of perfectly competitive markets since the x-axis does not show quantity but distance.

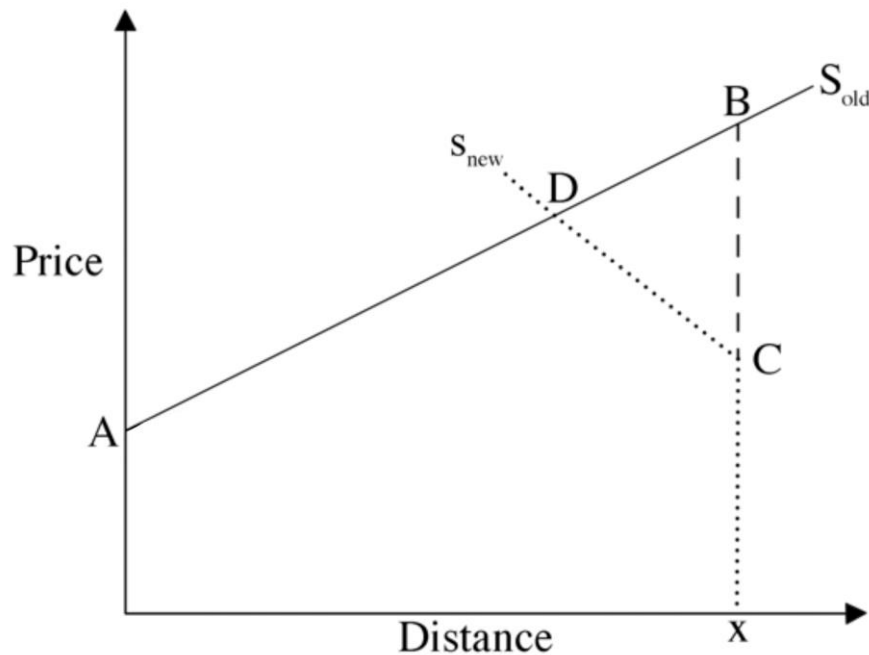


Figure 3.1: Price setting with two suppliers

Point A is the pithead price at the original source of supply. The price of coal increases linearly since longer transport distances increase marginal costs leading to a higher sales price. At a distance x from the pithead, coal is offered for price B. A new coal mine is opened at distance x where the pit head price is C. At x, the consumer price thus decreases by BC, and no coal should be supplied by the old supplier anymore. From the new supply, the coal price is increasing linearly with distance from the origin x. Both price functions intersect at point D where coals from both sources of supply sell at the same price. To the left of D, coals are supplied by the old supplier, and to the right, by the new supplier.

If the old supplier possessed market power and charged prices above marginal costs, the entry of an additional supplier would increase competition, and the price would decrease by more than we would expect based on the mere decrease in distance. Section 2.3.4 has examined the competitiveness of the market for Welsh bunker coals in detail, which is the most relevant for this chapter, since in the vast majority of cases British/Welsh coal was replaced. I found that the market was competitive mainly due to the large number of Welsh mines and coal merchants, though there seems to have been some collusion between coal merchants for certain ports and time periods. In those cases, the old supplier might also lower prices to marginal cost level, at least for places that the new competitor could reach at the current price level.

According to Fremdling, the historical context for continental European markets indeed suggests that no such clear-cut supply frontiers existed and coals from both regions could be consumed in bordering regions.²⁰⁵ The geographic scope of a coal trading network was not always determined by the sheer distance, but also subject to commercial policy considerations, and other factors.²⁰⁶ As an extreme example, the price for East Silesian coal at the mine, and thus for domestic consumers, was 14,24 RM per t in 1932; 600km away from the mine at the export harbour of Danzig it was quoted at 9,11RM.²⁰⁷ Therefore, in reality, the situation might be different to Figure 3.1 in certain regions and/or coal-supplying networks, but it appears reasonable to assume that production and transportation costs determined the areas in which certain coals were supplied.

²⁰⁵ In his conceptualisation of the process, Fremdling uses the *Launhardtschen Trichter*. This is a cone where the vertex is the price at the mine. All places of consumption with the same price are arranged in a circle around the vertex. Thus, with increasing distance from the circle, the shape of a cone is created.

²⁰⁶ Long-standing trade relationships between certain coal merchants and coal exporting regions, as well as long-term contracts, may have trumped distance as a sole determinant.

²⁰⁷ *ibid.*, p.86-87

3.4. Data

As in the previous chapter, the global market for bunker coals provides the framework for the following analyses since comparable kinds of coal (steam coals) were offered at the same type of location (coaling stations). The changing coals offered throughout its existence from the 1840s to 1960s reflect the emergence of new sources of coal supply and changes in the level of competition. The earliest available prices contained in Royal Navy records only refer to Welsh coals including very distant ports such as Hong Kong, Rio de Janeiro or in Sierra Leone. With the growth of coal consumption and the international expansion of coal mining, Welsh coal was increasingly rivalled by coal from other origins. As a rather early example, Japanese coals started competing with British coals from 1870 in Shanghai and with some delay also in Hong Kong and Singapore, subsequently driving British coals out of the market.²⁰⁸ In order to examine such changes in competition, this chapter considers prices for bunker coals from all origins, not only from South Wales as the previous chapter.

The sources for bunker coal prices have been described in Section 2.4 and are complemented here with additional sources for South Africa and India as well as on pithead price data. Averages prices of Indian and Welsh coals at Karachi and Bombay for the period 1899 to 1921 were taken from *Note on the Production and Consumption of Coal in India up to the Year 1910* and *Report on the Production and Consumption of Coal in India 1920*.²⁰⁹ The price descriptions are not entirely clear for the whole period, but refer to coals “trimmed into bunker” from 1909 for Karachi and “ex bunker” for Bombay 1917-18. Those descriptions, and that the stated underlying sources are trade circulars, make the

²⁰⁸ S. Sugiyama, *Japan's Industrialization in the World Economy, 1859-1899: Export Trade and Overseas Competition*, (London, 1988), p.221

²⁰⁹ Commercial Intelligence Department India, *Note on the Production and Consumption of Coal in India up to the Year 1910*, p.30, Department of Statistics India, *Report of the Production and Consumption of Coal in India 1920*, p.23

price data comparable with my other sources that refer to the f.o.b. price of bunker coals. For South Africa, prices at the exporting port of Durban (called Port of Natal) were derived by dividing the export volumes of Natal coals by their value for the years 1894 to 1914 published in the *Blue Book of the Colony of Natal* (later *Statistical Yearbook* [...]).²¹⁰ Given that Natal coals were predominately exported for bunkering, and no other continuous price series is available, those derived prices seem to fit well enough with the other price data.

In Section 3.6.4, prices of coals at the pithead are compared. *Coal Tables*, returns to the House of Commons containing “Statistical Tables relating to the Production, Consumption, Imports & Exports of Coal in the British Empire and the Principal Foreign Countries” are a valuable source for such data for the period 1883 to 1924. However, the prices were derived by dividing the value of output by volume. While they are thus representative of some national or regional average, the qualities of the coals underlying the sample remain unclear. Therefore, if available, other sources with more complete quality descriptions were preferred. For the USA, the coal price series of *Coal Tables* is used. This series is highly correlated to, but on average 45% lower than, a price series for Clearfield coal at Baltimore.²¹¹ Therefore, the *Coal Table* series was extended for the years 1924-1933 based on the Baltimore prices. The South African series is also taken from *Coal Tables* referring to Natal, and estimated for the years 1923-31 based on the price change for Natal coal at Durban.²¹²

Pithead prices for Britain, Germany, India and Australia come from multiple sources. For India prices for the period 1889-1920 are taken from the *Note on the Production and Consumption of Coal in India* introduced previously that refer from 1891

²¹⁰ Colony of Natal, *Blue Book for the Colony of Natal 1886(-93/94)* (Pietermaritzburg, 1887(-94)), Colony of Natal, *Statistical Yearbook for the Colony of Natal 1894(-99)* (Pietermaritzburg, 1895(-1900)), Colony of Natal, *Statistical Yearbook for the Year 1900(-09)* (Pietermaritzburg, 1901-10)

²¹¹ The pithead price series is estimated for 1924-33: $P_Coaltable_t = \alpha + \beta P_Baltimore_t + \gamma time_trend_t + \epsilon_t$ (Adj. R² 89%). Coal had to be transported from the Pennsylvanian mines via rail over the Appalachian Mountains, with a straight-line distance of at least 200 miles, which can thus explain the difference between the two price series.

²¹² In addition, for 1920-22, only a pithead price series for the Union of South Africa is available but the change in this price series was used to predict the Natal prices for those three years.

to the average value of coal per ton extracted from the Bengal mines (an average price for the two initial years was constructed from stated quantities and values). From 1920 prices are taken from Chakrabarti referring to the average price of coal in West Bengal.²¹³ The principal British series refers to South Wales (according to Walters the area of Glamorgan) and was taken from *Digest of Welsh Statistics*.²¹⁴ This source also contains a price series for North Wales, which is used in Section 3.6.4 to cross-check the South Welsh series. The price series for Australia refers to the “true raising costs” and may theoretically be lower than other pithead prices series, however, the average price from 1883-1900 of 0.37GBP/t is nearly identical to the average value per ton for New South Wales as provided in *Coal Tables* (0.38GBP/t). The pithead prices post-1913 were interpolated based on the change in the f.o.b. price for such coal at the port of Newcastle, Australia. The construction of the German price series was more straightforward since Jacobs and Richter give a price series of the sales price at the pithead of Ruhr mines in *Die Großhandelspreise in Deutschland von 1792 bis 1934*.²¹⁵

Since I have criticised other studies for potentially flawed analyses by comparing different qualities of coal, I apply a new approach to reduce such concerns to a minimum. First, I only use coal prices referring to bituminous steam coals. Secondly, and more importantly, I use carbon content information on the different types of coal and adjust prices, so that they all refer to the same standard level of carbon content. To a limited extent I also exploit differences in measured consumption rates as a quality adjustment factor. Both approaches are explained in detail further down.

²¹³ P. Chakrabarti, *Coal Industry in West Bengal* (New Delhi, 1989), p.31-32. Since Chakrabarti uses the prices from *Note on the Production and Consumption of Coal in India* for the years up to 1907, his price series seems to refer to pithead prices.

²¹⁴ R. Walters, 'The Economic and Business History of the South Wales Steam Coal Industry, 1840-1914' (University of Oxford, DPhil, 1975), L. Williams, *Digest of Welsh Historical Statistics* (Cardiff, 1985), Vol. I, p.337

²¹⁵ A. Jacobs and H. Richter, 'Die Großhandelspreise in Deutschland von 1792 bis 1934', *Sonderhefte des Instituts für Konjunkturforschung No.37*, (Berlin, 1935)

Regarding the first selection criterion, I have chosen bituminous coals since they are the most widely mined and consumed type, and they were used as bunker coals, which is the main source of my price data. Next to bituminous coals, the other two main classes are high quality anthracite as well as low quality lignite, both not part of this dataset. This considerably reduces variation since, on average, the heating value of bituminous coals amounts to 24 million BTU, as opposed to 18 million BTU for subbituminous and 13 million BTU for lignite.²¹⁶ Of bituminous coals only steam coals are included (the other main categories are coking and gas coals). Finally, the steamships consuming the bunker coals were bunkering along their international voyages and therefore bunker coals across the world had to work with the same steam engines and fulfil certain minimum requirements.

Contemporary coal statistics and other specialised publications reported test results on the constitution of many types of coal. I exploit the information on carbon content as a scientific way to reduce, and at best eliminate, remaining quality differences between steam coals. Carbon is the most important heat producing element of coal (a small amount is created by hydrogen).²¹⁷ Other elements such as ash content and sulphur negatively impact the quality of coal, and oxygen lowers the heating value of coal.²¹⁸ However, such elements only stand for a small share of coal while carbon accounts for typically 70% of bituminous coals, therefore making it the decisive determinant of coal's quality.

More specifically, I adjust prices of non-Welsh coals by taking into account the difference in carbon content as compared to Best Welsh coal. For instance, New River coal from West Virginia has a carbon content of 70.66%, as opposed to 88.26% carbon content of Best Welsh coal, and therefore the New River coal price is increased by 25%. In

²¹⁶ These figures relate to coals delivered to electric utilities in 1993 in the United States. United States Energy Information Administration, *Coal Data: A Reference*, (Washington, 1995), p.5

²¹⁷ *ibid.*, p.5

²¹⁸ *ibid.*, p.5: On the negative effect of oxygen content: "The higher the oxygen content of coal, the lower its heating value. This inverse relationship occurs because the oxygen in the coal is bound to the carbon and has, therefore, already partially oxidized the carbon, decreasing its ability to generate heat."

consequence, the original price of 0.62GBP/t increases to 0.78GBP/t, which should be interpreted as the price per ton of coal equivalent to Best Welsh steam coal.

As a complementary piece of information the shipping literature also contains results of trials where the daily consumption of different kinds of coal on a particular ship was compared. The differences in consumption rates can also be used as quality adjustment factors. Since carbon content information is available more plentifully and offers a more scientific measure, consumption-based factors will only be used in the absence of carbon content information. However, while being less scientific, those consumed quantities might reflect further quality aspects, such as whether particular coals deteriorate more quickly than others during transport from mine to ship, or whether certain coals generate heat quickly.

Therefore, it is worth comparing both approaches and the following example illustrates it. An American account reports daily consumption figures of their ships for different types of coals by two captains. One ship needed either 22t of No.1 Welsh coal or alternatively 29 to 30t of Indian, whereas the other ship consumed 25t of Best Welsh coals or 30t of Indian coal.²¹⁹ The conversion factors are calculated by setting their daily consumption of Indian coal in proportion to their consumption of Welsh coal; they burn 34% and 20% more Indian coal per day, respectively. The adjustment based on carbon content for Indian coals would inflate the price by 26%. While there is some variation, it is good to see that both derived conversion factors, one more scientific and the other one reflecting practical experience, fall into the same range in terms of size. And therefore I will complement the carbon-content factors with consumption based factors where information on the former is unavailable.

In Section 3.6.4 pithead prices are introduced and naturally they do not refer to bunker coal. However, the pithead price series refer to clearly defined mining regions of

²¹⁹ A. Kirkaldy, *British Shipping. Its History, Organisation and Importance*, (London, 1914), p.615

Britain (South and North Wales), Germany, India, South Africa and Australia. In these regions bituminous coal is mined and shares of the output actually end up being offered as bunkers at coaling stations. The US series is not as clearly defined, but since it is highly correlated with the price series of Clearfield coal at Baltimore, a bituminous type, it can be assumed that it largely represents bituminous coals. Therefore, it seems justified to extend my way of quality adjustment to those selected pithead price series.

A major source for the conversion factors is Kirkaldy's *British Shipping. Its History, Organisation and Importance* (1914), which includes the two reports on coal consumption trials as well as carbon content figures. *Coaling Docking, and Repairing Facilities of the Ports of the World, with Analyses of Different Kinds of Coal* (1900) by the US Office of Naval Intelligence is a second major source.²²⁰ The carbon figures for Westphalian coals come from Pechar's *Coal and Iron in all Countries of the World*. Finally, the conversion factor for Takashima coal stems from a British consular report on Nagasaki, and for Natal Navigation coal from evidence collected by a Dominions Royal Commission.

Today such prices would be reported in BTU, a common unit of expressing energy contents, which measures "the amount of heat required to raise the temperature of one pound water through 1°F."²²¹ Since we know the BTU value for Best Welsh steam coal, the price of 0.78GBP/t could also be expressed as 0.109USD/million BTU.²²² The unit of BTU is more straightforward than price per ton of Best Welsh steam coal equivalent. However, prices in the other two chapters, as well as in the vast majority of original sources, are expressed in GBP/t, and will thus for reasons of consistency also be applied in

²²⁰ A. Kirkaldy, *British Shipping. Its History, Organisation and Importance* (London, 1914), Office of Naval Intelligence, *Coaling, Docking and Repairing Facilities of the Ports of the World, with Analyses of Different Kinds of Coal*, 4th edn, (Washington, 1900), p.380-82

²²¹ B. Sharma, *Fuels and Petroleum Processing* (Meerut, 1998), p.2

²²² $0.109\text{USD/mBTU} = 0.62\text{GBP/t} * 1.25/15720\text{BTU/lb}/2204.64 * 1.000.000 * 4.865\text{USD/GBP}$. The reference of 15720BTU per lb is from Sharma (1998, p.3) and also states a quite high carbon content of 92.5% of Welsh steam coal. While the BTU figure might be rather high, it does not bias the comparison between the different types of coals used in this chapter.

this chapter. All conversion factors used are given in Table A1 stating the coal description, the adjustment factor, the underlying carbon content, if available, and the underlying source for each.

Another issue is that in the price descriptions the coal quality is less clearly defined as in the analyses of coal composition. Where coal prices refer to “Westphalian” coal, Pechar states five (slightly) different carbon contents for Westphalian coal. Since the description “Westphalian” must encompass a range of different Westphalian coals, I simply use the average of the carbon content of the available Westphalian coals. For Australia carbon contents are available for three different coals, but Mount Kembla coal stand out with a factor of 1.42. Since Australian coals are often offered at a similar price to Welsh coals, it appears unreasonable that such a large difference in carbon content should exist. Therefore, I believe that Mount Kembla is not representative of Australian coals, so I calculate a carbon content average from the other two coals.

Two aspects might require further attention: quality differences may not have been constant over the investigation period, and they may also have mattered less over time. Firstly, contemporary accounts occasionally state that coals, specifically from comparatively new mining regions such as Australia or India, were improving in quality. Since my carbon content conversion factors are based on contemporary analyses of coal, during the late nineteenth and early twentieth century, and thus fall within the investigation period 1886 to 1938, they should be quite representative of the quality of coal mined in different regions at the time.

The second point refers to the effect of technological change in steam engines. Over the nineteenth century steam engines improved dramatically, for instance with the introduction of multi-expansion engines during the 1880s; they were able to burn lower quality coal but also consumed less coal altogether. Therefore, the greater compactness of high quality coals (which saved cargo space) became less decisive once the total required

amount of bunker coal needed declined. The most significant improvements in technology were already adopted prior to the investigation period. Applying a fixed set of conversion factors based on contemporary sources for the whole period thus does not seem to be invalidated by the (limited) effects of technological change. It also reflects the best knowledge shipping agents and captains possessed at the time, and the most sophisticated adjustment possible given the available data.

At the port level multiple price quotations are often available for the same year. I adjust all available prices to the quality of Best Welsh coal first, and then I choose the cheapest coal. I do this for every year and then link the chosen price to form a series. In this way, my price series represent the cheapest available coal at a port. Overall, I have created 42 port prices series and seven quality-adjusted pithead price series using over 50 quality adjustment factors (shown in Table A1). Depending on the exact research question and related data requirements, I have used different subsets of this dataset in the following analytical sections, as specified where relevant.

3.5. Global trends in bunker coal prices, 1886-1932

The coverage of my bunker coal data set allows for the examination of global price trends in the bunker coal market over the investigation period from the 1880s to the 1930s. More precisely, the investigated time period starts in 1886 when competition between Welsh and other coals began to intensify. Furthermore, the data coverage is higher from the 1880s onwards since the available sources became more sophisticated in that they not only provide one price quotation, but prices for all major coals offered at a port given there were multiple suppliers. The chosen final year of 1932 reflects the level of price differences before bunker coals were increasingly replaced by oil, and some years later disturbed by

the trade restrictions resulting from World War II. This leaves us with a sample of 40 ports and offers an impressive geographic coverage. Ports from all continents bar Antarctica are included as shown in Figure 3.2 below. The list of all ports is given in Table A2. A further – and necessary – advantage is that the sample includes ports with different and changing levels of competition. There are ports that were dependent on Welsh imports only, ports that were initially dependent on Welsh coals but were subsequently supplied with new domestic or foreign coals, and ports that were already supplied with native coals in the 1880s.



Figure 3.2: World map with sample ports: ports supplied with Welsh (dot) and other kinds of coal (star) in 1886

The CoV is used here as the principal measurement of price trends since it is a simple, intuitive number. The CoV is calculated across the same 40 ports for each of the years 1886, 1900, 1908, 1912, 1924 and 1932. The exact choice of years was determined by data availability, so that prices for every port are available each year creating a perfectly

balanced dataset. A declining CoV indicates lower price dispersion between the prices of the sample ports in a year, and thus price convergence.

In the full sample of 40 ports certain regions are over-represented in that eight ports are located in the Mediterranean as well as in Asia, but only five in North America. Therefore *cov_small* refers to a smaller price dataset that includes five ports from each of the following regions: North America, Latin America, Mediterranean, Northern Europe, Africa and Asia (listed in Table A3). Due to the number of ports with available price data and the predominance of Europe in coal consumption, it seems appropriate to divide Europe into two regions. In Figure 3.3 the lines connect the CoV for each of the six benchmark years. Furthermore, it contains the CoV of the balanced sample of ports importing Welsh coal shown in Figure 2.5 of Section 2.6.2. This allows me to bridge the findings of the former chapter to the present one.

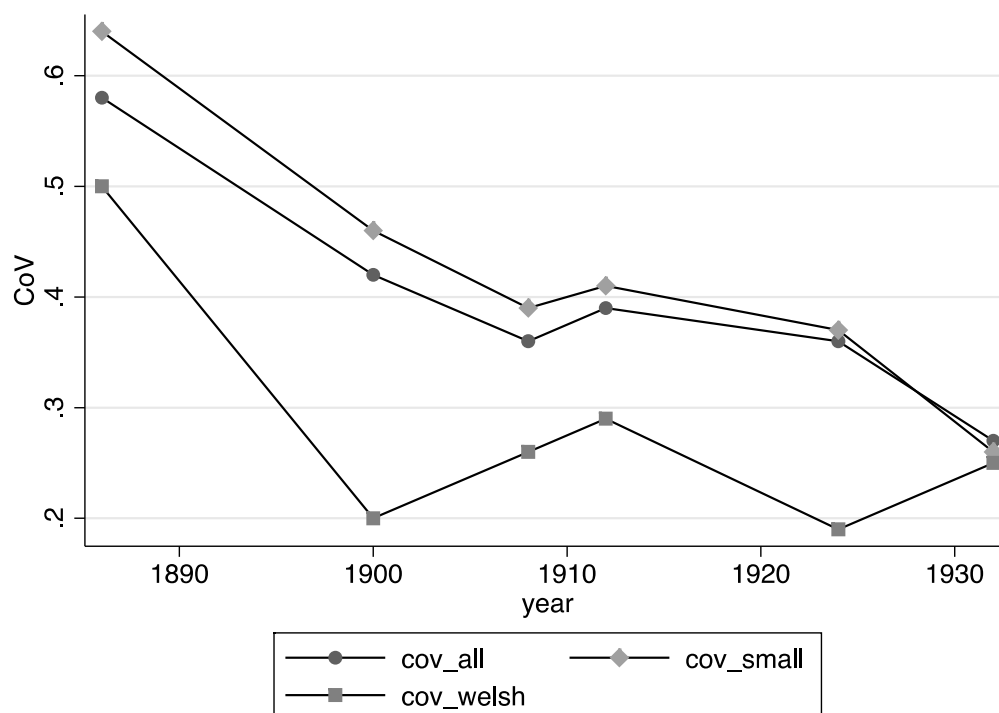


Figure 3.3: CoV across port samples, 1886-1932

While it is debatable exactly which sample of ports would be the most representative of global coal price changes, note that the development of *cov_small* trails *cov_all* closely. Changes in the selection of the sample ports within the available data only seem to alter the results marginally. Both show higher values than *cov_welsh* until 1932, which is to be expected, since the global samples contain a wide range of different types of coals and ports, and therefore include a higher variance in prices.

cov_welsh illustrates the previously shown trajectory of a falling CoV to 1900 and no clear trend thereafter. In contrast, both *cov_all* and *cov_small* continue to decline until 1908, dropping from circa 0.6 to 0.4. Then the global CoVs increase slightly, indicating a moderately higher price dispersion in 1914. Both then fall again reaching an all time low of 0.26 (*cov_small*) or 0.27 (*cov_all*) in 1932. This is a considerably different trend when compared to the stagnance in price convergence indicated by *cov_welsh* post-1900, which was also shown by the graphical and econometric analysis of the previous chapter.

The major difference in the CoV measures is that both global CoVs contain different types of coals, always using the cheapest available coal price, whereas *cov_welsh* only represents Welsh coal prices. This gives evidence in favour of the core argument of this chapter that prices for coal became more similar due to factors beyond changing trade costs (which should be picked up by *cov_welsh* as well), and as I argue, this trend can be traced to increased competition.

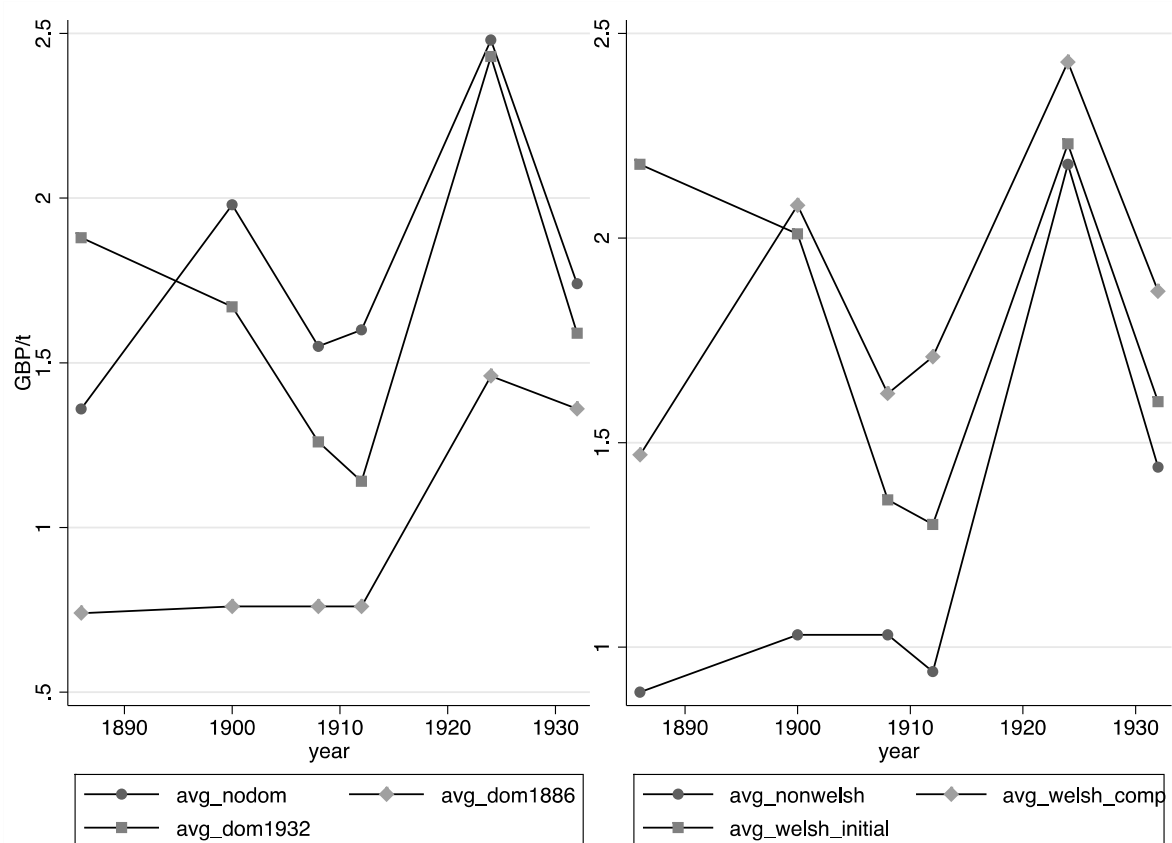


Figure 3.4, left: average coal prices distinguishing between ports in producing and importing countries; right: distinguishing between ports importing Welsh coals vs. other ports

Figure 3.4 above allows us to single out the effect of competition more precisely. The left-hand graph distinguishes between ports that imported foreign coals throughout the complete period 1883 to 1932 (*avg_nodom*), that already consumed domestically produced coal in 1886 (*avg_dom1886*), and ports that had switched to domestic coal by 1932 (*avg_dom1932*). Coal was much cheaper in ports with domestic coal. In 1886, coal was 1.8x more expensive in ports that only consumed domestic coal by 1932, and even 2.5x more expensive at ports that always consumed imported coal. The price difference between *avg_dom1886* and *avg_nodom* shrank since coal prices were 46% lower in coal-producing countries in 1886 as compared to 22% in 1932. This indicates the declining price advantage of domestic production, while at the same time trade cost remained substantial.

Most important is the trajectory of *avg_dom1932* since it illustrates the price depressing effect of competition at ports that successively replaced foreign coals by domestically produced coal. In 1886 the average price of *avg_dom1932* was still 38% higher than *avg_nodom*. However, through the replacement by domestic coals this reversed and by 1912 *avg_dom1932* was 29% cheaper. While the gap was lower in 1924, which reflected the highly volatile and inflated prices of coals due to their scarcity after World War I, the reversal remained in place and became more visible in 1932 again.

The right-hand graph of Figure 3.4 provides a different look at the same issue by distinguishing between ports never importing Welsh coals (*avg_nowelsh*), ports that stayed dependent on Welsh coals throughout the complete period (*avg_welsh_comp*) and ports that switched from Welsh coals to other coals in the meantime (*avg_welsh_initial*).²²³ In this way the latter is similar to the previous graph of *avg_dom1932*, but it also allows for ports to switch from Welsh coal to another foreign coal only, and not necessarily on to domestically produced coal by 1932. The price patterns resemble the left-hand graph since the prices of ports that experienced competition – *avg_welsh_initial* – approached the price level of the non-Welsh importing ports. In contrast, even by 1932 prices at *avg_welsh_comp* remained considerably higher and were 17% more expensive than at *avg_welsh_initial*.

²²³ While some ports in *avg_welsh_comp* were supplied temporarily with non-Welsh coals in one or two years during 1920-23, they never received significant amounts of non-Welsh coals in any of the benchmark years, and therefore this categorisation is valid.

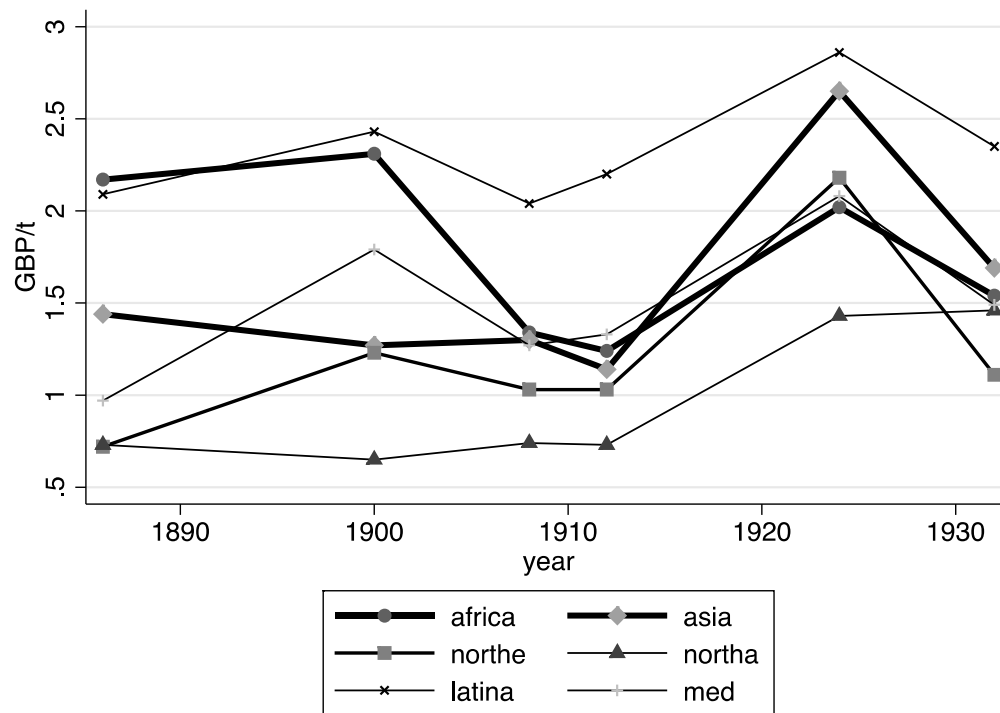


Figure 3.5: Prices per region in GBP/t

As a final piece of descriptive statistics, Figure 3.5 illustrates the changing price levels for the previously defined regions. Prices converged considerably from 1886 to 1932, while even during 1932 prices were significantly different, with Latin America as a clear outlier. In 1886 coals cost twice as much in Africa, the highest price region closely followed by Latin America, as in Northern Europe, where prices were virtually the same as in North America. While all regions seemed to converge in price until 1912, this was not true for Latin America, which was also as the only region predominately supplied by one country (Britain). Only post-WWII the maximum price gaps became significantly lower; for instance, the price gap between Latin America and North America reached 112% in 1932.

There are some striking observations on the trends in prices between the various regions. Coal prices in North America doubled between 1886 and 1932, and increased by over half in Northern Europe. North America only consumed domestic coal at the sample ports, and Northern European ports were all supplied by mostly British coal over

comparatively short shipping distances. Thus, raising prices may indicate higher production costs. The Mediterranean and Latin America followed a very similar pattern, bearing in mind both regions were very dependent on British coal imports, and thus freight rates from Britain. Noteworthy is the decline of prices in Africa, by 29% between 1886 to 1932 that reflected the emergence of South African coal. In Asia, some ports had already benefited from an increased number of suppliers, such as Australia and Japan, but in particular the declining trend from 1886 to 1900 was caused by the entry of Indian coal.²²⁴ Both regions South Africa and India will serve as case studies to examine the effect of raising domestic competition in greater depth in the next section.

3.6. Effects of increased competition on coal prices

To recapitulate, in this section I want to make very explicit what was the contribution of increased competition to the trend of global price convergence. In Section 3.6.1 the short-run effect on the prices for coal at the port-level is examined once either a domestic or foreign coal appeared for the first next to British coals. Section 3.6.2 examines the case study of India and Section 3.6.3 that of South Africa, since both countries went from relying on British imports to being exporters of domestically mined coal. Section 3.6.4 uses a Difference-in-Difference model to investigate the long-run effect of competition.

²²⁴ A similar development of replacing British coals by more proximate sources of supply also happened the region Asia-Pacific. However, this change to Australian and Japanese coals happened already in the early 1860s to 1880s and thus prior to the investigation period of this paper. Sugiyama's *Japan's Industrialization in the World Economy, 1859-1899: Export Trade and Overseas Competition* examines the spread of Japanese coal exports in the Pacific region.

3.6.1. Short-run effects of domestic vs. foreign competition

In this section I explore the effect of increased competition at the prices for coal at individual ports. The default position was that ports around the whole world were supplied with British or Welsh coals when the demand for steam coals emerged in the mid-nineteenth century. This was also due to the global operations of the British Royal Navy and dominance of British shipping. The two other early major coal-producing countries, the US and Germany, initially did not compete much in international markets. Coals from both countries were mainly absorbed by their domestic markets and coals transported inland by canal and railways. For instance, until the 1880s even the Northern German coastline was predominately supplied with British coals.²²⁵ As exemplified by the example of Germany, towards the end of the nineteenth century both countries attempted to enter the sea trade based export markets, and challenged Britain as the dominant coal supplier.

A greater threat to British hegemony in the global market was the spread of coal mining to further countries since new sources of supply were geographically closer to some areas than Britain. At the fringes of the Welsh coal-supplying network in Asia, competition from Australian and Japanese coals emerged from the 1860s.^{226,227} However, due to comparatively high prices, Australian coals retreated from global markets after

²²⁵ R. Fremdling, 'Regionale Interdependenzen Zwischen Montanregionen in Der Industrialisierung', in T. Pierenkemper (ed.), *Die Industrialisierung Europäischer Montanregionen Im 19ten Jahrhundert*, (Stuttgart, 2002), p.374

²²⁶ Australian bunker coal was mined in New South Wales (N.S.W.) from the 1860s, but it only received a spurt in growth in the 1890s when it started supplying South-East Asian bunker coal stations. While previously the export of bunker coal was linked to predominately British shipping routes and the need for a bulk cargo on the way to Asian ports, ships started to sail to Australia in order to collect bunker coal. The heyday of Australian bunker coal was only short-lived since after World War I a combination of comparatively high prices for N.S.W. coal, uncertainties of supply and competition from other coal mining countries almost led to a cessation of exports. (From K. Bukley, 'The Overseas Trade in New South Wales Coal and the British Shipping Industry, 1860-1914', *Economic Record*, Vol. 36, No. 75, (1960)).

²²⁷ One of the competitors to Australian exports was Japan, which initially imported coal. Japanese production volumes, however, increased rapidly after 1894 which stimulated the development of the export trade. Domestic demand was driven by industry as well as the bunker coal market that were both the most important consumers in the decade up to World War I (From G. Allen, *A Short Economic History of Modern Japan*, 4th edn, (London, 1981), p.83). Since coal output failed to significantly increase between 1913 and 1929, coupled with the military expansion following the Manchurian incident of 1931, Japan became a net importer of coal in the 1930s (From Y. Yasuba, 'Did Japan Ever Suffer from a Shortage of Natural Resources before World War II?', *The Journal of Economic History*, Vol. 56, No. 03, (1996)).

World War I, and the Japanese coal trade balance shifted back to a net import position. In contrast, South African and Indian coals, which entered the markets slightly later in the 1880s and 1890s, secured a more lasting presence in the market. The geographic position of India and South Africa meant that they were well positioned to supply export markets that were previously served by Wales.

This still left a large number of ports dependent on Welsh coals, mostly in the Mediterranean and Latin America. Only dramatically high prices during and after World War I led to a temporary influx of foreign coals, such as from the US, to ports in those two regions. In the Mediterranean competition intensified from the 1930s onwards in some ports such as Genoa and Piraeus, where German coals were offered. Latin America remained primarily supplied by Britain until the post-World War II period, which is beyond the investigation period of this chapter ending in 1938.

As became apparent, British coals faced competition at importing ports of their coal at different points in time. The following parsimonious OLS fixed-effects model should estimate the short-run effect of an additional kind of coal entering a port at the local price level. It is a higher-frequency model working with annual price observations during the period from 1883 to 1938.

The underlying data set consists of 21 ports that were exclusively supplied by Welsh coal before competition ensued at some stage within the stated period.²²⁸ The ports are located in Latin America, the Mediterranean and around the Indian Ocean. Ports from other regions are not included because they were never supplied by Welsh coals. This comprises of ports in Northern Europe, and ports where Welsh coal started competing before 1883, such as in Japan. A list of the ports can be found in Table A4, also stating the start year of competition. This leaves us with 727 annual price observations. Undoubtedly, this model gives a rough estimate since there is no clear rule when sources started to report

²²⁸ This is why Calcutta is not part of the sample, since British coal was already largely driven out of the market by 1883 as shown in the next Section 3.6.2.

prices for additional qualities. Furthermore, the price series have some gaps, so the start of competition may fall into such a gap. On the other hand, if something should contain accurate information of when coals were competing at a port, then this would most likely be the contemporary sources specialising on coal trade.

The dependent variable is the logged cheapest coal price at a port. The major explanatory variables are a dummy to measure competition by the entry of a domestic kind of coal, and a dummy for competition from foreign coal, which are both explained in the next paragraph. Port dummies are included to capture port-fixed effects that are independent from changes in the level of competition, and year dummies should account for common time trends in prices.²²⁹ Standard errors are clustered at the port-level.

The appearance of a price for a second quality in the coal price tables is regarded as the sign that coals competed at a port. For example, when the coal price tables of the journal *Coal Merchant and Shipper* state a price for Bengal coal in a non-Indian port in addition to Welsh coal in 1902, the dummy variable *Foreign* would switch to one. If at Durban a domestic coal price quotation would become available in 1890, the *Domestic* dummy variable would be switched on to one. Thus, both dummy variables estimate the effect of competition at the port level, but they distinguish between competition between foreign coals or between domestic and Welsh coals.

²²⁹ The competition dummy for Marseilles has been dropped from the regression.

Actual competition	
Domestic	-0.586** (0.236)
Foreign	-0.126** (0.052)
Port FE	YES
Year FE	YES
R^2	0.82
N	727

Table 3.1: OLS fixed effects model: the effects of competition on prices, 1883-1938

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors clustered at port-level.

Both competition dummies are significant at the 5%-level and confirm the price depressing effect of competition. When interpreting the size of the effect, the coefficient values have to be adjusted, since the dummy variables are not continuous in a log-linear model.²³⁰ Within the period 1883 to 1938, competition of a second foreign coal price quotation led to a decrease in price by 12%. In contrast, competition by a domestic coal led to a price decrease by 44%. This models shows that competition by domestic coals had a much more pronounced, depressing effect on the price level. This finding still holds in other specifications, for example allowing for time-varying port-fixed effects, which reflects changes in conditions at ports – for example, the port infrastructure – which in turn may have affected the prices at which coals were offered.²³¹ The emergence of domestic coals in the South African and Indian markets therefore considerably influenced the local price level, and the South African and Indian experience can be seen as being

²³⁰ Thus, if the competition dummy switches from 0 to 1, the % impact of D on Y is $100[\exp(c) - 1]$. For example, $\exp(-0.126) - 1 = -0.188$.

²³¹ Since I have one price observation per port and per year, I cannot interact each port dummy with every year dummy. However, I created time dummies for the three periods 1883-1900, 1901-1918 and 1919-1938 and interacted them with port-fixed effects. This approach allows for sufficient observations per time period and for variation of the port-fixed effects over three periods. Including these interaction variables instead of time-invariant port-fixed effect does not change the main finding that domestic competition decreases the price level most. The coefficient on *Domestic* is highly significant and very similar in size (-0.463). *Foreign* is also similar in size, but misses the 10%-significance level by a small margin (coefficient of -0.141 and a standard error of 0.087).

representative of the replacement process concerning imported coals, mostly British, as it also occurred in Japan, and, in a similar way, in China too.²³² Therefore, the emergence of South African and Indian coal will be examined more carefully in the next section.

3.6.2. The market entry of domestic coals in India

India was predominately supplied by British, mostly Welsh, coals and imports peaked in 1887/88 before the exploitation of native coal gained momentum.²³³ This process offered the potential for India to benefit from significantly cheaper coal prices. The vast majority of coal was mined in Bengal; in 1894 the output of Bengal mines was 2 out of a total of 2.75 million tons, and thus this analysis is confined to Bengal coals.²³⁴ These coal fields are spread out circa 230km to the North-East of Calcutta. Thus the shift from British imports to domestic coal supplies also meant that Bombay, and the west coast more generally, lost its competitive advantage with respect to the cheapest coal supplies in India for the Eastern region around Bengal. The expansion of Indian coal mining went hand in hand with increasing domestic demand from the Indian railways and the replacement of predominately British coal:

“At the beginning of this period (1890) the total consumption of coal was about 858,000 tons, of which foreign coal constituted nearly one-fourth. Ten years later (1899) the total consumption was 1(2/3) million tons, and Indian coal represented nearly 95 per cent, thus making a rapid and vigorous displacement of foreign coal.”²³⁵

Railways kept in line with the absolute growth in Indian coal consumption, accounting for around 1/3 of it during the period 1889 to 1921.²³⁶ This was a period when

²³² In China, British coals were initially replaced by Japanese coals before they were in turn driven out by domestically mined coals.

²³³ A. Ghosh, *Coal Industry in India. An Historical and Analytical Account*, (New Delhi, 1977), p.58

²³⁴ S. Punekar and R. Varickayil, *Labour Movement in India: Documents: 1850-1890*, (New Delhi and Bombay, 1989), p.68

²³⁵ Department of Statistics India, *Report of the Production and Consumption of Coal in India 1920* (Calcutta, 1922), p.6

²³⁶ *ibid.*, p.7

domestic coal production increased from 1.7m tons to 17.1m tons.²³⁷ In 1924, railways (still) accounted for 32% of domestic consumption and other major domestic consumers were the cotton industry (12%), the coal bunkering trade (10%), and metallurgical industries (8 %).²³⁸

From 1900 India started exporting Bengal coal mostly to Southeast Asian countries, but also to the ports of Mauritius and Aden, and exports exceeded imports. At times, Indian coal exports were subject to Indian governmental policies, for instance by blocking coal exports in 1920 and during World War I, but also through supportive measures such as lowering railway rates after the Great Depression.

A more permanent problem for Indian coal exports were quality concerns. At Singapore, Indian coal traded at a discount to Japanese coal, not to speak of British coal.²³⁹ Since Japanese coal was at least as poor as Indian coal in terms of quality, it seems that the comparatively low carbon content was not a problem.²⁴⁰ Rather the varying quality of delivered Indian coals seemed to have been the real issue. Mr. H.H. Macleod argued in his speech to the Indian Mining Association: “In my opinion nothing can be so damaging to our future prospects as the shipment of indiscriminate qualities.”²⁴¹ Thus, Indian coals were not always processed and screened in a manner that achieved certain, stable quality requirements.

We would expect significantly lower prices once domestic coal crowded out its Welsh counterpart. Figure 3.6 allows us to evaluate this process over time, plotting Indian and Welsh coal prices at four important port cities. The graphs are arranged by distance of the cities from the Bengal mines: Calcutta, Colombo, Bombay and Karachi. Conversely,

²³⁷ 1.7m was the average production during the period 1886-1890 per year and 17.1m refers to 1920, *ibid.* 13

²³⁸ H. Hoar, *The Coal Industry of the World with Special Reference to International Trade in Coal* (Washington, 1930), p.215

²³⁹ W. Dunstan, *The Coal Resources of India, and their Development* (Calcutta, 1902), p.377

²⁴⁰ A. Kirkaldy, *British Shipping. Its History, Organisation and Importance*, (London, 1914), p.645

²⁴¹ Dunstan, *The Coal Resources of India, and their Development*

they differ significantly in their shipping distance to Cardiff with the closest 5,914nm (Karachi) and the furthest 7,770nm (Calcutta) away.

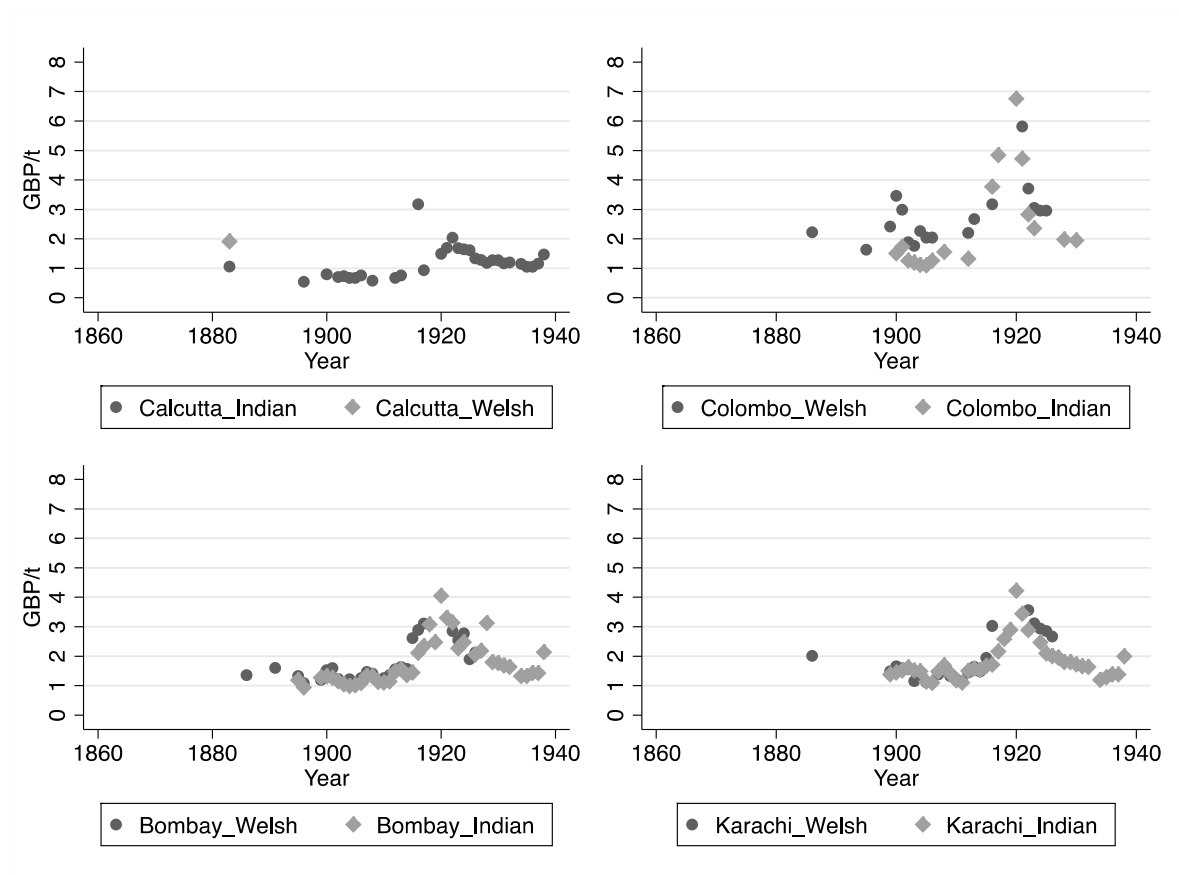


Figure 3.6: Indian and Welsh coal prices at Calcutta, Colombo, Bombay and Karachi

Figure 3.6 shows that Welsh coal quotations stopped much earlier for Calcutta as compared to the other three ports. Ghosh writes that imports, and by extension Welsh coal, lost importance in the Calcutta market by 1879:

“Indeed, imported coal had ceased to be of importance in Bengal by 1879 when Raniganj coal was being used on the E.I.R., in the steamers employed in river and coasting traffic, in cotton, jute and other mills in Calcutta and its neighbourhood.”²⁴²

A Welsh coal price quotation is still available for 1883, which indicates that smaller shipments of Welsh coal still reached Calcutta after 1879. Such coal was most likely bought by consumers with specific quality requirements such as men-of-war who therefore accepted a comparatively high price.

²⁴² A. Ghosh, *Coal Industry in India. An Historical and Analytical Account*, (New Delhi, 1977), p.58

In contrast, Welsh coal prices were quoted uninterruptedly until 1916 at Karachi and 1917 at Bombay (partially concealed by the Indian price quotations in Figure 3.6). In 1895, Punekar and Varickayil claim that the cost advantage of Bengal coal versus British coals at Bombay was too small to compensate for the quality disadvantage.²⁴³ While Ghosh does not state a clear date, he argues that

“Bombay, however, continued to be an important market for foreign coal even by the end of the nineteenth century as the then state of the development of transport, coal from Cardiff was not more costly than from Calcutta and some coal consumed there was of a quality not produced in India.”²⁴⁴

Thus, compared to Calcutta, Indian coal certainly needed at least more than 20 years until it captured most of the Bombay market. Once again there seemed to have been some market, probably for high-quality coals or to satisfy spikes in demand, that was catered for by Welsh coals until the early 1920s.

Apart from Calcutta, where Bengal coal was already 45% cheaper than Welsh coals in 1883 and took the market, Welsh coal seemed to have been able to compete based on price at the other ports. Apart from the price hike in the Welsh coal price around 1900 at Colombo (an effect of the miner’s strike in Wales), prices series for both coals followed a similar trend of stable prices until 1914, with sharp rises during World War I and declining prices in the early 1920s. British coal and Indian coal prices were influenced by different cost functions, for instance British imports were driven by freight rates whereas Indian coal prices by railway charges. Nonetheless, prices were following a very similar trend, which suggests that prices were set reflecting the competitor’s pricing.

²⁴³ S. Punekar and R. Varickayil, *Labour Movement in India: Documents: 1850-1890*, (New Delhi and Bombay, 1989), p.69

²⁴⁴ A. Ghosh, *Coal Industry in India. An Historical and Analytical Account*, (New Delhi, 1977), p.58

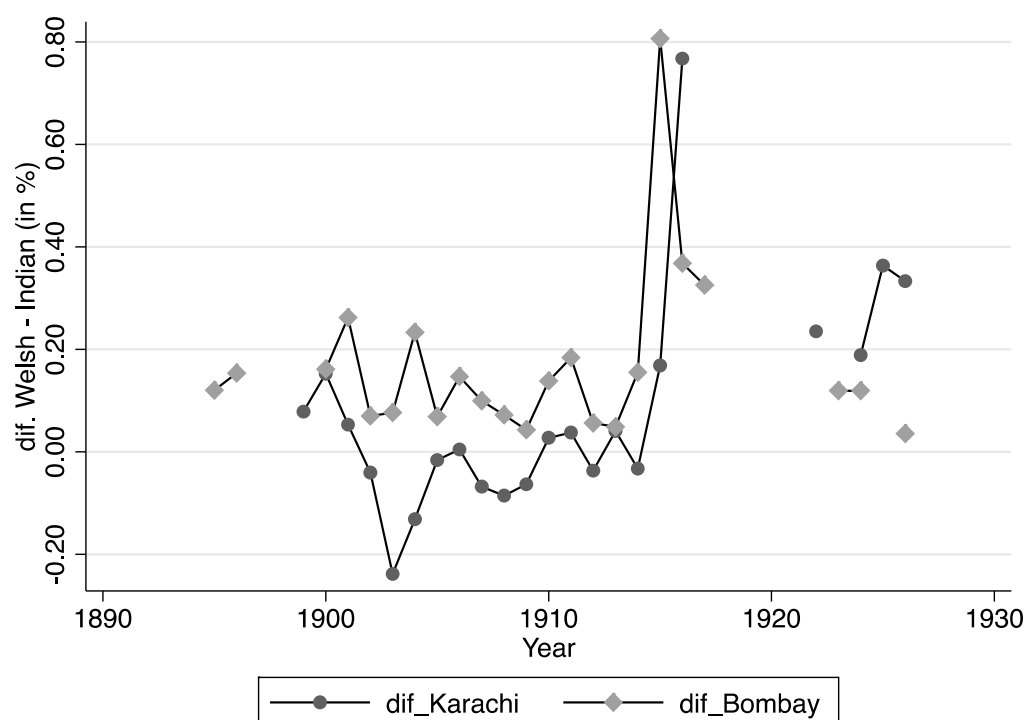


Figure 3.7: %-price difference between Welsh and Indian coal prices at Bombay and Karachi, respectively

Figure 3.7 zooms in on the percentage price difference between both coals at Karachi and Bombay. Pre-World War I, Welsh coal was slightly more expensive than Indian coal at Bombay while the opposite held for Karachi, bearing in mind that the Indian coal prices are quality-adjusted. These differences were caused by two reinforcing factors. The railway freight rates from the Ranjiganj coal fields in Bengal in 1910 were with 0.75GBP/t slightly lower than to Karachi 0.86GBP/t.²⁴⁵ Despite the lower distance to Cardiff, Karachi did not seem to have benefited from lower freight rates for Welsh coals, as those to Bombay were cheaper in two out of three available years with freight rates available for both ports.²⁴⁶ Since coal was often taken as ballast, Bombay may have been comparatively more attractive due to the amount of return cargo.

²⁴⁵ Commercial Intelligence Department India, *Note on the Production and Consumption of Coal in India up to the Year 1910*, p.6

²⁴⁶ Jacks and Pendakur's freight data only offer freight rates for Cardiff-Karachi for the years 1885-87. For Bombay three different freight rate series are available for the three years, so I took their average. The freight rates in GBP/t compare as follows:

During World War I, prices for Welsh coals increased more dramatically than for Indian, and consequently left the market in 1916 (Karachi) and 1917 (Bombay.) Welsh price quotations are again available for a brief interlude at Bombay and Karachi during the 1920s with the latest quotations dating to 1926, and it seems fair to assume that Welsh coal could not compete with Bengal coal based on price any longer.

While Indian coal already took the Calcutta market in the late 1870s, it only conquered the Bombay market by around 1900. Even then some demand was met by Welsh coals since Indian coals was of too poor a quality, and more problematically, the delivered quality was perhaps variable and did not always meet expectations, as outlined above. Within India, the emergence of domestic supplies meant that Calcutta rather than Bombay had access to the cheapest coal.

Exports of Indian coal

Another way of substantiating the evidence that new sources of supply led to global coal price convergence is provided by trading volumes. During the period 1891-95, India imported 705,000 tons, of them 96% were British, which accounted for 21% of total consumption.²⁴⁷ Significant amounts of coal ranging between 200,000-500,000 tons were still imported until 1915, but the importance diminished due to the expanding production of domestic coal in India from 2.8m tons per year during the period 1891-95 to 15.4m tons on average in each year 1911-15. Arguably, the greatest effect of the emergence of Indian

Year	Cardiff-Bombay	Cardiff-Karachi
1885	0.83	0.79
1886	0.74	0.77
1887	0.86	0.99

The freight data stem from the following publication: D. Jacks & K. Pendakur, 'Global Trade and the Maritime Transport Revolution', *Review of Economics and Statistics*, Vol. 92, No. 4, (2010): The freight data are available on Jacks's personal webpage: <http://www.sfu.ca/~djacks/data/publications/index.html>

²⁴⁷ All data on consumed and traded coal volumes in this paragraph are taken from: Department of Statistics India, *Report of the Production and Consumption of Coal in India 1920* (Calcutta, 1922), p.25

coal was on the domestic market, but in the region, too, Indian exports played some role. By 1920, India exported 1.7m tons (7% of total production).

The following map illustrates the geographic expansion of the Indian coal trade indicating the time of entry in foreign markets. At the same time, it states when British coal exited the market.

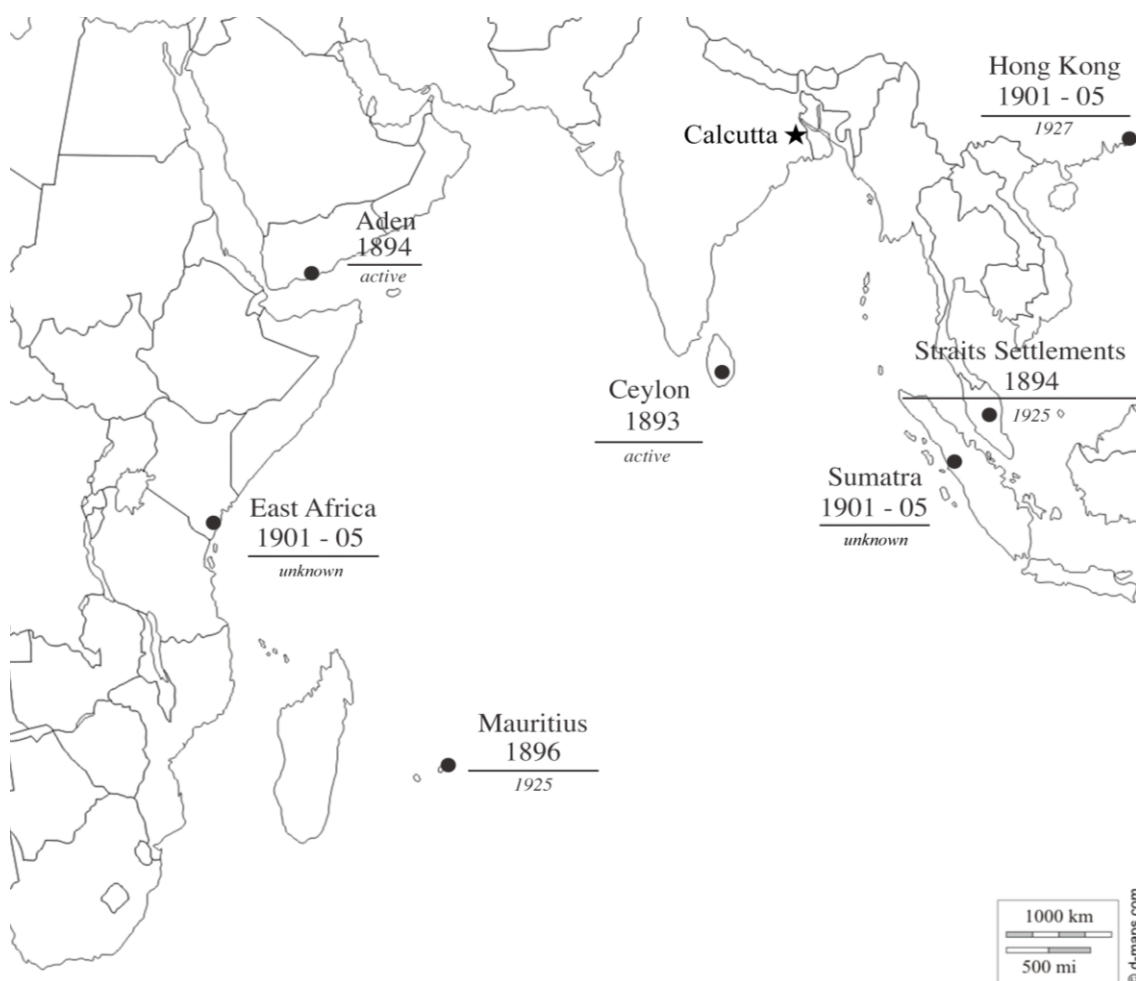


Figure 3.8: The expansion of Indian coal exports

Notes: the first date describes the year when above 5,000t of Indian coal were supplied; the second date under the line in italics stands for the year in which Britain supplied at least 5,000t for the last time. “Active” indicates that >5000t of British coal were still supplied in 1928. “Unknown” means that I do not have information on whether British coal supplies fell below 5,000t. The star highlights that Calcutta is the exporting port, whereas the other points importing ports. Sources: For Indian exports, see *Indian coal statistics* (1920) and *Coal Table* (1901) and for British exports Hoar (1930).²⁴⁸

²⁴⁸ Department of Statistics India, *Report of the Production and Consumption of Coal in India 1920*, (Calcutta, 1922), p.25, H. Hoar, *The Coal Industry of the World with Special Reference to International Trade in Coal* (Washington, 1930), p.86

Indian coals entered foreign markets around the Indian Ocean from the late nineteenth century onwards. It appears that more proximate ports were supplied earlier, with the exception of Aden, and the last markets were entered between 1901-05, which were East Africa, Sumatra and Hong Kong.²⁴⁹ However, Indian coal left Hong Kong in 1908 again, and only returned sporadically. The main foreign markets for Indian coals were the Straits Settlements and Ceylon. Despite the entry of Indian coal, British coals continued to compete in the markets albeit at a smaller scale, and started to leave some of the markets from the mid-1920s onwards. At the port of Aden, for example, British coal exports shrank from 181,000t in 1913 to 50,000t in 1928.²⁵⁰

3.6.3. The market entry of domestic coals in South Africa

South Africa falls into the same category as India, since it was a British colony, a traditional importer of Welsh coals and also developed a domestic coal industry. The main coaling areas were Natal and Transvaal. At Natal, large-scale coal mining started with the exploitation of the Northern Natal coal fields from 1889.²⁵¹ The rise of the Natal coal industry was linked to the extension of the Durban railway beyond Pietermaritzburg, which was initiated by the discovery of the main Witwatersrand gold reef, not the Natal coal deposits.²⁵² Natal produced higher quality coal that was primarily used in steam engines and, over time, increasingly competed with Welsh coal also in export markets. In 1909 46.8% of Natal's coal output was supplied to the bunkering station of Durban.²⁵³ The export trade dominated the sales of Natal coal, which proved problematic from the 1920s onwards when the share of oil-fired ships rose rapidly. At the time, however, Natal was

²⁴⁹ According to *Coal Table 1901* small amounts of coal were also exported to Arabia, Natal and the Philippine Islands. These are not shown on the map since the amounts did not exceed 5,000t (Arabia & Philippine), or only in one year (Natal).

²⁵⁰ *ibid.*, p.86

²⁵¹ B. Guest, 'Commercial Coal-Mining in Natal: A Centennial Appraisal', *Natalia*, Vol. 18, (1988), p.41

²⁵² *ibid.*, p.41

²⁵³ P. Alexander, 'Challenging Cheap-Labour Theory: Natal and Transvaal Coal Miners, Ca 1890-1950', *Labour History*, Vol. 49, No. 1, (2008), p.48

able to benefit from the emerging demand stemming from power stations, as well as its reputation as the preferred producer of coking coal in South Africa.²⁵⁴ In contrast, Transvaal, the other major coalfield in South Africa, which produced lower quality coal, primarily supplied the gold mines and other domestic users. Overall, coal available for domestic consumption increased from 3,642m tons per annum during the period 1901-05 to 7,822m tons in 1924, when 3,342m tons of coal were exported.²⁵⁵ While this was a considerable increase, coal consumption per head (a contemporary measure) reached 1.07 tons per head in South Africa, around a quarter of the British consumption per head, itself amounting to 3.85 tons.²⁵⁶

Adjusting prices for quality differences is not as straightforward as in the Indian case, since the quality of South African coal is not discussed in the previously used shipping literature. The evidence given before the Dominions Royal Commission in 1914 reveals very different views on the quality ranging from a favourable account by Mr. Audas from the Mines Department stating “our tests showed the coal to be equal in many respects to Welsh coal” to the more negative comment by Mr. Steart, Inspector of Mines: “It is not anything as good as best Welsh, in my opinion...I should say 7 to 10 of best Welsh.”²⁵⁷ I have relied on the most reliable measure, the carbon content for Natal Navigation stated as 78.12%, which is probably the highest quality South African coal.²⁵⁸ Figure 3.9 shows Welsh as well as (adjusted) Natal coal prices for Cape Town and Durban in South Africa, and Maputo in Mozambique.²⁵⁹

²⁵⁴ B. Guest, 'Commercial Coal-Mining in Natal: A Centennial Appraisal', *Natalia*, Vol. 18, (1988), p.56

²⁵⁵ British Parliamentary Papers, 1925 [168], Coal Tables, 1924. Return to an Order of the Honourable the House of Commons, Dated 6 August, 1925;--for, Copy "of Statistical Tables Relating to the Production, Consumption, and Imports and Exports of Coal in the British Empire and the Principal Foreign Countries in Recent Years, as Far as the Particulars can be Stated; Together with Statements Showing the Production of Lignite and Petroleum in the Principal Producing Countries for a Series of Years (in Continuation of Parliamentary Paper, no. 285, of Session 1913), p.30 & p.34

²⁵⁶ *ibid.*, p.34

²⁵⁷ Dominions Royal Commission 1914 [Cd. 7077], Royal Commission on the Natural Resources, Trade, and Legislation of Certain Portions of His Majesty's Dominions. Minutes of Evidence Taken in the Union of South Africa in 1914. Part II, p.29 & p.31

²⁵⁸ *ibid.*, p.31

²⁵⁹ The price for Maputo in 1908 refers to Transvaal coal.

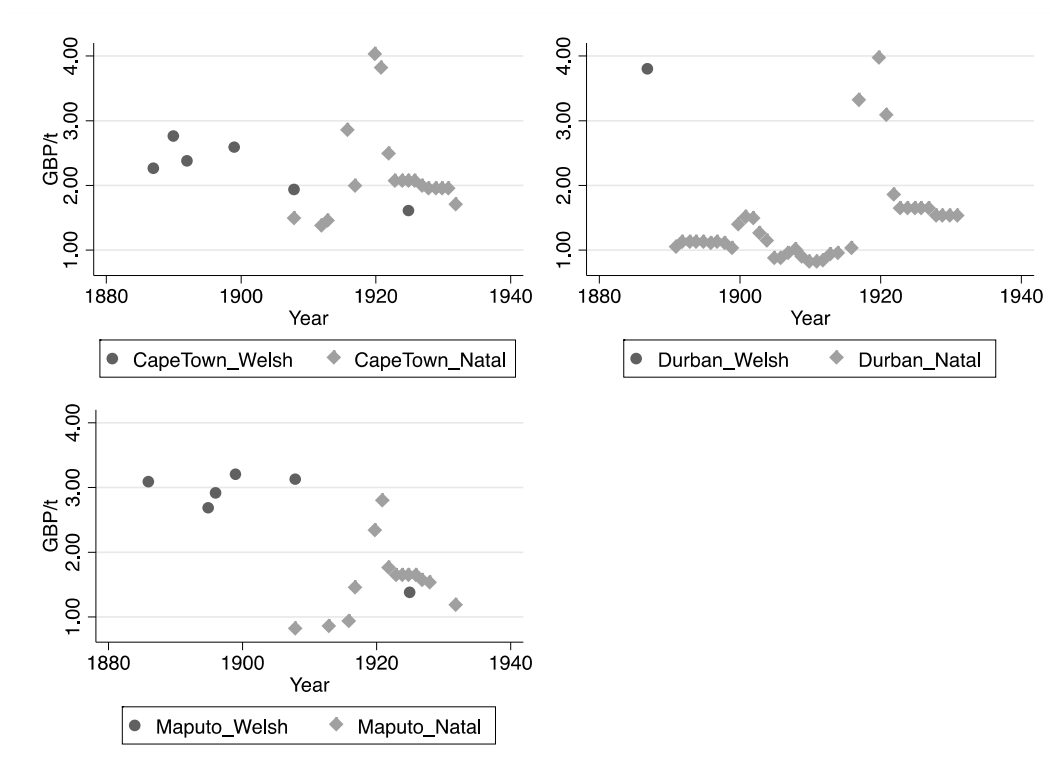


Figure 3.9: Prices for coal at Cape Town, Durban and Maputo, 1887-1932

The graphs offer a similar picture to India in that the rise of domestic coal seemed to have had the greatest effect at Durban, which is the closest of the three ports to the Natal region and furthest away from Cardiff, just like Calcutta. In 1887, the Welsh coal price at Durban was slightly higher than at Maputo, but 68% more expensive compared to Cape Town. For 1908, quotations for Natal and Welsh coal at Cape Town and Maputo are available, but only for Natal coal at Durban, which suggests that Welsh coal had been withdrawn from this market first.

In 1908, the price of Natal coal at Cape Town was significantly higher than at Maputo and Durban. Given the relatively small shipping distance from Durban to Cape Town of 800nm, significant domestic price differences for Natal coal are surprising, and hint at comparatively high domestic transportation costs. Over time the domestic South African markets seemed to have integrated further since the percentage price gap between Durban and Cape Town for Natal coal came down to 26% in 1925.

The considerably cheaper prices for Natal coal trigger the question why Welsh coals were still offered at Cape Town and Maputo in 1908. Guest hints at reservations of customers regarding the quality of Natal coals:

"In 1907 the Union-Castle Company's largest liner, the *Kenilworth Castle*, completed the return voyage to England entirely on Natal coal instead of the mixture of Natal and Welsh coal used previously. Thereafter bunkering at Durban became a standard procedure for all the mailships, which was an important vote of confidence in the reliability of the local product..."²⁶⁰

Next to actual or perceived quality issues, Guest also mentions frequent problems with the rail transport of Natal coal and inadequate loading facilities at the port of Durban.²⁶¹ Thus, the case of South Africa offers a picture that once again domestic coals needed some time to capture the market due to quality problems and, most likely, deficiencies in local infrastructure.

²⁶⁰ Guest, B., 'Commercial Coal-Mining in Natal: A Centennial Appraisal', *Natalia*, Vol. 18, (1988), p.44-45

²⁶¹ *ibid.*, p.44



Figure 3.10: The expansion of Natal's coal exports

Note: the first date describes the year when above 5,000t of Natal coal were supplied; the second date under the line in italics stands for the year in which Britain supplied at least 5,000t for the last time. "Active" indicates that >5000t of British coal were still supplied in 1928. "Unknown" means that I do not have information on whether British coal supplies fell below 5,000t. The star highlights that Durban is the exporting port, whereas the other points importing ports. Sources: For Natal, *Blue Book for the Colony of Natal* (1892-1894) and *Statistical Yearbook of the Colony of Natal* (1892-1899), and for British exports Hoar (1930).²⁶² As an exception, the year of entry for Aden is based on a Natal price quotation from A. Kirkaldy & A. Evans, *The History and Economics of Transport*, 5th edn, (London, 1931).

As shown in Figure 3.10, from Durban Natal coal initially expanded into the most proximate markets of Cape Town, which was part of another British colony until the foundation of the Union of South Africa in 1910, and Maputo of Mozambique. The

²⁶² Department of Statistics India, *Report of the Production and Consumption of Coal in India 1920* (Calcutta, 1922), p.25, H. Hoar, *The Coal Industry of the World with Special Reference to International Trade in Coal*, (Washington, 1930), p.86

exception was Ceylon that already received meaningful quantities of Natal coal in 1892.²⁶³ The initial expansion of the Natal export trade coincided in time with the surge in Indian coal exports. Natal coals were even supplied from time to time to the Bombay markets starting in the late 1890s. The degree of competition made Bombay an unattractive market though:

“Bombay in recent years has been considered a relatively unprofitable field of operation for South African colliers, since Indian and European coal has been largely favoured there.”²⁶⁴

It is remarkable how the ports around the Indian Ocean within years lost their dependence on British coal exports and could increasingly choose between suppliers, which should have also lowered the volatility of prices, since in times of increasing prices for one coal supplier another could fill the void. While not shown in Figure 3.10, post-World War I tens of thousands of tons were shipped even further and, for example, competed against Indian as well as Japanese coals in the Straits Settlements. Post-World War II price quotations for Natal coal also appeared at Latin American ports, such as Buenos Aires, finally ending the times of comparatively little competition in that region.

3.6.4. A different perspective: coal prices at the pithead

So far I have treated domestic coal as a binary condition, whether it was available at a port or not. This means that domestic coal must have been at least as expensive as imported coal, and that ports come rather late in the process of driving out foreign competitors since they can be reached most cheaply by them. In this section, I will therefore compare pithead prices between Wales, India, South Africa and also the US, Germany and Australia as other major coal-producing countries.

²⁶³ The export volumes of the official statistics contain bunker coals, and therefore also list Britain as an importer of Natal coal. However, it can be assumed that the coal was consumed on the ship destined for Britain.

²⁶⁴ H. Hoar, *The Coal Industry of the World with Special Reference to International Trade in Coal*, (Washington, 1930), p.209

										% Δ 1909-13 to 1889-93	
	1889-93	'94-98	1899-1903	'04-08	'09-13	'14-18	'19-23	'24-28	'29-33	1889-93	1889-93
<i>GBP/t</i>											
IND	0.24	0.21	0.21	0.24	0.27	0.34	0.70	0.56	0.31	11.0%	26.3%
ZAF	0.55	0.55	0.87	0.51	0.36	-	0.54	0.44	0.41	-53.4%	-39.4%
SWLS	0.45	0.35	0.53	0.50	0.56	0.88	1.48	0.86	0.75	20.1%	53.4%
NWLS	0.36	0.31	0.45	0.39	0.43	0.75	1.13	0.83	0.67	16.3%	71.4%
GER	0.43	0.43	0.49	0.53	0.60	-	-	0.87	0.89	28.2%	76.8%
USA	0.58	0.45	0.58	0.60	0.60	0.93	5.04	1.46	1.55	4.0%	162.4%
AUS	0.38	0.43	0.44	0.48	0.86	0.80	0.82	0.77	0.83	55.4%	52.4%

Table 3.2: Five-year averages of pithead prices

This first price quotation for India, not shown in Table 3.2, became available in 1886 with 0.29GBP/t, which was 3ct/t more expensive than South Welsh coal. During the five-year period 1889-93, this order quickly reversed in that the Indian pithead price declined whereas the South Welsh equivalent slightly increased: South Welsh coals averaged 0.45GBP/t as opposed to 0.24GBP/t for Indian, and 0.55GBP/t for South African as shown in Table 3.2. Over the next decades South Welsh coal continued to follow an upward trend whereas South African pithead prices came down to the low level of Indian coal prices. It thus appears that costs of production declined in the earlier phase of mining expansion, as evident by the slightly falling price of Indian coals, and more so for South African coal prices where mining started the latest. This also implies that the relatively long presence of Welsh coals in India was rather a consequence of expensive transportation since pit head prices had always been comparatively low. In contrast, the initial pithead price of South Africa was quite high, but quickly became more competitive.

The popularity of South Welsh coals may fuel the assumption that it may have increased more in price than other British coals. However, the comparison to North Welsh coals shows that such coals even increased more, by 71% between 1889-93 to 1909-13 as compared to only 53% for South Welsh. Therefore, the upward trend was not a phenomenon of South Welsh coals only. A comparison with the two other major producing and exporting countries, the US and Germany, reveals that initially Westphalian coals were

mined most cheaply, but by 1909-13 pithead prices in the three dominating coal mining regions South Wales, USA and Germany had become very similar. Coal prices inflated even more in the traditional coal mining countries with US-pithead prices increasing by 162% between the period 1889-93 to 1929-33. In contrast, South African and Indian coals had established themselves as the lowest cost producers; Indian coals only cost 0.31GBP/t in the last observation period.

From a production-cost side, South Africa and India were serious competition to Welsh, and by extension British, coals in the world market. However, one should bear in mind that the Union of South Africa only produced 10.4m metric tons in 1920 and India 18.2m metric tons against a production of 233.2m metric tons in the UK.²⁶⁵ Nevertheless, even though the production volumes were relatively small, they contributed to oversupply post-WWI that increasingly became a serious problem for Britain as the major exporting country. Scientific progress and the strengthened efforts of previously importing countries, responding to the poor supply relations during World War I, to develop their own coal industry depressed demand and expanded supply at the same time. As a result, between 1913 to 1928 coal consumption only grew by 4%.²⁶⁶ A League of Nations' report with the telling title "The Problem of the Coal Industry" concluded that Britain suffered most since "in 1913, her mines raised 292,000,000 tons; in 1928, they raised 244,000,000. There are to-day 170,000 British miners without work."²⁶⁷

²⁶⁵ League of Nations, (1929), *The Problem of the Coal Industry*, Table 1, p.20

²⁶⁶ *ibid.*, p.7

²⁶⁷ *ibid.*, p.9

3.6.5. A Difference-in-Difference approach to domestic supply shock effects

This additional empirical strategy relies on a simple Difference-in-Difference model (DID-model) as used for instance by Nunn and Qian.²⁶⁸ The aim is to identify the long-run effect of new domestic sources of coal supply on prices in Indian and South African ports. The relative change in the price of coal at Indian and South African ports is estimated between a time of import dependency on Welsh coals, the year 1886, and a period when domestic coals were consumed, the years 1908, 1912, 1924 and 1930. This change is compared to a sample of ports that remained dependent on Welsh coals throughout all years. They thus provide the counterfactual what price developments would have been like in India and South Africa in the absence of domestic mining.

The chosen sample contains two groups of ports. The treatment group consists of Indian ports (Bombay, Karachi & Colombo) and South African ports (Durban, Cape Town and Maputo). Those ports were exclusively supplied with Welsh coal in 1886 and by 1908 only domestic coal from Natal (South Africa) and Bengal (India) was offered. The control group encompasses ports, mainly in the Mediterranean and Latin America, that also imported Welsh coal and did not experience domestic supply shocks – in other words, they continued to import Welsh coals. Ports, such as Aden, where other foreign coals were offered alongside Welsh coals during the period 1886 to 1930 are excluded. Due to foreign competition such ports do not form a robust control group. Therefore, a conservative data strategy has been chosen in that only ports which predominately imported Welsh coals throughout the investigation period constitute the control group.

The choice of the pre-treatment date, 1886, and the first post-treatment date, 1908, is confirmed by two different pieces of evidence. First, the price data for the years 1886 and 1908 are taken from the shipping guide *Ports of the World* published by the US Naval

²⁶⁸ N. Nunn and N. Qian, 'The Potato's Contribution to Population and Urbanization: Evidence from a Historical Experiment', *The Quarterly Journal of Economics*, Vol. 126, No. 2, (2011)

Office,²⁶⁹ and in 1886 only prices for Welsh coal are given. For 1908 prices for Indian or South African coal are stated.²⁷⁰ The exception is Calcutta, which is in proximity of the Bengal mines, where Bengal coals were already offered in 1883. Therefore, Calcutta is dropped from the sample. Based on the assumption that prices are quoted for the most popular kinds of coal, Indian and South African coal took the market between 1886 and 1908.

Second, the secondary literature on the histories of coal mining in India and South Africa confirms that large-scale coal mining only started after 1889 in the Natal region.²⁷¹ In India, Bengal coal had not yet taken the important Bombay market from Welsh coal in 1895.²⁷² Both types of sources thus confirm that domestic coals gradually drove Welsh coals out of the domestic markets, except Calcutta in proximity to the Bengal mines, between 1886 and 1908, but were not offered in the pre-treatment year 1886.

The main specification of the DID-model is as follows:

$$\ln_cheapest_price_{x,t} = \alpha + \beta post_shock_t + \gamma t_group_x * post_shock_t + \delta port_x + \varepsilon_{x,t}$$

where x indicates the port and t indicates the years which are 1886, and either 1908, 1912, 1924 or 1932. $post_shock_t$ is a time dummy that equals one after the supply shock has happened, that means, for the years 1908, 1912, 1924 and 1932. The supply shock is the replacement of imported Welsh coals by domestic coals. Since the price quotations change from Welsh to Indian or South African, the determinant of the price shock is

²⁶⁹ Office of Naval Intelligence, *Coaling, Docking and Repairing Facilities of the Ports of the World, with Analyses of Different Kinds of Coal*, Office of Naval Intelligence, *Coaling, Docking and Repairing Facilities of the Ports of the World, with Analyses of Different Kinds of Coal*, 5th edn, (Washington, 1909)

²⁷⁰ Sometimes a Welsh coal quotation was still stated, but it was only offered for a small number of customers, such as Navies, that preferred Welsh coal.

²⁷¹ B. Guest, 'Commercial Coal-Mining in Natal: A Centennial Appraisal', *Natalia*, Vol. 18, (1988), p.41

²⁷² Punekar and Varickayil, *Labour Movement in India: Documents: 1850-1890* (New Delhi and Bombay, 1989), p.69; Calcutta was dominated by Bengal coals already in 1879 due to the proximity of Bengal mines, thus it is excluded from the DID-estimation.

evident, which eliminates a frequent weakness of DID-models that other (unaccounted) factors taking place at the same time might be driving the results.

The interaction term $t_group_x * post_shock_t$ is one for all ports that are part of the treatment group, South Africa or Indian ports, post-supply shock. $port_x$ stands for the port-fixed effects, and thus accounts for all time independent effects that are different between ports. The dependent variable $ln_cheapest_price_{x,t}$ is the natural log of the cheapest coal on offer at port x in year t . As described in the data section of this chapter, coal prices are adjusted to account for quality differences of the respective coals. If more than two types of coal are on offer at the same port and year, the cheapest price after quality adjustment is chosen.

The main coefficient of interest is γ of the interaction term between $post_shock_t$ and t_group_x , where the latter is not included on its own in the specification above since $port_x$ takes account of whether a port is part of the treatment group or not. It shows the estimated effect of the supply shock on prices in the treatment ports, thus any additional effect that is going beyond a time-invariant effect on prices affecting treatment ports only ($port_x$) and any common time period effect ($post_shock_t$), such as price inflation over the years. A negative coefficient indicates that domestic coal prices fell further in ports of countries that developed domestic coal mining than at other ports without such a supply shock.

An important assumption underlying any DID-approach is that the treatment and the control group followed a parallel trend prior to the treatment; thus any deviation from the common trend of the treatment group post-treatment should be due to the treatment, here the supply of domestic coals. Figure 3.11 plots the time trend of the treatment and of the control group prior to the treatment, from 1840 to 1886. The price data underlying the

time trends includes all available price data for ports that are part of the DID-model.²⁷³

Figure 3.11 gives the trends for control and treatment group combining the average prices for certain available years in each decade from 1840 to 1886.²⁷⁴

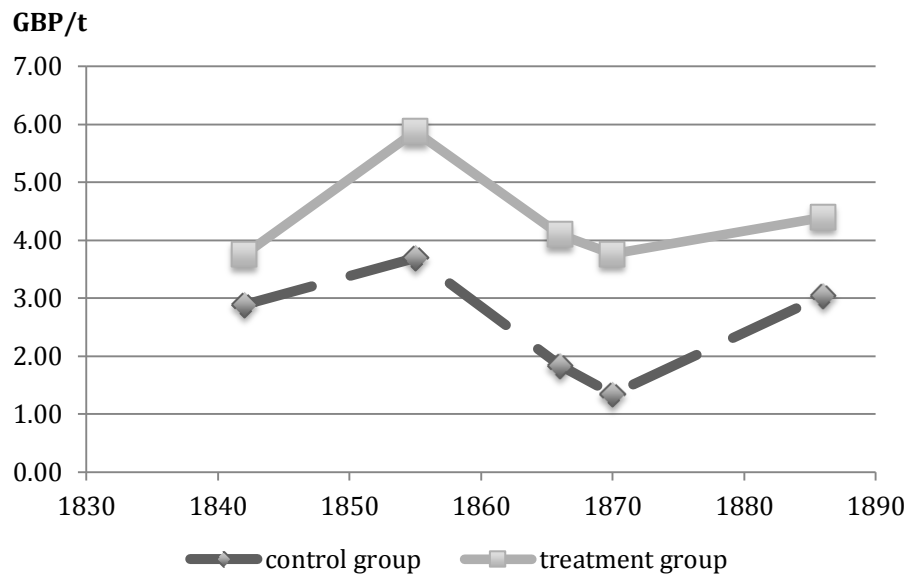


Figure 3.11: Test parallel trend assumption, 1840-86

Both time series indeed show a very similar pattern while the overall price level was lower in the control group. Prices increased from 1841 to 1856 before they fell again to 1870. While the treatment group only showed a very slight price increase to 1886, it was more pronounced in the control group. The difference in level stems from the comparatively long distance from Cardiff to South Africa and India, and thus high prices at the ports of destination. In contrast, the control group contains rather distant Latin American ports but also the more proximate ports of the Mediterranean.

²⁷³ The ports of the control group are Aden, Bahia, Genoa, Gibraltar, Montevideo, Recife, Port Said and Rio de Janeiro. The ports of the treatment group are Bombay, Cape Town, Delagoa Bay, Karachi and Trincomalee. Prices are not available for every listed port for every year.

²⁷⁴ The specification of the underlying regression is $\text{xi: reg price i.time i.time*group1}$ (where group 1 is whether a port is part of the treatment group or not). The fitted values were separated by group as plotted above. As an alternative procedure, the dataset was divided into a control group and a treatment group sample and the time trends were estimated separately yielding very similar results (see Figure A8 in the Appendix).

3.6.6. Results

Various specifications of the main DID-model have been estimated. First, the models have been estimated for a number of different post-shock years in order to identify the time-varying size of the effect. Second, $post_shock_t$ is interacted with a dummy for Indian as well as South African ports in order to allow for different effects of the shock in these two parts of the treatment group.

Model 1A is a pooled DID model that compares 1886 against all post-shock years 1908, 1912, 1924 and 1932. In Model 1B the effect of the supply shock on each of the post-shock periods is estimated. In Model 1C the shock effect is estimated for each post-shock year allowing for separate effects in the two countries of the treatment group, India and South Africa. The results of Model 1A are shown below in Table 3.3.

	Pooled DID
post_shock	0.239*** 0.073
t_group_post_shock	-0.688** 0.243
Port FE	YES
R^2	0.61
N	95

Table 3.3: Model 1A, DID Pooled 1886-1930

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors clustered at port-level.

In line with our expectations, the coefficient of $t_group_post_shock$ is negative and highly significant. The prices for coal offered at South African and Indian ports were on average lowered by 50% by the supply shock.²⁷⁵ All other variables being zero, the prices during the period 1908-30 were 27% higher than in 1886 as shown by $post_shock$. The coefficients measuring the fixed-effects at port level are highly significant and negative

²⁷⁵ As described previously, the effect of the dummy variables in this log-linear model is calculated according to this formula: $100[\exp(c) - 1]$.

(apart from Rosario) indicating on average lower price in the control group which resonates well with the “parallel trends” graph in Figure 3.11. Furthermore, and as expected, the coefficients were more negative for South American as compared to Mediterranean ports that are closer to the coal-exporting ports of Britain. Overall, Model 1A already explains 61% of the variation in coal prices which is driven by the port-fixed effects (excluding them reduced the adjusted- R^2 to 0.17).

	DID 1886/1908	DID 1886/1912	DID 1886/1924	DID 1886/1930
$t_group*’08$	-0.740** (0.332)			
$t_group*’12$		-0.818** (0.357)		
$t_group*’24$			-0.580 (0.336)	
$t_group*’30$				-0.613** (0.263)
Year FE	YES	YES	YES	YES
R^2	0.77	0.77	0.72	0.81
N	38	38	38	38

Table 3.4: Model 1B, DID for sub-periods

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors clustered at port-level.

Model 1B above shows that the estimated supply shock effects vary by post-shock year as expressed by the coefficient on the interaction terms between the treatment group and shock dummy. The coefficient on $t_group*’08$ is smaller than on $t_group*’12$, that means, the price depressing effect of domestic supplies increased from 1908 to 1912. Given that the development of new coal mining areas requires significant investments into the coal mining technology and transportation infrastructure, it appears reasonable that the domestic conditions improved over time and prices for domestic coals continued to fall. The insignificant interaction coefficient of 1924 needs to be acknowledged as an outlier. As alluded to before, coal prices were driven up by scarcity during World War I and the

immediate postwar years. Only in 1923 had global coal production reached the pre-1913 level it once enjoyed.²⁷⁶ In these volatile conditions, coal prices rose globally, and in my dataset the difference between South African and Indian as opposed to Welsh prices declined, which most likely explains the coefficient's insignificance.²⁷⁷ The estimated coefficient on $t_group*'30$ is highly significant, but smaller than the interaction coefficients referring to 1908 and 1912, which indicates that the size of the effect of domestic coal prices may have declined again.

	DID	DID	DID	DID
	1886/1908	1886/1912	1886/1924	1886/1930
India	0.056 (0.079)	-0.030 (0.123)	-0.026 (0.097)	-0.049 (0.101)
South Africa	0.353* (0.200)	0.341 (0.203)	0.423** (0.154)	0.392** (0.155)
India'08/ India'12/India'24/India'30	-0.336** (0.157)	-0.391 (0.247)	-0.138 (0.194)	-0.322 (0.202)
SA'08/SA'12/SA'24/SA'30	-1.145** (0.400)	-1.245*** (0.405)	-1.021*** (0.309)	-0.903*** (0.309)
Year FE	YES	YES	YES	YES
Port FE	YES	YES	YES	YES
R^2	0.87	0.87	0.85	0.87
N	38	38	38	38

Table 3.5: Model 1C, DID for sub-periods, distinction between India and South Africa

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors clustered at port-level.

Model 1C combines the analysis per sub-period with the distinction between India and South Africa. It shows that the domestic supply shock decreased prices more considerably in South Africa as compared to India. Up to 1908 coal prices had decreased by 29% in Indian ports as opposed to 68% for South African. Both interaction terms also

²⁷⁶ H. Hoar, *The Coal Industry of the World with Special Reference to International Trade in Coal* (Washington, 1930), p.23

²⁷⁷ In 1912, the average coal price in the control group exceeded the average price in the treatment group by 46% and in 1930 by 20%; in 1924 prices in the control group were only 13% higher on average.

show the declining effect of the supply shock from 1912 to 1924, and also up to 1930. With port-fixed effects, distinguishing by sub-periods as well as between India and South Africa, the explanatory power of the model reaches at least 85%.

3.7. Conclusion

Global coal price differences were declining during the late nineteenth century but also during the interwar period when trade costs did not decrease further. This chapter does not rely on the traditional approach to market integration – that is, studying differences between the import and export prices of a traded commodity – but it compares the prices for the same quality of coal at different ports. By employing three different quantitative methods of analysis – a global CoV, an OLS regression as well as a DID model – this chapter identified that the spread of coal mining and the accompanying intensification of competition between coals from different origins can explain this development of price convergence.

The average coal price charged at ports without domestic coal mines was 46% higher than at ports with access to domestic coal in 1886; this difference declined to 22% in 1932 (see Figure 3.4). While naturally a reduction in trade costs contributed to this effect, intensified competition between a greater number of supplying countries also explains a share. Between 1883-1938 the entry of an additional coal supplier, often ending a monopolistic market position enjoyed by British coals, led to a price decrease of on average 13% at the importing port (see Table 3.1). The case studies of South Africa and India illustrate how both countries initially took over their domestic markets from British imports, and then gradually expanded their export markets around the Indian Ocean.

The effect of competition between foreign coals on price was moderate as compared to the price depressing effect of the availability of a domestic coal. The OLS model as well as the DID model show that the entry of South African and Indian coals approximately halved the price charged for coals at their domestic ports (see Tables 3.1 and 3.3). However, this convergence process from a dependence on foreign imports to domestic coal took years, especially in India where Bengal coal was offered alongside Welsh coal. A major obstacle was the varying quality of both Natal and Bengal coals which was due inadequate processing. Conversely, if local infrastructure including coal processing had been developed earlier and more thoroughly, coal prices would have sunk many years earlier. This chapter thus lends support to Wright's hypothesis that the discovery and development of natural resources contributed to a convergence of global commodity prices particularly during the interwar period, when trade costs stagnated as shown in the previous chapter.

4. Cheap Coal and High Wages: Factor Price Ratios, Directed Technical Change and the Spread of Industrial Development, 1870-1940

Abstract

Allen (2009) has given the debate about the significance of coal for the Industrial Revolution a new twist by arguing that the ratio of coal prices to wages led to the British Industrial Revolution.²⁷⁸ High wages created incentives for research in labour-saving technology and steered technical progress towards the exploitation of comparatively cheap coal. Using my new coal price data set introduced in Chapter Two, and my approach of adjusting for quality differences in coals (Chapter Three), this chapter investigates the relationship between coal price/wage ratios for 23 countries from 1870 to 1940 and the manufacturing output growth estimates from Bénétrix, O'Rourke and Williamson.²⁷⁹ The underlying assumption is that countries with a similar factor-price ratio to Britain – high wages and low coal prices – should have had higher manufacturing output growth since they were able to adopt the most modern, mainly steam engine-based, technology.

My results confirm that countries with a low coal price/wage ratio had higher levels of GDP per capita, but also that the ratio is negatively correlated with manufacturing output growth. An increase of coal prices by 50%, holding wages constant, decreased manufacturing output growth by between 0.32% to 0.13% per annum. These are lower bound estimates since the effect may have been even greater pre-1870 when steam engines were less efficient. In my fixed effects models the level of the coal price/wage ratio refers to the first year of each decade, e.g. 1870 for 1870-79, in order to partially counter endogeneity concerns. The results are robust to controlling for decadal fixed effects, and other potential determinants such as trade openness, human capital development and institutional environment. In addition, it remains robust to various changes to the dataset, such as excluding the WWI-period. These results increase our confidence that coal price/wage ratios were proximate determinants of industrial development, acknowledging that the level of coal prices itself is partially determined by infrastructure and technology.

²⁷⁸ R. Allen, *The British Industrial Revolution in Global Perspective* (Cambridge, 2009), p.22

²⁷⁹ A Bénétrix, K. O'Rourke & J. Williamson, 'The Spread of Manufacturing to the Poor Periphery 1870-2007', *Open Economics Review*, Vol. 26, No. 1, (2015)

4.1. Introduction

Coal has featured prominently as a potential determinant of the British Industrial Revolution, and economic growth more generally, not least because Britain was the first to exploit her large coal deposits. Wrigley argues that the “switch to coal may be regarded as a necessary condition for the industrial revolution [...]”, since an organic economy based on firewood could not provide the energy consumed during the Industrial Revolution.²⁸⁰ Energy-intensive industries using steam engines often located near the mines where coal was offered most cheaply. Britain was particularly fortunate since coal deposits were located within reach of iron ore deposits. The importance of coal has been challenged by Mokyr, amongst others, who claims that the Industrial Revolution “did not absolutely ‘need’ steam [...] nor was steam power absolutely dependent on coal.” However, he acknowledges that coal-using technology would emerge in a coal rich economy.²⁸¹ Technology may have been increasingly biased towards cheap coal, and according to Allen, it was labour-saving too, since British wages were so high.²⁸² Building on the common ground that technological progress was biased towards coal, and leaving aside whether or not coal was necessary to initiate the Industrial Revolution, a question is raised if countries with similar factor prices to Britain – cheap coal and high wages – may have adopted more modern technology earlier and more successfully. This may then explain different growth experiences between countries during the second half of the nineteenth and first half of the twentieth century. Since my coal price dataset starts in the mid-nineteenth century and contains a large sample of globally dispersed countries, it allows for the empirical testing of the effect of coal prices relative to wages on the global spread of economic, and in particular, industrial development.

²⁸⁰ E. Wrigley, *Energy and the English Industrial Revolution* (Cambridge, 2010), p.21

²⁸¹ J. Mokyr, *The Enlightened Economy: An Economic History of Britain, 1700-1850* (New Haven, 2009), p.101-2

²⁸² R. Allen, *The British Industrial Revolution in Global Perspective* (Cambridge, 2009), p.22

4.2. Coal, technological diffusion and economic growth

As shown in the previous chapters, coal prices varied dramatically between different locations - even during the twentieth century - since coal is bulky and costly to transport. The global spread of coal mining beyond Europe and the US to Asia and South Africa brought coal closer to a number of countries, but regions such as Latin America remained far away from coal mines. Pollard argued that high transportation costs favoured locations for industries close to the coal deposits such as in the North of England, but also in Belgium and the Ruhr region in Germany.²⁸³ For the US, Wright acknowledged the importance of its resource abundance for its industrial success during the first half of the twentieth century.²⁸⁴ However, he emphasised that technology and skill allowed the US to locate and exploit its resources.

Conversely, the failures of France (Boserup) and Italy (Bardini) to industrialise as early as Britain have been attributed to comparatively high coal prices.²⁸⁵ Importing coal could not solve the problem since it left Italy with a considerable cost disadvantage (coal cost twice as much as in Britain), and substitution with electric energy only became successful after World War I when electric engines became directly attached to machine tools. While China possesses significant coal deposits, Pomeranz argued that they were in “the wrong place” in the North-East of China, far away from the major population centres.²⁸⁶

Those country-based approaches have been criticised on the grounds that price differences between producing and importing countries were not that high and/or that price

²⁸³ S. Pollard, *Peaceful Conquest: The Industrialization of Europe 1760–1970* (Oxford, 1981), p.40 & p.121

²⁸⁴ G. Wright, 'The Origins of American Industrial Success, 1879-1940', *The American Economic Review*, Vol. 80, No. 4, (1990)

²⁸⁵ M. Boserup, 'Agrarian Structure and Take-Off', in W. Rostow (ed.), *The Economics of Take-Off into Sustained Growth*, London, (1965), C. Bardini, 'Without Coal in the Age of Steam: A Factor-Endowment Explanation of the Italian Industrial Lag before World War I', *Journal of Economic History*, Vol. 57, No. 3, (1997)

²⁸⁶ K. Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World* (Princeton, N.J., 2000)

differences did not matter so much for total production costs. Mokyr has argued that coal prices in pre-famine Ireland exceeded British prices by 100 to 150%, but only stood for up to four per cent of total costs in non-metallurgical industries.²⁸⁷ However, such “cost-accounting approaches” appear as half-hearted attempts to quantitatively assess the effect coal prices, and it seems more meaningful to use econometric analyses to establish a direct relationship between coal mining and economic growth.

In a recent econometric contribution to this literature, Fernihough and O’Rourke establish that city growth, as a commonly employed as a proxy for GDP, was much larger in urban areas in proximity to coal deposits post-1800.²⁸⁸ As striking as this finding is, it may overstate the effect of coal mining, since initially some industry may have located due to the proximity to the coal deposits, but later industrial settlements may have followed the initial factories in order to benefit from the agglomeration/clustering effects of industries. In their quantitative analysis on why the British textile industry was so concentrated in Lancashire, Crafts and Wolf find evidence for the importance of both access to coal and industrial networks: cheap coal was positively correlated with the size of the cotton mills, while agglomeration increased the probability of finding a cotton mill in a given location.²⁸⁹

The “new economic geography” genre, formed by Krugman in 1991, considers the location of production and its varieties of geographical concentration, and attempts to explain it by examining the dependencies between market size, trade costs and economies of scale.²⁹⁰ According to Redding and Venables, there are two major mechanisms in which

²⁸⁷ J. Mokyr, *Why Ireland Starved: A Quantitative and Analytical History of the Irish Economy, 1800-1850* (London, 1983), p.152-58

²⁸⁸ A. Fernihough and K. O’Rourke, 'Coal and the European Industrial Revolution', *NBER Working Paper 19802*, (2014)

²⁸⁹ N. Crafts and N. Wolf, 'The Location of the UK Cotton Textiles Industry in 1838: A Quantitative Analysis', *The Journal of Economic History*, Vol. 74, No. 04, (2014), p.1124-25

²⁹⁰ P. Krugman, *Geography and Trade*, (Cambridge, Mass., 1991)

geographic location matters.²⁹¹ One is the distance from countries that supply manufactures as well as inputs for production. This, for example, is reflected in the level of coal prices in my analysis. The other mechanism is distance to markets where the output is sold, which I do not test for in the following analysis. Among economic historians, there is a growing literature on the effect of market potential, which jointly considers both demand and access to a market, often proxied by GDP per capita and divided by the costs of serving that market.²⁹²

In the context of coal, Gutberlet finds that in Germany access to coal rather than output markets mattered more during the nineteenth century.²⁹³ By contrast, according to a working paper by Heilmann, distance to coal fields cannot explain differences in economic growth between British counties during the nineteenth century; unfortunately Heilmann fails to explain what then determined regional growth patterns.²⁹⁴ Although there seems to be more evidence that coal may have mattered for industrial development, it still remains very unclear to what extent coal deposits favoured the settlement of industry, also referred to as the *location*-hypothesis by Fernihough and O'Rourke, and to what extent it directly generated economic growth, their *growth*-hypothesis.

In order to evaluate the latter hypothesis, technological progress must be at the core of the explanation, and as aforementioned, Allen has linked the ratio of coal prices to wages to the take-off of economic growth in Britain. During the eighteenth century, high wages incentivised British entrepreneurs to invent labour-saving technology, which was

²⁹¹ S. Redding & A. Venables, 'Economic Geography and International Inequality', *Journal of International Economics*, No. 62, Vol.1, (2004)

²⁹² An early contribution is by Roses on the location of industry in Spain 1797 to 1810. Wolf considers Poland pre-1918, and Crafts examines Britain. More recently, Galizia offers a European perspective. See J. Roses, 'Why isn't the Whole of Spain Industrialized? New Economic Geography and Early Industrialization, 1797-1910', *Journal of Economic History*, No. 63, Vol. 4, (2003), N. Wolf, 'Endowments vs. Market Potential: What Explains the Relocation of Industry After the Polish Reunification in 1918?' *Explorations in Economic History*, No. 44, Vol. 1, (2007), N. Crafts, 'Market Potential in British Regions, 1871-1931', *Regional Studies*, No. 39, Vol. 9, (2005), P. Caruana Galizia, 'Economic Development and Market Potential. European Regional Income Differentials, 1870-1913' (London School of Economics, PhD-Thesis 2015)

²⁹³ T. Gutberlet, 'Cheap Coal, Market Access, and Industry Location in Germany 1846 to 1882' (University of Arizona Mimeo, 2014)

²⁹⁴ K. Heilmann, 'The Importance of Access to Coal in the Industrial Revolution', at http://econweb.ucsd.edu/~kheilman/pdfs/Coal_Paper.pdf, accessed 06 October 2015

then using coal that was available in abundance and consequently cheap. And according to Kander et al., only Britain possessed the perfect ratio of high wages and low coal prices.²⁹⁵ Allen's argument reminds us of the "Habakkuk thesis" that scarce labour in the US during the first half of the nineteenth century created incentives to mechanise production, replacing unskilled workers. According to Habakkuk, the US embarked on a more capital-intensive industrialisation.²⁹⁶

Habakkuk's and Allen's theories share the idea that factor prices shaped innovation by steering technological progress towards the heavier use of one factor of production. Acemoglu formalises this process of development in his framework of "directed technical change." This idea rests on the assumption that technological progress is endogenous and can be directed towards one or another factor of production.²⁹⁷ In the context of this chapter, the two factors of production would be *coal* and *labour*. According to Acemoglu's weak bias-theorem, when *coal* supply increases, the market size for technologies based on *coal* increases, and consequently further energy-based technologies will be developed. Acemoglu argues that the market size effect is always greater than the price effect. Thus, in the long-run, increasing supplies of *coal* would bias technical change towards *coal*.

Moving on from the process of innovation, the factor price ratio also matters for the diffusion of such technology to other countries, which is the focus of this chapter. If technology is invented with one set of relative prices (i.e. relatively cheap coal) in mind, then it may not pay to adopt it in countries with relatively expensive energy, or there might be a technology/skill mismatch in these countries.²⁹⁸ Catching up with Britain would then become more difficult for other countries given that factor prices would not converge to

²⁹⁵ A. Kander, P. Malanima, et al., *Power to the People: Energy in Europe Over the Last Five Centuries* (Princeton, 2013)

²⁹⁶ H. Habakkuk, *American and British Technology in the Nineteenth Century: The Search for Labour-Saving Inventions* (Cambridge, 1962)

²⁹⁷ D. Acemoglu, 'Directed Technical Change', *The Review of Economic Studies*, Vol. 69, No. 4, (2002)

²⁹⁸ D. Acemoglu and F. Zilibotti, 'Productivity Differences', *The Quarterly Journal of Economics*, Vol. 116, No. 2, (2001), p.580

British levels. In this way, technological progress may increase income differentials between countries over time.

Technological progress was indeed heavily skewed towards steam engines with predominately coal heated boilers in textile and metallurgical industries. An implication of this, then, is that steam engines also became much more efficient over time, as neatly summarised by Crafts:

“The upshot of improvements in steam engine design was that coal consumption (per hp per hour) improved from about 30 lb. with the Newcomen engines prior to James Watt, to 12.5 lb. with the Watt engine, 5 lb. with the move to high pressure in the mid 19th century and 2 lb with very high pressure in the early 20th century [...].”²⁹⁹

Not only the engine itself, but also related technologies advanced. In railways, improvements in track design and signalling allowed for greater capacity trains and a heavier utilisation of networks. Steamships gained from the application of iron hulls and the compound engine, amongst other improvements described in the second chapter that all reduced the amount of coal consumed on a ship’s voyage dramatically.

The greater efficiency of steam engines eroded the British advantage as compared to other countries with more expensive coal and also paved the way for spreading such technologies to those countries. Allen dates the adoption of modern British technology in continental Europe to the period 1850 to 1873, and argues that

“The slow adoption of British technology on the continent had less to do with war, institutions and culture than with the economics of the new technology, which was not profitable to adopt outside Britain.”³⁰⁰

Whereas water power became uncompetitive against steam by the mid-nineteenth century in Britain, higher coal prices made it relatively more attractive in France. In 1899, water power still accounted for 56 per cent of newly installed prime movers in terms of

²⁹⁹ N. Crafts, 'Productivity Growth in the Industrial Revolution: A New Growth Accounting Perspective', *The Journal of Economic History*, Vol. 64, No. 2, (2004), p.526

³⁰⁰ R. Allen, *The British Industrial Revolution in Global Perspective* (Cambridge, 2009), p.2

horsepower.³⁰¹ The longer reliance on water power rather than coal shaped the industrial development of France

“since the resulting pattern included small firm size, geographical dispersion of industry and slow urbanization, characteristics displayed also by other coal-poor industrial nations.”³⁰²

As exemplified by the case of France, the unique combination of coal prices and wages, and also the availability of substitutes, determined the point in time when it became profitable to adopt modern British technology in other countries.

While coal succeeded water energy, it also came under pressure by other forms of energy, as Landes notes: “Each innovation seems to have a life span of its own, compromising periods of tentative youth, vigorous maturity, and declining old age.”³⁰³ While coal still dominated as the major source of energy during the twentieth century, electricity (which can be generated from gas, water and other sources of primary energy) and oil slowly opened up a path of industrial development without coal. Traditionally, steam engines, and also water wheels, were directly connected to the machinery in factories rotating “line shafts.”³⁰⁴ In 1883, electric motors were used probably for the first time to drive manufacturing machinery, thus breaking the link between the source of energy creation and machinery.³⁰⁵ However, it was only in 1920 that electrical motors passed steam engines as the major “source of mechanical drive” in the US.³⁰⁶ According to Bardini, the widespread application of electric power was one of the factor contributing to Italy’s catch-up in industrial development.³⁰⁷ As another important substitute oil replaced coal as the fuel of choice for ships but only after World War I as I have explained in

³⁰¹ R. Cameron, 'A New View of European Industrialization', *The Economic History Review*, Vol. 38, No. 1, (1985), p.14

³⁰² *ibid.*, p.14

³⁰³ D. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge, 1969), p.3

³⁰⁴ W. Devine, 'From Shafts to Wires: Historical Perspective on Electrification', *The Journal of Economic History*, Vol. 43, No. 2, (1983), p.350

³⁰⁵ *ibid.*, p.353

³⁰⁶ *ibid.*, p.349

³⁰⁷ C. Bardini, 'Without Coal in the Age of Steam: A Factor-Endowment Explanation of the Italian Industrial Lag before World War I', *Journal of Economic History*, Vol. 57, No. 3, (1997)

greater depth in the second chapter. Despite these developments, there were also limits to substitution, and steel smelting, notably, always required large amounts of coke.

As the previous literature review indicates, there is disagreement whether, and if so, to what extent cheap coal actually contributed to economic growth from the Industrial Revolution into the twentieth century. Coal prices may have been decisive in determining whether it paid to adopt modern technology. Steam engines, burning coal, were the most advanced form of technology to provide mechanical power. Over time, the greater efficiency of steam engines and the increasing availability of substitutes for coal worked together to reduce the importance of coal prices as a barrier to technology adoption. Forming a ratio with wages increases the notion of a determinant of technology adoption since using labour may have been the alternative if mechanisation proved relatively more expensive. As far as I am aware, no study has empirically investigated the effect of a measure of the incentive to adopt technology – proxied by the ratio of coal prices to wages – on an economic output variable. It may well be the case that coal was actually not that important, particularly towards the twentieth century. However, it is impossible to judge on this a priori and irrespective of whether the results will confirm the importance of the ratio. As such, this investigation appears as a worthwhile endeavour.

4.2.1. Other determinants

Certainly other factors may well feature more prominently in explanations of industrial development and they also need to coincide in order to create favourable conditions. For example, it is hard to see how the most modern technologies could have been applied profitably absent a skilled workforce to operate them. Rather than establishing them as opposing arguments, other important and measureable drivers of industrial development will be discussed here, and later included as control variables in the econometric exercises.

Already in the eighteenth century, Adam Smith argued that trade leads to economic growth since countries can exploit their comparative advantage and benefit from a larger market. In their ground-breaking contribution, Sachs and Warner show with their cross-country panel regressions that trade openness was positively correlated with economic growth and that countries with a high ratio of natural resource exports grew less during the period 1971-89.³⁰⁸ A more recent contribution of 2015 by Bravo-Ortega and de Gregorio confirms a positive effect of trade openness in a very similar exercise again for the post-WWII period.³⁰⁹

The positive relationship between trade openness and economic growth – and the negative effect of natural resource exports – seems not to be a universal truth, and amongst other conditions, time-dependent. Allen shows that the US developed its manufacturing sector under tariff protection during the nineteenth century since it was uncompetitive to British manufactures.³¹⁰ Rodrik and Rodríguez, after a review of the empirical studies on the effect of trade barriers on economic growth, remain unconvinced of a negative relationship between trade barriers and growth.³¹¹ Lehmann and O'Rourke draw a distinction in that, pre-World War I, the effect of protectionism was dependent on the sector of the economy: “manufacturing tariffs were positively related to growth, while agricultural tariffs were generally negatively related to growth.”³¹² And Clemens and Williamson shift the breaking point when the correlation between economic growth and tariff rates reversed after World War II, with a positive before and a negative relationship

³⁰⁸ J. Sachs and A. Warner, 'Natural Resource Abundance and Economic Growth', *National Bureau of Economic Research*, No. w5398, (1995)

³⁰⁹ C. Bravo-Ortega and J. De Gregorio, 'The Relative Richness of the Poor? Natural Resources, Human Capital, and Economic Growth', *Natural Resources, Human Capital, and Economic Growth (January 2005). World Bank Policy Research Working Paper*, No. 3484, (2005)

³¹⁰ R. Allen, 'American Exceptionalism as a Problem in Global History', *The Journal of Economic History*, Vol. 74, No. 2, (2014)

³¹¹ F. Rodríguez and D. Rodrik, 'Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence', *NBER Macroeconomics Annual*, Vol. 15, (2000)

³¹² S. Lehmann and K. O'Rourke, 'The Structure of Protection and Growth in the Late Nineteenth Century', *Review of Economics and Statistics*, Vol. 93, No. 2, (2011), p.615

thereafter.³¹³

Based on my examination period of 1870 to 1940, I would expect a negative effect of trade openness. Some openness to trade was clearly a necessary condition for the spread of manufacturing industries to other countries, at least in the very beginning of establishing a domestic industry, since modern technology, especially during the nineteenth century, had to be imported from Britain, and exports would provide the foreign exchange in order to pay for them. Later in the process, protectionism may have been advantageous for large economies in particular to foster domestic industry as it proved successful in the case of the US alluded to before. For smaller economies in particular, Rodríguez and Rodrik, along with Lehmann and O'Rourke, emphasise Grossman and Helpman's original argument that the effect depends on whether comparative advantage pushes countries to research and development and the other advances that lead to long-term growth.³¹⁴

Next to importing the machinery, building up a manufacturing sector required more skilled workers who could operate such machinery. Immigration may have initially helped to satisfy demands, but in the longer term, countries needed to train and educate their own workforce. Heckscher described how its comparatively educated workforce helped Sweden to adopt British metallurgical technology and subsequently, to establish its iron and steel industry.³¹⁵ Bravo-Ortega and de Gregorio find a positive effect of human capital, measured by the average years of schooling among a population aged 25 or older, on growth. Such a relationship may appear in the following analysis, though Clemens and Williamson note that education may have been much less important in the nineteenth as compared to the twentieth century.³¹⁶

³¹³ M. Clemens and J. Williamson, 'Why did the Tariff-Growth Correlation Change After 1950?', *Journal of Economic Growth*, Vol. 9, No. 1, (2004)

³¹⁴ S. Lehmann and K. O'Rourke, 'The Structure of Protection and Growth in the Late Nineteenth Century', *Review of Economics and Statistics*, Vol. 93, No. 2, (2011), G. Grossman and E. Helpman, *Innovation and Growth in the Global Economy* (Cambridge (Ma.), 1991)

³¹⁵ E. Heckscher, *An Economic History of Sweden* (Cambridge (Ma.), 1968)

³¹⁶ J. Sachs and A. Warner, 'Natural Resource Abundance and Economic Growth', *National Bureau of Economic Research*, No. w5398, (1995)

The quality of institutions sparked interest in the debate about the long-run determinants of economic growth through the contributions by Acemoglu, Johnson and Robinson. In *The Colonial Origins of Comparative Development* they argue that in countries with high settler mortality, European colonisers set up extractive institutions whereas lower mortality rates encouraged them to create better institutions that protected property rights.³¹⁷ The effect is still present today and distinguishes Latin America from North America. Particularly the idea of secure property rights is important when establishing a manufacturing sector. Investments and entrepreneurship flourish more in countries with a stable institutional environment. I expect that better institutions should lead to higher manufacturing output growth, while there is most likely some correlation with other controls, especially human capital.

Land abundance is another sensible control, particularly, since most “New World” countries were land-rich and “Old Europe” land-scarce. A high mass of arable land per capita could incentivise countries to develop a comparatively large agricultural sector, and also export agricultural products. This may lead to industrial activities processing agricultural products, which is usually less technology intensive than “heavier” industrial sectors such as the iron and steel industry. Following this line of argument, land abundance might be in the way of strong industrial development. As a counter argument, land abundance was often correlated with high wages creating incentives to replace labour. O’Rourke, Taylor and Williamson find that in the “New World” technological progress was labour-saving during the late nineteenth century, and in this way, high wages may

³¹⁶ C. Bravo-Ortega and J. De Gregorio, 'The Relative Richness of the Poor? Natural Resources, Human Capital, and Economic Growth', *Natural Resources, Human Capital, and Economic Growth (January 2005)*. *World Bank Policy Research Working Paper*, No. 3484, (2005), M. Clemens and J. Williamson, 'Where did British Foreign Capital Go? Fundamentals, Failures and the Lucas Paradox 1870-1913', *NBER Working Paper Series*, No. 8028, (2000), p.8

³¹⁷ D. Acemoglu, S. Johnson and J. Robinson, 'The Colonial Origins of Comparative Development: An Empirical Investigation', *National Bureau of Economic Research*, No. w7771, (2000)

have induced mechanisation resulting in industrial development.³¹⁸ The effect of land abundance on industrial development does therefore not seem to be so straightforward and would depend on the ways it influenced technological progress.

4.3. Coal price/wage ratio dataset

4.3.1. Sources and selection criteria

The country sample was chosen in order to achieve a vast global coverage and to contain a maximum of variation between countries in terms of their coal prices and wages. Since coal prices are the less available type of data, I first tried to find coal price data for as many countries as possible, and then matched it with unskilled wage data. The major driver of variation in coal prices is whether countries exploited domestic coal deposits or not. In total, my sample includes 23 globally dispersed countries with annual data starting as early as 1840 until lasting through 1940. Some countries exploited domestic coal deposits throughout the nineteenth century such as the USA, UK and Germany; others remained importers of coal in the twentieth century such as Italy, Egypt and Argentina, and a third group increasingly reduced import dependence through the growth of domestic output such as China, India and South Africa. Since coal prices are on average negatively correlated with income per capita, the selection of (varying) coal prices automatically leads to a country selection with great differences in wage levels. Overall, my sample covers circa 71% of the world economy in terms of GDP in 1913 (relying again on Maddison's GDP estimates in 1990 Int. GK\$).³¹⁹ It is thus representative of global developments, and the

³¹⁸ K. O'Rourke, A. Taylor and J. Williamson, 'Land, Labor and the Wage-Rental Ratio: Factor Price Convergence in the Late Nineteenth Century', *International Economic Review*, Vol. 37, No. 3, (1996)

³¹⁹ For Singapore, Hong Kong and South Africa manufacturing output growth is not available, or too late. If we exclude them (for Singapore, no GDP figure exists for 1913), the effect is negligible and my sample still captures 71% of global GDP (A. Maddison. *Statistics on World Population, GDP and Per Capita GDP*, at <http://www.ggdc.net/MADDISON/oriindex.htm>, accessed 09 December 2012)

only important missing countries are the USSR and Japan. Nevertheless, it would appear unlikely that those two countries could lead to significantly different results.

For each country, the lowest available coal price series was chosen under the assumption that coal-consuming industries should have located there. Such price series refer to major ports for coal-importing countries and pithead prices for coal-producing countries. I tried to find the wage rate from the most proximate location, and in many cases the unskilled wage series and coal prices series refer to the same city (e.g. Amsterdam – Amsterdam).³²⁰ In the cases of Germany, France (from 1912), Norway and Sweden national wage averages were taken. Greater data availability leads to an increasing sample over time. Coal and wage series are available for France and the UK by 1840, for five countries by 1860 and for seventeen countries by 1871. The full sample is reached in 1889 with the addition of Greece as summarised in Table 4.1 below.

³²⁰ M. Morys and M. Ivanov, 'The Emergence of a European Region: Business Cycles in South-East Europe from Political Independence to World War II', *European Review of Economic History*, Vol. 19, No. 4, (2015)

No.	Country	City: wage	From	City: coal price	From	Both
1	Germany	National	1871	Ruhr-Area (pithead)	1850	1871
2	UK	London	1840	South Wales, Glamorgan (pithead)	1840	1840
3	US	Philadelphia	1840	Pennsylvania (pithead)	1857	1857
4	France	Paris (to 1911), then National	1840	Bordeaux, then French pithead avg.	1840	1840
5	Netherlands	Amsterdam	1840	Amsterdam	1883	1883
6	Denmark	Copenhagen	1848	Copenhagen	1858	1858
7	Sweden	National	1871	Gothenburg	1840	1871
8	Norway	National	1850	Bergen	1884	1884
9	Greece	Ruse (Bulgaria)	1889	Piraeus	1869	1889
10	Italy	Milan	1840	Genoa	1870	1870
11	Portugal	Lisbon (only to '13)	1850	Lisbon	1870	1870
12	Spain	Madrid (to '14), National	1840	Barcelona	1870	1870
13	Australia	New South Wales	1861	New South Wales (pithead)	1871	1871
14	China	Beijing	1841	Shanghai	1866	1866
15	Hong Kong	Beijing	1841	Hong Kong	1842	1842
16	India	Bombay	1873	Bombay, then Calcutta (pithead)	1867	1873
17	Singapore	Singapore	1885	Singapore	1871	1885
18	Argentina	Buenos Aires	1864	Buenos Aires	1862	1864
19	Brazil	Rio de Janeiro	1830	Rio de Janeiro	1869	1869
20	Uruguay	Montevideo	1870	Montevideo	1869	1870
21	Turkey	Constantinople	1840	Constantinople	1869	1869
22	Egypt	National	1858	Alexandria	1869	1869
23	South Africa	Natal (only to '13)	1855	Cape Town, from 1889 Natal (pithead)	1889	1889

Table 4.1: Country coverage of the coal/wage data set

Note: I thank Matthias Morys for making the Bulgarian wage data available to me prior to publication.³²¹ The data can be found on the website of the Bank of Greece.³²² Thanks are also due to Sofia Henriques and Paul Sharp for contributing the Danish coal price series, to Jan Tore Klovland for the Norwegian coal prices, and to Astrid Kander for Swedish coal price data.³²³

Finding the appropriate wage data requires a decision concerning what skill level the wage rates should reflect. In his argument on Britain's factor price ratio, Allen compares high wages for *unskilled* workers with coal prices, though he mentions that

³²¹ *ibid.*

³²² *Bank of Greece*, 'South-Eastern European Monetary and Economic Statistics from the Nineteenth Century to World War II', at <http://www.bankofgreece.gr/Pages/en/Publications/Studies/SeemhDataVolTables.aspx>, accessed 15 January 2016

³²³ The price series is described in Table A6.

wages for skilled workers were also high in Britain. O'Rourke, Rahman and Taylor give a motivation for the preference of unskilled wages, since "the initial stages of industrialization had to be unskilled-labor-intensive simply because there were so many more unskilled laborers in the workforce than skilled laborers."³²⁴

With the advance of technology, machinery became increasingly skill-using during the twentieth century. One could therefore argue that very high wages for skilled workers may have prevented the adoption of modern technology since it would have been more profitable to rely on unskilled labour and manual work. However, even in this context, it holds that higher unskilled wages would have increased incentives to use modern coal-based technology. From a practical point of view, it is difficult to find skilled wage series for different countries, which refer to the same, or at least, a very similar skill level. In comparison, unskilled wages are much more available. Therefore, also for practical reasons, this chapter will focus on unskilled wages and the investigation of the coal price/wage ratio as proposed by Allen in his original argument.

Nominal wages are chosen over real wages, since they are used in a ratio relative to coal prices, which removes any concerns about finding adequate deflators for both variables. The wage data was collected from a myriad of sources that all refer to urban unskilled workers who often worked in the building industry. A significant share of the underlying price data comes from Williamson and Allen.

Unfortunately, the nominal wage data series, which Williamson constructed in order to calculate real wages, seem to have been lost. However, the publications on Latin America and the Mediterranean contain nominal wage indexes, and I could use these indexes to re-construct the nominal wage series for Argentina, Brazil, Egypt, India and Turkey. In these cases, I looked up the original source stated by Williamson to find the level of the nominal wage corresponding to the index value of a particular year. Then, I

³²⁴ K. O'Rourke, A. Rahman and A. Taylor, 'Luddities, the Industrial Revolution, and the Demographic Transition', *Journal of Economic Growth*, Vol. 18, No. 4, (2013), p.16

used this year as a benchmark and applied the changes of the nominal index, in order to obtain the nominal wage series for all other years. A complete overview of all sources including the individual wage series descriptions can be found in Table A5, which also states what original sources I used to reconstruct nominal wages series from Williamson's nominal wage indexes.

Allen's dataset *Laborers' Relative Wages* was used for the European countries Britain, France, Italy, the Netherlands and Spain.³²⁵ For these countries prices from other sources, which have in some cases also been used by Williamson, were linked to extend the nominal wage series until 1940. Those sources were amended with a number of country-specific studies, which again can be found in Table A5.

All wage series were converted into GBP per year. Fourteen out of 25 wage series were daily wages and converted into annual wages based on 250 working days per year. This assumption follows Allen who argues that "the balance was accounted for by Sundays, religious holidays, illness and slack time."³²⁶ It appears reasonable to use this assumption since some of the daily wage series are taken from his work and this chapter investigates his argument. Two wage series were recorded weekly, three monthly and three hourly; they were converted based on twelve month per year, 50 weeks, five working days a week with ten working hours which is again consistent with 250 working days.³²⁷ In the small number of cases that the underlying sources explicitly stated other conversion factors, those were applied: de Zwart calculated annual wages for Natal and Cape Town based on 300 working days a year, and Caruana-Galizia assumed 320 working days in Egypt.³²⁸ While I have taken great care in choosing the most sensible number of working

³²⁵ *Global Prices and Income Database*, 'Laborers' Relative Wages (Allen)', at <http://gpih.ucdavis.edu/Datafilelist.htm>, accessed 20 August 2015

³²⁶ R. Allen, *The British Industrial Revolution in Global Perspective* (Cambridge, 2009), p.38

³²⁷ The remaining three wage series are already given in annual terms.

³²⁸ For the period 1890 to 1933 *The Historical Statistics of the United States* gives, in addition to the hourly wages rates, average hours worked per week, the latter measure being what I have used instead of 50 hours. United Bureau of Labor Statistics, *History of Wages in the United States from Colonial Times to 1928. Revision of Bulletin No. 499 with Supplement, 1929-1933*, p.186 & p.529 (prices from 1929). However, the

days, this choice becomes less of a problem in the regression analysis of Section 4.5. The country fixed effects should remove any persistent difference in wage levels between countries, which may have been caused by different assumptions on the number of working days.

The sources for coal price data at ports have already been discussed in detail in Chapter Two, and the quality adjustments based on different levels of carbon content in Chapter Three. The major advance of this chapter is the addition of coal prices at the pithead, which will therefore be introduced here in greater detail. This concerns the major coal-producing countries US, Britain, Germany and Australia, and a second group of countries where prices initially refer to port prices until a meaningful domestic coal industry was established. France, India and South Africa belong to the latter. Again, finding pithead price data was not a straightforward task and required the combination of sources. As outlined in the previous chapter, quality differences between different kinds of coals were eliminated to the extent possible by adjusting for the level of carbon contained in the various coals. A detailed description of all coal prices series can be found in Table A6.

The British pithead price series refers to Glamorgan, South Wales, and was interpolated backwards from 1877 to 1840 based on the f.o.b. price for large steam coals at Cardiff, which developed very similarly for the overlapping period until 1913. From 1900, the Glamorgan price series increases slightly more than the available pithead price series for North Wales and the UK average pithead price series stated in *Coal Tables*.³²⁹

average hours worked per week decline from 58.5 in 1890 to 44 in 1907, and are thus, on average, very close to my conversion factor.

³²⁹ British Parliamentary Papers, 1925 [168], *Coal Tables*, 1924. Return to an Order of the Honourable the House of Commons, Dated 6 August, 1925;--for, Copy "of Statistical Tables Relating to the Production, Consumption, and Imports and Exports of Coal in the British Empire and the Principal Foreign Countries in Recent Years, as Far as the Particulars can be Stated; Together with Statements Showing the Production of Lignite and Petroleum in the Principal Producing Countries for a Series of Years (in Continuation of Parliamentary Paper, no. 285, of Session 1913)

However, all three price series are similar in trend and level and it therefore seems justifiable to take the South Wales series as representative for the UK.

The mentioned *Coal Tables* are an important source since they contain pithead prices for a high number of countries from 1883 to 1924. However, the prices are averages calculated dividing the value of output by volume. While they are thus representative for the overall price level, cross-country comparisons are distorted by quality differences. For the US, the *Coal Table* series follows a very similar trend to the prices series for Clearfield coal at Baltimore, which was also used by Allen, though it is on average 45% lower. Coal had to be transported via rail over the Appalachian Mountains, with a straight-line distance of at least 200 miles which explains a larger price difference as observed between Glamorgan and Cardiff. Following the mantra of using the cheapest prices series, I chose the coal table-series and extended it based on the Baltimore-series for the years 1857-1882 and 1824-1940.³³⁰

The price series for Australia refers to the “true raising costs” and may thus be lower than other pithead prices series, however, the average price 1883-1900 is with 0.37GBP/t nearly identical to the average value per ton given for New South Wales in *Coal Tables* with 0.38GBP/t.³³¹ The pithead prices post-1913 were interpolated based on the change in the f.o.b. price for such coal at the port of Newcastle, Australia. The construction of the German price series was more straightforward since Jacobs and Richter give a price series at Essen and at the pithead of Ruhr coal mines in *Die Großhandelspreise in Deutschland von 1792 bis 1934*.³³² While the pithead price should in principle be lower than the price for coal delivered to Essen, this is not always the case,

³³⁰ The pithead price series is estimated for 1857-1883 & 1924-40: $P_Coaltable_t = \alpha + \beta P_Baltimore_t + \gamma time_trend_t + \epsilon_t$ (Adj. R² 89%).

³³¹ British Parliamentary Papers, 1902 [213], *Coal Tables. Statistical Tables Relating to the Production, Consumption, and Imports and Exports of Coal in the British Empire and the Principal Foreign Countries in Recent Years, as Far as the Particulars can be Stated* (Issue 1901)

³³² A. Jacobs and H. Richter, 'Die Großhandelspreise in Deutschland von 1792 bis 1934', *Sonderhefte des Instituts für Konjunkturforschung No.37*, (Berlin, 1935)

which suggests quality differences between the two price series. I have always taken the cheaper of the two available price series in every available year.

Finally, the price series for France, India and South Africa stand out since all countries developed meaningful domestic coal mining industries during the period under investigation, when South Africa and India turned into net coal exporters. The French case is different since it saw both an expansion of British coal imports from 1834 as well as of domestic mining especially in the Pas-de-Calais region from the mid-nineteenth century.³³³ The net effect was that British coals increased its market share in France, and during the period 1851/56 the share of imports in French coal consumption reached 41%.³³⁴ My price data reflects this dynamic to a certain extent, since the first price series refers to Welsh coals imported to Bordeaux until 1883, and then to the average value of coal mined in France from *Coal Tables*.³³⁵ While domestic French coals accounted for a larger share than imports before 1883, the lack of available pithead price data for earlier years forces me to work with British import prices, which were also an important source of supply, and dominated in the coastal regions.

Pithead prices for Bengal become available in 1886, which was the cheapest coal mining region with the highest output. Large-scale coal mining had started earlier, around 1870. It reached an output of on average 2.8m tons per year during the period 1891-95 accounting for 79% of total Indian coal consumption. Since coal production only reached

³³³ R. Fremdling, *Anglo-German Rivalry on Coal Markets in France, the Netherlands and Germany, 1850-1913*, Research Memorandum GD-21 vols., Gronningen, (1995), p.6, *European Route of Industrial Heritage*, 'Industrial History – France', <http://www.erih.net/industrial-history/france.html> accessed 15 December 2015

³³⁴ Fremdling, 1995, Appendix, Table 3, based on Crouzet, F., 'Le Charbon anglais en France au XIXe siècle', in L. Trénard (ed.), *Charbon et Sciences humaines*, (Paris, 1966), p.178

³³⁵ British Parliamentary Papers, 1913 [285], *Coal Tables*, 1912. Return to an Order of the Honourable the House of Commons Dated 11 August 1913;--for, Copy "of Statistical Tables Relating to the Production, Consumption, and Imports and Exports of Coal in the British Empire and the Principal Foreign Countries in Recent Years, as Far as the Particulars can be Stated; Together with Statements Showing the Production of Lignite and Petroleum in the Principal Producing Countries for a Series of Years (in Continuation of Parliamentary Paper, no. 403, of Session 1912)", British Parliamentary Papers, 1925 [168], *Coal Tables*, 1924. Return to an Order of the Honourable the House of Commons, Dated 6 August, 1925;--for, Copy "of Statistical Tables Relating to the Production, Consumption, and Imports and Exports of Coal in the British Empire and the Principal Foreign Countries in Recent Years, as Far as the Particulars can be Stated; Together with Statements Showing the Production of Lignite and Petroleum in the Principal Producing Countries for a Series of Years (in Continuation of Parliamentary Paper, no. 285, of Session 1913)

1m tons in 1880, it can be assumed that Indian coal replaced British coal as the most consumed coal at some stage during the 1880s (Section 3.6.2 has examined the emergence of Indian coal). It therefore seems reasonable to use the prices for British coals at Bombay, where import prices were cheapest, for the years pre-1886, than the prices in Bengal as illustrated.

4.3.2. Datasets for regression analysis

A database of manufacturing output growth has recently been established by Bénétrix, O'Rourke and Williamson and the data will form the main dependent variable in the subsequent analysis.³³⁶ Thanks to these new data, my analysis can accurately determine the effect of the coal price/wage ratio on the manufacturing sector, rather than less specific indicators such as GDP growth. The dataset spans the period 1870-1913 and 1920-2007 while the number of countries increases over time to 175 for the last period 1990-2007. Details about the underlying sources and how the data were constructed can be found in their paper, but it should be noted here that

“to the extent that other countries were experiencing modern industrialization before they started to collect industrial statistics, what we are documenting here understates the early spread of modern manufacturing.”³³⁷

Since manufacturing output growth is not available for Hong Kong, Singapore and South Africa only from 1920 (a period for which I lack wage data), the sample for the following regression analyses does not include these three countries, but is otherwise the same as presented in Table 4.1.

Three datasets have been constructed that differ in the amount of estimated coal price observations and consequently in size. *Robust* only contains coal prices as found in

³³⁶ A Bénétrix, K. O'Rourke & J. Williamson, 'The Spread of Manufacturing to the Poor Periphery 1870-2007', *Open Economics Review*, Vol. 26, No. 1, (2015)

³³⁷ *ibid.*, p.6

the underlying sources (after quality adjustment) and thus has comparatively the most gaps in terms of missing annual observations. For *Default* additional prices have been estimated for importing countries of Welsh coal based on the coal freight rate between Cardiff and the respective ports. *Interpolated* contains the estimated prices based on freight rates and has all remaining missing years between price quotations filled by linear interpolation.

The approach of using freight rates to construct import prices (for *Default* and *Interpolated*) has been used before, for example by Bukley and Coll Martín and Sudrià, whose prices I use for Singapore and Spain, in order to estimate prices at importing ports.³³⁸ Coll Martín and Sudrià use the f.o.b. British export price series from Mitchell's *Historical Statistics*, adding freight rates to the Spanish ports and the applying import tax.³³⁹ However, this understates the prices at which coal was offered at the importing ports since the coal trading business had expenses for storing coal and loading it on the ship again as well as a profit margin. I therefore regress the freight rates as well as the coal price at Cardiff and a time trend against the available price data at ten importing ports to fill the gaps in the price series.³⁴⁰ Table 4.2 below gives a summary of the three datasets.

³³⁸ K. Bukley, 'The Overseas Trade in New South Wales Coal and the British Shipping Industry, 1860-1914', *Economic Record*, Vol. 36, No. 75, (1960), S. Coll Martín and C. Sudrià, *El Carbón En España, 1770-1961: Una Historia Económica* (Madrid, 1987)

³³⁹ B. Mitchell, *British Historical Statistics* (Cambridge, 1988)

³⁴⁰ The coal prices at the importing ports have been estimated individually using the following specification $p_{port_{x,t}} = \alpha + \beta freight_{x,t} + \gamma p_{Cardiff_t} + \delta time_trend_t + \epsilon_{x,t}$ where x is the port and t a year from 1869 to 1913. The prices were estimated for Alexandria (Egypt), Bombay (India), Constantinople (Turkey), Piraeus (Greece), Buenos Aires (Argentina), Hong Kong (Hong Kong), Lisbon (Portugal), Montevideo (Uruguay), Rio de Janeiro (Brazil) and Bordeaux (France). The estimated prices were only used for years in which no original price quotation was available.

	Robust No of Obs.		Default No of Obs.		Interpolated No of Obs.	
No. obs. <i>coal</i>	1,249		1,359		1,553	
No. obs. <i>start_coal/start_wage/ start_cw_ratio</i>			112		119	
No. of countries (clusters)	20		20		20	
Obs. per cluster min	1		1		2	
Obs. per cluster mean	4.6		5.6		6	
Obs. per cluster max	7		7		7	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
<i>start_coal</i> (GBP/t)	2.22	3.02	2.12	2.76	2.08	2.69
<i>start_wage</i> (GBP/p.a.)	71.79	74.61	63.74	70.08	62.39	68.4
<i>start_cw_ratio</i>	0.06	0.12	0.07	0.11	0.07	0.11
<i>ch</i> (10 year avg.)	3.80	2.81	3.76	2.95	3.88	3.05
<i>tariff</i>	0.14	0.09	0.15	0.10	0.15	0.10
<i>schooling</i>	4.69	2.24	4.15	2.37	4.14	2.35
<i>ha_land</i>	2.44	5.08	2.42	4.67	2.33	4.53
<i>polityIV</i>	2.69	6.06	1.77	6.15	1.77	6.01
<i>gdp_pc_start</i>	2.81	1.44	2.57	1.43	2.49	1.45
<i>gdp_start</i>	89.91	135.53	76.29	126.14	75.76	124.26

Table 4.2: Description of datasets and variables³⁴¹

Notes: When the additional controls *ha_land*, *polityIV*, *schooling*, *gdp_pc_start* or *gdp_start* are included, the samples size is reduced to 85 (robust), 104 (default), 111 observations (interpolated). The descriptive statistics for those variables refer to the reduced samples.

The results of the freight interpolations are that *Default* and *Interpolated* contain more decades with data for coal importing countries, and in particular a greater number of prices for the earlier decades of 1870-79 and 1880-89 such as for Brazil and Uruguay. The closed gaps of the linear interpolations in *Interpolated* allow for the inclusion of a few further decades for some countries. The most significant and welcomed effect of the data additions is an almost 30% larger sample of *Interpolated* as compared to *Robust*. The effect, though, on the average size and standard deviations of the variables is small. The most meaningful difference is that the means of *gdp_pc_start*, *gdp_start*, and *start_wage* are a bit lower. A higher share of coal importing countries, which were on average poorer

³⁴¹ Number of clusters is the sample of 23 countries minus Singapore, Hong Kong and South Africa where *ch* is not available (it is available for South Africa from 1920, but reliable wage data only until 1913).

than countries with domestic deposits, and the larger share of prices from the beginning of the observation period, explain this difference. Again, this is also reflected in lower values for *schooling*, and particularly *polityIV*, in *Interpolated* and *Default* as compared to *Robust*. The differences between the three datasets on the individual data point level (country & year) can be found in Table A7.

4.4. Descriptive statistics

4.4.1. Manufacturing output growth

I have divided my country sample for the following statistical exercise into three groups of countries that (1) produced domestic coal throughout the whole period, (2) developed a domestic coal industry during the period, and (3) predominately remained dependent on imports. The first group consists of Australia, Germany, Britain and the US. The second group contains China, France, India and South Africa. France is an ambiguous case since it had a considerable domestic coal industry. However, since it developed mines comparatively later than for example Germany and Britain, and continued to import foreign coals accounting for around 30% of the domestic consumption, it fits better in the second group. The third group encompasses thirteen countries from Europe, Northern Africa and Latin America. Table 4.3 below gives the ten-year average manufacturing growth rates per group. For a few countries manufacturing output growth rates are not available for the complete period. The data for China, for instance, only becomes available by 1890. I have therefore calculated the group averages across all countries, a slightly unbalanced panel, and across a consistent sample for all countries with available data from 1870 to 1940. The growth rates for each individual country, and when they become available, can be found in Table A8.

Countries	1870-79	1880-89	1890-99	1900-09	1910-19	1920-29	1930-40	1870-1940
All								
Coal	2.9	5.0	2.9	3.4	2.8	4.0	2.8	3.4
Developers	0.5	1.9	4.5	4.3	6.8	7.1	4.2	5.9
No coal	3.6	5.4	4.7	3.1	3.0	5.3	3.4	4.1
Con. sample								
Coal	2.9	5.0	2.9	3.4	2.8	4.0	2.8	3.4
Developers	0.5	1.9	2.0	1.8	-0.3	5.6	1.1	1.8
No coal	3.6	5.8	5.0	3.3	2.6	5.8	2.6	4.1

Table 4.3: Average annual manufacturing output growth rate per decade 1870-1940 (in %)

Source: data from A Bénétrix, K. O'Rourke & J. Williamson, 'The Spread of Manufacturing to the Poor Periphery 1870-2007', *Open Economics Review*, Vol. 26, No. 1, (2015).

Based on the consistent sample, manufacturing output growth was on average 4.1% p.a. for countries without coal as opposed to coal-mining countries with 3.4% p.a. When comparing the averages across all countries, which includes countries where data becomes available after 1870, the developers show the highest growth rate with 5.9%. This value is driven by China and South Africa, which experience strong growth always exceeding 6% once data become available from 1890, China, and 1910, South Africa (see Table A8). Since later data availability is a sign of a later start of the industrial development process, this exemplifies that growth rates were higher in the early phase of that process when manufacturing output was at very low levels. The coal-producing countries Britain, US, Germany and to some extent Australia, are relatively early industrialisers whereas the other two groups contain a majority of peripheral countries that industrialised later. Britain, US and Germany may have experienced higher growth rates pre-1870. Examining GDP growth rates allows for investigating this thought in more detail, since the data available go back to 1820, as shown below in Table 4.4.

	1820- 29	'30- 39	'40- 49	'50- 59	'60- 69	'70- 79	'80- 89	'90- 99	1900- 09	'10- 19	'20- 29	'30- 40	1820- 69	1870- 1940
Con. sample														
Coal	4.1	5.0	4.8	8.4	3.4	4.1	3.5	2.9	3.5	0.6	2.9	3.5	5.1	2.8
Dev.	0.8	1.5	1.0	1.3	0.3	1.2	1.3	1.4	1.4	-0.2	3.8	-0.2	1.0	1.2
No coal	1.7	1.6	1.6	1.9	1.8	3.1	2.7	2.8	3.9	2.3	4.8	1.4	1.7	3.0

Table 4.4: Growth in GDP per decade 1820-1940 (in %)

Source: based on Maddison's GDP data (1990 Int. Geary–Khamis dollar)

The GDP growth rates of Table 4.4. are calculated for the same consistent sample as in Table 4.3, with the slight difference that Argentina and Uruguay are not available for the decades pre-1870. The GDP growth figures are considerably lower than the previous manufacturing output growth figures, yet there are similarities. Countries without domestic coal production show 0.2% higher GDP growth than coal-producing countries throughout the observation period 1870 to 1940, where this order also holds for manufacturing output growth. More importantly though, Table 4.4 confirms my previous speculation that during the early phases of coal mining, here illustrated by the period 1820-69, coal-producing countries grew significantly more – 5.1% vs. 1.7% – than countries without own coal production. We should keep in mind that this period pre-1870 is not part of the following regression analyses, and that the difference in GDP growth between groups noted above had vanished post-1870.

Manufacturing output growth is the preferable measurement for this investigation of the adoption and diffusion of technology since GDP per capita figures could also be driven by, for example, the growth of private consumption. However, manufacturing output growth was a strong contributor to GDP growth in the nineteenth century and thus the high GDP growth rates of coal-producing countries from 1820 to 1870 most probably also meant higher manufacturing output per capita rates. Therefore, the start of my investigation period of 1870 leaves out the greater part of the nineteenth century when industrial development began to spread. During this period, coal price differences were

more pronounced and steam engines less efficient and the effect of the coal price/wage ratio may have been even greater than what this investigation may find.

4.4.2. Graphical analyses

The graphical inspection as shown in Figure 4.1 reveals a striking negative correlation between the GDP level per capita of the sample countries and their coal price/wage ratios. The cheaper coal was, and the higher wages were, the wealthier a country was between 1870-79. The relationship looks similar to a decreasing logarithmic function with a long tail and an increasing slope towards zero. The relationship still holds for the period 1900-09 and the addition of Egypt and Singapore. Wages should be positively correlated with GDP p.c. and therefore the results are not so surprising. However, the graphs on the right hand-side plotting the coal price on the x-axis confirm that the coal price on its own is negatively correlated with GDP per capita. Forming the ratio with wages leads to a more curved and steeper slope.

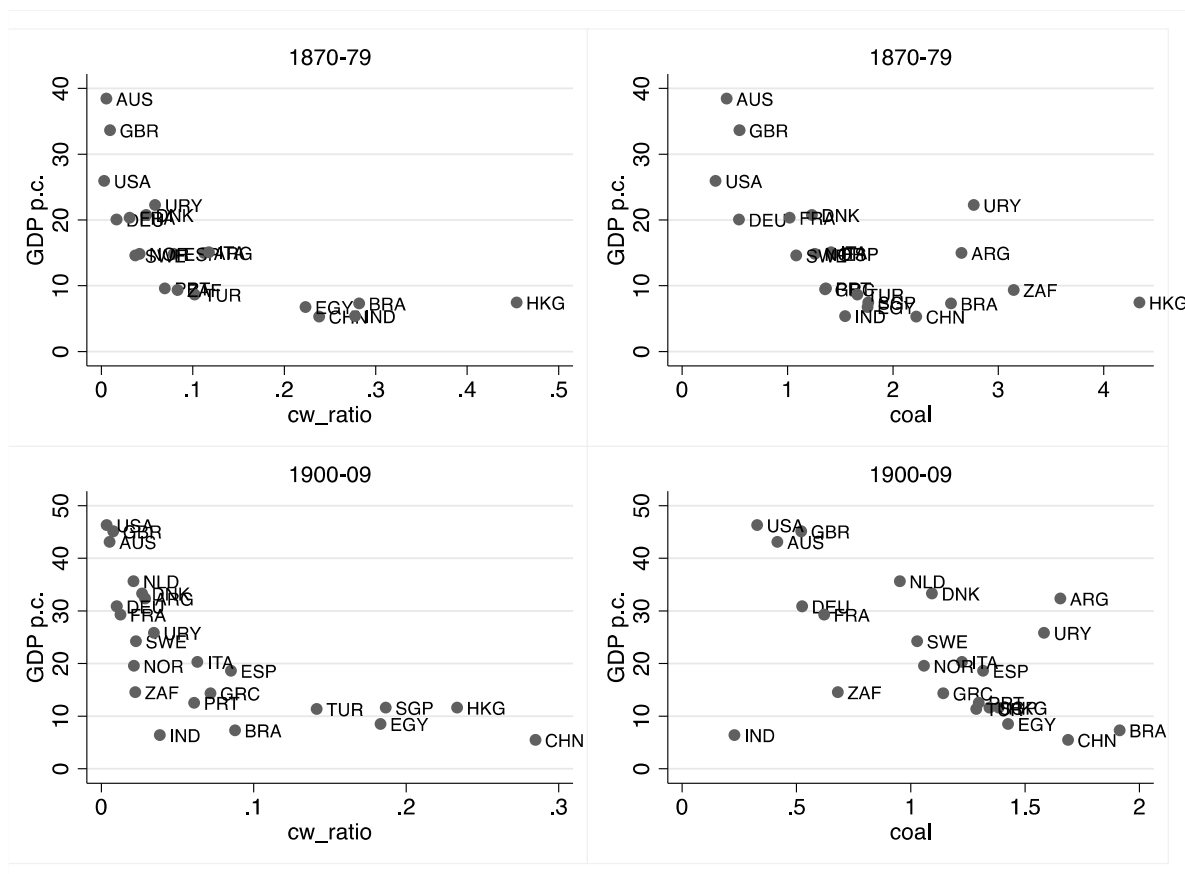


Figure 4.1: Scatter plots cw-ratio and coal price on GDP per capita

Notes: GDP per capita in 100USD (GK); cw_ratio is the coal price in GBP/t divided by the annual wage in GBP of the respective year; coal is the coal price in GBP/t.

On a country level, Uruguay and Argentina show very similar coal price/wage ratios to Denmark and other countries during both periods. However, both countries stand out in the right-side graph in that they were relatively rich and had high coal prices. Here taking the ratio aligns Uruguay's and Argentina's experience with the common trend of all countries, and suggests that the price of coal on its own was probably not a decisive determinant of economic development, and indeed the ratio and technology diffusion may have mattered more.

The right hand-side *coal* graphs show a significant drop in the coal prices of South Africa and India between 1870-79 and 1900-09, reflecting the emergence of domestic coal mining in those two countries. They did not converge to the GDP p.c. level of countries with similarly low coal prices. This could either indicate that it took more years to benefit

from lower coal prices and to establish this relationship, or that this relationship did not emerge anymore for countries that developed coal mining in the early twentieth century. While I do not want to over-emphasise this observation, let us think once more about the underlying mechanism. In principle, the causation could have gone in two different directions, or even in both directions at the same time: cheap coal may have led to higher incomes as measured by GDP per capita. Or alternatively, since relatively rich countries may simply have had acquired the skills and technology to exploit coal resources, cheap coal is a result rather than a cause of development. The graphs cannot reveal even a tentative answer to this question, but it appears that it is therefore very important to control for the initial levels of GDP, and I will control for them, since otherwise the coal price/wage ratio might act as a proxy for GDP levels.

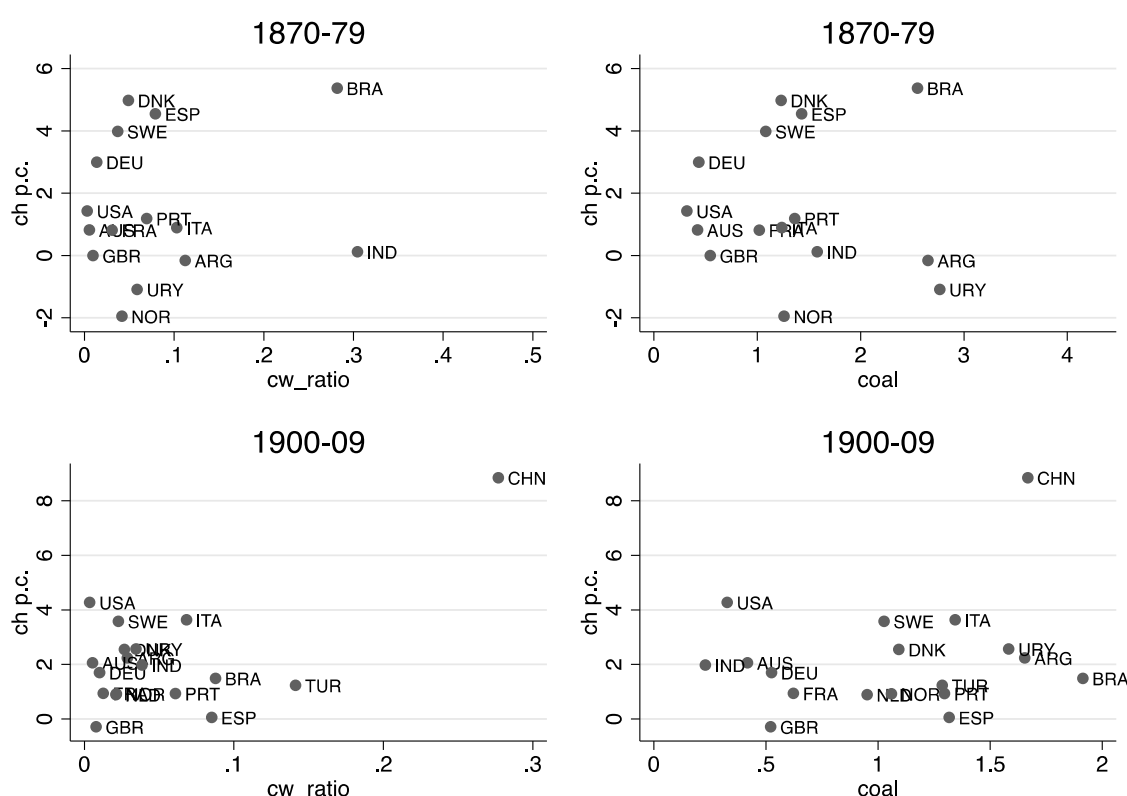


Figure 4.2: Scatter plots cw-ratio and coal price on manufacturing output growth per capita

Notes: ch is the estimated average manufacturing output growth per capita rate for the decade indicated, where the population growth rate, calculated from Maddison's population size data, has been subtracted from manufacturing output growth; cw_ratio is the coal price in GBP/t divided by the annual wage in GBP of the respective year; $coal$ is the coal price in GBP/t.

If a low coal price/wage ratio, or low coal prices, would be negatively correlated with the manufacturing output growth rate per capita, this would bring us closer to potentially observe a causal mechanism. As Figure 4.2 shows, such a negative correlation can not be identified clearly in neither of the two periods, nor when examining the coal price individually. If there is a correlation, it is obstructed by other determinants, and the following econometric analysis will attempt to filter out the effect of the coal price/wage ratio.

4.5. Regression analysis

4.5.1. Specification

The linear regression models aim to identify the effect of coal prices relative to wages on manufacturing output growth while controlling for other potential determinants. The baseline fixed-effects specification is as follows

$$ch_{c,t} = \beta_0 + \beta_1 start_cw_ratio_{c,t} + \beta_2 t_fe_t + \beta_3 tariff_{c,t} + \beta_4 schooling_{c,t} + \beta_5 land_{c,t} + \beta_6 institutions_{c,t} + \beta_7 start_GDP_{c,t} + \beta_8 start_pop_{c,t} + \beta_9 c_{fe_c} + \varepsilon_{c,t}$$

where β stands for each coefficient, c for each of the 20 countries and t indicates the seven decades from 1870-79 to 1930-40. The independent variable $ch_{c,t}$ stands for the average manufacturing output growth rate during a decade t of country c . Ten year averages of ch are used in order to smooth out business cycle movements; especially in the first decades of recorded manufacturing output growth rates were very volatile. For

instance, during 1870-79 the minimum value of ch for Brazil was -19.4% (1879) and the maximum 52.5% (1870).

The main dependent variable is the coal price measured in GBP per t divided by the annual wage of an unskilled worker in GBP in the start year of each decade (i.e. coal price 1870/annual wage 1870 on ch 1870-79). The specification of the ratio has been carefully chosen since it offers multiple advantages. First, we do not have to worry about inflation; while real wages have been calculated, it would have been difficult to find an adequate deflator for the coal price of such a large set of countries and a long time period. A second important consideration is endogeneity; there might be reverse causality and/or the coal price/wage ratio might be correlated with the error term due to omitted variable bias. Reverse causality means that the causation could run from manufacturing output growth to changing the coal price/wage ratio. For instance, an expanding industrial sector may drive wages up and perhaps also initiate improvements in transportation infrastructure, or even new explorations of mines, eventually leading to lower coal prices. However, I use the level of coal prices and wages, and not their growth rates, which takes away power from the previous argument. Even more importantly, this problem is avoided by using the ratio at the start of each period since industrial growth cannot determine past coal prices and wages. In order to address the omitted variable bias, I include other major potential determinants of manufacturing output growth as control variables.

Since an instrumental variable approach is a common way of circumventing endogeneity issues, its feasibility needs to be considered here. It seems very difficult to find a decent instrument for $start_cw_ratio_{c,t}$. While GDP lagged by twenty years would be sufficiently correlated with the ratio, it is difficult to argue that the lagged GDP would not have a direct effect on industrial growth. Alternatively, but equally unsatisfying, were my attempts to instrument for both factors – coal prices and wages – separately. I used distance to Cardiff as an instrument, but it only turned out to be a weak instrument, and it

is not completely free from endogeneity concerns, since proximity to Britain may have mattered for the adoption of coal based technology.³⁴² Distance to the nearest mine would certainly be more correlated with coal prices but is even more endogenous, since demand from industry incentivises the opening of mines.³⁴³ Even more difficult to find are potentially suitable instruments for wages, since for example unemployment is also affected by manufacturing output growths. In consequence, instrument variables do not appear as an entirely endogeneity-free and feasible approach.

Depending on the specification, there are a number of other controls that have been discussed in Section 4.2.1. Therefore, I will outline the construction of those variables here. Following an established tradition in the trade literature, I use the import weighted ad valorem tariffs (AVE) derived by dividing import tariff revenues by import values for $tariff_{c,t}$. This means that a higher value corresponds to more restricted trade, and we should expect a negative coefficient. The data comes from Clemens and Williamson, with the additions of the Netherlands from Lampe and Sharp, and South Africa from Bent.³⁴⁴ $schooling_{c,t}$ measures the average years of schooling of the population aged fifteen or older. The data stems from Morrisson and Murtin and Foldvari, van Leeuwen and van Leeuwen-Li for China.³⁴⁵ The institutional quality variable is taken from the PolityIV

³⁴² In the first-stage regression the F-value statistic is only 1.04 when using *start_coal*, and 7.28 with coal (thus more observations). Both fall short of 10, which is believed to be the threshold indicating a strong instrument. This only worked without country-fixed effects, since distances do not vary over time. If the results would have been more promising, one could have multiplied the distance to Cardiff by coal production in Wales, or some other related factor, in order to make the instrument time-variant.

³⁴³ An option would be to calculate distance to the nearest coal supplying country today when one could argue that all exploitable coal deposits have been found and accessed. But then again Germany and the UK import the larger share of their coal consumption, and thus today's distances wouldn't correlate well with prices pre-WWII for European countries.

³⁴⁴ M. Clemens and J. Williamson, 'Where did British Foreign Capital Go? Fundamentals, Failures and the Lucas Paradox 1870-1913', NBER Working Paper Series, No. 8028, (2000), M. Lampe and P. Sharp, 'Tariffs and Income: A Time-Series Analysis for 24 Countries', *Cliometrics*, Vol. 7, No. 3, (2013), P. Bent, personal communication, 09 April 2016

³⁴⁵ C. Morrisson and F. Murtin, 'The Century of Education', *Journal of Human Capital*, Vol. 3, No. 1, (2009), J. van Leeuwen, J. van Leeuwen-Li, Foldvari, P., 'Average Years of Education (Average, Total Population 15 Years and Older), 1850-2010', *Working Paper CLIO-INFRA*, Available from: <https://www.clio-infra.eu/datasets/>, accessed 09 May 2016

database.³⁴⁶ This variable $institutions_{c,t}$ measures institutional quality according to the polity score scale from -10 to +10. Since Hong Kong and Singapore were British colonies during the investigation period, data on these three control variables are not available (the institutional quality variable for Egypt only becomes available in 1922). $land_{c,t}$ is the hectares of usable land (crop land and pasture) divided by the population size per country taken from Goldewijk.³⁴⁷

In every specification, I control for time and country-fixed effects. In OLS-models country-dummies would be included – c_fe_t – while my preferred fixed-effects estimation automatically controls for time-persistent differences between countries.³⁴⁸ t_fe is a decade-fixed effect controlling for common time trends.

In order to account for changing differences between countries, GDP at the start of each decade, and alternatively GDP per capita, are used as further controls. GDP and GDP per capita are measured in 1900 Int. GK m\$ and taken from Maddison.³⁴⁹ How rich (GDP per capita) or how large economies were (GDP) may also affect the development of its industrial sector. And more importantly, as I have stated in Section 4.2.1, the coal price/wage-ratio is correlated with GDP p.c., and therefore GDP p.c. should be included as an individual factor. In addition, $start_pop_{c,t}$ stands for the population size at the start of each decade, and is used as a control (the data come again from Maddison). $\varepsilon_{c,t}$ is the idiosyncratic error term. In all specifications, standard errors are clustered at the country level.

³⁴⁶ M. Marshall. 'Polity IV Project: Political Regime Characteristics and Transitions, 1800-2012', Available from: <http://www.systemicpeace.org/polity/polity4.htm>, accessed 25 August 2013

³⁴⁷ K. Goldewijk, 'Pasture Per Capita by Decade and Country', *Working Paper CLIO-INFRA*, Available from: <https://www.clio-infra.eu/datasets/>, accessed 05 May 2016, K. Goldewijk, 'Cropland Per Capita Area by Decade and Country', *Working Paper CLIO-INFRA*, Available from: <https://www.clio-infra.eu/datasets/>, accessed 06 May 2016

³⁴⁸ The applied STATA command is `xtreg...., fe`.

³⁴⁹ A. Maddison, 'Statistics on World Population, GDP and Per Capita GDP', at <http://www.ggdc.net/MADDISON/oriindex.htm>, accessed 09 December 2012

4.5.2. Results

The main results presented here use the *Robust*-dataset since it does not involve any interpolations. If those regressions are significant, we can be more confident in the results. The fixed effects model removes all constant variation, for example between countries, and decadal fixed effects are included. Running the following regression specifications as OLS-models with country dummies gives slightly higher standard errors but the same coefficients. Table 4.5 states the main results of this chapter.

	(1)	(2)	(3)	(4)	(5)	(6)
start_cw_ratio	-8.924** (3.387)	-8.853** (3.342)	-8.626** (3.335)	-8.889** (3.240)	-8.858*** (3.049)	-8.851*** (3.046)
tariff	12.528** (5.705)	13.686** (6.094)	14.237* (6.825)	13.641** (5.821)	13.718** (5.969)	13.665** (6.207)
start_gdp		0.003 (0.003)	0.003 (0.003)	0.004 (0.003)		
start_gdp_pc					0.857 (0.808)	0.875 (0.842)
start_pop						-0.002 (0.024)
land				0.070 (0.046)	0.082 (0.060)	0.083 (0.061)
schooling				-1.885** (0.788)	-2.191** (0.945)	-2.215** (0.932)
institutions				-0.061 (0.066)	-0.123 (0.080)	-0.127 (0.093)
Decadal FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
R^2	0.38	0.39	0.40	0.44	0.44	0.44
N	92	92	85	85	85	85

Table 4.5: FE-estimation results, *Robust*-sample, 1870-1940

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors are clustered at the country-level.

Column (1) shows that *start_cw_ratio* is significant at the 5%-level in the baseline specification, and confirms that a higher ratio of coal prices to wages reduces manufacturing output growth. Trade openness is also significant at the 5%-level and positive, which means that the higher tariff revenues were relative to import values, the higher was manufacturing output growth. This is in line with my expectation that was informed by Lehmann and O'Rourke's as well as Clemens and Williamson's findings on a negative relationship between economic growth and trade openness reaching up to World War II.³⁵⁰ The adjusted-R² is 0.38 and increases to 0.44 through the addition of further controls shown in columns (4) to (6).

The controls *land*, *schooling* and *institutions* are included for the first time in column (4). These controls are only available for a slightly smaller sample with 85 observations. Therefore (3) is using the same specification as (2) with the smaller sample in order to show that results are not driven by the differences in sample size. While *land* is not significant, it is close to the 10%-significance threshold indicating that perhaps more land abundant countries experienced higher manufacturing output growth. *institutions* is always insignificant. In contrast, *schooling* is significant at the 5%-level and always negatively correlated with *ch*. While we would in principle expect that human capital accumulation should benefit economic growth, I am not the first one to come across this puzzle. According to Taylor, human capital proved unsatisfactory to explain economic convergence for the period from 1870 to 1914 between five European countries, the US and Australia.³⁵¹ As another potential explanation, we should remember that if education is positively correlated with the wage level, it enters the coal/wage ratio, and in the ratio higher wages would lead to higher manufacturing output growth.

³⁵⁰ S. Lehmann and K. O'Rourke, 'The Structure of Protection and Growth in the Late Nineteenth Century', *Review of Economics and Statistics*, Vol. 93, No. 2, (2011), M. Clemens and J. Williamson, 'Why did the Tariff-Growth Correlation Change After 1950?', *Journal of Economic Growth*, Vol. 9, No. 1, (2004)

³⁵¹ A. Taylor, 'Sources of Convergence in the Late Nineteenth Century', *European Economic Review*, Vol. 43, No. 9, (1999)

The control variable *start_gdp* is included from specification (2) to (4) and shows a positive sign being always, yet insignificant. The same counts for *start_gdp_pc* shown under (5) is positive but insignificant, though both turn significant in the *Interpolated*-dataset and will be discussed then. Accounting for population size separately, *start_pop* in (6) shows a negative and insignificant coefficient, with very little effect on the size of the *start_gdp_pc* coefficient. Since I have previously stressed that GDP per capita might be correlated with the coal price/wage ratio, I have also run all specifications of Table 4.5 including *start_gdp_pc*, and not *tariff*, from the start as shown in Table A9. However, this modification does not alter my main results; GDP per capita is insignificant while the coal price/wage ratio coefficient remains significant and negative. This also proves that the ratio is independent of whether the *tariff* control is included or not.³⁵²

Coming back to our main indicator *start_cw_ratio*, it appears to be very similar in all specifications reaching -8.89 in the full specification of column (4) of Table 4.5. If we form the coal price/wage ratio using the mean coal prices of 2.22GBP/t and the mean annual wage of 71.79GBP, both stated in the column for the *Robust*-dataset of Table 4.2, we get a coal price/wage ratio of 0.031. A doubling of the coal prices, or alternatively a decrease by half of the wage level, would increase the ratio to 0.062, or by 1/32 of a unit change. This translates into a decrease of *ch* by 0.28%. Though undoubtedly hard to judge, it appears very plausible that a significantly higher coal price, or lower wage level, marginally reduced growth, but that the majority of manufacturing output growth was determined by other factors.

³⁵² Amid efforts to allow for an easy comparison, Table A10 contains the same regression specifications as Table A9, with the sole difference being that *start_gdp* instead replaces *start_gdp_pc*.

	(1)	(2)	(3)	(4)	(5)	(6)
start_cw_ratio	-3.635** (1.406)	-3.664** (1.393)	-3.405** (1.551)	-3.729** (1.741)	-3.549** (1.645)	-3.538** (1.621)
tariff	18.510** (6.598)	19.220*** (6.642)	20.678** (7.593)	20.759*** (6.914)	21.075*** (7.107)	21.007*** (7.212)
start_gdp		0.003 (0.003)	0.003 (0.003)	0.005* (0.003)		
start_gdp_pc					0.986* (0.535)	1.002* (0.503)
start_pop						-0.003 (0.023)
land				0.026 (0.057)	0.035 (0.052)	0.035 (0.052)
schooling				-0.960 (0.748)	-1.232 (0.724)	-1.246* (0.706)
institutions				-0.003 (0.067)	-0.057 (0.077)	-0.060 (0.079)
Decadal FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
R ²	0.34	0.35	0.35	0.37	0.37	0.37
N	119	119	119	111	111	111

Table 4.6: FE-estimation results, *Interpolated-sample*, 1870-1940

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors are clustered at the country-level.

The results employing the larger *Interpolated-sample* as shown above, confirm my previous observations. *start_cw_ratio* is significant in all specifications and always shows a negative effect. The size of the coefficient is smaller and reaches -3.729 in (4), which is around 60% smaller than in the *Robust-sample*. *tariff* is positive, significant and considerably larger. Noteworthy changes are that *start_gdp* in (4) as well as *start_gdp_pc* in (5) and (6) turn significant as compared to the *Robust-sample*. Thus, the larger the economy, the larger manufacturing output growth was. This implies that economic divergence between countries continued. This is in line with the coefficient on GDP per capita, representing a higher level of economic development, which is positively correlated

with manufacturing output growth. Overall, the chosen variables explain less of manufacturing output growth with an adjusted- R^2 of up to 0.37. The results of the *Default* - sample have been included in Table A11, since they are very similar to, and support the results displayed in, Table 4.6. When running the previous regression specification with including coal prices and the wage level as separate variables, it turns out that both are insignificant. This observation, increases our confidence further that indeed a lower coal price/wage ratio – rather than both factors individually – had a negative effect on manufacturing output growth during the period 1870 to 1940.

4.5.3. Robustness checks

Apart from the three different samples, there are a few other ways in which we can check the robustness of my results. Table 4.7 below presents slightly different specifications. The decade 1910-19, due to World War I, was characterised by coal scarcity and rocketing prices. This led to increased efforts, for example by the Netherlands, to expand domestic coal mining. Therefore, I have excluded the World War I decade, but it does not influence my results. Similar to the coal price/wage ratio, there might be some time lag until the other explanatory variables may have affected *ch*. Since the main right-hand side variables *tariff*, *schooling* and *institutions* measured by decade, I have lagged them by 10 years or one period. In this specification, *start_cw_ratio* remains highly significant, while the lack of significance of *tariff* perhaps indicates that increasing trade barriers have a more pronounced short-term effect.

	(excl. WWI)	(lagged controls)	(w/o quality adust.)
start_cw_ratio	-8.833** (3.247)	-12.094*** (3.790)	-12.214* (6.724)
tariff	14.123** (5.884)		22.905*** (7.676)
land	0.061 (0.043)		-0.011 (0.077)
schooling	-1.889** (0.840)		-0.240 (1.130)
institutions	-0.053 (0.068)		0.069 (0.089)
start_gdp	0.004 (0.003)		0.008*** (0.003)
tariff10		18.226 (11.146)	
land10		0.096 (0.085)	
schooling10		-0.760 (1.147)	
institutions10		0.025 (0.149)	
start_gdp10		0.004 (0.004)	
Decadal FE	YES	YES	YES
Country FE	YES	YES	YES
R^2	0.44	0.40	0.40
N	75	77	85

Table 4.7: FE-estimation robustness checks, *Robust*-sample, 1870-1940

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors are clustered at the country-level.

While the previous two checks proved robustness to different specifications and whether the sample included price interpolation, this last check is supposed to confirm that my coal quality adjustments did not determine the results. The data of the regression results of the last column in Table 4.7 contain prices for the same countries and years as *Robust*, but I have always taken the cheapest price at a port before quality adjustment. The danger is that coal importing countries usually consumed higher quality coal since, due to the high transportation costs, it was most sensible to get as much power for the transportation expense. In contrast, close to the mines cheaper coals were also consumed. So, not adjusting coal prices tends to widen price gaps between importing (consuming

rather higher quality coals) and exporting countries (also consuming lower quality coals). The last column of Table 4.7 shows the results using the *Robust*-data set without carbon-content based quality adjustments. *start_cw_ratio* is still significant and larger in size, and the same applies to *tariff* when compared to the quality adjusted results of Table 4.5. The adjusted R-squared is four percentage points lower, which implies that the quality adjustments indeed help to improve the data quality. Nevertheless, those results confirm that the conclusions drawn are not dependent on my way of adjusting for quality.

4.6. Conclusion

Allen's argument can be extended in that the coal price/wage ratio did not only incentivise the start of the Industrial Revolution in Britain during the eighteenth century, but it also mattered for the spread of industrial development to further countries during the late nineteenth and early twentieth century. My regression results confirm a robust negative effect of the coal price/wage ratio on manufacturing output growth. Depending on the sample, the estimated effect of a 50% increase in the coal price, holding the wage constant, on manufacturing output growth varies between 0.32% (*Robust*-sample) and 0.13% (*Interpolated*-sample). These estimates may rather understate the ratio's importance. The investigation period only started in 1870, when industrialisation had already spread at least across Europe. In addition, manufacturing output data are often not available for the initial years of industrial expansion in a country. However, especially in the years pre-1870, the coal price/wage ratio may have been more decisive, since steam engines became more efficient over time and substitutes for coal became available. There still remains ample room for other factors to have determined industrial development, and my results show, for

example, that the more closed countries were, the more able their economies were to generate manufacturing output growth.

Undoubtedly, there are a few limitations to this study, which often stem from data considerations. As mentioned above, it would be interesting to see the effect on manufacturing output pre-1870 specifically for early industrialising countries; while such data are currently not available, it does not appear impossible that estimates will become available for the US and a few European countries. Similarly, while the dataset has a wide geographic scope, perhaps more landlocked countries, as well as Japan, could be added. However, the number of potential additions is indeed quite limited, so it would be surprising if they would significantly affect the results. Finally, as outlined, identifying strong instrumental variables for coal and wage separately, would be another way of removing endogeneity. So far, I have tried to mitigate the problem by using the lagged ratio and including arguably the most important controls.

5. Concluding Remarks

This thesis has investigated coal prices in relation to trade, to the spread of coal mining and market integration, and as a determinant of technology adoption. The scale of this undertaking was increased by the global framework of the study and the long timeframe from 1840 to 1960, which crosses otherwise convenient boundaries such as World War I and World War II. This scope was only possible, while allowing for sufficient depth at the same time, by basing the investigation on the global market for bunker coals. This offered both a framework and the essential coal price data. The case study allowed me to view trade and resource abundance not as distinct determinants of economic growth, but rather as having separate and combined effects on global coal price differences; and, as a result of this, influencing the relative prices of coal and labour, and thus influencing the spread of industrial growth.

By using the bunker coal market as the nucleus, this thesis makes a contribution to the literature in three major ways. Finding coal price data for the nineteenth and twentieth centuries, especially for peripheral countries, remained a major challenge until I realised that the contemporary shipping literature offers a wealth of such data. Price currents reported bunker coal prices for a large number of ports and coal types. While not many original price currents seem to have survived, I found their prices reported in trade publications and other sources, allowing me to build up perhaps the largest, global dataset of historical coal prices. I believe that these data may prove fruitful for future research, especially for cross-country econometric analyses using coal prices as one potential

explanatory variable. Second, the demands for bunker coal quality around the world were practically the same and Welsh bunker coals were exported far afield. Comparing Welsh coal quotations was one way to compare like-with-like. The quality adjustment based on contemporary accounts of carbon content was a second way of removing quality differences. Both ways are more rigorous than most existing coal price comparisons, which often ignore differences in quality. And finally, the sources stated prices for major types of coal offered, which was essential in order to track and evaluate changes in competition in the market.

An important source of inspiration for this thesis was Wright's suggestion that the US lost its comparative advantage in resource intensive manufacturing in the first half of the twentieth century through either declining trade costs or increased exploitation of resources in other countries. My findings indicate that, while both mattered, the spread of mining was the decisive factor due to its timing. My second chapter finds that price gaps for Welsh coal between Cardiff, as the major coal exporting port, and a global set of coal importing ports show strong price convergence from the 1880s onwards until the early twentieth century (1840-80 price differences remained volatile without a clear trend). Even though this development fits well with the overall development trajectory of the global economy, coal market integration was markedly different during the interwar period. While the Great Depression, the failure of the interwar Gold Standard and rising protectionism tore world markets apart, this is not evident in coal markets: price gaps remained at the level of pre-World War I thanks to stagnant freight rates and the lack of significant changes to tariff rates.

During the second half of the nineteenth century, British coal was facing increasing competition in the global bunker coal market by Australian, Indian and South African coals, amongst others. This trend continued in the interwar period with the effect of coal mining coming closer to places of consumption as well as more competition between coal

from different origins. Thus, while trade cost improvements had come to a hold, coal production in a greater number of countries and the ensuing competition led to global price convergence during the interwar period, supporting Wright's second hypothesis.

The results of these first two analytical chapters illustrate that a commodity-specific approach can reveal new insights regarding the history of global market integration, and suggest a number of promising avenues of research. A commodity-specific approach appears superior to making inferences from other studies on other commodities, particularly if they are as unique as coal in terms of transport suitability and prominence in tariff considerations. A similar study on the global price differences of iron ore, as the other major input in industrial production, would be interesting. The results of such research could, combined with my findings, allow for a more thorough analysis of why, and where, industrial clusters emerged. In addition, while classic studies of market integration on price convergence of traded products are important, other levels of integration, such as the spread of technology, also need to be considered. I have widened the focus on studying market integration in order to gain a more holistic understanding by examining when and where coal mining spread, as well as the effects on competition. My research on this part is rather descriptive and it would be interesting to document these trends using case studies, which would attempt to explain why coal mining was starting comparatively late or early in a country. Was it a lack of exploration skills and funding, or the conviction that there would be insufficient demand for coal? This brings us back to the fact that coal in itself is a reflection of many factors that could independently contribute to economic growth.

Combining the results from Chapter Two and Chapter Three confirms that domestic coal mining meant a considerable price advantage and raises the question to what extent it mattered. Allen argues that the ratio of high wages and low coal prices resulted in the British Industrial Revolution by incentivising research in coal-based technology. I use this

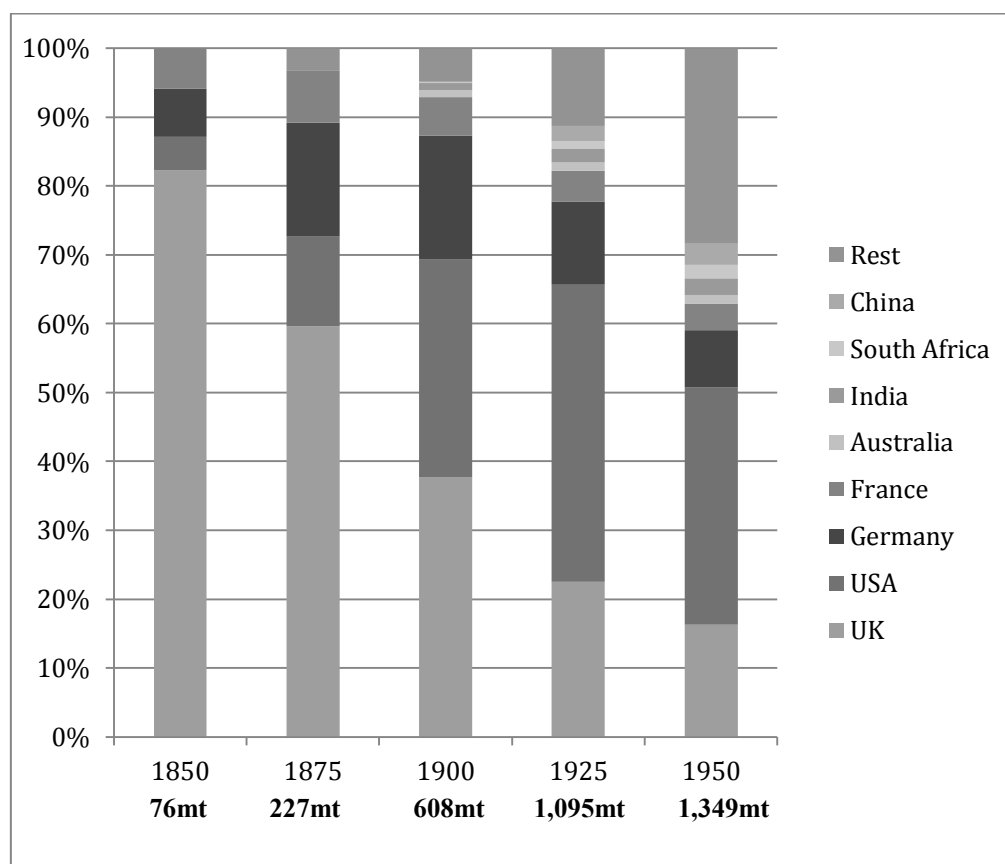
ratio to see whether countries with a similar coal price/wage ratio experienced higher manufacturing output growth during the period from 1870 to 1940. The question is whether this ratio was related to the ease of adoption of the most advanced technology – based on steam engines – and thus to technological diffusion. Countries with a low ratio and countries with low coal prices were indeed richer. I could also throw light on the underlying mechanism since countries with a low ratio at the start of a decade experienced higher manufacturing growth within that decade. This result is robust to multiple changes to the dataset, specifications and inclusion of control variables. It is arguably the most important finding of this thesis that, by increasing the likelihood to use modern technology, cheap coal (relative to wages) influenced industrial development.

Instead of siding with supporters of access to coal as a direct determinant of economic growth, such as Deane, Wrigley or Pomeranz, or opponents on the other side, such as Clark and Jacks or Mokyr, I have suggested a way in which cheap coal, relative to labour, may have led to higher industrial development by easing the diffusion of modern technology.³⁵³ This is not an essay of prediction. It is not supposed to offer direct economic policy implications. Nevertheless, the findings of this thesis have implications beyond economic history, and highlight why economic history is important. The more recent economics literature on the relationship between natural resource exploitation and economic growth has revolved around the “resource curse” – that is, the Dutch disease effect – implying a negative correlation. Most empirical studies derive these results based on data from the post-World War II period. My thesis shows that such results are time-dependent, and may therefore very well change in the future. In times of high transportation costs, and by driving technological progress and diffusion, resource extraction can indeed have positive effects on a country’s growth performance.

³⁵³ P. Deane, *The First Industrial Revolution* (Cambridge, 1965), E. Wrigley, *Energy and the English Industrial Revolution* (Cambridge, 2010), p.21, K. Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World* (Princeton, N.J., 2000), J. Mokyr, *The Enlightened Economy: An Economic History of Britain, 1700-1850* (New Haven, 2009)

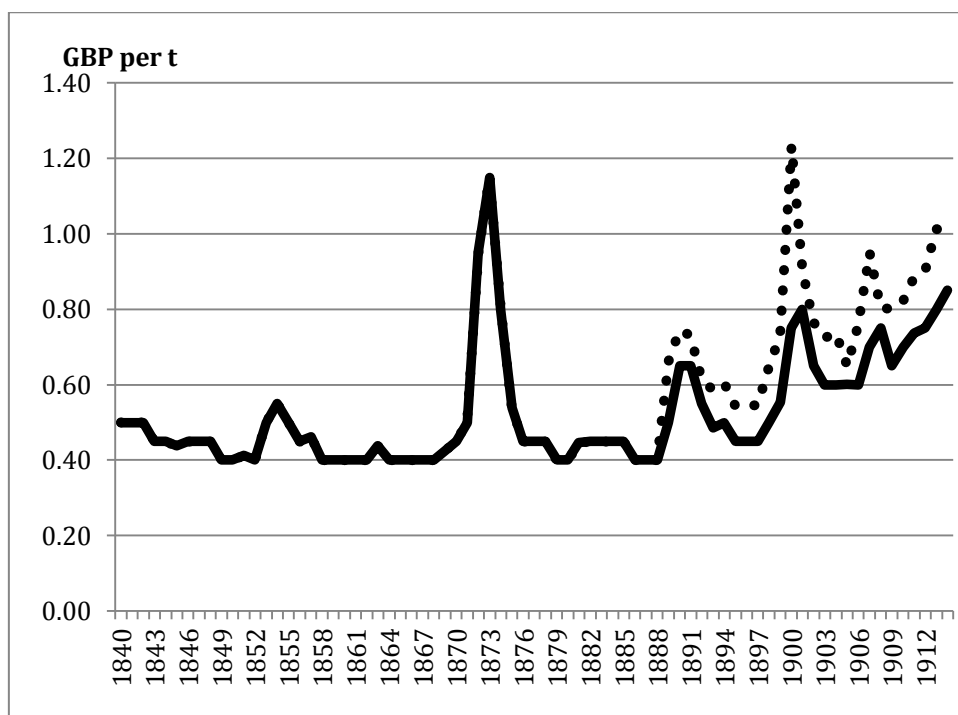
Appendices

Figure A1: Share of countries in global coal production



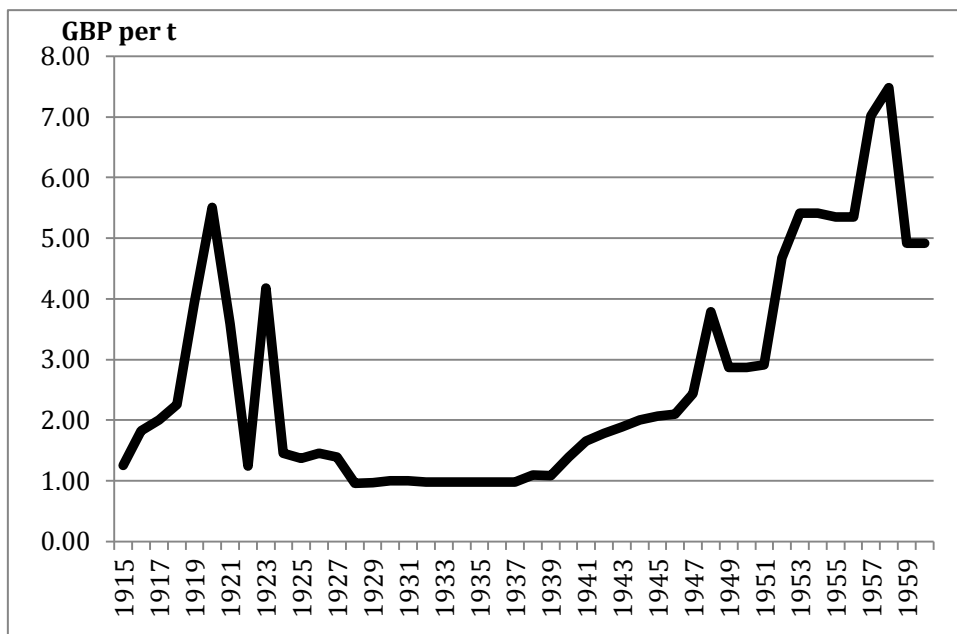
Note: Total coal production in million metric tons for each year is stated under each column. Data come from B. Mitchell, *International Historical Statistics: Africa, Asia & Oceania, 1750-2005*, 5th edn, (Basingstoke, 2007), B. Mitchell, *International Historical Statistics: Europe, 1750-2005*, 6th edn, (Basingstoke, 2007), B. Mitchell, *International Historical Statistics: The Americas 1750-2005*, 6th edn, (Basingstoke, 2007)

Figure A2: Welsh coal price series, 1840-1914



Note: Best steam coal f.o.b Cardiff, solid line: Walter's price series; dotted line: my combined price series from 1888 as described in the text.

Figure A3: Welsh coal price series, 1914-1960



Note: Best steam coal f.o.b Cardiff, 1914-1960

Figure A4: The effect of a change in source of the Cardiff price 1888/89 using my series

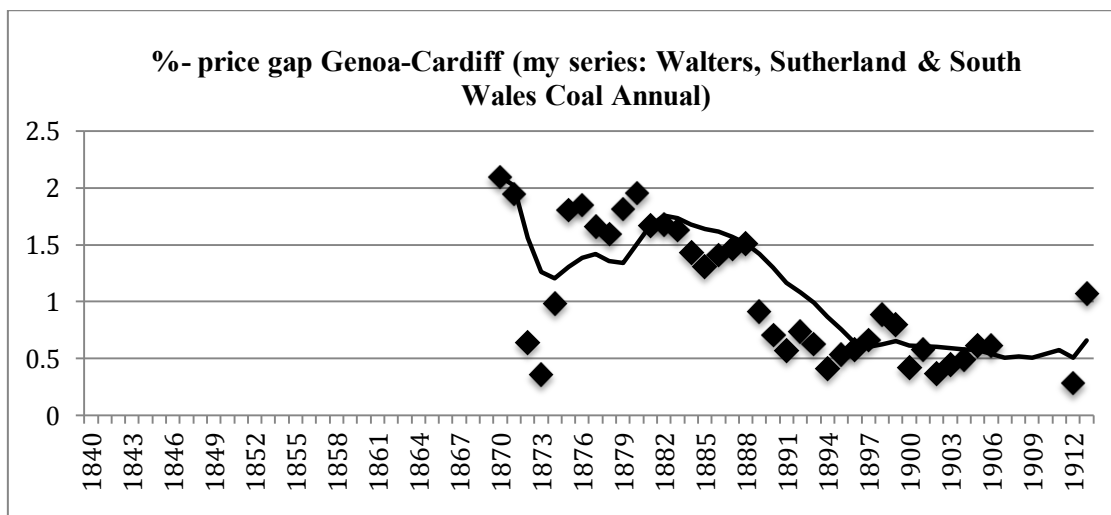


Figure A5: The effect of a change in source of the Cardiff price 1888/89 using Walters series

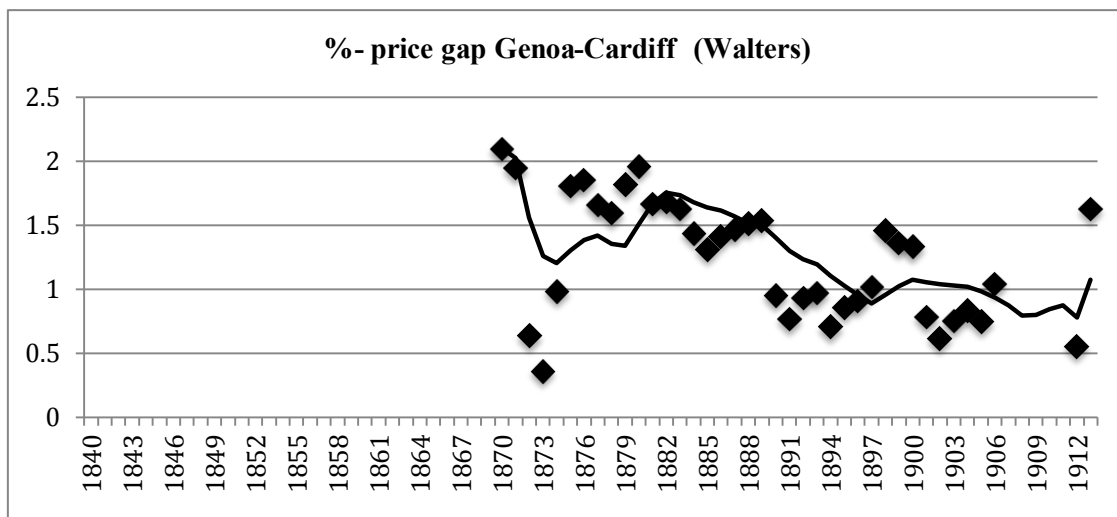
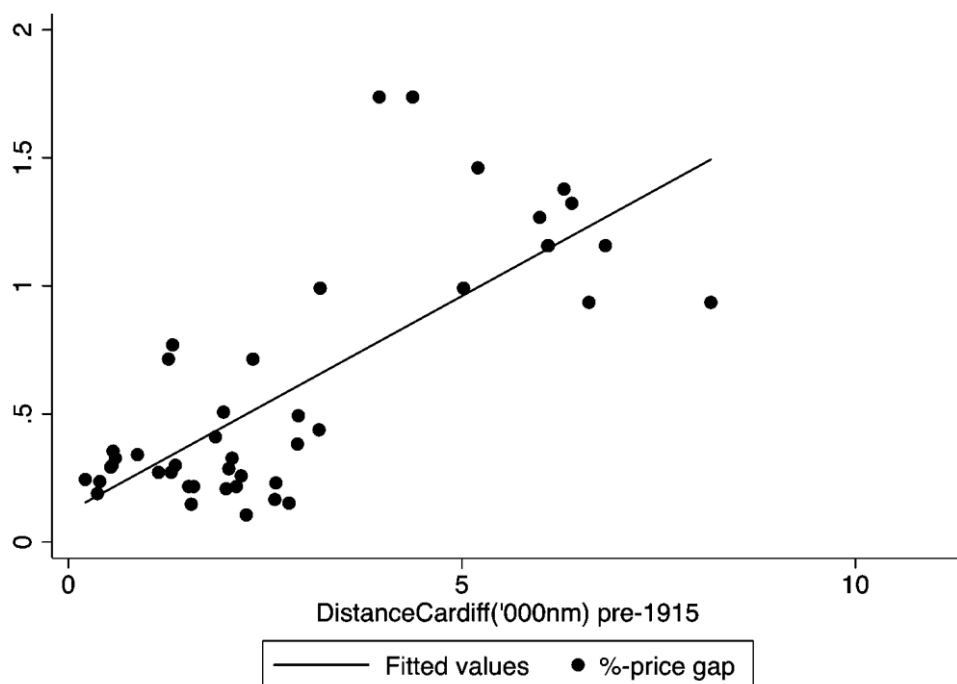


Figure A6: Shipping distances regressed on percentage price gaps in 1912



Note: Label on y-axis, for instance, 2 stands for a price gap of 200%. For the x-axis, for instance, 5 means 5,000nm shipping distance (before the opening of the Panama Canal) from Cardiff to the respective port. For data sources see text.

Figure A7: Coal freight index, 1839-1913 by C. Harley (1989), ‘Coal Exports and British Shipping, 1850-1913’³⁵⁴

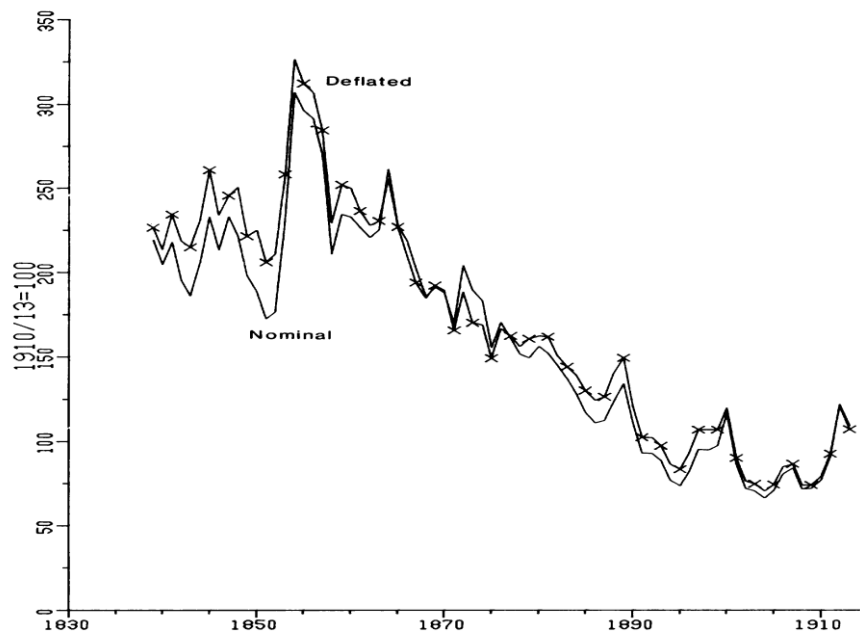


FIG. 2. Coal freight indices, 1839–1913.

Table A1: Coal quality adjustment factors

Country & Coal description	Adjustment factor	Type of Evidence	Carbon content (%)	Source
United Kingdom				
Welsh, best	1		0.88	Kirkaldy (1914), p.611
Durham	1.10	Carbon content	0.80	<i>Ports of the World</i> (1900), p.380
Yorkshire	1.13	Carbon content	0.78	<i>Ports of the World</i> (1900), p.380
Scotch, ordinary	1.26	Carbon content	0.70	<i>Ports of the World</i> (1900), p.380
English North Country Coal	1.07	Usage Ratio / UK exp.		Kirkaldy (1914), p.614 (English shipmaster)
Tyne	1.14	Usage Ratio / US exp.		Kirkaldy (1914), p.614 (American source)

³⁵⁴ C. Harley, 'Coal Exports and British Shipping, 1850–1913', *Explorations in Economic History*, Vol. 26, No. 3, (1989), p.316

Welsh run-of-mine	1.18	Usage Ratio / US exp.		Kirkaldy (1914), p.614 (American source)
Lancashire	1.27	Usage Ratio / US exp.		Kirkaldy (1914), p.614 (American source)
Tyne	1.27	Usage Ratio / US exp.		Kirkaldy (1914), p.614 (American source)
Avg British	1.18			
Avg English	1.16			
United States				
Alabama, Pratt seam, Great Warrior Field	1.37	Carbon content	0.64	<i>Ports of the World</i> , (1900), p.380
Pennsylvania, Clearfield County, Powelton Broadtop	1.13	Carbon content	0.78	<i>Ports of the World</i> , (1900), p.380
Virginia, Pocohontas Flat Top (avg. 10 samples)	1.19	Carbon content	0.74	<i>Ports of the World</i> , (1900), p.380
Virginia, Pocohontas Flat Top (avg. 15 samples)	1.21	Carbon content	0.73	<i>Ports of the World</i> , (1900), p.380
West Virginia, New River	1.25	Carbon content	0.71	<i>Ports of the World</i> , (1900), p.380
American, bituminous	1.21	Carbon content	0.73	Kirkaldy (1914), p.611
Clearfield, as supplied at New York	1.08	Usage Ratio / UK exp.		Kirkaldy (1914), p.614 (English shipmaster)
West Virginian, New River	1.11	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Alabama	1.18	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Pocohontas	1.20	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Australia				
New South Wales, Wallsend	1.09	Carbon content	0.81	<i>Ports of the World</i> (1900), p.382
New South Wales, Waratah	1.10	Carbon content	0.80	<i>Ports of the World</i> (1900), p.382
New South Wales, Mount Kembla	1.42	Carbon content	0.62	Kirkaldy (1914), p.611
Avg. Australian (excl Mount Kembla)	1.09			
Australia, Southern	1.12	Usage Ratio/ UK exp.		Kirkaldy (1914), p.614 (English shipmaster)
New South Wales Coal, Newcastle	1.20	Usage Ratio/ UK exp.		Kirkaldy (1914), p.614 (English shipmaster)
Australia, Brisbane	1.30	Usage Ratio/ UK exp.		Kirkaldy (1914), p.614 (English shipmaster)

Western Australian	1.40	Usage Ratio/ UK exp.		Kirkaldy (1914), p.614 (English shipmaster)
Australian, Newcastle	1.11	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Avg. usage ratio Newcastle	1.16			
Canada				
Nova Scotia, Cape Breton, Sydney Mines	1.44	Carbon Content	0.62	<i>Ports of the World</i> (1900), p.381
France				
French, bituminous	1.05	Carbon Content	0.84	<i>Ports of the World</i> (1900), p.380
Indonesia				
Labuan	1.37	Carbon Content	0.65	<i>Ports of the World</i> (1900), p.380
PuloLaut	1.51	Carbon Content	0.59	<i>Ports of the World</i> (1900), p.380
Taiwan				
Formosa, Keelung mines	1.13	Carbon Content	0.78	<i>Ports of the World</i> (1900), p.380
India				
Indian (average)	1.26	Carbon Content	0.70	Kirkaldy (1914), p.611
Indian	1.34	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Indian	1.20	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Japan				
Japan, Avg. 25 Collieries in Fukuoka Prefecture	1.66	Carbon Content	1.66	Kirkaldy (1914), p.614
Japan, Avg. 4 Collieries in Saga Prefecture	1.67	Carbon Content	1.67	Kirkaldy (1914), p.614
Japan, Avg. 4 Collieries in Nagasaki Prefecture	1.54	Carbon Content	1.54	Kirkaldy (1914), p.614
Japan, Avg. 7 Collieries in Kumonotoi Prefecture	1.09	Carbon Content	1.09	Kirkaldy (1914), p.614
Japan, Avg. 4 Collieries in Hokkaido Prefecture	1.68	Carbon Content	1.68	Kirkaldy (1914), p.614
Japan, Avg. 5 Collieries in Honshu (Main Island) Prefecture	2.40	Carbon Content	2.40	Kirkaldy (1914), p.614
Japanese	1.34	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
Japanese	1.36	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)

Takashima	1.25	Usage experience		CR, Nagasaki for 1867 (1868?), p.238
Chile				
Chilean	1.36	Usage Ratio/ US exp.		Kirkaldy (1914), p.614 (American source)
South Africa				
Natal Navigation	1.13	Carbon Content	0.78	Dominions Royal Commission (1914), p.31
Russia				
Russian, Minus River, bituminous	1.05	Carbon Content	0.84	<i>Ports of the World</i> (1900), p.380
Germany				
Ruhrkohle, Essen	1.03	Carbon Content	0.86	Pechar (1878), <i>Coal and Iron in all Countries of the World</i> , p.72
Ruhrkohle, Bochum	1.03	Carbon Content	0.86	Pechar (1878), <i>Coal and Iron in all Countries of the World</i> , p.72
Ruhrkohle, Dortmund	1.07	Carbon Content	0.82	Pechar (1878), <i>Coal and Iron in all Countries of the World</i> , p.72
Ruhrkohle, Barop	1.13	Carbon Content	0.78	Pechar (1878), <i>Coal and Iron in all Countries of the World</i> , p.72
Ruhrkohle, Witten	1.05	Carbon Content	0.84	Pechar (1878), <i>Coal and Iron in all Countries of the World</i> , p.72
Ruhrkohle, average	1.06	Carbon Content	0.83	

Table A2: List of ports underlying CoV, full sample of 40 ports

Region	Ports per region
Africa	Aden, Port Said, Alexandria, Durban, Maputo, Cape Town
Latin America	Bahia, Montevideo, Recife, Rio de Janeiro, Rosario, Santos, Buenos Aires
Mediterranean	Genoa, Gibraltar, Marseilles, Lisbon, Piraeus, Barcelona, Bilbao, Constantinople

Northern Europe	Amsterdam, Hamburg, Copenhagen, Bergen, Dunkirk, Cardiff
Asia	Sydney, Sinagpore, Hong Kong, Shanghai, Bombay, Colombo, Karachi, Calcutta
North America	Baltimore, Mobile, Newport News, New York, Philadelphia

Table A3: List of ports underlying CoV, small sample with five ports per region

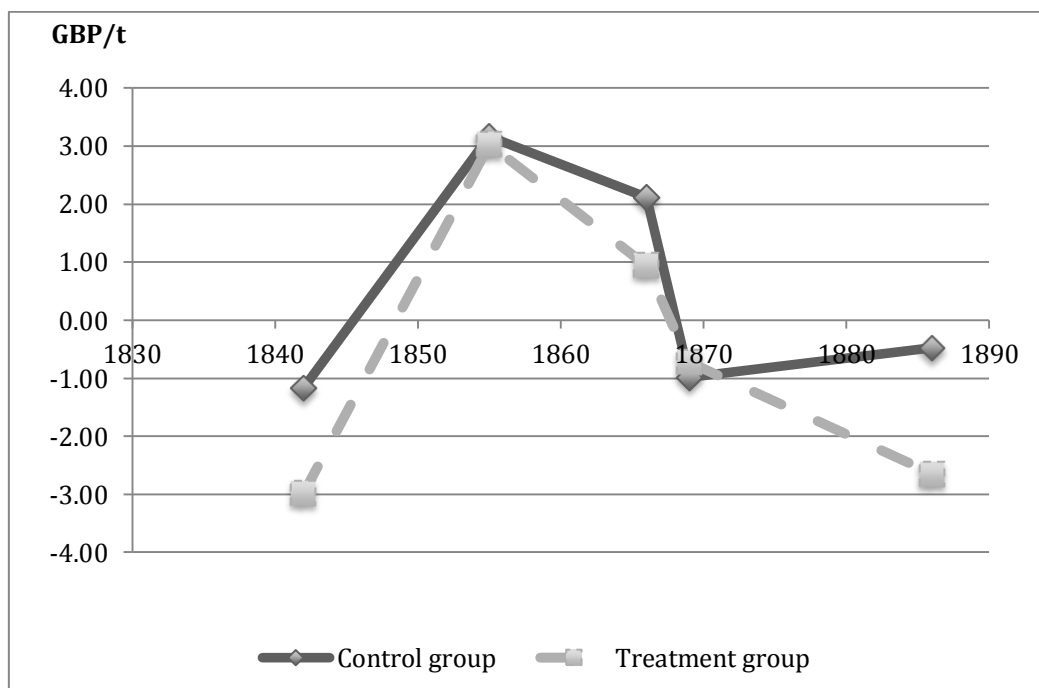
Region	Ports per region
Africa	Aden, Alexandria, Durban, Maputo, Cape Town
Latin America	Recife, Rio de Janeiro, Rosario, Santos, Buenos Aires
Mediterranean	Genoa, Gibraltar, Marseilles, Barcelona, Constantinople
Northern Europe	Amsterdam, Hamburg, Bergen, Dunkirk, Cardiff
Asia	Sydney, Sinagpore, Shanghai, Bombay, Calcutta
North America	Baltimore, Mobile, Newport News, New York, Philadelphia

Table A4: Start of competition at each port

Start of Competition		
Port	Foreign	Domestic
Aden	1902	
Perim	1902	
Bahia	1917	
Bahia Blanca	1920	
Buenos Aires	1920	
Montevideo	1920	
Recife	1920	
Rio de Janeiro	1920	
Santos	1920	
Genoa	1920	
Gibraltar	1922	
Marseilles	1888	
Lisbon	1920	
Piraeus	1921	
Bombay		1896

Colombo		1900
Karachi		1908
Cape Town		1900
Maputo		1900
Durban		1890

Figure A8: DID-Model alternative test of parallel trends assumption



Test of parallel trends assumption running two separate regression for control and treatment group

Note: The exact specification is $\text{price}_{x,t} = c + \text{year}_t + \text{port}_{x,t} + \varepsilon_{x,t}$ where the standard errors are clustered at port-level.

Table A5: Wage data

Country	Source	Kind of data (location, profession, frequency)	Period covered
Argentina	Nominal wage index from Williamson, J., 'Real Wages and Relative Factor Prices in the Third World 1820-1940: Latin America', <i>Harvard Institute of Economic Research Working Paper No. 1853</i> , Appendix Table 1.1 Nominal wage level for benchmark year 1910 Conde, R., <i>El Progreso Argentino, 1880-1914</i> , (Buenos Aires, 1979), p.226	Buenos Aires, urban unskilled workers, monthly	1864-1940
Australia	Withers, Glen, Endres, Perry (1987) 'Australian Historical Statistics', available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 04 May 2015	New South Wales, unknown, weekly; from 1915: NSW, avg. male earnings in manufacturing, annual	1861-1939
Brazil, Pernambuco	Nominal wage index from Williamson, J., 'Real Wages and Relative Factor Prices in the Third World 1820-1940: Latin America', Appendix Table 2.4 Nominal wage level for benchmark year 1900 from Levine, R., <i>Pernambuco in the Brazilian Federation 1889-1937</i> , (Stanford, 1978)	Pernambuco, urban unskilled workers, daily	1855-1935
Brazil, Rio de Janeiro	Williamson (1998) 'Real Wages and Relative Factor Prices in the Third World 1820-1940: Latin America' (Nominal wage index); Nominal wage level for benchmark year 1937 from <i>Year-Book of Labour Statistics</i> (Geneva, 1938)	Rio de Janeiro, urban unskilled workers, hourly	1830-1937
Bulgaria (Proxy Greece)	Morys, M., Ivanov, M., 'The emergence of a European region: business cycles in South-East Europe from political independence to World War II', <i>European Review of Economic History</i> , Vol. 19, No. 4, (2015), p.382-411	Ruse, day labourer, daily	1887-1945
China - Beijing, Sichuan, Canton	Ma, D. (2008) <i>China_wages_1807-1925.xls</i> , available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 02 April 2015	Beijing, unskilled workers in suburbs of or in Beijing, daily	1841-1925

Denmark	To 1913: Khaustova E., Sharp, P., 'A Note on Danish Living Standards through Historical Wage Series', 1731-1913, <i>EHES Working Papers in Economic History</i> , No. 81, (2015), p.20-22 From 1914: 2. Mitchell, B., <i>International Historical Statistics: Europe, 1750-1988</i> , (Basingstoke, 2003), p.196-7	Copenhagen, urban labourer, male, per day	1848-1938
Egypt	Nominal index: Williamson, J., http://scholar.harvard.edu/files/jwilliamson/files/1842appendix.pdf , accessed 13 January 2015 Wage level 1914 from Hansen, B., <i>Marginal productivity wage theory and subsistence wage theory in Egyptian agriculture</i> , (Cairo, 1966), p.405	National, rural unskilled laborers, daily	1858-1941
France	1840-1911: Allen, R., 'European labourers 1264-1913', available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 22 May 2014 then Singer-Kerel, J. <i>Le Coût de la vie à Paris de 1840 à 1954</i> , (Paris, 1961), p.538-9	1840-1911 by Allen: Paris, building labourers, daily; from 1912 Allen's series is extended by applying the nominal wage index by Singer-Kerel for Salaries nominaux Paris, masculins hebdom	1840-1940
Germany	Bry, G., <i>Wages in Germany 1871-1945</i> , (Princeton, 1960), Table A-5, p.339-341	Avg. Berlin, Nuremberg & Rostock, building workers, weekly	1871-1930
India, Bengal	Allen, R., Studer, R., 'Prices and Wages in India, 1595-1930 Indian_Allen-Studer_vs.pl.xls', available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 22 May 2014 This wage series has been extended from 1905 by applying Williamson's nominal wage index Williamson, J. (1998) 'Real Wages and Relative Factor Prices in the Third World 1820-1940: Asia', <i>Harvard Institute of Economic Research Discussion Paper No. 1844</i> , (1998), Data Appendix	Bengal (Calcutta from 1905), unskilled labourers (in agriculture until 1905), daily (to 1905)	1874-1938
India, Bombay	Allen, R., Studer, R., 'Prices and Wages in India, 1595-1930 Indian_Allen-Studer_vs.pl.xls', available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 22 May 2014 this wage series has been extended from 1910 by applying Williamson's nominal wage index Williamson, J. (1998) 'Real Wages and Relative Factor Prices in the Third World 1820-1940: Asia', <i>Harvard Institute of Economic Research Discussion Paper No. 1844</i> , (1998), Data Appendix	Bombay, unskilled labourers (in agriculture until 1910), daily (to 1910)	1873-1940
Italy	1840-1913: Allen, R., 'European labourers 1264-1913', available online on <i>Global Price and Income History Group</i> -	to 1913: Milan, building labourers, daily; then national, males in industry and transport,	1840-1939

	database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 22 May 2014 1914-1939 Mitchell, B., <i>International Historical Statistics: Europe, 1750-1988</i> , (Basingstoke, 2003), p.197-98	daily	
Netherlands	Allen, R., 'European labourers 1264-1913', available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 22 May 2014 until 1910, then van der Veen and van Zanden 'Real-Wage Trends and Consumption Patterns in the Netherlands, c.1870-1940', in Scholliers, P., <i>Real Wages in 19th and 20th Century Europe</i> , (New York and Oxford, 1989), p.208-09	1840-1910 by Allen: Amsterdam, building labourers, daily; then extended by applying the nominal index, national, industry wages, daily	1840-1939
Norway	Gryten, O., <i>Historical Statistics for Norway - Part II</i> Chapter 5, Nominal wages in Norway 1726-1940 by occupation, p.286, available at: http://www.norges-bank.no/pages/64940/Nominal_wages_in_Norway.pdf	National, avg. of 5 professions in construction (mostly road and railway construction), daily	1850-1940
Portugal	Martins, C., 'Trabalho e condicoes de vida em Portugal (1850-1913)', <i>Análise Social</i> , Vol XXXII (142), No.3, (1997), p.533-34	Wages for 14 industrial and industrial tasks, daily	1850-1913
South Africa - Cape Town	de Zwart, P., 'South African Living Standards in Global Perspective South_Africa_w_1837-1913a.xlsx', (2011), available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 12 October 2014	Cape Town, coloured labourers, daily	1854-1909
South Africa - Natal	de Zwart, P., 'South African Living Standards in Global Perspective South_Africa_w_1837-1913a.xlsx', (2011), available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 12 October 2014	Natal, coloured labourers, daily	1855-1913
Spain	1840-1911: Allen, R., 'European labourers 1264-1913', available online on <i>Global Price and Income History Group</i> -database: http://gpih.ucdavis.edu/Datafilelist.htm , accessed 22 May 2014 from 1912: Carmona, A., <i>El trabajo industrial en la Espana contemporánea (1874-1936)</i> , (Barcelona, 1989), p.548 & p.525	Madrid, unskilled Labourers, daily (until 1913), from 1914-20 & '30 interpolated based on Carmon's 'Evolución de los salarios industriales'	1840-1930
Sweden	Historical Monetary and Financial Statistics of Sweden (2010) <i>Exchange rates, prices, and wages, 1277-2008</i>	National, weighted average by employment shares of male wage in mining, metal, engineering, quarrying, wood, paper, food, textile, chemical, hourly	1871-1960
Turkey	1840-1911: Pamuk, S., Arroyo Abad, L., <i>Istanbul 1469-1913.xls</i> , (2005), available online on <i>Global Price and Income</i>	Istanbul, unskilled, daily (Williamson's data from 1914 refers to industrial wages and, to	1840-1941

	<i>History Group-database:</i> http://gpih.ucdavis.edu/Datafilelist.htm, accessed 28 May 2014 from 1912 the series has been extended by applying Williamson's nominal wage index Williamson, J. 'Real wages and relative factor prices in the third world 1820 1940: The Mediterranean Basin', <i>Harvard Institute of Economic Research Discussion Paper No. 1853</i>, (1998), Data Appendix	a lesser extent, to the wages of construction workers)	
United Kingdom	1840-1913: Allen, R., 'European labourers 1264-1913', available online on <i>Global Price and Income History Group-</i> <i>database:</i> http://gpih.ucdavis.edu/Datafilelist.htm, accessed 22 May 2014 Bowley, A., <i>Prices and Wages in the United Kingdom, 1914-20</i>, (Oxford, 1921), p.113 Bowley, A, <i>Wages and Income in the United Kingdom since 1860</i>, (Cambridge, 1937), p.10	London, building labourers, daily (until 1913, then various)	1840-1920, '25, '33, '36
United States	1. for 1840-80: Margo, R., 'Hourly Wages in Manufacturing, by Industry: 1865– 1914', in <i>Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition</i>, edited by S. Carter, S. Gartner, M. Haines, A. Olmstead, R. Sutch, and G. Wright, (New York, 2006), Table Ba4219 2. for 1881-1889: Margo, R., 'Hourly Wages in Manufacturing, by Industry: 1865–1914', in <i>Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition</i>, Table Ba4290-4297 3. for 1890-1933: United Bureau of Labor Statistics, <i>History of Wages in the United States from Colonial Times to 1928.</i> <i>Revision of Bulletin No. 499 with Supplement, 1929-1933</i>, p.186 & p.529 (prices from 1929)	1. 1840-80: Philadelphia, labourer, daily (partially interpolated based on other series) 2. 1881-1889: Hourly wages in manufacturing, all trades, used to interpolate the Philadelphia labourer series 3. 1890-1933: Philadelphia labourer, per hour	1840-1933
Uruguay	1870-85: Bertola, L, Calicchio, L, Camou, M., Porcile, G., 'Southern Cone Real Wages Compared: A Purchasing Power Parity Approach to Convergence and Divergence Trends, 1870-1996', <i>Documentos de trabajo (Programa de Historia Economía y Social, Unidad Multidisciplinaria, Facultad de Ciencias Sociales, Universidad de la República</i>, Appendix, Table A1.3 From 1886 nominal index from: Williamson, J., 'Real Wages and Relative Factor Prices in the Third World 1820- 1940: Latin America', Appendix Table 6.1	Urban, unskilled building workers up to 1926, then to 1936, that of casual workers; and thereafter, that of workers in manufacturing	1870-1940

Singapore	Bassino, J-P., van der Eng, P. 'The First East Asian Economic Miracle: Wages, Living Standards and Foundations of Modern Economic Growth in Southeast Asia, 1880-1938', <i>Working Paper</i> , (2013), p.23	Singapore, unskilled urban wages (colle), daily	1885-1935 (every 10 years to 1915, then every 5 years)
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Table A6: Coal prices

Note: This table explains how the underlying data sources were combined to form the price series. For more information on the underlying sources, see Section 2.4 for coal prices referring to port cities, Sections 3.4 and 4.3 for pithead price series.

Country	City	Period	Details (coal quality, underlying source)
Argentina	Buenos Aires	1862-1913, 1916-17, 1920-32 & 1935-50	Welsh (only 1946-48 South African); 1883, 1890-91, 1898, 1908 (<i>Ports of the World</i>), 1900-04 & '06, 1920-22 (<i>Coal Merchant & Shipper</i>), 1912-13, 1916-17 (Kirkaldy), 1923-32 & 1935-90 (<i>Fairplay</i>)
Australia	New South Wales mines	1871-1913	N.S.W.; N.S.W. raising costs, Northern part (Bukley)
Brazil	Rio de Janeiro	1881-88, '90, '94 & '97, 1900-06, 1912-13, 1916-17 & 1920-52	Welsh (only 1920-23 US/Welsh & 1949-52 South African/US); 1881-88 & '90 (Wilson), '94 & '97 (<i>Ports of the World</i>), 1900-06 & 1920-22 (<i>Coal Merchant & Shipper</i>) 1912-13, 1916-17 (Kirkaldy), 1923-52 (<i>Fairplay</i>)
China	Shanghai	1866-73, 1875-78, 1882-1908, 1912-13, 1916-17, 1920-21, 1924, 1930	Various qualities; coal market reports (from Jardine Matheson Archive) and <i>North China Herald</i>
Denmark	Copenhagen	1858-1939	Newcastle, England; price data until 1914 are taken from Henriques, S., Sharp, P., 'The Danish Agricultural Revolution in an energy perspective: a case of development with few domestic energy sources', <i>The Economic History Review</i> , Vol. 69, No. 3, (2016), then 1920-21 & '23 (<i>Coal Merchant & Shipper</i>), 1924 (Kirkaldy), from 1925 (<i>Fairplay</i>)
Egypt	Alexandria, Port Said (1913-1926)	1879, '87, '89, '94 - 1903, '05, '12, '13, '16-'17, '20-'26, '28, 1930-32, 1934-35, 1938-53	Welsh; 1879 & '87 (Consular Reports), '89 & 1905 (<i>Ports of the World</i>), '94 -1903 (<i>Royal Commission on Coal Supplies</i>), '12 (Kirkaldy), then all <i>Fairplay</i> '28, 1930-32, 1934-35, 1938-53
France	Bordeaux, pithead price	1840-1913, 1920-23, 1925, 1929-32, 1934-36,	1840-81: Welsh coal at Bordeaux interpolated based on freight rates from C. Harley ('Coal Exports and British Shipping, 1850–1913) and coal prices from <i>Commission on Coal Supplies</i> , then French pit head price to 1920

		1938-40	(<i>Coal Tables</i>), again Welsh at Bordeaux 1921-22 (<i>Coal Merchant & Shipper</i>), afterwards from <i>Fairplay</i>
Germany	Ruhrgebiet (mine)	1850-1913, 1924-34	Cheapest of the two series (<i>Die Großhandelspreise in Deutschland von 1792 bis 1934</i>): 1. Zeche Ver. Sälzer u. Neuack, bestmellierte Fettkohle 2. Essen Fett/Förderkohle
Greece	Piraeus	1873, 1883, 1894-1903, 1908, 1912, 1921-40	Welsh (apart from 1922 & '34 Durham, '36 German, '37 & '38 Russian/German); 1873 (British Colonial Report), 1883 & 1908 (<i>Ports of the World</i>), 1894-1903 (<i>Royal Commission on Coal Supplies</i>), 1908 & '12 (Kirkaldy), 1921-40 (<i>Fairplay</i>)
Hong Kong	Hong Kong	1842-43, '55, 1857-59, 1866-70, 1879-86, 1888-89 & 1891-93, '98, 1900-04, '06, 1912-13, '17, '21, '30	Welsh 1842-43, '55, 1857-59, 1866-70 (Royal Navy), Australian or Takashima 1879-86, 1888-89 & 1891-93 (Jardine Matheson), Japanese 1898 (<i>Ports of the World</i>), Japanese 1900-04 & '06 (<i>Coal Merchant & Shipper</i>), Chinese 1912, 1913 & 1916-17 (Kirkaldy), Japanese 1921 (<i>Coal Merchant & Shipper</i>), Chinese 1930 (Kirkaldy)
India	Bombay, later Bengal	1869-1940	1869-1885: Welsh coal at Bombay (<i>Royal Navy, Ports of the World</i> – missing years are estimated based on Jack's freight series, available here: http://www.sfu.ca/~djacks/data/publications/index.html) 1886-88 then average value (per ton) of Coal extracted in Bengal (<i>Coal Tables</i>), 1889-1920 average value of coal per ton extracted from the Bengal mines (<i>Note on the Production and Consumption of Coal in India</i>), from 1920 average price of coal in West Bengal (P. Chakrabarti, <i>Coal Industry in West Bengal</i> , (New Dehli, 1989) p.31-32)
Italy	Genoa	1870-1913, 1916, 1920-35, 1947-56	Cardiff coal, al vagone from 1870 (<i>Dinamica die prezzi</i>), then Welsh for all later years: 1916, 1920 (Kirkaldy), 1921-22 (<i>Coal Merchant & Shipper</i>), afterwards <i>Fairplay</i>
Netherlands	Amsterdam	1883, 1893-1906, '08, '12, 1920-27, 1929-32, 1934-40, 1947-51, 1953-60	German 1883 & 1908 German (<i>Ports of the World</i>), 1893-99 British/German (<i>Royal Commission on Coal Supplies</i>), 1900-06 German/Westphalian, '20 American & 1921-22 Westphalian (<i>Coal Merchant & Shipper</i>), '12 & '24 Westphalian (Kirkaldy), '23 Durham & 1925-27, 1929-32, 1934-40 Westphalian (only '26 Durham), 1947-51 & '53 Westphalian, 1954-60 Bunker [assumed to be West.] (from 1923 all <i>Fairplay</i>)
Norway	Bergen	1866-1937	British 1895-1903 (<i>Royal Commission on Coal Supplies</i>) interpolated backwards to 1866 based on Klovland's coal price index, and also forward to 1919 (from J. Klovland, 'Contributions to a history of prices in Norway: Monthly price indices, 1777-1920', <i>Working Paper Norgen Bank's Bicentenary Project</i> , No.23, (2013); coal import price series made available by personal communication); from 1922 all North Country: 1920-23 (<i>Coal Merchant & Shipper</i>), 1924 (Kirkaldy), 1925-26, 1929-32 & 1934-37 (<i>Fairplay</i>)

Portugal	Lisbon	1884, 1889-1906, 1912-13, 1917-18, 1920-53 (single years missing)	1884 & 1889 Welsh (<i>Ports of the World</i>), 1900-06 & 1920-22 Welsh (<i>Coal Merchant & Shipper</i>), 1912-13 & 1917-18 North country and American (Kirkaldy), from 1923 Welsh (<i>Fairplay</i>)
Singapore	Singapore	1871-1903 (single years missing), 1904-06, 1912-13, 1916-17, 1920-30	1871-1903 apparent landing cost at Singapore (f.o.b.+freight rate) (Bukley), 1904-06 Japanese & Welsh (<i>Coal Merchant & Shipper</i>), 1912-13 Australian & 1916-17 Japanese (Kirkaldy), 1920-29 various qualities (<i>Coal Merchant & Shipper</i>), 1930 Japanese (Kirkaldy)
South Africa	Cape Town, Natal pithead price	1869-1913, 1920-31	1869-1888: Welsh coal at Cape Town (<i>Ports of the World</i>), missing years are estimated based on Jack's freight series, available here: http://www.sfu.ca/~djacks/data/publications/index.html), from 1889 pithead price of Natal coal (<i>Coal Table</i> , estimated for the years 1923-31 based on the price change for Natal coal at Durban)
Spain	Barcelona	1870-1926, 1928-32, 1934, 1937	1870-1925 Apparent cost of Welsh coal at Barcelona (Coll Martín, S., Sudrià, C., 'El Carbón en España, 1770-1961: una historia económica', (Madrid, 1987), p.435-438; their price series is constructed by adding freight rates and tariff dues to a British export price; I have slightly adjusted the estimation by using my Cardiff series as the export price since after this adjustment the price series is more similar to the few actual price data points I have for Barcelona), afterwards Welsh (<i>Fairplay</i>)
Sweden	National (most representative of Gothenburg)	1840-1940	1890-1940 Ljungberg's price series Lokomotivkol P9159 (J. Ljungberg, <i>Priser och marknadskrafter i Sverige 1885-1969</i> (Lund, 1990.)); earlier years extrapolated based on "Schöns prisindex. Serie för stenköl, som han baserat på Sven Aage Hansen: Ökonomisk växt i Danmark, och växelkurser mellan Sverige och Danmark, för 1800-1815 har Schön använt prisindex för relaterad vara, för då finns inte uppgifter i Hansen."
Turkey	Istanbul	1873, '79, '82, '94, 1891-92, '96 & 1908, 1912-13 & '16, 1920-32, 1934-37, 1946-49, 1951-54	1873, '79, '82, (Consular Reports), '94 (<i>Fairplay article</i>), 1891-92, '96 & 1908 (<i>Ports of the World</i>), Welsh 1912-13 & '16 (Kirkaldy), American 1920-21 & Welsh '22 (<i>Coal Merchant & Shipper</i>), then all from <i>Fairplay</i> : Welsh 1923-30, Marine 1931-32, 1934-37 Candilly 1946-49 & 1951-54
UK	Glamorgan	1840-1938	Prices at pithead in South Wales (Walters) Interpolated backwards for 1840-77 based on the change in the price series of large Steam coal, f.o.b., at Cardiff. (see Section 2.4.1)
Uruguay	Montevideo	1885-86, 1888-89, 1894-96, '99 & 1908, 1912-13 &	1885-86, 1888-89 Welsh (Wilson), 1894-96, '99 & 1908 Welsh (<i>Ports of the World</i>), 1912-13 & 1916-17 & '20 (Kirkaldy), 1921-22 US (<i>Coal Merchant & Shipper</i>), 1923-45 Welsh & 1946-1955 South African, US or Bunker (<i>Fairplay</i>)

		1916-17, 1920-55	
USA	USA (avg.)	1883-1913, 1916, 1920-40	Average value (per ton) of coal produced, United States; most likely reflecting prices from coal mining in Pennsylvania (<i>Coal Tables</i>) Pithead price series is interpolated for 1857-1883 & 1924-40 based on the price for Clearfield coal at Baltimore (S. Carter, S. Gartner, et al., <i>Historical Statistics of the United States: Earliest Times to the Present</i> , Millennial Edition On Line edn, (Cambridge, 2006, Series No. 266)

Table A7: Outline datasets

Note: *Robust* is the baseline dataset and the years show which decades for the respective countries are included in the regression analysis. Further years stated under *Default* mean that those decades are included in addition to the ones listed under *Robust*. Further years under *Interpolated* are additions to the *Default*-dataset.

Country	<i>Robust</i>	<i>Default</i>	<i>Interpolated</i>
ARG			1870
			1880
	1890		
	1900		
		1910	
	1920		
AUS	1930		
	1880		
	1890		
	1900		
	1910		
	1920		
BRA	1930		
			1870
			1880
	1890		
	1900		
		1910	
CHN	1920		
	1890		
	1900		
			1910
DEU	1920		
	1880		
	1890		
	1900		
	1910		
DNK			1920
	1930		
	1870		
	1880		
	1890		
	1900		
	1910		
	1920		
	1930		

EGY	1920	
	1930	
ESP	1870	
	1880	
	1890	
	1900	
	1910	
	1920	
	1930	
		1870
		1880
FRA	1890	
	1900	
	1910	
	1920	
	1930	
GBR	1870	
	1880	
	1890	
	1900	
	1910	
	1920	
	1930	
GRC		1910
		1920
	1930	
IND		1880
	1890	
	1900	
	1910	
	1920	
	1930	
ITA	1870	
	1880	
	1890	
	1900	
	1910	
	1920	
	1930	
NLD		1890
	1900	
		1910
	1920	
	1930	
NOR	1870	
	1880	
	1890	
	1900	
	1910	
	1920	
	1930	
PRT		1870
		1880
		1890
	1900	
		1910
SWE	1880	
	1890	
	1900	
	1910	
	1920	

	1930	
TUR		1880
		1890
	1900	
		1910
	1920 1930	
URY		1870
		1890
		1890
		1900
	1920 1930	1910
USA		1870
		1880
		1890
		1900
		1910
		1920
		1930

Table A8: Average manufacturing output growth rate per country per decade 1870-1940 (in %)

Countries	1870-79	1880-89	1890-99	1900-09	1910-19	1920-29	1930-40	1870-1940
Coal-prod.								
AUS	2.8	6.0	0.5	3.5	2.2	4.6	2.8	3.2
DEU	4.0	3.8	3.9	3.2	2.3	2.3	2.8	3.2
GBR	1.0	4.0	2.4	0.6	1.4	3.6	2.6	2.2
USA	3.7	6.0	4.6	6.2	5.4	5.7	3.2	5.0
Coal-dev.								
CHN			9.4	9.4	11.2	9.8	6.5	9.3
FRA	0.8	2.7	3.0	1.1	0.5	6.6	-0.1	2.1
IND	0.3	1.2	1.0	2.5	-1.0	4.6	2.2	1.5
ZAF					16.7	7.4	8.3	10.8
No coal								
ARG	3.2	7.0	14.2	5.9	3.6	7.2	2.9	6.3
BRA	7.2	14.7	4.1	3.6	6.3	3.8	5.0	6.4
DNK	6.0	4.9	7.5	3.7	3.0	3.8	3.5	4.7
EGY						1.6	1.6	1.6

ESP	4.9	2.7	2.1	0.7	1.5	5.4	-3.1	2.0
GRC					12.1	6.4	4.1	7.5
ITA	1.5	3.1	1.9	4.4	-1.0	5.8	2.2	2.6
NLD	5.2	3.3	2.6	2.3	2.6	11.0	2.9	4.3
NOR	-0.9	8.3	3.3	1.6	2.2	5.7	3.6	3.4
PRT	1.8	2.5	3.7	1.8	-0.1	5.7	1.6	2.4
SWE	4.9	4.4	7.7	4.3	4.4	3.5	4.2	4.8
TUR		1.8	1.8	1.8	-2.4	2.6	12.1	2.9
URY	1.9	6.7	3.1	4.3	3.2	6.0	3.0	4.0

Table A9: FE-estimation results, *Robust*-sample, 1870-1940, *start_gdp_pc* in all specifications

	(1)	(2)	(3)	(4)	(5)
start_cw_ratio	-11.254** (4.612)	-8.912** (3.371)	-8.912** (3.371)	-8.733** (3.369)	-8.858*** (3.049)
start_gdp_pc	-0.655 (0.613)	0.027 (0.693)	0.027 (0.693)	0.042 (0.793)	0.857 (0.808)
tariff			12.620* (6.716)	13.061* (7.002)	13.718** (5.969)
land					0.082 (0.060)
schooling					-2.191** (0.945)
institutions					-0.123 (0.080)
Decadal FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
R ²	0.32	0.38	0.38	0.39	0.44
N	92	92	92	85	85

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors are clustered at the country-level.

Table A10: FE-estimation, *Robust*-sample, 1870-1940, *start_gdp* in all specifications

	(1)	(2)	(3)	(4)	(5)
start_cw_ratio	-11.409** (4.521)	-8.853** (3.342)	-8.853** (3.342)	-8.853** (3.342)	-8.889** (3.240)
gdp_start	0.000 (0.002)	0.003 (0.003)	0.003 (0.003)	0.003 (0.003)	0.004 (0.003)
tariff			13.686** (6.094)	13.686** (6.094)	13.641** (5.821)
land					0.070 (0.046)
schooling					-1.885** (0.788)
institutions					-0.061

					(0.066)
Decadal FE	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
R^2	0.31	0.39	0.39	0.39	0.44
N	92	92	92	85	85

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors are clustered at the country-level.

Table A11: FE-estimation results, *Default*-sample, 1870-1940

	(1)	(2)	(3)	(4)	(5)	(6)
start_cw_ratio	-4.482*** (1.521)	-4.495*** (1.534)	-4.260** (1.751)	-4.464** (1.919)	-4.182** (1.899)	-4.137** (1.861)
tariff	16.867** (6.617)	17.481** (6.684)	18.883** (7.695)	18.998** (7.120)	19.587** (7.288)	19.400** (7.325)
start_gdp		0.003 (0.003)	0.003 (0.003)	0.004 (0.003)		
start_gdp_pc					0.889 (0.598)	0.945 (0.600)
start_pop						-0.008 (0.022)

land				0.006 (0.055)	0.017 (0.051)	0.018 (0.051)
schooling				-0.815 (0.822)	-1.113 (0.819)	-1.160 (0.803)
institutions				-0.025 (0.057)	-0.075 (0.075)	-0.085 (0.078)
Decadal FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
R ²	0.37	0.38	0.38	0.39	0.40	0.40
N	112	112	104	104	104	104

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, standard errors are clustered at the country-level.

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Long Abstract

This thesis investigates to what extent coal prices differed globally during the nineteenth and twentieth centuries, and whether those differences mattered for economic development. The backbone of my empirical investigation is a new dataset of annual coal prices spanning the years 1840 to 1960 for, on average, over 30 globally distributed ports. This dataset is complemented by pithead prices for all major coal-producing countries. My analysis includes all major steam coals and I eliminate quality differences by accounting for differences in their carbon content.

I construct my argument by examining two major drivers of differences in coal prices. First, I examine trade costs for Welsh steam coals, which were shipped to most regions of the world. Secondly, I estimate the effect of the spread of coal mining, for example to India, on local coal prices by initiating competition between coals from different origins. While trade costs declined most during the late nineteenth century, the spread of coal mining led to continued price convergence in the interwar period. And yet, global coal price differences remained significant, especially between producing and importing countries.

Arguably, my most interesting finding is on the effect of those coal price differences. More specifically, I calculate the ratio of coal prices to wages, and explore whether countries where this ratio was closer to the British ratio were in the best position to use most advanced steam technology. My econometric results indeed show that countries with a low coal price/ wage ratio experienced higher manufacturing output growth during the period 1870 to 1940. This finding of my thesis highlights one potential way in which different levels of coal prices may have contributed to varying degrees of technology adoption between countries and ultimately economic growth.

This second chapter examines global price convergence in coal over a 120-year long period by using the market for Welsh bunker coal as a case study. Market integration studies have shown price convergence during the long-nineteenth century, and the limited available evidence hints at disintegration during the interwar period for a number of commodities. Due to the higher bulk-to-value ratio of coal, and the different development of tariff protection levels, integration patterns may have been very different in coal. I have compiled a novel data set of prices for Welsh bunker coal, the preferred type for fuelling ships, which allows for the comparison of a homogenous kind of coal across space and time. The data set consists of 2,616 annual price quotations from the period 1840-1960 with on average over 30 international ports per year. Results indicate that international

price gaps remained relatively stable in the mid-nineteenth century until they converged significantly from the 1880s onwards. The interruption by World War I was dramatic but temporary since prices swiftly converged in the 1920s. However, during the interwar period prices did not converge beyond the pre-World War I levels. Analyses also reveal that absolute price gaps remained at high levels after World War II. These findings suggest that one should pursue a more commodity-specific view of market integration, in light of the significantly different patterns and more continuous course of integration for commodities such as coal. As such, these findings have implications for the debates on the harmonisation of global energy prices and the persistence of comparative geographic advantages

In Chapter Three, I examine trends in global coal prices during the late nineteenth century until the late interwar period and the spread of coal mining as a potential determinant of global coal price convergence. This chapter does not rely on the traditional approach to market integration of studying price differences of a commodity traded between the importing and exporting location. Instead, I compare the prices of bunker coals at a vast and globally dispersed sample of 40 ports. In order to compare like-with-like, the prices are adjusted based on their different levels of carbon content. The results confirm global convergence in coal prices during the complete period, including the interwar years when trade costs stagnated. The discovery and exploitation of domestic coal mining in further countries was key to this development. Coal prices declined by up to 50% at South African and Indian ports, where domestically produced coals replaced British coal. Over time, coals from both newcomers established growing export networks and increased competition led to declining prices at other ports. Even though the gains from domestic mining were huge, the process of developing domestic mines and processing the coals adequately took years, even decades, from the initial discovery until the takeover of the domestic market. This finding highlights the importance of investment,

technology and skills as necessary conditions for benefitting from cheap coal next to the actual endowment.

Chapter Four follows up on Allen's recent argument (2009) that the ratio of coal prices to wages led to the British Industrial Revolution. High wages created incentives for research in labour-saving technology and steered technical progress towards the exploitation of comparatively cheap coal. Using my new coal price data set introduced in Chapter Two, and my approach of adjusting for quality differences in coals (Chapter Three), this chapter investigates the relationship between coal price/wage ratios for 23 countries from 1870 to 1940 and the manufacturing output growth estimates from Bénétrix, O'Rourke and Williamson. The underlying assumption is that countries with a similar factor-price ratio to Britain – high wages and low coal prices – should have had higher manufacturing output growth since they were able to adopt the most modern, mainly steam engine-based, technology.

My results confirm that countries with a low coal price/wage ratio had higher levels of GDP per capita, but also that the ratio is negatively correlated with manufacturing output growth. An increase of coal prices by 50%, holding wages constant, decreased manufacturing output growth by between 0.32% to 0.13% per annum. These are lower bound estimates since the effect may have been even greater pre-1870 when steam engines were less efficient. In my fixed effects models the level of the coal price/wage ratio refers to the first year of each decade, e.g. 1870 for 1870-79, in order to partially counter endogeneity concerns. The results are robust to controlling for decadal fixed effects, and other potential determinants such as trade openness, human capital development and institutional environment. In addition, it remains robust to various changes to the dataset, such as excluding the WWI-period. Those results increase our confidence that coal price/wage ratios were proximate determinants of industrial development, acknowledging that the level of coal prices itself is partially determined by infrastructure and technology.

The final chapter summarises the findings of the three analytical chapters. I highlight that my results confirm that, at least for coal markets, a commodity-specific analysis is necessary, since price convergence did not follow the mainstream trajectory of market integration. In addition, I have suggested a way in which cheap coal, relative to labour, may have led to higher industrial development by easing the diffusion of modern technology. This contradicts the more recent economics literature on the relationship between natural resource exploitation and economic growth has evolved around the “resource curse” – that is, the Dutch disease effect – implying a negative correlation. I emphasise that such results are time-dependent, and may therefore very well change in the future. In times of high transportation costs and by driving technological progress and diffusion, resource extraction can indeed have positive effects on a country’s growth performance.