5 Biological Globalization: The Other Grain Invasion

Alan L. Olmstead and Paul W. Rhode

Jeffrey Williamson has inspired a fruitful collaborative investigation into the causes and consequences of the great globalization wave that transformed the world economy over the long nineteenth century. Surging flows of goods and factors of production signaled a significant increase in the international division of labor that greased the skids of economic growth. In Williamson's analysis, innovations in transportation technologies and more efficient institutional structures propelled the globalization process by driving down the costs of moving goods over long distances. In this chapter we argue that in addition to transport innovations, the development and spread of new biological technologies were crucial for the emergence of the new global economy. We concentrate on world wheat production, but many of the same lessons apply to most other major crops and livestock products.

Studies of more recent globalization experiences suggest that our focus on past biological innovations may pay dividends. As an example, the economic development literature highlights the contribution of research and development to agricultural productivity growth and trade. The Green Revolution and the Genetic Revolution are part and parcel of the modern globalization debates. The role of research institutes such as the International Maize and Wheat Improvement Center (CIMMYT) in advancing agricultural technologies takes center stage. We argue that the nineteenth century also witnessed biological innovations that fundamentally changed economic opportunities around the world. This was not just a haphazard process because well before CIMMYT existed, institutional structures and networks developed to convey these innovations across the planet. The opportunities to increase productivity were immense because it is unlikely that all the miraculous achievements of the recent Green Revolution exceed the importance of the Columbian Exchange when biological technologies were transferred between the Old and New Worlds (Crosby 1972). This involved nothing less than learning how to adapt alien crops to whole continents. The unlocking of the productive potential of the vast expanses of virgin land that would make cheap grain exports possible involved much more than laying railroad tracks. Agricultural innovations were especially important because of the relative size of the agricultural sector. In the nineteenth century agricultural products dominated international trade, and global labor and capital flows were closely linked to agricultural development. Thus, innovations that affected agricultural productivity and helped transplant agricultural production across a wide range of geoclimatic zones deserve attention.

The insights of endogenous growth theory suggest another reason to pay heed to biological innovations of the past. In the models of Grossman and Helpman (1991), the flow of ideas across international borders reduces the fixed cost of product development. We argue that international spillovers in the agricultural sector were important in explaining the process and consequences of globalization in the pre–World War I period. Biological innovations in past centuries were generally not subject to patenting as were mechanical innovations, and thus we must look elsewhere for what Paul Krugman has termed a "paper trail of ideas." The paper trail exists in the records of farmers and scientists. This collective record shows that not only were the technological advances nonexclusive but inventors preferred it this way. Much like CIMMYT created and promoted the diffusion of new germplasm, nineteenth- and early twentieth-century plant breeders made spectacular advances and freely exchanged both their methodologies and their creations. The new technologies often spread rapidly. Moreover, unlike primary products, which mostly flowed from the periphery to the center, the flow of ideas and biological technologies moved in every direction. The Great European Grain Invasion of the late nineteenth century was itself the product of the earlier invasion of the Americas and Oceania by Eurasian plants that were essentially invasive species in their new homes.

Biologists who catalog invasive species usually include wild oats but not wheat. Why? Both are non-native plants, imported to many of the areas where they are now grown. The difference in billing is likely because wild oats are weeds, hardy but worthless, whereas wheat is of economic value but does not thrive without the sweat of our brows. If the invasive species are defined as non-native organisms that "completely take over and entirely change whole established ecosystems," then wheat grasses, aided by their human cultivators, clearly fit the bill.[1] Vast tracts of forest

and grass lands were cleared and broken in the Americas and Australia to allow for the cultivation of wheat. O'Rourke (1997) has called attention to the effects of cheap grain from the periphery on factor prices in Europe and on pressures for protectionism. This chapter highlights the advances in knowledge behind the earlier biological invasion that made cheap grain exports from the periphery possible.

Of Williamson and Wheat

The grain trade has figured prominently in Williamson's work, including his first book, *American Growth and the Balance of Payments, 1820–1913* (1964). His classic application of general equilibrium modeling to history asked whether Midwestern grain lubricated the U.S. export engine of growth (Williamson 1974). The grain trade remains central to his more recent analysis as, for example, in *Globalization and History* (O'Rourke and Williamson 1999). Narrowing price gaps for wheat between the Chicago (or Odessa) and the Liverpool markets frequently serve as the key indicator of falling transport costs and increasing globalization (O'Rourke and Williamson 1999, 43, 53; Persson 2004). The repeal of the Corn Laws in Britain was the key event signaling the beginning of an era of freer trade. And "the invasion of cheap New World and Ukrainian grain, which threatened to reduce agricultural incomes" in Europe was the "major event" initiating the political backlash against the nineteenth-century globalization wave (O'Rourke and Williamson 1999, 93). Indeed, the backlash is introduced with language ringing with the themes of this chapter:

> The impact of the railroad and the steamship was reinforced by political developments after 1860 as European economies moved rapidly toward free trade. The world was becoming a much smaller place, and to an observer in 1875, it must have seemed as if it was going to get a lot smaller. Yet nothing is inevitable. History shows that globalization can plant the seeds of its own destruction.

O'Rourke and Williamson (1999, 53) argue that falling transportation costs undermined the "tyranny of distance" and encouraged the growth of wheat production across the world's periphery. Our earlier work documented the dramatic geographic shift of U.S. grain production. Based on county-level agricultural output data, we showed that the mean geographic center of U.S. grain production was near Wheeling, West Virginia, in 1839 but moved roughly 1,260 kilometers northwest to the region around Omaha, Nebraska, by 1919 (Olmstead and Rhode 2002;

2003). To give context to these movements, we can combine our production data with the local 1910–1914 farm-gate prices reported in Zapoleon (1918). The differentials in these prices are typically interpreted as reflecting transport costs.[2] These data indicate that under the 1839 distribution, wheat producers were roughly 10 cents (that is, 13 percent of the average farm-gate price) closer to the consumer markets than under the 1909 distribution. An important implication of the change in the locus of production is that the reduction in transportation costs between two fixed locations (e.g., Chicago and Liverpool) overstates the cost decline to marginal producers who were pushing the frontier out from Chicago.

The Changing Locus of World Wheat Production

How far from the consumption centers of Western Europe did wheat production spread during the great globalization wave, and how did the new areas of production compare to the old? Given the scope of the task required to answer these questions, we rely on aggregate national-level data. As discussed in the chapter appendix, we used Food Research Institute (FRI) data to compile a comprehensive production series for the 1885–1930 period, which we linked to the available production and export data for 18 nations over the 1866–1899 period. Our calculations required measuring distance from each country—the convention in gravity model literature is to use the national capitals—to a single global center, for which we used London. The appendix discusses our reservations with this approach, but we note that the movements of the wheat belts to the interiors of the leading new producing countries suggest that the capital-to-capital measures generally understate the increase in distance.

Figure 5.1 shows the changing average distance of wheat production between 1866 and 1930. The distance from London almost doubled, climbing from 2,377 km in 1866–1870 to 4,725 km in 1920–1925. The most rapid change occurred between 1866 and 1880, when the average distance grew 2.5 percent p.a., or about 1,000 km. Growth slowed thereafter, but almost 600 km were added by the First World War. There was another rapid rise and then retreat in the aftermath of this conflict.

What geographic shifts explain these changes? Figure 5.2 charts wheat production statistics by major country from 1885 to 1930. The fluctuating distance over WWI and its aftermath was due to the Bolshevik Revolution. Russia's share (2,130 km from London) of world production fell from 25 percent in 1913 to 8 percent in 1922 and then rebounded to 21 percent by 1930. The rise in the shares of world production of Australia

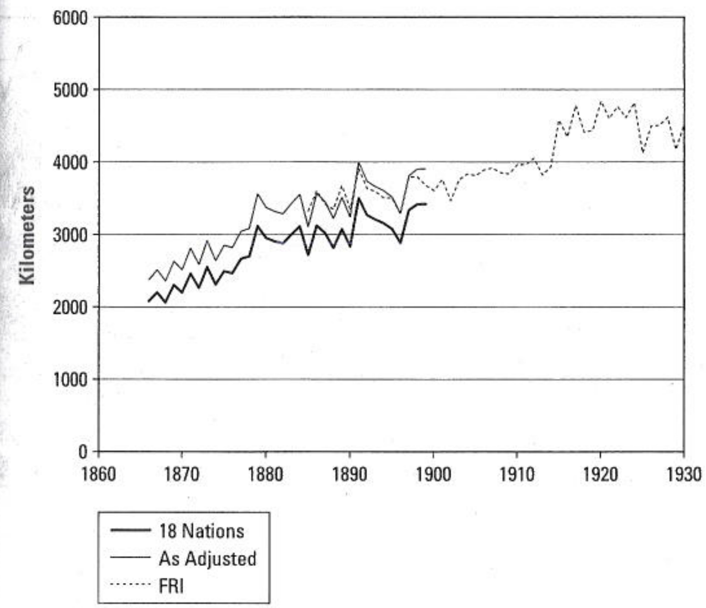

Figure 5.1
Average distance of world wheat production from London, 1866–1930.

(16,956 km), Argentina (11,052 km), and Canada (5,401 km) largely explains the increasing distance from 1885 to 1914. The combined share of these three exporters rose from less than 4 percent in 1885 to over 10 percent in 1913 and then to 19 percent in 1930. Their growth accounted for four-fifths of the measured increase in distance between 1885 and 1930. Over this period, the output share of European countries excluding Russia fell from just over one-half of world production to less than one-third. India's share (6,747 km) declined by a similar percent, whereas the U.S. share (5,932 km) was roughly equal at the beginning and end of the period. These data obviously cannot explain the rapid growth of distance before 1885. But it is clear that the United States was driving that change. It was the major country experiencing a rapidly growing share of world production (almost a doubling) that was also located further than the average distance of producers from London.

The global shift of wheat cultivation had dramatic effects on typical growing conditions, with a movement onto drier and colder lands. Table 5.1 documents these changes.[3] World production in 1926–1930 was distributed to lands that, on average, were 3.2°C colder and received 10.8

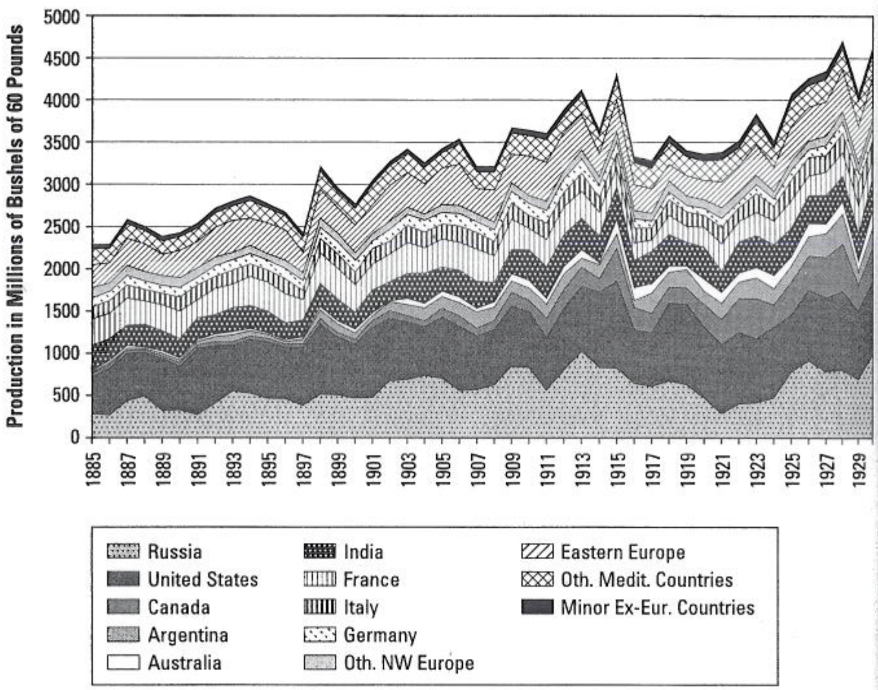

Figure 5.2
World wheat production, 1885–1930.

Table 5.1
Changing Climatic Conditions of Wheat Production

	Annual Temperature (degrees C)	Pre-Harvest Temperature (degrees C)	Annual Precipitation (cm)	Yield (M tons/ hectare)
1866–1870	14.4	20.1	72.8	1.01
1886–1890	12.7	18.6	68.1	0.94
1910–1914	11.7	18.3	63.9	0.91
1926–1930	11.2	18.0	62.0	0.90

Note: The series was derived from fixed national climate and yield values reflecting typical 1920–1934 conditions and changing national shares in global wheat production. The 1866–1870 data were derived from splicing the 1866–1899 series for the 18 countries to the 1885–1930 series calculated for the full FRI sample.

fewer centimeters of precipitation than the areas where wheat had been cultivated in 1866–1870. Given large and expanding production in Europe, the changes in the conditions facing farmers near the frontier were significantly greater than the changes displayed in table 5.1. The 1926–1930 land base was also associated with lower average yields per planted hectare. Had the acreage been distributed as it was in 1866–1870, yields would have been about 12 percent higher. Clearly, global wheat cultivation was shifting to poorer lands, making the growth of world yields over this period all the more impressive. Actual world yields rose 17 percent between 1886–1890 and 1926–1930 in spite of a geographic redistribution of production that should have led to a 4 percent decline.

These changes in average climatic conditions were not exogenous to the globalization process. Rather, they were the predictable consequences of lower transportation costs opening the continental interiors to profitable production. As the FRI researchers noted, there was a tendency

> for yields of wheat to decline from east and west toward the interior regions of each of the principal land masses, North America and Eurasia. The central regions of such large continents not only suffer from generally light precipitation, but are also characterized by extreme variations in precipitation and temperature. . . . These climatic characteristics are generally unfavorable for wheat yields. (Bennett and Farnsworth 1937, 283)

Globalization had induced a shift of wheat cultivation from maritime areas with temperate climates to interior regions with harsher continental climates.[4]

These findings are in keeping with our earlier results for the United States, where grain production moved from the humid East to the dry and harsh Great Plains. Accounting for such internal shifts would increase the measured global changes.

In the United States pushing wheat production onto the new lands required new technologies—the development and diffusion of new types of wheat and new cultural methods. If western farmers had persisted in planting old varieties, the boom in wheat production that fueled the global economy simply would not have been forthcoming. All the transportation improvements imaginable could not have induced English wheats to thrive in North Dakota. Success in the United States and Canada also depended on innovations that mitigated the destructive forces of ever-evolving pest and disease environments.

The biological transformation in the United States was part of a worldwide process. The farmers who extended the wheat frontier in Canada, Australia, Argentina, and Russia faced similar challenges of producing in new and harsh environments. In all these areas the first attempts to grow wheat failed. Success depended on biological innovation. Farmers and plant breeders from all these countries scoured the globe for varieties that might meet local needs. They selected and increased the seeds from particularly promising plants, and by the end of the nineteenth century a number of scientists were creating hybrids that combined the favorable traits of varieties drawn from around the world. This was a purposeful and sophisticated process led by people whom plant scientists today still revere as the pioneering giants of their discipline. Advances were accelerated by a loose but effective international network of plant scientists that facilitated the exchange of ideas, methods, and varieties. These exchanges highlight the importance of international technological spillovers in the globalization process.

The technological changes based on plant selection and breeding flowed in every direction. At first, they flowed from the center to the periphery. But the wheat varieties that made the expansion of the extensive margin possible for the most part did not come from the old center, but from the old periphery. Poland, Ukraine, Russia, India, and Africa supplied much of the germplasm underpinning the Grain Invasion. The international flow of technology was even more complex because new varieties developed in the New World were sent back to the old center, where breeders selectively combined their strengths (earliness, rust resistance, tolerance for drought and cold, and high gluten content and baking quality) with the best of northern European varieties (typically high-yielding). By the early twentieth century the new generations of successful European wheats—distinct varieties tailored for the United Kingdom, France, Germany, or Italy—often contained germplasm introduced from North America and Australia (as well as directly from other regions of the old periphery, including Russia, Ukraine, India, and Japan). A similar exchange linked the different lands of the New World; varieties developed in North America were a crucial factor in the expansion of the Australian wheat frontier, and Australian varieties proved valuable to producers in California and the Pacific Northwest. A brief account of the biological dynamics that accompanied the global expansion of wheat production will illustrate these general points.

The Development of Wheat Breeding in Britain and the Core

During Britain's age of industrialization, there were many key advances in cereal production. British farmers had long experimented with new wheats from across the Channel (Walton 1999, 34). Largely through

chance discoveries and "selections from a single particularly fine or productive individual," agricultural improvers developed several new wheats by 1840, and in the process invented the method of pure-line selection.[5] John Le Couteur of Jersey discovered "Bellevue de Talavera"; Banham selected Browick from a field of Scotch Annat in Norfolk; and Patrick Shirreff, the Scottish agriculturalist, discovered Mungoswell in Haddingtonshire, Scotland, in 1819 and found the basis for the Hopetoun line in a single ear in a field near Sussex in 1832.[6] The efforts of Shirreff and Le Couteur received lengthy notice in Charles Darwin's *Variation of Animals and Plants Under Domestication* (1868).[7]

Over the 1840–1870 period, "more organized attempts were set up to find superior specimens" (Brassley 2000, 525). Building on British attempts to hybridize wheat dating to the 1790s, Hallett began extensive trials near Brighton in the late 1840s, employing a variety of red and white wheats from England and Australia, the latter "which were fixed upon on account of their quality alone" (Hallett 1861). The leading new variety was Squarehead, which "offered a new combination of high yield and strong straw which was to have a profound influence on wheat breeding throughout north and central Europe, extending to Scandinavia, Germany, and even to Poland" (Lupton 1987, 51, 64–65). Squarehead was purportedly discovered in 1868; Mr. Scholey of Yorkshire increased and sold the seed of the new variety beginning in 1870. After 1870 the pace of improvement picked up with "a spate of selections, introductions and hybridizations" that would come to dominate the market by 1914. In 1873, Shirreff published his classic memoir, *Improvement of the Cereals*, detailing his selection and hybridization efforts (Shirreff 1873; Roberts 1929, 110–117). Among the important introductions was Japhet (marketed in England as Red Marvel), developed by Henri Vilmorin of Paris in the 1890s. The leading new hybrid wheat was Squareheads Master, derived from a cross between Scholey's Squarehead and Golden Drop in 1880. The new varieties had important consequences in the battle against diseases.

The most serious rust problems in humid Britain were stripe rust and leaf rust. Angus (2001, 111–112) indicates that Squareheads Master was developing problems with stripe rust. But periodically, stem rust—the type that bedeviled growers in the arid lands of the United States, Canada, and Australia—also struck. In Britain this fungal disease was known as wheat mildew. During a serious outbreak, as in 1892, stem rust could have locally devastating consequences, inducing a frantic search for less susceptible varieties.[8] Once a strain of rust adapted to attack a specific variety, that variety remained vulnerable.

At the turn of the century the rediscovery of Mendel's laws of inheritance opened up new possibilities. The most innovative work was done by Cambridge University's Rowland H. Biffen, who initiated a hybridization program in 1901. In addition to advancing basic science, Biffen made practical innovations such as Little Joss (1908), a cross between Squareheads Master and the rust-resistant Russian spring wheat, Ghirka (Brassley 2000, 525). The ability of Little Joss to withstand stripe rust made it popular with farmers following its release in 1910. Breeding research in the United Kingdom became more institutionalized in 1912 with the creation of the government-supported Plant Breeding Institute at Cambridge (Angus 2001, 111–113; Lupton 1987, 64–65). Another key advance came in 1916 with the release of Yeoman. This cross between Browick and the Canadian variety, Red Fife, offered superior milling and baking qualities and high yields. By this time, British breeders were transforming the wheat varieties grown in the United Kingdom by combining germplasm drawn from western Europe, North America, Australia, and Russia.

A similar process was at work on the continent. Before 1850 in France and Belgium, a number of wheat varieties had been adapted for specific regions. For example, the wheat grown in eastern France was more tolerant of cold than that grown in the west. However, in any region there was little variation from farm to farm, resulting in "slow evolution over the centuries from the effect of natural selection due to the environment and the mass selection done by man selecting the best filled grains." After 1850 new varieties imported from Odessa gained importance in southern France, and English varieties such as Squarehead became popular in the north. These introductions were followed by a succession of new varieties developed by pioneering breeders. Most prominent was Henri Vilmorin, who began experimenting with wheat hybridization in 1873. By the mid-1880s, Vilmorin had successfully crossed wheats from Aquitaine (which were themselves recent imports from the Ukraine) with the high-yielding Squarehead. Although French breeders made important strides in the nineteenth century, it was not until 1921 that the government established a formal breeding program with the founding of the Institut de Recherches Agronomiques (Bonjean, Doussinault, and Stragliati 2001; Lupton 1987, 53–56).

From the Center to the Periphery

The histories of other land-abundant, labor-scarce economies such as Canada, Australia, and Argentina support our emphasis on the importance of biological learning in the long nineteenth century. The Canadian literature emphasizes the crucial role that new rapid fruiting and drought and cold-tolerant varieties played in western settlement, and in particular credits Charles Saunders's path-breaking achievement in creating Marquis. In a similar fashion, the Australian literature emphasizes the work of William Farrer in developing drought-hardy and rust-resistant varieties. Mechanization plays a prominent role in the histories of both nations, but there is a clear recognition that biological innovation was essential for the expansion of the wheat belts in both countries.

Canada

Wheat cultivation was introduced to Canada in 1605 at the first French settlement at Port Royal in what is now Nova Scotia. Cultivation in eastern Canada expanded over the coming centuries but generally suffered from diseases, insects, and the propensity of the soft white winter wheat to die from winterkill. Farmers tried a "succession of types or landraces," including Red Chaff, White Flint, Kentucky White Bearded, and Genesee White Flint, "in search of ones that would overcome some of the impediments to successful wheat production" (White 1995, 6; DePauw, Boughton, and Knott 1995; DePauw and Hunt 2001). The key breakthrough came with the development of Red Fife by David and Jane Fife of Peterborough, Ontario. The Fifes selected and increased the grainstock from a single wheat plant grown on their farm in 1842. The original seed came from a Scottish source out of a cargo of winter wheat shipped from Danzig to Glasgow (the grain itself likely originated in Ukraine). Mrs. Fife, who was the daughter of a farmer and seedsman, evidently saved the precious seed stock from foraging cattle. Red Fife proved to be the first successful hard spring wheat grown in North America, and it became the basis for the westward and northern spread of the wheat frontier. It also provided much of the parental stock for later wheat innovations (Buller 1919; Symko 1999).

Wheat cultivation in the region west of the Great Shield experienced an even more troubled development. The first sustained attempt to grow wheat was made in the 1810s by members of the ill-fated Selkirk settlement on the Red River near Lake Winnipeg. Winter wheat, first tried in 1811–1812, proved a failure. The fields were resown with spring wheat, which died due to drought. In 1813–1814 the settlers obtained a small amount of spring wheat from Fort Alexander, which produced sufficient grain for the colony to continue cultivation. But in 1818 grasshoppers devoured most of what had been a promising crop. In 1819 another grasshopper attack devastated the colony's wheat crop, leaving it without seed.

In the dead of winter, a band of the desperate settlers traveled over 1,060 km to Prairie du Chien on the upper Mississippi River to secure replacement seed. This spring wheat performed well, but it was not until 1824 that the settlers had their first truly successful wheat crop. Over the next several decades, the region's farmers experimented with varieties from England, Ireland, and Ukraine.

Mennonites, who settled in southern Manitoba in 1874–1875, are generally credited as the first Europeans to cultivate wheat on Canada's open prairie. These migrants planted a seed, White Russian, which they brought with them from Europe. But the future wheat of Manitoba, indeed the entire west, was Red Fife. According to one account, immigrants from Ontario first introduced Fife to the region around 1857.[9] An alternative account suggests Fife came in only after the devastating grasshopper attack that "destroyed every vestige of the crop in 1868."[10] The success of the hard red wheat was due in part to the efforts of Minnesota millers to import Hungarian techniques in the mid-1870s. With the application of the steel roller mill, flour made from Red Fife acquired a reputation of unparalleled quality. Fife wheats became the dominant cultivars on the Canadian prairies as they opened to greater settlement after 1885. These wheats also played a role in Sir John A. Macdonald's national policy of incorporating the west into Canada. To encourage the more rapid development of the prairies, the Canadian government and the Canadian Pacific Railway gave new settlers free Red Fife seed (DePauw, Boughton, and Knott 1995, 6–14).

But the role of state intervention was far greater. In 1886, Parliament created the Canadian federal experiment station system, with the Central Experimental Farm established in Ottawa and additional stations subsequently opened across the country. William Saunders began breeding work at Central Farm shortly after its inception. One of Saunders's early (if only partial) successes was the introduction of the Ladoga cultivar from northern (60° N) Russia in 1887. This wheat matured earlier than Red Fife but yielded poorer-quality flour. The value of earliness was reinforced by the virtual destruction of the western crop in 1888 by a very early autumn frost. William Saunders's more lasting contribution resulted from a systematic program of hybridizing early-maturing cultivars with high-quality cultivars. In 1903 his son, Charles Saunders, took over the work. The most valuable result of their combined research efforts was Marquis, a cross between Red Fife and Red Calcutta, a very early wheat from India.[11] Released in 1909, this cultivar matured about ten days earlier than Red Fife and was more resistant to disease. These qualities led to

its rapid adoption. By 1918, Marquis accounted for over 80 percent of western Canada's wheat (Buller 1919, 254).

Ward (1994) has convincingly linked the famed Canadian wheat boom to these biological developments. His estimates show that between 1885 and 1910 the ripening period of wheat at four Canadian experiment stations fell on average by 12 days—days that meant the difference between success and failure in many years. His regression estimates capture other effects besides the switch to Marquis. He notes, for example, that the time of ripening of Red Fife declined over the period because of changes in cultural techniques such as the use of grain drills. Kenneth Norrie's quantitative study of the settlement of the Canadian prairies between 1870 and 1911 found that pushing the wheat frontier further north and west required the adoption of dry farming technologies and the development of drought-resistant and early-ripening wheat varieties suitable for the region. Midway through the period, by the 1890s, Canadian farmers were pushing the commercial wheat belt above 55° latitude.[12]

As wheat culture spread onto the prairies, it was increasingly subject to attacks of leaf and stem rusts. Rust was first noted in western Canada in 1891 and some damage was reported in 1892 and 1896 (Johnson 1961). Much more serious outbreaks occurred in 1902, 1904, 1911, 1916, 1927, and 1935. Eastern Saskatchewan and all of Manitoba proved especially prone to rust problems. In response to the severe 1916 epidemic, when 100 million bushels were destroyed, the Dominion Rust Research Laboratory was established in 1924 at the University of Manitoba. Its plant breeders, working closely with plant pathologists, developed a line of wheats possessing enhanced resistance to the rust diseases. These varieties, including Apex, Renown, Regent, and Redman, together with Thatcher from Minnesota rapidly replaced Marquis after it succumbed to the rust in the devastating 1935 attacks.

Argentina

In *Frontier Development*, Adelman (1994) makes a classic comparison between the expansion of wheat cultivation in Canada and Argentina. No Argentine figure emerges to play the starring role as prominently as did the Saunderses in Canada. The Spanish introduced wheat into Argentina in the sixteenth century, but the crop did not emerge as an important export commodity until the mid-1880s (Scobie 1964, 70). In the first half of the 1920s, Argentina ranked fourth in the world in wheat production and third in exports, behind only the United States and Canada (Canada 1925).

Much less is known about nineteenth-century breeding activities in Argentina than in the other major New World producers. Scobie is downright disdainful of the farming methods generally employed. He maintains that Argentine wheat growers "knew or cared little about seed selection" and often sold their best seed for consumption and kept poorer-quality seed for planting.[13] Even if his critical assessment captures the attitudes and behavior of the vast majority of farmers, it is likely there was still considerable progress. By the turn of the century an important new Italian wheat variety, Barletta, had gained widespread favor, indicating that at least some farmers were making improvements.[14] Barletta was well suited to a wide range of Argentine conditions because of a tolerance for drought, the ability to survive relatively extreme temperatures, and rust resistance. In addition, it had high gluten content and was prized by European millers (Scobie 1964, 87). The names of some of the other popular varieties in the early twentieth century, including Ruso, Hungaro, Rieti, Japones, Costa De Bari, Frances Blanco, and Frances Colorado, suggest that the globalization of germplasm had not bypassed the Southern Cone (Bicknell 1904, 51–54; Nisi and Antonelli 2001, 535).

A major step was taken in 1912 when the Minister of Agriculture hired William O. Backhouse, who initiated the country's first formal wheat-breeding program. Backhouse, a Cambridge graduate who studied under Biffen, tested foreign varieties at diverse locations to establish their suitability for Argentine conditions. In 1913 he began crossing the best local varieties with the imports to fight leaf rust. Barletta was becoming increasingly vulnerable to rust, which destroyed roughly one-fifth of the nation's crop in 1916. Backhouse's endeavor was a global undertaking as he imported varieties from India, North America, Europe, and China. One by one Backhouse narrowed his search. The Indian wheat varieties, obtained through A. C. Howard, director of economic botany at Pusa, adapted very well to the new environment but showed no resistance to leaf rust. The North American imports showed almost complete resistance to leaf rust but did not mature at the same time as their potential breeding partner, Barletta. Further experiments were conducted with Rieti (from Italy, containing English, Dutch, Italian, Japanese, and likely Ukrainian germplasm) and Chino. Chino, a native of Szechuan, possessed immunity to leaf rust. In 1925 the Backhouse team released a Chino-Barletta cross, wheat cultivar 38 M.A., which rapidly gained popularity over a wide region. Until the mid-1940s this variety accounted for roughly 20 percent of Argentine production (Backhouse 1917; Backhouse and Brunini 1925; Nisi and Antonelli 2001, 535–536; Guitierrez 1985, 13).

The Argentine program benefited from similar developments underway in Uruguay. In 1912–1913 two German scientists, Alberto Boerger and Enrique Klein, began breeding programs at the National Nursery of Toledo near Montevideo and at the Agronomic Station of Cerro Largo in northeastern Uruguay. In 1919, Klein moved to Argentina, where he founded the privately owned Argentine Plant Breeding Company (Nisi and Antonelli 2001, 519, 535–541). Backhouse, Boerger, and Klein were part of a growing cadre of plant scientists trained at European universities who brought their expertise to the far-flung periphery, including Kenya and India.

Australia

As in Canada, wheat breeding plays a prominent role in Australia's historiography. William Farrer, the nation's most famous wheat scientist, is regarded as Australia's "Great Benefactor" with his likeness adorning the two-dollar bill. In his authoritative account, Davidson tells us that the first attempt to grow wheat near Sydney failed:

> The original seed brought from Britain by Phillip failed to germinate. This was probably fortunate as these were the English winter wheats which are sown [in Britain] in the autumn and ripen in the shortening days of the following autumn. As they are light-sensitive they will not ripen when the days are lengthening. What was required in Australia was wheat which could be sown in autumn, grown through the winter and spring and ripen in the lengthening days of late spring before the summer drought sets in. By good fortune the next wheat seeds were obtained from Rio de Janeiro and were of the early flowering Mediterranean types which, because they are insensitive to light will ripen in a period when the hours of daylight are increasing.[15]

Other accounts confirm these difficulties: "The early colonists found themselves attempting to grow wheat under conditions that were completely different from anything that they had known, in a new country, in a new hemisphere" (O'Brien et al. 2001, 611). But there is disagreement about what types of wheat the early settlers planted. Many assert that the first successful varieties were winter wheats from England (Red and White Lammas), while others speculate that they were spring wheats (Macindoe and Walkden-Brown 1968, 2, 147, 152; Dunsdorfs 1956, 16, 73, 101).

An intriguing study by Aitken (1966) suggests an answer to this puzzle. She argues that "the first wheats must have been early types, and it is likely that they were unwittingly introduced from Mediterranean stocks via Rio de Janeiro" following the failure of the English and South

African seed sown in 1788. Aitken's evidence is impressive. Drawing on contemporary testimony, she first reconstructs the dates of sowing, flowering, and harvesting for the years 1789 to 1805 showing that the crops were mostly planted in June and harvested in November or early December. Aitken then conducted field experiments with several early and late flowering wheats, including Red Lammas. The results showed that the late varieties did not ripen until January, whereas the early varieties ripened in time for an early December harvest. The puzzle of the early years appears resolved—the first successful wheats grown in Australia most likely did not come from England.[16]

Starting with the first pioneers, there was an ongoing effort to discover varieties more suitable for Australian conditions. In 1822 the Agricultural Society of New South Wales initiated a program to introduce and test new wheat varieties, but with little success. Although scores of varieties were introduced, the first significant breakthrough occurred around 1860 in South Australia with the selection of the Purple Straw variety.[17] This variety ripened earlier than previous varieties, providing some rust protection and helping extend the wheat-sheep frontier. At about the same time, Dr. Richard Schomburgh, director of Botanic Gardens in Adelaide, introduced Du Toit from South Africa. Du Toit was distributed "widely in South Australia, where it became popular because of its early maturity and moderate resistance to stem rust" (Macindoe and Walkden-Brown 1968, 2). Over the next several decades, astute farmers and plant breeders selected varieties, including Ward's Prolific, Steinwedel, and Gluyas, that were more suitable for the drier areas of South Australia. Another important variety, Early Baart, was introduced from South Africa in 1884 by Professor Custance of the Roseworthy Agricultural College (Macindoe and Walkden-Brown 1968, 2; Wrigley and Rathjen 1981, 99–103; Dunsdorfs 1956, 189–190). These new varieties provided the genetic material for many subsequent varieties developed by deliberate hybridization.

By the 1880s successful programs to artificially outcross wheat were underway in England, the United States, Germany, France, Australia, and Austria-Hungary, among others. The first Australian efforts to hybridize wheat date to the work of A. B. Robin (also of Roseworthy), who evidently was experimenting with F1 hybrids by 1887. But the most prominent plant breeder of this era was William Farrer.

Farrer belongs to a small group of scientists who fundamentally changed the agricultural prospects of a nation. Farrer became interested in rust after witnessing the enormous damage it caused in 1882. Drawing on both his reading of Darwin and his knowledge that European and U.S. breeders were developing disease resistance in other crops, Farrer reasoned that creating rust-resistant wheat varieties might be possible. Without conducting any experiments, he published his plans for "making" high-quality rust-resistant wheats. This bold pronouncement earned him considerable scorn, as befitting of an unknown dilettante with no formal training in plant sciences.[18]

Farrer would have the last laugh. He began his experimental work in 1885 at the age of 41, and in 1889 he commenced work on hybridization. His objectives were to breed for rust resistance, to increase the gluten content and lower the starch content, to develop wheat to meet Australian conditions, and finally to increase yields in a farming regime characterized by low inputs. He would succeed on all fronts (Evans 1980, 3–13; Farrer Memorial Trust). Farrer's most important creation was Federation. In 1894 he discovered a particularly early maturing plant with purple straw (probably a pure Purple Straw) growing in a row of Improved Fife. In 1895, Farrer crossed this purple straw with Yandilla, a variety that he had previously created by crossing Improved Fife (obtained from Canada) with Etawah (from India). In 1901, Farrer released the new variety, Federation, and by 1910 it had become the most popular variety on the continent, proving remarkably productive over a diverse range of growing conditions (Macindoe and Walkden-Brown 1968, 110–111). Within a decade Federation became an important variety on the West Coast of the United States. It was early-maturing, rust-resistant, of excellent quality, and because of its Purple Straw lineage, relatively high-yielding. It possessed short, strong straw suitable for stripper harvesting as practiced in Australia. Before Farrer, wheat growing had been largely limited to the cooler table lands where later maturing varieties could survive. Federation, along with new varieties (based on drought-resistant introductions from South Africa and India), allowed farmers to push wheat cultivation into drier, hotter regions, less susceptible to rust. The early maturation of Farrer's wheats gave them added rust protection because there was less time for the spores to multiply. In New South Wales alone wheat acreage increased from 1 to 4 million acres largely because of Farrer's accomplishments.

In the course of his work he would experiment with varieties from all over the world. Many of these varieties were sent by other breeders. Farrer returned the favor. Evans (1980, 13) captures the essence of these transactions: "In 1894 he [Farrer] wrote, 'I have been sending wheats to Europe and America, and intend to send some to India and France. I hope also to soon be able to start a correspondence with people in different parts of the world. . . .' He was, in fact, a one-man international agricultural research centre." In addition to exchanging seeds, Farrer discussed experimental procedures and myriad details of his research with some of the leading breeders of the day, including Henri Vilmorin in France, A. E. Blount, B. T. Galloway, and Mark A. Carleton in the United States, Charles Saunders of Canada, and Rowland H. Biffen in England (Evans 1980, 5, 10; Farrer Memorial Trust). The international exchange of ideas and germplasm represents an important way that the world was getting smaller.[19]

Aitken's (1966) agronomic studies highlight the importance of the new varieties. In the late 1950s she conducted experiments on the physical development of a number of modern and obsolete wheat varieties. The out-of-date varieties included the winter wheats Purple Straw, Red Lammas, and Little Joss and the spring wheat Federation. Under a variety of geoclimatic conditions the winter wheats suffered damage to their root structures because of high soil temperature, and they were later to mature, thus exposing them to environmental risks. The root damage was far more serious than generally thought, lowering yields and in some instances preventing fruiting. Of special interest, she found that when it was winter-sown, Federation wheat flowered five weeks earlier than Lammas and developed leaf structures more suitable to hot climates.[20]

Although wheat producers in Canada and Australia confronted dramatically different environments, major concerns being frigid weather in Canada and hot weather in Australia, there were also striking similarities in conditions and in the responses. In both countries, farmers pushed wheat production into arid regions unlike anything experienced in the old northern European center. Moreover, the challenge created by both cold and heat called for spring wheat varieties with relatively short growing seasons. A variety that did not ripen early was in danger of being damaged or killed by frost in Canada and by heat in Australia. Thus both Charles Saunders and William Farrer followed a common path by cross-breeding Red Fife (originating in the Ukraine, shipped to Poland, forwarded to Scotland, reshipped to Canada, and later sent to Australia) with Indian wheats noted for early ripening and drought tolerance. Such were the international pedigrees of the two wheat varieties, Marquis and Federation, credited with making possible the opening of millions of acres of new wheat lands.

Conclusion

The long nineteenth century saw substantial changes in the loci of wheat production. Between the late 1860s and the late 1920s, the average distance of world wheat production from London almost doubled, as measured in our capital-to-capital calculations. This change in average distance occurred in spite of a large increase in production in western Europe. Allowing for internal shifts *within* the United States, Canada, and other producing countries on the periphery would add further to the economically meaningful change in distance. Relative to the 1860s, wheat cultivation in the 1920s was distributed to lower-yielding lands that were typically both colder and drier. The geoclimatic differences between the old center and the frontiers of wheat production were so great that few varieties grown in western Europe were of value in the new lands. These shifts in production would not have been possible without a sustained and highly successful research and development effort to find wheat varieties that would prosper in the more hostile conditions. This was truly an international endeavor that depended on identifying, transferring, selecting, and genetically recombining varieties from both the center and distant locales on the periphery.

Wheat breeding in many ways reflected the character of the nation where it was conducted. In Britain the work was performed by heroic improvers such as Shirreff, Le Couteur, and Biffen. In the United States improvement efforts were more decentralized at the state agricultural experiment stations, with federal officials like Mark A. Carleton concentrating on discovering and testing appropriate varieties from around the globe. Efforts were more organized in Canada, resulting in the early creation of Marquis, which crossed eastern European and Indian wheats. Australia followed a similar course. In Argentina the first varieties were imported by migrants, with wheats from Italy, Hungary, and Russia gaining popularity. Later breeding involved scientists from Britain and Germany who were well connected to the scientific institutions of Europe. Although the breeding efforts in different countries evolved in ways reflecting their individual national character and environmental conditions, by the end of the nineteenth century, breeding had become a global enterprise with the exchange of ideas, scientists, and germstock between every continent. These exchanges were facilitated by the research and extension programs that flourished in every major wheat-producing nation (and within the United States in every important wheat-producing state). The scientific community functioned more efficiently as personal contacts, informal networks, and professional journals united researchers into a closely knit community.

Wherever wheat was grown commercially in the nineteenth and early twentieth centuries, it was constantly being reformulated to fit local conditions, conditions that were constantly evolving because of changing disease and pest environments. Even more than the immigrants who populated the new lands, the grains they grew were the product of "melting pots," with their "ancestors" coming from areas across Europe, Asia, and many of the periphery countries of recent settlement.[21] Advances in basic science and the international exchange of ideas and biological material constituted the "other grain invasion" that was a necessary condition for and an integral part of the globalization story popularized by Williamson and others.

Appendix

Wheat Production

Comprehensive data on world wheat production from 1885 to 1930 are available in the Food Research Institute's *Wheat Studies*. The data cover 43 wheat-producing countries spread across every continent (except, of course, Antarctica).[22] The FRI data exclude "large wheat-producing areas in China and southwestern Asia, and also numerous insignificant producing areas," but this is not too worrisome because little wheat from these areas was exported to European markets. What is more important is that the series, assembled by leading authorities, contain reasonably consistent data for every major player in world grain markets.

Production data before 1885 are more problematic. Our approach was to assemble annual series, where available, for the period between 1866 and 1896. We relied heavily on Mitchell's *International Historical Statistics*. Reasonably consistent production data exist for many European countries (Austria, France, Denmark, Great Britain, Germany, Hungary, Italy, the Netherlands, Romania, and Sweden) as well as Algeria, Australia, Canada, and the United States.[23] We thank Albert Carreras for providing his unpublished production series for Spain. Long annual series exist for exports (though not total production) from Argentina, Russia, and British India. Unfortunately, we located annual production series for only a few of the small producing countries in Europe, Asia, and Africa. Given that the consistent data available for Russia

before 1885 cover only exports (which represent less than one-third of the total crop during the brief 1870–1877 period when both series are reported), the series from the early period understates the average distance of production from London. In the 1885–1896 period, when the comprehensive FRI-based series and our 18-nation series overlap, the ratio between the two distances averages 1.142. For purposes of comparison, we raised the 1866 distance from 2,081 km to 2,377 km, and so on, to form the adjusted series.

Distance

It is conventional in the international trade literature investigating gravity models to measure distance between countries based on the locations of their capitals.[24] Using London as the center of the world wheat market is not too problematic. Liverpool might be a better choice, but the differences are small. Taking Buenos Aires and Canberra as the centers of production in Argentina and Australia, respectively, will likely raise concerns among some scholars. But each of these capitals is located near its nation's main grain-producing belt. We have far stronger reservations about using Washington, D.C., as the center for U.S. wheat production and Ottawa as Canada's center. For example, based on our earlier work, we know that the geographic center of U.S. wheat production circa 1839 was well north and west of the nation's capital and moving further westward over time. Whereas London was always 5,932 kilometers from Washington, D.C., it was 6,136 km from the 1839 center and 6,989 km from the 1919 center. The difference in the distances measured from London is less than the distance between the two centers because the three locations form a triangle rather than lying on a straight line. The 1919 centroid was also closer to London in latitude (though further in longitude) than the 1839 centroid.

An examination of maps for Canada showing the spread of wheat production from Ontario to Manitoba, Saskatchewan, and Alberta, indicates a similar process was at work. But to abide by the conventions of the gravity literature, we retained Washington, D.C., and Ottawa as the measuring points for the United States and Canada, respectively. The North American examples do suggest that our calculations likely understate the increase in distance during the great globalization wave. We know that between 1885 and 1904 the Russian wheat belt moved about one-half a degree in longitude to the east. And we suspect similar results would hold for other expanding producers on the periphery.[25]

Climate Data

The climate data were constructed from data in Bennett and Farnsworth (1937, appendix, 303–308). This source presents a highly detailed survey of the geographic distribution of wheat acreage, yields, and climates covering 223 subunits. As an example of the detail, the province of Saskatchewan is divided into nine subregions. For each of the subunits, the FRI reports the acreage (planted), yields, and average precipitation and temperature that were typical during the 1920–1934 period. From these data, we can form national aggregates, reflecting average conditions prevailing in the wheat-producing areas, that can be combined by using weights derived from the production data investigated before to derive series showing the changing conditions under which wheat was grown. Note that the national aggregate captures conditions prevailing at the end of the period, and to the extent that there were shifts in the location of production within the United States, Canada, Russia, and other countries that pushed wheat production into harsher environments, our series likely understate the overall changes in climatic conditions.

Notes

We thank Julian Alston, Liam Brunt, Albert Carreras, Dana Dalrymple, Robert C. Feenstra, Jeffrey Graham, Shelagh Mackay, and Pablo Reynolds for providing comments, research materials, and assistance to make this chapter better. Work on this chapter was facilitated by a fellowship granted by the International Centre for Economic Research (ICER).

1. The definition of invasive species is at ⟨http://www.eco-pros.com/invasive_non-native_species.htm⟩. Weeds are typically defined as plants that grow where they are not wanted, plants that are hardy, aggressive, and prone to spread quickly.

2. Williamson was well aware of the importance of measuring the difference between farm prices (as opposed to Chicago prices) and urban markets, and in *Late Nineteenth-Century Economic Development* (1974, 257–262) he calculated that between 1870–1875 and 1905–1910 the gap fell by about 55 percent between Iowa and New York City, and Wisconsin and New York City. But this calculation fails to capture the effect of the moving wheat frontier over that period.

3. The construction of the data, which is discussed in the appendix, involves aggregating regional FRI statistics on acreages, yields, and climates (Bennett and Farnsworth 1937).

4. The calendar of the world wheat harvest also filled out, dampening seasonal fluctuations in supplies and prices. Formerly the harvest relevant for the center countries occurred almost exclusively in June, July, and August. By the 1920s about one-quarter of the harvest took place in the Northern Hemisphere's nonsummer months. Australia and South America gathered their wheat crops in December and January; India, Iran, Turkey, and Mexico, in March, April, and May (*Wheat and Rye Statistics* 1926, 23; *Monthly Crop Reporter*, July 1920, 71).

5. Brassley (2000, 522–532); Angus (2001, 111–113). For a comprehensive examination of the general forces (other than breeding activities) determining yields, see Brunt (2004).

6. de Vries (1907, 29–90) includes an extensive discussion of the ideas and work of Le Couteur and Shirreff.

7. See volume 2, chapter 9, "Cultivated Plants: Cereal and Culinary Plants." An alternative to the Le Couteur and Shirreff approach, which stressed initial selection and then multiplication of the self-pollinating wheat, was offered by F. Hallett, who attempted to improve the seed by growing the plants under favorable conditions and continuing selection. Hallett developed and sold a series of pedigreed wheats under this name (Carleton 1916, 192–195).

8. British Board of Agriculture (1894). We thank Liam Brunt for this reference.

9. Murray (1967, 37); Pritchett (1942, 113, 228). Fife had the decided advantage of maturing about ten days earlier than the variety from Prairie du Chien.

10. DePauw, Boughton, and Knott (1995, 6). These native insects had also injured the crops in 1857, 1858, 1864, and 1867. For a general treatment, see Lockwood (2004).

11. The actual cross leading to Marquis was probably made in 1892. William Saunders led the effort, and his sons Arthur and Charles assisted (Pomeroy 1956, 48–52; Clark and Bayles 1935, 69; de Kruif 1928, 42; Morrison 1960).

12. Ward (1994). Buller (1919, 175–176) credits Marquis with giving adopters about one extra week between harvest and freeze-up, thus giving farmers a significant advantage in preparing their land for the next season (de Kruif 1928, 41).

13. Scobie (1964, 77). This account draws heavily on Bicknell (1904, 38–39).

14. Presumably many other varieties were tried and rejected. As an example, Bicknell (1904, 54) reports that in 1902–1903 the USDA sent leading Argentine farmers a number of varieties for local testing, including Pelissier from Algeria, and Crimean and Kubanka from Russia.

15. Davidson (1981, 49). The early settlers also obtained an unknown variety in Cape Town, but this too failed (Macindoe and Walkden-Brown 1968, 1; Wrigley and Rathjen 1981, 96–98; Campbell 1937).

16. The blanket assertion that winter wheat could not be grown is undermined by an 1868 survey of wheat varieties. But we still have little idea why farmers adopted late varieties such as Red Lammas. Such varieties evidently would ripen, albeit dangerously late, in the relatively favorable wheat-growing areas of New South Wales, Victoria, and South Australia, which composed the early Australian wheat belt. They would be totally unacceptable for what would eventually become the new areas of production in the more arid inland regions. For regional production data, see Dunsdorfs (1956, 206, 531–533).

17. Macindoe and Walkden-Brown (1968) and many others attribute Purple Straw to a selection made by a now anonymous farmer in the Adelaide area ca. 1860, but based on an 1862 Adelaide newspaper account, Wrigley and Rathjen (1981, 100) attribute the creation to John Fraine, whom they credit with employing relatively sophisticated pure-line breeding methods to develop Purple Straw. Also see Dunsdorfs (1956, 148).

18. Evans (1980, 3–5); Wrigley and Rathjen (1981, 105). Farrer attended Pembroke College, Cambridge, where he studied mathematics. He worked as a surveyor from 1875 to 1886 before becoming one of the world's leading plant scientists.

19. The exchange, even very early in his career, was a two-way street. Evans (1980, 6) notes that Farrer's mention of using cross-breeding to improve wheat quality was an innovative proposition and that Farrer put the idea into practice a decade before Biffen's successes in England.

20. Federation also outperformed Red Fife, which was the latest of the spring wheats tested.

21. Some of the flows of wheat germplasm may be interpreted as a variant of the South-South migration that Hatton and Williamson highlighted in their studies on nineteenth-century labor flows. Hatton and Williamson (2002) observe that the causes and consequences of the migration of 50 million Europeans before 1914 have attracted intense scholarly attention, whereas the 50 million people who left their homes in China and India for jobs elsewhere in the periphery have largely escaped notice.

22. Bennett (1933). The FRI series do make adjustments for the United States and Russia that create differences from standard series. For a critical evaluation of these data, see Malenbaum (1953, 54–62).

23. In a handful of cases we extrapolate and interpolate the series for smaller producers to extend and fill in their series over small stretches. It would be possible to add series for Finland and Norway using this procedure, but wheat production is negligible in those countries.

24. Another convention is that distance is measured as zero in the home country and in all countries sharing a land border. Further, the calculations use great arc distance between the capitals. One might well object that, at least before the advent of aircraft, great arc distances poorly reflect the number of kilometers that shipments would actually travel. To take an extreme example, San Francisco and Liverpool are 8,362 km apart by great arc distance, but wheat shipped from the California port to the English had to travel 25,006 km around the Straights of Magellan, or 14,492 km after the Panama Canal became available.

25. The exception might be Australia, where production moved westward as well as inland. We will make one important concession to the actual geography of production for Russia by using the Ukrainian capital, Kiev, in place of Moscow. Kiev is 2,130 km from London and is located proximate to (if somewhat west of) the nation's wheat-producing region, whereas Moscow (2,512 km away from London) is far outside the wheat belt.

References

Adelman, J. 1994. *Frontier Development: Land, Labour, and Capital on the Wheatlands of Argentina and Canada, 1890–1914*. Oxford: Clarendon Press.

Aitken, Y. 1966. Flower Initiation in Relation to Maturity in Crop Plants: The Flowering Response of Early and Late Cereal Varieties to Australian Environments. *Australian Journal of Agriculture Research* 17: 1–15.

Angus, W. J. 2001. United Kingdom Wheat Pool. In *The World Wheat Book: A History of Wheat Breeding*, ed. A. P. Bonjean and W. J. Angus, 103–126. Paris: Intercept.

Backhouse, W. 1917. *Mejoramiento de Trigos: Orientación General, Primeros Resultados.* Talleres Gráficos del Ministerio de Agricultura de la Nación.

Backhouse, W., and V. Brunini. 1925. *Genética del Trigo: Observaciones Generales sobre su Cultivo: Conclusiones Extraidas de los Trabajos de Mejoramiento de la Semilla.* Talleres Gráficos del Ministerio de Agricultura de la Nación.

Bennett, M. K. 1933. World Wheat Crops, 1885–1932. *Wheat Studies* 9 (7): 239–274.

Bennett, M. K., and H. C. Farnsworth. 1937. World Wheat Acreage, Yields, and Climates. *Wheat Studies* 13 (6): 265–308.

Bicknell, F. W. 1904. *Wheat Production and Farm Life in Argentina.* USDA Bureau of Statistics Bulletin 27.

Bonjean, A. P., G. Doussinault, and J. Stragliati. 2001. French Wheat Pool. In *The World Wheat Book: A History of Wheat Breeding*, ed. A. P. Bonjean and W. J. Angus, 140–149. Paris: Intercept.

Brassley, P. 2000. Crop Varieties. In *The Agrarian History of England and Wales*, ed. E.J.T. Collins. Vol. 7, *1850–1914*, 522–532. Cambridge: Cambridge University Press.

British Board of Agriculture. 1894. Report of the Intelligence Department on Rust or Mildew on Wheat Plants, 1893–1894. *British Parliamentary Papers* 23.

Brunt, L. 2004. Nature or Nurture? Explaining English Wheat Yields in the Industrial Revolution, c. 1770. *Journal of Economic History* 64 (1): 193–225.

Buller, A.H.R. 1919. *Essays on Wheat*. New York: Macmillan.

Campbell, W. S. 1937. Wheats in New South Wales from the Foundation of the Colony. *Royal Australian Historical Society Journal and Proceedings* 22: 406–433.

Canada as a Producer and Exporter of Wheat. 1925. *Wheat Studies* 1 (8): 218.

Carleton, M. A. 1916. *The Small Grains*. New York: Macmillan.

Clark, J. A., and B. B. Bayles. 1935. *The Classification of Wheat Varieties Grown in the United States*. USDA Technical Bulletin 459.

Crosby, A. 1972. *The Columbian Exchange: Biological and Cultural Consequences of 1492*. Westport, Conn.: Greenwood.

Davidson, B. R. 1981. *European Farming in Australia: An Economic History of Australian Farming*. Amsterdam: Elsevier.

de Kruif, P. 1928. *Hunger Fighters*. New York: Harcourt, Brace and World.

de Vries, H. 1907. *Plant-Breeding: Comments on the Experiments of Nilsson and Burbank*. Chicago: Open Court.

DePauw, R. M., G. R. Boughton, and D. R. Knott. 1995. Hard Red Spring Wheat. In *Harvest of Gold: The History of Field Crop Breeding in Canada*, ed. A. E. Slinkard and D. R. Knott, ch. 2. Saskatoon, Canada: University Extension Press, University of Saskatchewan.

DePauw, R. M., and T. Hunt. 2001. Canadian Wheat Pool. In *The World Wheat Book: A History of Wheat Breeding*, ed. A. P. Bonjean and W. J. Angus, 479–515. Paris: Intercept.

Dunsdorfs, E. 1956. *The Australian Wheat-Growing Industry: 1788–1948*. Melbourne: Melbourne University Press.

Evans, L. T. 1980. Response to Challenge: William Farrer and the Making of Wheats: Farrer Memorial Oration, 1979. *Journal of the Australian Institute of Agricultural Science* 46.

Farrer Memorial Trust. William James Farrer Papers, February 1885–May 1906. CGS 55. ⟨http://www.records.nsw.gov.au/cguide/ab/agric.htm⟩.

Grossman, G. M., and E. Helpman. 1991. *Innovation and Growth in the Global Economy*. Cambridge, Mass.: MIT Press.

Guitierrez, M. 1985. *El Origen de las Semillas Mejoradas de Trigo y Maiz en la Argentina: La Dinámica de las Creatión y las Modalidades de Investigación Publica y Privada*. Buenos Aires: Centro de Investigaciones Sociales sobre el Estado y la Administración.

Hallett, F. F. 1861. On "Pedigree" in Wheat as a Means of Increasing the Crop. *Journal of the Royal Agricultural Society of England* 22: 371–381.

Hatton, T. J., and J. G. Williamson. 2002. What Fundamentals Drive Mass Migration? NBER (National Bureau of Economic Research) Working Paper 9159. ⟨http://www.nber.org/papers/W9159⟩.

Johnson, T. 1961. *Rust Research in Canada and Related Plant-Disease Investigation*. Agriculture Canada Publication 1098.

Lockwood, J. A. 2004. *Locust: The Devastating Rise and Mysterious Disappearance of the Insect That Shaped the American Frontier*. New York: Basic Books.

Lupton, F. G. H. 1987. History of Wheat Breeding. In *Wheat Breeding: Its Scientific Basis*, ed. F. G. H. Lupton, 51–70. London: Chapman and Hall.

Macindoe, S. L., and D. C. Walkden-Brown. 1968. *Wheat Breeding and Varieties in Australia*. 3d ed. Sydney: New South Wales Department of Agriculture.

Malenbaum, W. 1953. *The World Wheat Economy: 1885–1939*. Cambridge, Mass.: Harvard University Press.

Morrison, J. W. 1960. Marquis Wheat: A Triumph of Scientific Endeavor. *Agricultural History* 34 (4): 182–188.

Murray, S. N. 1967. *The Valley Comes of Age: A History of Agriculture in the Valley of the Red River of the North, 1812–1920*. Fargo, N.D.: Institute for Regional Studies.

Nisi, J. E., and E. F. Antonelli. 2001. Argentine Wheat Pool. In *The World Wheat Book: A History of Wheat Breeding*, ed. A. P. Bonjean and W. J. Angus, 519–547. Paris: Intercept.

O'Brien, L., M. Morrel, C. W. Wrigley, and R. Appels. 2001. Genetic Pool of Australian Wheats. In *The World Wheat Book: A History of Wheat Breeding*, ed. A. P. Bonjean and W. J. Angus, ch. 23. Paris: Intercept.

Olmstead, A. L., and P. W. Rhode. 2002. The Red Queen and the Hard Reds: Productivity Growth in American Wheat, 1800–1940. *Journal of Economic History* 62 (4): 929–966.

———. 2003. Biological Innovation in American Wheat Production: Science, Policy, and Environmental Adaptation. In *Industrializing Organisms: Introducing Evolutionary History*, ed. S. Schrepfer and P. Scranton, 43–83. New York: Routledge.

O'Rourke, K. H. 1997. The European Grain Invasion, 1870–1913. *Journal of Economic History* 57 (4): 775–801.

O'Rourke, K. H., and J. G. Williamson. 1999. *Globalization and History: The Evolution of the Nineteenth Century Atlantic Economy*. Cambridge, Mass.: MIT Press.

Persson, K. G. 2004. Mind the Gap! Transport Cost and Price Convergence in the Nineteenth Century Atlantic Economy. *European Review of Economic History* 8: 127–147.

Pomeroy, E. M. 1956. *William Saunders and His Five Sons: The Story of the Marquis Wheat Family*. Toronto: Ryerson Press.

Pritchett, J. P. 1942. *The Red River Valley, 1811–1849: A Regional Study*. New Haven, Conn.: Yale University Press.

Roberts, H. F. 1929. *Plant Hybridization before Mendel*. Princeton, N.J.: Princeton University Press.

Scobie, J. R. 1964. *Revolution on the Pampas: A Social History of Argentine Wheat, 1860–1910*. Austin: Texas University Press.

Shirreff, P. 1873. *Improvement of the Cereals and an Essay on the Wheat-Fly*. London: Blackwood.

Symko, S. 1999. From a Single Seed: Tracing the Marquis Wheat Success Story in Canada to Its Roots in the Ukraine. ⟨http://res2.agr.gc.ca/publications/marquis/index_e.htm⟩.

Walton, J. R. 1999. Varietal Innovation and the Competitiveness of the British Cereals, 1760–1930. *Agricultural History Review* 47: 29–57.

Ward, T. 1994. The Origins of the Canadian Wheat Boom, 1880–1910. *Canadian Journal of Economics* 27 (4): 864–883.

Wheat and Rye Statistics. 1926. USDA Statistical Bulletin 12.

White, W. J. 1995. Plant Breeding in Canada's Formative Years. In *Harvest of Gold: The History of Field Crop Breeding in Canada*, ed. A. E. Slinkard and D. R. Knott, ch. 1. Saskatoon, Canada: University Extension Press, University of Saskatchewan.

Williamson, J. G. 1964. *American Growth and the Balance of Payments, 1820–1913: A Study of the Long Swing*. Chapel Hill: University of North Carolina Press.

———. 1974. *Late Nineteenth-Century American Development: A General Equilibrium History*. Cambridge: Cambridge University Press.

Wrigley, C. W., and A. Rathjen. 1981. Wheat Breeding in Australia. In *Plants and Man in Australia*, ed. D. J. Carr and S. G. M. Carr, 96–135. Sydney: Academic Press.

Zapoleon, L. H. 1918. *Geography of Wheat Prices: Summary of Conditions Affecting Farm Prices of Wheat in Different Parts of the United States*. USDA Bulletin 594.

6 Other People's Money: The Evolution of Bank Capital in the Industrialized World

Richard S. Grossman

Jeffrey G. Williamson and like-minded practitioners of the New Comparative Economic History focus on analyses of historical events, highlighting issues of contemporary importance. Because of its long-run comparative framework, the New Comparative Economic History can provide insights into current-day policy issues that research based on shorter time series and narrower geographic scope cannot. In the spirit of Williamson's work, this chapter takes a long-run comparative approach to the evolution of bank capital in Europe, the United States, Canada, Australia, and Japan from the nineteenth century through the Second World War.

From the enactment of the first commercial banking codes in Britain (1844) and Sweden (1846), through the establishment of the Basel (1988) and Basel II (2004) capital accords, policymakers have argued that capital promotes bank "soundness and stability" (Basel Committee 1988; 2004). Even in the absence of explicit government regulation of capital, the investing and depositing public has an interest in bank capital levels, what Berger, Herring, and Szegö (1995) refer to as "market capital requirements." The goal of this chapter is to present data on the evolution of bank capital-to-asset ratios across countries and U.S. states, and to assess the relative importance of market capital requirements, government capital regulation, and other factors in that evolution.

Briefly, I find that capital-to-asset ratios declined consistently across countries from the mid-nineteenth century through the end of World War I. The findings from the interwar period are less clear-cut. I find an important role for market capital requirements: banking crises and other indicators of increased risk are associated with higher capital-to-asset ratios. The effects of government policies, such as deposit insurance and other aspects of the bank safety net, are more ambiguous, although these policies are notoriously difficult to measure accurately. Interestingly,