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The Long American Grain Invasion of Britain: Market integration and the wheat trade between North America and Britain from the Eighteenth Century

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The Long American Grain Invasion of Britain: Market integration and the wheat trade between North America and Britain from the Eighteenth Century[1]

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Abstract: This paper provides evidence that transatlantic commodity market integration began prior to the "first era of globalization" at the end of the nineteenth century. It does so by giving a long term perspective to the story of the development of an Atlantic Economy in wheat between the United States and Britain. Both trade statistics and contemporary comment reveal the importance of this trade from the middle to late eighteenth century, long before the so-called grain invasion of the late nineteenth century. Using data on imports from America and a large volume of substantiating primary evidence, specific periods are identified when market integration might have been possible. Using price data for wheat in America and Britain, some evidence is found that markets were integrated, but this process was continuously being interrupted by "exogenous" events, such as trade policy, war and politics. Transportation costs cannot be seen to be the driving force behind periods of increased trade, which are more attributable to the absence of these exogenous events.

JEL Classifications: N7

Keywords: Grain invasion, wheat, globalization, American colonial trade

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1. Introduction

"Sire, have you not taken away the only remedy for this scarcity; the only relief to which we can now look under a bad harvest – by closing the corn market of America."

– Brougham, Parliamentary Debate, 1812[2]

The concept and consequences of globalization have recently enjoyed a vast amount of scholarly attention. In this literature economic historians have played a key role in demonstrating that globalization is not a new phenomenon, but rather something that has occurred in a series of waves, the first of which was in the nineteenth century (see for example O'Rourke & Williamson, 1999). Moreover, this body of research has been at pains to point out that the traditional indicators, such as volumes of trade in the case of commodity markets, are not sufficient when defining globalization. Trade volumes have for example increased in earlier periods, such as with the discovery of the Americas by Europeans. Globalization is thus defined as commodity market integration, with the increase in trade merely a result of this.

Might economic historians be guilty of the same mistake, however, when choosing in which period to date the "first era of globalization"? Focus has naturally been directed at the late nineteenth century, when trade volumes boomed, and has concentrated primarily on the trade in wheat between the US and the UK. This trade took off at the end of the nineteenth century after a period of many decades of high protectionism. With very few exceptions, however, and despite this scholarly enthusiasm for the famous "Grain Invasion" of the late nineteenth century, very little attention has been paid to the trade in wheat between America and Britain going back even further to a time when volumes were relatively small: the eighteenth century.[3] And this despite the finding long ago by Shepherd & Walton (1972) that wheat and flour exports were of one of the major export commodities of the colonies, only exceeded in importance by tobacco.

Indeed, politicians and farmers of the mid- to late nineteenth century seem to have been under the impression that the importance of grain imports from North America started in their time, and economic historians seem to have been content to accept this (see for example O'Rourke & Williamson 1999). That trade volumes were modest, however, does not mean that there was no globalization or commodity market integration. Moreover, although the levels of trade in wheat between the US and the UK were relatively small, they were in fact not insignificant for many years, meaning that market integration was certainly possible. The difficulty of looking for market integration in this period, is, however, that trade was continuously being cut off by various "exogenous" events, such as biological phenomena, war and politics. These correspond to those

[2] Quoted by Galpin (1922, p. 24).
[3] There has been more attention on the export of wheat from Britain, see for example Ormrod (1985).

identified by O'Rourke (2006) who notes the possibility that market integration (globalization) might have started earlier if it had not been for the impact of such shocks[4].

This paper considers the development of the trade in wheat between America and Britain from the beginning of the eighteenth century to the end of the nineteenth century. No apology is made for the focus on just two countries and one commodity. Similar studies have formed the basis of our understanding of market integration in the late nineteenth century.

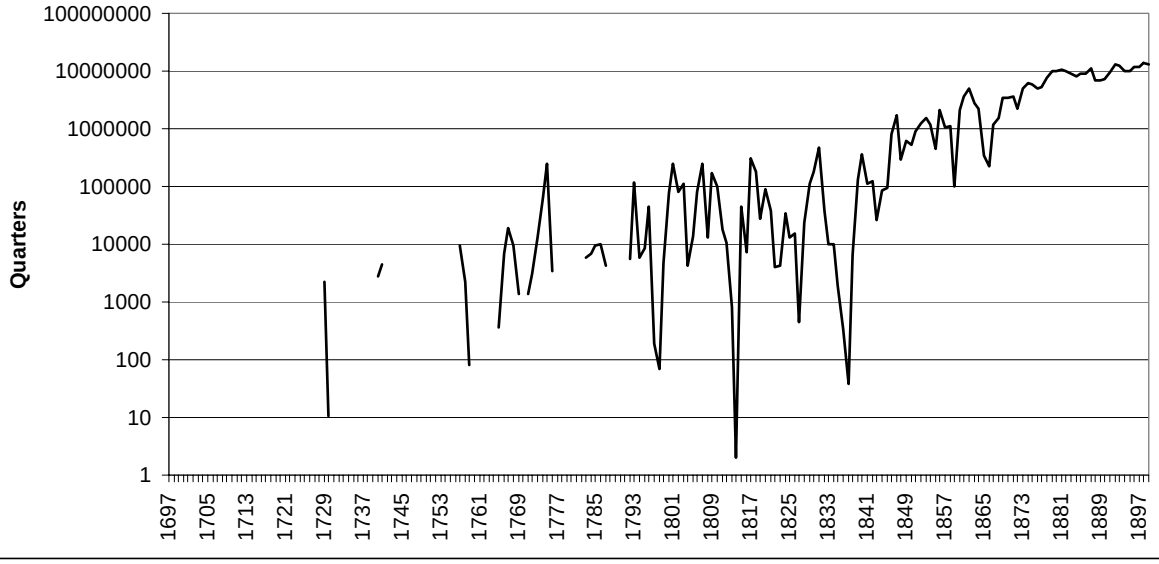
The pre-nineteenth century transatlantic grain trade has been almost completely neglected in the recent literature. It is in fact necessary to go back to the work of W. Freeman Galpin (1922, 1925) to find otherwise. Galpin painstakingly establishes the importance of the American supply of grain for Britons at home and to British forces stationed in Spain and Portugal during the French and Napoleonic Wars. However, even he was under the impression that the "importance… of American grain in English history presented itself for the first time during the Napoleonic era". He does not, however, back his assertion up with any evidence.

Establishing that there was market integration in the eighteenth century requires a number of different steps. First, in section 2 the fact that there was a trade in grain between America and Britain stretching back to the early years of the eighteenth century is established by looking at the available data on wheat imports from America to Britain from 1697 to 1899. This means that evidence for market integration cannot be dismissed as spurious. Comparing the level of imports with estimates of total wheat consumption in each year also helps motivate the study of this important trade. In section 3 the "exogenous" episodes which might be expected to impact on market integration are identified. These correspond to years of below-trend wheat trade as identified from the data presented in section 2 and are explained with reference to evidence mainly gathered from a number of primary sources. This section also demonstrates the importance attached by eighteenth century Britons to the supply of grain from America, a fact not recognized in recent work. Section 4 looks at the behaviour of prices over the period and tests for market integration. Section 5 concludes.

[4] Jacks (2005, 2006) was one of the first to note that transatlantic market integration began prior to the second half of the nineteenth century and this point has recently been conceded by Williamson (2008).

2. The long grain invasion of Britain

Figure 1: UK imports of wheat and wheat flour from North American Colonies / United States 1697-1899 (Log scale)



The available data on wheat imports from the North American Colonies and the United States is illustrated in figure 1, which covers the period from 1697, when the office of Inspector General of Imports and Exports was established, with the first imports of wheat from North America recorded in the 1720s.[5]. The data is plotted on a logarithmic scale in order to better illustrate the variability of imports in the period before the 1870s. Unfortunately, plotting the data in this way means that years with zero imports appear as missing observations. In fact, data is available for every year.

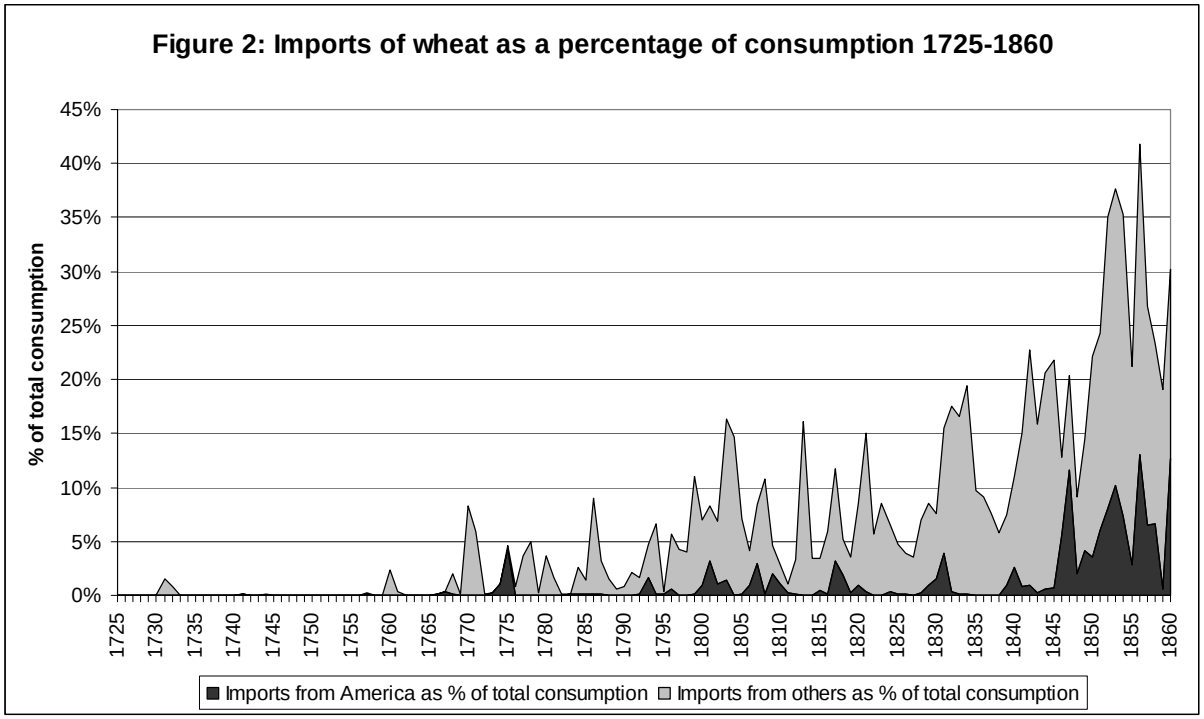
Of course, the levels of imports in the eighteenth century are tiny compared to later years. However, population was also rather smaller, so in order to get an idea of the importance of these imports it is useful to compare the level of imports from America with total imports and estimates of total consumption of wheat in Britain.

Collins (1975) provides a number of estimates of annual wheat consumption per head in the nineteenth century, ranging from 6 to nearly 9 bushels. He also shows, however, that this was

[5] The data from 1697-1787 is for wheat only and comes from BPP (1789). The data includes trifling imports from Canada. Before 1755 the data does not include Scotland. Afterwards it is for the island of Great Britain. I have not been able to locate data for the years 1788-1791. From 1792 all imports are for wheat and wheat flour combined. From 1792-1799 they are from BPP (1815), from 1800-1824 they are from BPP (1827a), from 1825-1828 from BPP (1827b), from 1829-1830 from BPP (1832), from 1829-1839 from BPP (1843) and from 1840-1899 from the *Annual Statements of Trade 1853-1900*. Total imports (including from Ireland) are taken from BPP (1843) until 1842 and the *Annual Statements of Trade 1853-1900*. Where this is not already done in the sources, imports of wheat (measured by volume: quarters) is added to imports of wheat flour (measured by weight: hundredweight, cwt) using the assumption that there are 392 lbs (i.e. 3.5 cwt) of flour to a quarter of wheat (the assumption made in British Parliamentary Papers). For later years imports of wheat are also recorded by weight, and for the sake of comparison it is thus assumed that there are 4.4 cwt of wheat to the quarter.

changing over time, since in 1800 only 66 per cent of grain consumption was for wheat, as opposed to 88 per cent in 1850 and 97 per cent in 1900. This means that an assumption of 0.9 quarters (over seven bushels) of wheat per person per year is almost certainly an overestimate for the eighteenth century. Nevertheless, making this fairly heroic assumption and multiplying it by the population statistics compiled by Wrigley & Schofield (1981) and Mitchell & Deane (1953, pp. 8-9) it is possible to get an idea of the levels of consumption.

Figure 2: Imports of wheat as a percentage of consumption 1725-1860



As figure 2 illustrates, even in the late 1700s imports from America were often supplying up to about three or four per cent of consumption. They were thus supplying a significant share of the population. Using data on total imports it is also possible to give an impression of the relative importance of US imports compared to those from other countries: for many years they were are a large proportion of total imports. The rest of the imports are predominantly coming from Prussia/"Germany", which for most years supplies in excess of half of all imports. The lesson is nevertheless clear: the United States' importance as a grain exporting country dates to the eighteenth century. There are, however, large fluctuations.

3. Explaining the fluctuations

It turns out that these fluctuations are surprisingly easy to explain. They are all the result of exogenous shocks to the developing Atlantic Economy, which in some cases cause imports to dwindle to a trickle for many years. It is convenient to divide this story into three periods: one until the 1760s and '70s, when Britain was a net exporter of wheat; the next from the industrial revolution and the accompanying population boom, which resulted in Britain becoming a net importer up until the end of the French and Napoleonic Wars; and finally from the introduction of

extreme protectionism after 1815 until the abolition of the Corn Laws sliding scale in 1849. The period after the repeal of the Corn Laws, when American grain assumes its huge importance, which it maintains until the 1930s, is covered by Sharp (2007).

3.1 Imports as a response to harvest failure: The period until 1773

It turns out that the sporadic imports of wheat in the first period are easily explained by harvest failure in Britain. This can be seen by comparing the years in which imports are present with the annual evidence on English harvests collected by Jones (1964). So, for example, Jones records that 1728 and 1729 (the first years for which he collects evidence) were marked by "great dearth". And indeed, we find that American imports are first present in 1729. 1730 to 1739 was, however, a decade of "good harvests", and we find that American imports are entirely absent until 1740, following a "wet, late harvest" in 1739 and "extraordinary scarcity" in 1740. Jones then records that harvests were generally excellent until 1755, when the harvest was late, and 1756, "a year of scarcity". And of course we then find that imports from America appear in 1756 and 1757. The success of American exporters in these years provoked an embargo on "all American vessels laden with corn, flour, &c" in 1757 (Pitt 1792, p. 266) Harvests are then recorded as being good until 1766, 1767 and 1768 which were all marked by food riots. This resulted in an embargo on the *exportation* of corn from England. Imports from America were then again welcome (Pitt 1792, p. 368), indeed, an "Act for allowing the Importation of Wheat and Wheat-flour from His Majesty's Colonies in America, into this Kingdom, for a Time to be limited, free of Duty" was passed in 1766 (BPP 1766, p. 29) and was continued the following year (BPP 1767, p. 429).

Until this point we have learned nothing new: imports were largely the consequence of scarcity at home, a point well known from previous studies. However, it might be noted that American farmers were clearly looked to as a source of supply after a bad harvest, and were also obviously able to react. Every year there was a bad harvest the American colonies stepped in to help meet the deficit.

During this period, however, America was mostly seen as competition for British producers, and Britain was of course still at this time a net-exporter of grain. As early as 1713 a parliamentary committee heard of the quality of American wheat, superior to that Britain was able to export to the continent (BPP 1713, p. 368) and similar concerns were expressed in 1737 (BPP 1737, p. 116).

Already in 1740 a bill was read in parliament which proposed to prohibit the exportation of grain from North America, which met with condemnation by traders in the colonies themselves, as well as merchants involved in the trade in London (BPP 1740). In 1742, a petition was sent to Parliament "in Behalf… all the Farmers in Great-Britain" in which the petitioners made clear their fear that "great Quantities of Corn Land" were to be brought into production, and that wheat would be exported into Europe "at those Places, which always have been the British Farmers Markets",

and requesting that Parliament "prohibit the Exportation of Corn from America into Europe, and other Things that may prejudice the British Farmer and Tradesman". A petition from "several Merchants of London" also makes the point that they are unable to compete with the Americans on exports of wheat to the Continent (BPP 1749, p. 1032).

The advantages enjoyed by American farmers were concisely summarized by William Ellis, a farmer, in a letter from 1742. He expresses concern that Americans "by their great Increase of Land… have been tempted… to carry on the Cultivation of Corn, and have made such Progress in its Improvements, that they are become Masters of prodigious Crops of Grain, especially the finest of Wheat, by enjoying, perhaps, one of the best Opportunities the World affords" and that "they have the richest of Land both dry and wet, a very potent Influence from the Sun's Heat, their Acknowledgement or Rent, little or nothing, their Slaves labour for a Trifle Charge, *and withal the great Cheapness and Conveniency of Water Carriage for transporting their Corn into Europe, to the infinite prejudice of Great-Britain*." (Ellis 1750, emphasis added). The last point he makes is one that has sometimes been neglected by economic historians when focussing on the role of transoceanic transportations costs: the fact that oceanic transport is relatively cheap compared to land or canal transport, meaning that the considerable distance between Britain and America need not necessarily imply large barriers to trade. This point will be taken up again in section 3.4.

What is clear, however, is that the importance of American wheat during these years was only apparent during times of harvest failure and contemporary comment focussed for most years on the problems of competing with this supply for foreign markets.

3.2 The first era of free trade: 1773 to 1815

From the 1770s something changes however, perhaps not coincidentally at the same time as Britain industrialized, experienced a population boom and started to become a permanent net importer of wheat. 1771 and 1772 are recorded by Jones as being years of poor harvests, and American supply seems to respond in the usual way. Harvests are however recorded as being "fine" in 1773, unremarkable but not bad in 1774 and even "plentiful" in 1775, and yet these years see the beginning of large-scale imports from America. Although imports continue to fluctuate greatly after this date, there is no longer the clear correspondence between imports and scarcity that there was in the earlier period.

It is probably no coincidence that large volumes of American grain started in arrive in British ports after the enactment of the Corn Law of 1774, which ushered in a period of "practically free" trade in grain, as stated in a report of an 1821 Parliamentary Select Committee (BPP 1821, p. 15). From 1791 the Corn Laws became more protectionist, but the onset of the French and Napoleonic Wars drove prices so high that only nominal duties were payable on imports (Sharp 2006). The

considerable swings in imports from the US we see during this period do, therefore, not seem to be principally related to trade policy. Neither can they be explained by harvest failure in the UK.

The sudden dearth of imports from America after 1775 is actually very easy to explain. First, there was the American War of Independence from 1775-1783 which of course had some impact on wheat and flour production in America. Hunter (2005) notes three phases of the impact of the war: the first until 1777, which saw an increase in demand. Then, with the British invasion of the Philadelphia region in 1777, there was difficulty until 1779. For example, General George Washington ordered the removal of millstones to prevent the British from acquiring flour and the British targeted merchant mills. In addition, throughout the war, the British intermittently from 1776 tried to mount a blockade and in 1778 Congress imposed its own embargo, prohibiting the export of grain and flour, although some illegal exports were possible. The overseas trade was reopened in 1780 and, combined with good harvests, this marked the beginning of the final phase, one of recovery.

Perhaps more important, however, was the impact of the Hessian fly invasion from 1776 which decimated wheat crops. Unfortunately, I have been unable to locate data for wheat imports from America for the years 1787-1791. It is known, however, that in 1788 Philadelphia merchants were planning to ship large amounts of wheat to England, and that this resulted in a total ban on wheat imports from the United States from June 25 that year. How much this ban was attributable to a fear of introducing the fly to England and causing "a Calamity of much more extensive and fatal Consequences than the Admission of the Plague", and how much was due to an antagonism towards the newly independent United States is unclear, although Pauly (2002) notes that the Privy Council Committee for Trade were favourable towards ideas that would realign imperial trade and allow the Americans to suffer the consequences of independence. They also favoured policies that would stimulate home production at a time when higher general tariffs were not politically feasible.

The ban led to a considerable amount of debate and the publication by Parliament in March 1789 of a pamphlet, *Proceedings of His Majesty's Most Honourable Privy Council, and Information Received, Respecting an Insect, Supposed to Infest the Wheat of the Territories of the United States of America*, which attempted to justify the ban to the world[6]. The ban was poorly timed, however, because harvest failures in 1788 and 1789 made Britain's dependence on imports only too clear. The ban was reversed, and HMS *Echo* arrived in New York in February 1790 with the news (Pauly 2002). It appears likely that British leaders decided in 1789 that the United States would in the future be an important reserve food supply, and that the risk posed by French-style revolution was greater than that posed by the fly (Ritcheson 1969, cited by Pauly).

[6] This useful publication furnished the statistical information on early wheat imports from America used in this paper.

Hunter (2005) notes that "wheat and flour together served as a cornerstone of America's newly independent transatlantic commerce" and from an early date, wheat enjoyed a special status, Revolutionaries considering it to be the "ideal republican crop" in contrast to tobacco, with its association with "royal government, debt, slavery and poor agricultural practices" (Matson 2006, p. 246). The Hessian Fly itself might even have contributed to the long-run success of American wheat production, since it helped spur agricultural improvement, through for example experiments in diversification (Matson 2006, chapter eight). A similar point is made by Hunter (2005), who suggests that the French Revolutionary and Napoleonic Wars helped to ensure America's later success in wheat and flour exports by stimulating the adoption of new milling technologies and regional specialization.

The years from 1792 are of course marked by war. Generally imports from the United States continued their upwards trend, although some years stand out for having no imports or particularly high levels of imports. Wheat exports from America to all destinations started dropping from 1792 when the Hessian fly arrived in Delaware and Maryland, at that time the centres of production. From 1795 to 1799 America virtually ceased exporting wheat, the recovery only coming in the first years of the nineteenth century (Matson 2006, p. 253). In vain successive Committees of the British Privy Council asked witnesses about the possibility of imports from the United States (BPP 1795a).

The recovery when it came, however, was quite impressive. Harvests in Europe were poor in 1799, but those of America were abundant and mostly free of the Hessian fly. Parliament enacted measures for bounties on the import of American wheat (Galpin 1925, p. 136) and by 1801 very large imports of American wheat came in. Indeed, in this year "the Americans so completely drained themselves of corn for this traffic, that bread became as dear, or dearer, at New York, than it was in England" (Board of Agriculture 1806, p. 277). Despite this, a combination of good harvests in England and poor harvests in the US contributed to the low level of imports from the US in the following years.

The imposition of Napoleon's Continental System from late 1806 presented a great opportunity for American exporters, however, and contributed to the large volume of imports from the US in 1807, the year in which the US consul at Liverpool was led to declare that "such quantities of wheat and flour from the United States have lately poured into this market that prices have declined"[7]. This encouraged the belief "in the permanency of this seemingly inexhaustible granary" (Galpin 1925, p. 44). However, in the wake of the Royal Navy's impressment of American citizens on the high seas, the United States itself imposed a trade embargo from 1807, reflected in testimony before a British parliamentary committee that trade in London declined in 1808 after the American embargo (Galpin 1922, p. 24). However, illegal wheat exports continued and Napoleon

[7] Quoted in Galpin (1922, p. 24)

was quick to conclude that it was impossible to starve Britain, at least in part due to the availability of supplies from the United States. He thus soon, in the wake of bumper harvests in France, allowed exports of grain to resume (Galpin 1925, p. 168). There is no doubt, however, that the years of the embargo and the Non-Intercourse Act of 1809 were an important dampener on the level of trade (Galpin 1925, p. 147).

From this point on relations between the US and the UK gradually deteriorated and this, combined with good harvests in Europe, contributed to the low level of imports from America. The last years of the Napoleonic Wars saw the beginning of a new war, this time between the United States and the United Kingdom. The war lasted from the summer of 1812 to the beginning of 1815 and witnessed a blockade by the British of the American coastline (Galpin 1925, p. 149).

Although farmers continued to voice predictable concerns[8], what is notable about contemporary comment over this period is rather than it changes from being focussed on the danger of American competition to a focus on the opportunities the American supply presented for meeting the demands of a growing population in Britain. Donaldson (1775), previously of the Jamaican government, wrote in a letter to the king that "The lands so liberally granted in America should be cultivated… and the mother country supplied from their industry; what magazines of corn might we hope to see from such resources!" This idea became more and more widely accepted, so that by 1790, a report of the British Privy Council (BPP 1790) concluded that "whenever the crops fail, in any degree, the deficiency can only be supplied from the harvests of America" (Glasgow Chamber of Commerce and Manufactures 1790). Although John Lord Sheffield argues vehemently against this conclusion in his *Observations on the Commerce of the United States*, other commentators were quick to back it up (Sheffield 17xx, Anon 17xx). A committee "on the high price of corn" looked first to the United States and the "abundant" supply there as a means of affording relief caused in part by the poor harvest in England (BPP 1795b, p. 85). By 1800, the British Board of Agriculture stated that "America be, or is hereafter to be the granary of Europe" (Board of Agriculture 1800, p. 148). A committee to "consider of the present high price of provisions" in 1801 also looked to America (BPP 1801a, p. 7, BPP 1801b, p. 8) as did a committee of 1805 (BPP 1805, p. 13).

Although the available statistics do not discriminate between imports of wheat and imports of wheat flour, it seems that most imports during these years were in fact of flour, in contrast to the years before the onset of the French Wars, when imports of wheat were "very considerable" (BPP 1813, p. 115). This caused millers to complain, and evidence was presented before a select committee in 1813 from a miller to the effect that the imports of flour from the United States in 1806, 1807, 1809 and 1810 were bad for millers (BPP 1813, p. 99). Indeed, it seems they had good

[8] For example, "A Farmer" writing in 1773 writes that "The only country from whence we can apprehend such an importation [of grain which could sell cheaper than British farmers could sell it for] is America" (A Farmer, 1773).

reason to. Select Committees heard that US flour was of very high quality owing to a sophisticated system of inspections and branding, and that it was easy to transport (BPP 1813, BPP 1814).

3.3 Prohibitive tariffs and the movement to free trade: 1815 to 1849

With peace, the Corn Laws soon became protectionist and this is reflected by the decline in American imports after 1818 (when prices fell sufficiently from wartime levels for imports to be prohibited under the terms of the Corn Law of 1815). Imports only really recovered with the introduction of the new Corn Law and the sliding scale of 1828 at which point swings in imports become clearly related to swings in import duties, which varied considerably from year to year (Sharp 2006), although it might be noted that during the 1830s America was again suffering from attacks of the Hessian fly.

In general, however, these years see a gradual decline in interest in the supply from America. Mentions in Parliamentary reports are rare[9] despite the huge volume of material published by Parliament during the debate in the run up to the repeal of the Corn Laws. So William Jacob's famous report on the "Agriculture and Corn of some of the Continental States of Europe" (BPP 1827) was just that, with no mention of America, and before a select committee in 1833 he dismissed the importance of the American supply (BPP 1833, p. 6).

With the repeal of the sliding scale in 1849, import duties become insignificant and were eventually abolished, allowing the great expansion of trade with America which was to become known as the Grain Invasion.

An important lesson from this paper is thus an understanding of the importance of the American grain supply far back into the eighteenth century[10]. That this was the case is strikingly brought home by the following: In 1791 a petition was presented to the House of Commons by "Merchants of the City of London, concerned in the Commerce with the United States of America" (BPP 1791b, p.445) and petitions were received from Norwich, Somerset, Dorset, making it clear that these areas were unable to supply themselves with grain (BPP 1791b, pp. 466-467). A petition from Bailiffs and Burgesses of the Borough of Bridport, Dorset explicitly requested that Bridport be made a "Granary Port" so that the town might enjoy a "greater Connection with America, and that the Merchants will thereby be enabled to import Wheat, in Part, for their Manufacturies" (BPP 1791b, p.469). Even more explicitly a "Petition from the Mayor, Merchants, and principal Inhabitants, of the City of Bristol" stated that "the Western Part of the Kingdom does not grown Corn sufficient for the Consumption of its Inhabitants" and relied on imports "chiefly from

[9] Those there are concern rumours of small-scale smuggling of American grain via Canada (BPP 1820, pp. 18, 30 & 35; BPP 1821, pp. 277, 314-5 & 320-1; BPP 1836a, p. 43; BPP 1836b, pp. 113-4) and a brief mention that the Corn Laws harmed bilateral trade with the United States (BPP 1840).

[10] There is also some evidence of its importance for other European countries, such as Portugal and Spain (Galpin 1922) and France (Kaplan 1976, p. 634).

America" through the port of Bristol (BPP 1791b, p. 653). If American crops had not have been ruined by the Hessian fly, and war had not intervened, might not the Anti-Corn Law League have emerged at this time? And then quite possibly we would now date the grain invasion – and possibly even the origins of globalization – to the late 1700s, rather than a century later.

3.4 The role of transportation costs

Until now no mention has been made of the role of transportation costs, which are often cited as being the main reason for the grain invasion of the late nineteenth century.

Recent research on the grain invasion of the late nineteenth century has concentrated on the role of falling domestic transportation costs, allowing grain to be shipped more easily from new production areas as the centre of American agriculture moved westward. However, the role of domestic transportation costs must have been negligible for the early days of the Atlantic wheat economy, since the vast majority of American wheat was grown near the east coast. Indeed, even as late as 1839, the geographic centre of production was east of Wheeling, (West) Virginia, with cultivation concentrated in Ohio and upstate New York and relatively little grown as far west as Illinois (Olmstead & Rhode 2002, p. 936).

The evidence on transatlantic rates is sketchy, but intriguingly, it appears that freight rates were *highest* at the times when imports were greatest. For example, Douglass North's British import freight rate index, available from 1790, is highest in the years 1799-1801 and again in 1807, which correspond to years when imports from America were greatest. No "meaningful" freight index is available from 1808-1813, when "freights rose to very high levels", but even for these years historically significant levels of wheat imports were arriving from the United States for most years. This pattern repeats itself in the figures North collected for the East Coast American freight factor for wheat, available from 1826. This is again highest from 1829-1831 and from 1845-47, the years of greatest imports[11] (North 1958). Unless we are to believe that high transportation costs encouraged imports, then one possible alternative explanation is that the high volumes of imports were pushing up demand for shipping and increasing freight rates.

Some evidence on transatlantic costs of transporting wheat is available for the eighteenth century. For example, A Farmer (1773, p. 102) gives a detailed breakdown of the cost of transporting wheat from America, although some of his assumptions might be rather suspect[12], since he is trying to show that British farmers have nothing to fear from imports. But by far the largest cost he records is for freight, which amounts to 8 shillings per quarter of wheat. By 1791, information received by the Committee of Privy Council for Trade suggested that it amounted to 8s.

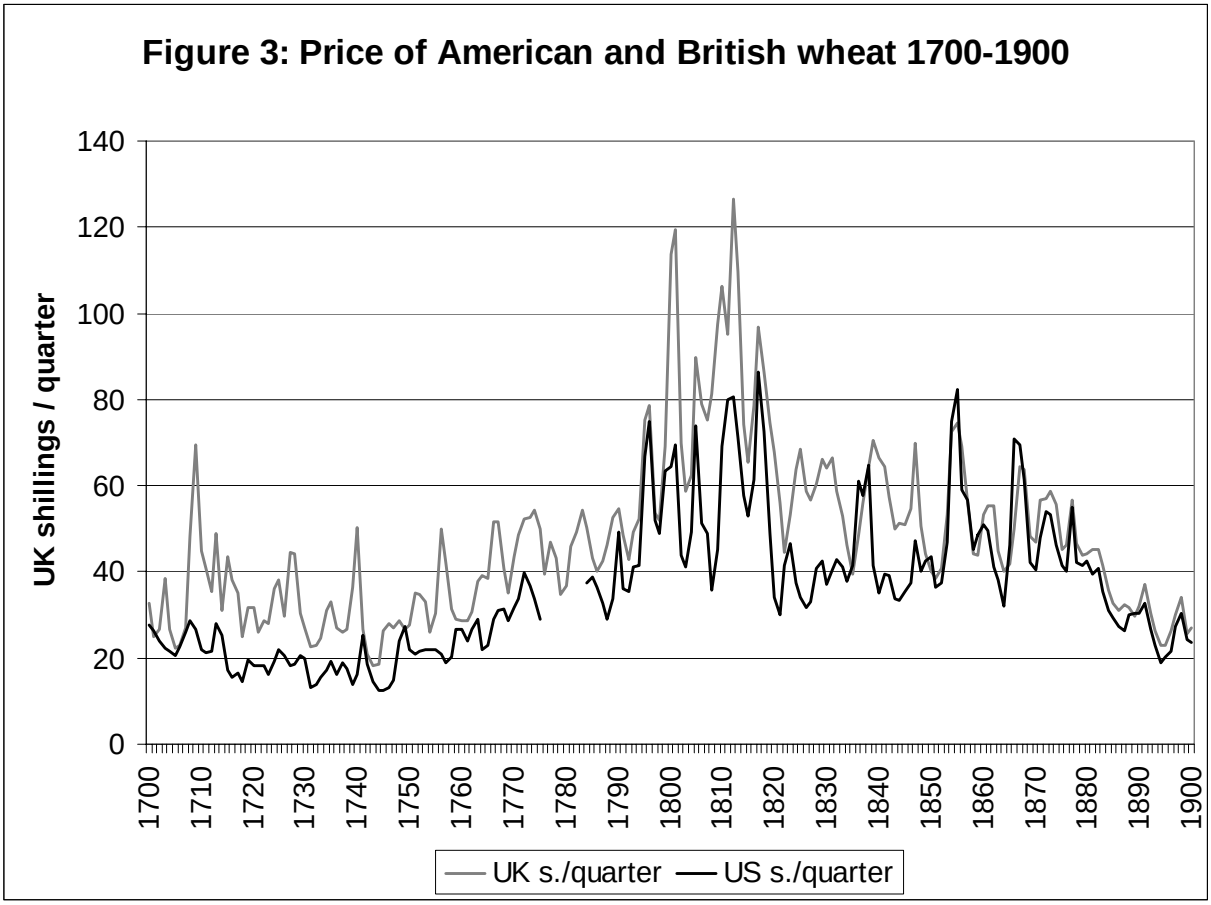
[11] He provides no data for the years 1839-1841, when imports were also high.
[12] Such as that 10 per cent must be added to the cost due to waste and damage and an additional cost due to the decline in value because the grain has been on the ship for too long.

8d. (BPP 1791a). Dividing this by the price of wheat in Britain for each year gives freight factors of 15 and 17 per cent respectively, about the same as for most of the early nineteenth century and only marginally below that of the late nineteenth century, after the "transport revolution" (Sharp 2007). Perhaps surprisingly, in evidence before a select committee in 1821, one witness describes the difficulty of Irish competing with American flour due to the cheapness of freight. It was actually cheaper to ship flour from America to Liverpool than from Ireland through Dublin to Liverpool, which required the use of expensive canal transport (BPP 1821, p. 319).

In short, it seems that at no time were transportation costs an important barrier to trade. Indeed, this was the point made long ago by Ellis (1750) - as quoted above.

4. Looking for market integration

With the available statistical evidence we cannot hope to fulfil the stringent conditions for testing market integration described for example in Persson (2004). There is no record of, for example, grain qualities, the only price information being for "wheat" in various markets. Nevertheless, when the available data are assembled, it does in fact seem possible to draw some meaningful conclusions.



Looking at figure 3[13], the first thing that is striking is how the prices move together over the long run. The usual way of testing for long run market integration (or, more precisely, that the trading cost adjusted law of one price is valid) is to test for cointegration between the series (see for example Ejrnæs, Persson & Rich, 2008).

Cointegration is tested for using Dynamic OLS (DOLS) by estimating the following model:

$$puk_t = \beta_0 + \beta_1 puk_{t-1} + \beta_2 puk_{t-2} + \beta_3 pus_t + \beta_4 pus_{t-1} + \beta_5 pus_{t-2} + \beta_6 t + \varepsilon_t \quad (1)$$

where *puk* and *pus* are the logarithms to the UK and US prices respectively, *t* is the trend and ε_t is the error term, which is assumed to be iid normally distributed. This estimation technique has the advantage, compared to the usual static Engle-Granger approach, that the model is well-specified (since it includes dynamic effects) so, given cointegration, t-ratios constructed from the standard errors follow standard normal distributions under the null.

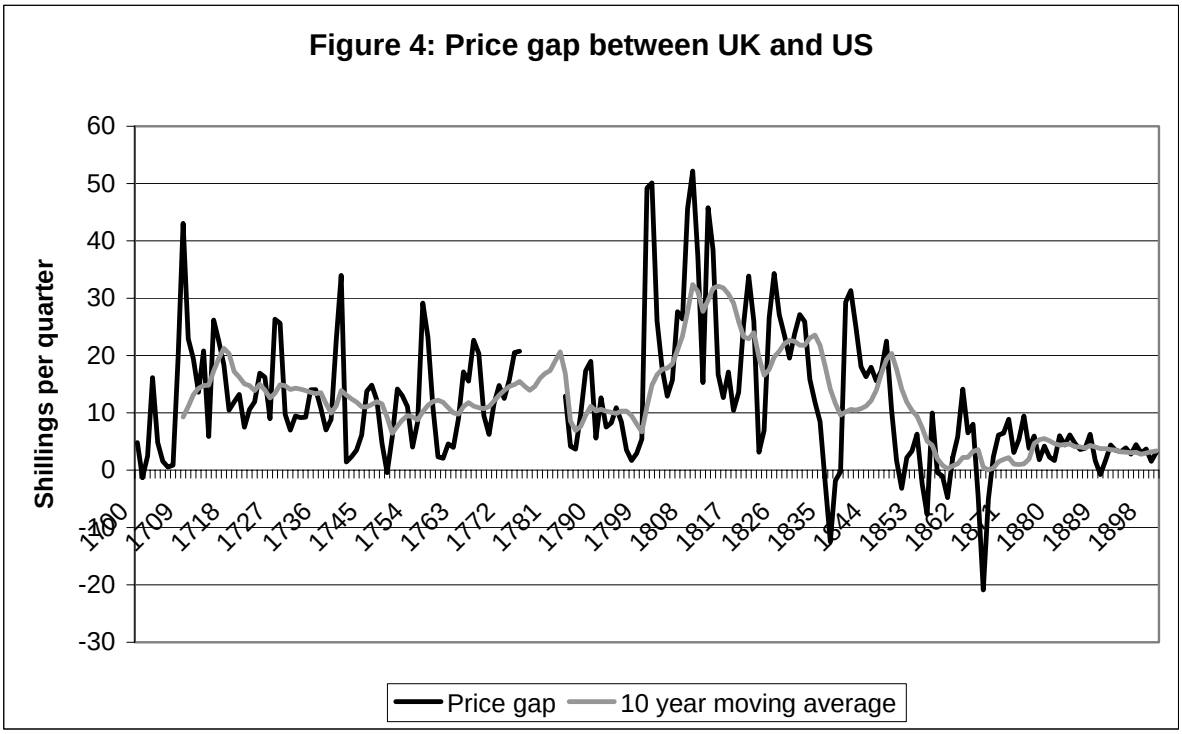
Initially the model is estimated for the whole of the eighteenth and nineteenth centuries. The estimation results and some model specification tests are given in appendix A1. It is clear that the model is not well specified, because the iid normality assumption for the residuals is not met. This is due to the presence of unmodelled events giving large residuals for the years 1704, 1714, 1715, 1727, 1741 and 1756. After introducing dummies for these years, the model is much better specified - see appendix A2. We can now solve for the static long-run solution of the model (the estimation is performed using PCGive) and check for cointegration. This is shown in appendix A3.

The coefficient to *pus* is 0.93, implying that US and UK prices almost perfectly follow each other in the long run. Moreover, the unit root t-statistic, which gives the test for the null of no cointegration, is -9.29 – and thus very strong evidence of cointegration.

In appendix A4, the sample has been restricted to the eighteenth century only, and as is to be expected the evidence for market integration is less strong. Nevertheless, the long-run coefficient to *pus* is still 0.78 and the unit root t-statistic is -7.81. The conclusion must be that prices were cointegrated and thus markets integrated in the eighteenth century – to a lesser extent than in the nineteenth century, but still convincingly so, especially in the light of the fact that this period includes many years before the trade in wheat really took off.

Another measure which is commonly referred to when assessing the degree of market integration is the price gap between the two markets. This is illustrated in figure 4.

[13] The data for Britain is taken from Mitchell & Deane (1953) and is the "Winchester" series until 1770, and thereafter the *Gazette* series. The American data is taken from Carter et al (2006). Until 1783 the prices are taken from series Eg252 converted from Pennsylvania shillings to UK currency using the exchange rates given in series Eg318. No prices are available between 1776-83, and the price has thus assumed to be unchanging for these years. From 1784 the prices are in dollars per bushel from series Cc205-208 converted to British shillings per quarter using the exchange rates given in Officer (2008). The missing exchange rates before 1791 are assumed to be the same as in 1791. In all cases, volumes are converted to imperial quarters using the fact that there are 8.256 American bushels to the imperial quarter.



Except for extraordinary periods, such as during the American Civil War, and a time during the 1830s when American harvests were ravished by the Hessian fly, the price gap is positive over the entire period. The general trend is illustrated by the ten year moving average: for the part of the eighteenth century when the wheat trade was significant, the price gap fluctuates around a level of about 10 shillings per quarter, clearly compatible with the likely level of trading costs given in section 3.4 and thus with the trading costs adjusted law of one price. Prior to this, there is little or no trade, and the price gap does indeed seem on average to exceed the level of trading costs. After the repeal of the Corn Laws the gap falls to around half this level in line with the fall in transatlantic shipping costs (Persson 2004). The disruption caused by the Napoleonic Wars and the Corn Laws (see Sharp 2006) is also clear.

Looking more closely at the data, the times when trade is possible do indeed seem to be reflected in a narrowing of the price gap, most notably after the liberalization of trade in the 1770s, but even for shorter periods, such as around the extraordinary year of imports in 1807 and the short lived period of free trade immediately following the Napoleonic Wars. Thus, when trade was possible, there was a marked tendency of prices to respond in accordance with the law of one price.

To summarize, using one traditional measure of market integration, the degree of cointegration, markets were integrated. Looking at the price gaps adds another dimension, showing the importance of understanding exogenous events when looking at divergence from the law of one price. However, the data point to trade being quite possible throughout the eighteenth century, if it hadn't been for the various disruptions outlined in section 3.

Ideally, it would be possible to examine the speed of adjustment back to the law of one price equilibrium. However, the data are not frequent enough to allow for testing in the sense described by Ejrnæs et al (2008). Clearly, however, when trade was relatively free, prices converged and levels of imports could reach those first experienced again half a century later.

5. Conclusion

The most important lesson from this paper is that, if we accept market integration as the appropriate definition of globalization, then it is necessary to look beyond the outcome variable – increasing levels of trade – when deciding when to date the first era of globalization.

Some degree of long run market integration was already present in the trade in wheat between the US and the UK from the eighteenth century. This trade was not insignificant, as the words and actions of contemporaries confirms. The change in the nineteenth century was not that prices began to follow each other, and neither was it particularly significant that the price gap narrowed (Persson 2004). The important change was that prices adjusted faster towards the law of one price equilibrium, as demonstrated by Ejrnæs et al (2008). It is not possible to test for this with the eighteenth century data, but it is clear that trade was too sporadic for markets to develop sufficiently.

What is interesting, however, is that trade could and did increase during the periods when exogenous events did not preclude this from happening. Volumes could not feasibly have been as high as they were by the end of the nineteenth century (when the US was exporting more than she produced in total in the eighteenth century), but they were significant. And importantly this was without the transport revolution. Whether we call this globalization or not, it is an important precursor to the globalization story of the nineteenth century, and an illustration of the beginning of the story of the American grain invasion of Britain.

References

A FARMER (1773). *An Inquiry into the Connection between the present Price of Provisions, and the Size of Farms.* London: T. Cadell

ANON (17xx). *A Brief Examination of Lord Sheffield's Observations on the Commerce of the United States.*

BOARD OF AGRICULTURE (1800). *Communications to the Board of Agriculture: Vol. II.* London: W. Bulmer & Co.

BOARD OF AGRICULTURE (1806). *Communications to the Board of Agriculture: Vol. V, Part I.* London: W. Bulmer & Co.

BPP (various). *Annual Statement of Trade 1853-1900.*

BPP (1713). *Journals of the House of Commons.*

BPP (1737). *Journals of the House of Commons.*

BPP (1740). *Considerations on the Bill for Prohibiting the Exportation of Corn, &c. from North America.*

BPP (1749). *Journals of the House of Commons.*

BPP (1766). *Journals of the House of Commons.*

BPP (1767). *Journals of the House of Commons.*

BPP (1789). *Proceedings of His Majesty's Most Honourable Privy Council, and Information Received, Respecting an Insect, Supposed to infest the Wheat of the Territories of the United States of America.*

BPP (1790). *Representation of the Lords of the Committee of the Council, appointed for the Consideration of all Matters relating to Trade and Foreign Plantations.*

BPP (1791a). *Information received by the Lords of the Committee of Privy Council for Trade, from Mr. Claude Scott, relative to the Charges for Freight of Corn.*

BPP (1791b). *Journals of the House of Commons.*

BPP (1795a). Various

BPP (1795b). *Journals of the House of Commons.*

BPP (1801a), *First Report from the Committee appointed to consider of the present High Price of Provisions.*

BPP (1801b), *Second Report By the Lords Committees, to whom it was referred to consider so much of His Majesty's Speech as relates to the Dearth of Provisions.*

BPP (1805). *Report from the Committee to whom the several Petitions, praying Relief from the Effects of an Act, passed in the last Session of Parliament, intituled, "An Act to regulate the Importation and Exportation of Corn, and the Bounties and Duties payable thereon," were referred.*

BPP (1813). *Report from the Select Committee on Petitions relating to the Corn Laws of this Kingdom.*

BPP (1814). *Reports Respecting Grain, and the Corn Laws.*

BPP (1815). *An Account of the Quantity of Grain, Meal, and Flour Imported into Great Britain, from Foreign Countries; and also, from Ireland, in each Year, from 1792 to 1814, both inclusive; distinguishing the Countries from which Imported, and the different kinds of Grain.*

BPP (1820). *Report from the Select Committee on Petitions complaining of Agricultural Distress, &c.*

BPP (1821). *Report from the Select Committee to whom the several petitions complaining of the depressed state of agriculture of the United Kingdom were referred.*

BPP (1825). *Account of Grain, Meal and Flour Imported into Great Britain from Foreign Parts and From Ireland.*

BPP (1827a). *Account of Quantity of Wheat and other Grain imported and exported from Great Britain, 1697-1825.*

BPP (1827b). *Account of Grain, Meal and Flour imported into Great Britain, 1825-26.*

BPP (1827c). *Second Report, made to the Lords of the Committee of His Majesty's Privy Council for Trade, on the Agriculture and Corn of the Continental States of Europe; with Observations: Collected in a Journey through those States, in the Autumn of 1827; By William Jacob, Esq. F.R.S. Comptroller of Corn Returns.*

BPP (1832). *Account of Grain, Meal and Flour imported into Great Britain, 1827-31.*

BPP (1833). *Report from the Select Committee on Agriculture.*

BPP (1836a), *Second Report from the Select Committee appointed to inquire into the State of Agriculture.*

BPP (1836b), *Third Report from the Select Committee appointed to inquire into the State of Agriculture.*

BPP (1840). *Report from the Select Committee on Import Duties*

BPP (1843). *Corn.*

CARTER, S.B. et al (2006). *Historical Statistics of the United States Millenial Edition.* Online version

COLLINS, E.J.T. (1965). Dietary Change and Cereal Consumption in Britain in the Nineteenth Century. *The Agricultural History Review* **23:2**, pp. 97-115

DONALDSON, W. (1775). *Agriculture considered as a Moral and Political Duty*. London: T. Becket

ELLIS, W. (1750). *The Modern Husbandman, Complete in Eight Volumes.* London: D. Browne

EJRNÆS, M, PERSSON, K.G. & RICH, S. Feeding the British: convergence and market efficiency in the nineteenth-century grain trade. *Economic History Review* **61:S1**, pp. 140-171

GALPIN, W.F. (1922). The American Grain Trade to the Spanish Peninsula, 1810-1814. *The American*

Historical Review **28:1**, pp. 24-44

GALPIN, W.F. (1925). The *Grain Supply of England During the Napoleonic Period.* New York: Macmillan

GLASGOW CHAMBER OF COMMERCE (1790). *Third Report of a Committee of the Chamber of Commerce and Manufactures.* Glasgow: R. Chapman and A. Duncan

GUETTER, F.J. & MCKINLEY, A.E. (1924). *Statistical Tables Relating to the Economic Growth of the United States.* Philadelphia: McKinley Publishing Co.

HUNTER, B. (2005). Wheat, War, and the American Economy during the Age of Revolution. *The William and Mary Quarterly* **62:3**, pp. 505-5xx

JACKS, D.S. (2005). Intra- and international commodity market integration in the Atlantic economy, 1800-1913. *Explorations in Economic History* **42**, pp. 381-413

JACKS, D.S. (2006). What drove 19th century commodity market integration? *Explorations in Economic History* **43**, pp. 383-412

JONES, E.L. (1964). *Seasons and Prices. The Role of the Weather in English Agricultural History*. London: George Allen & Unwin Ltd.

KAPLAN, S.L. (1976). *Bread, Politics and Political Economy in the Reign of Louis XV: Volume 2*. The Hague: M. Nijhoff

MATSON, C. (2006). *The Economy of Early America.* Pennsylvania: Penn State University Press

MITCHELL, B.R. & DEANE, P. (1953). *Abstract of British Historical Statistics.* Cambridge: Cambridge University Press

NORTH, D.C. (1958). Ocean Freight Rates and Economic Development 1750-1913. *The Journal of Economic History* **18:4**, pp. 537-555

OFFICER, L.H. (2008). *Dollar-Pound Exchange Rate From 1791*. MeasuringWorth.com

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

ORMROD, D. (1985). *English Grain Exports and the Structure of Agrarian Capitalism 1700-1760*. Hull University Press: Occasional Papers in Economic and Social History No. 12

O'ROURKE, K.H. (2006). The worldwide economic impact of the French Revolutionary and Napoleonic Wars, 1793-1815. *Journal of Global History* **1**, pp. 123-149

O'ROURKE, K.H. & WILLIAMSON, J.G. (1999). *Globalization and History.* London: The MIT Press

PAULY, P.J. (2002). Fighting the Hessian Fly: American and British Responses to Insect Invasion, 1776-1789. *Environmental History* **7:3**, pp. 485-507

PERSSON, K.G. (2004). Mind the Gap! Transport costs and price convergence in the nineteenth century Atlantic economy. *European Review of Economic History* **8:2**, pp. 125-147

PITT, W. (1792). *Anecdotes of the Life of The Right Hon. William Pitt, Earl of Chatham.* Dublin: W. Porter

RITCHESON, C.R. (1969). *Aftermath of Revolution: British Policy Toward the United States, 1783-1795*. Southern Methodist University Press

SHARP, P.R. (2006). *1846 and All That: The Rise and Fall of British Wheat Protection in the Nineteenth Century.* Department of Economics, Copenhagen, Discussion Paper 06-14

SHARP, P.R. (2007). *Pushing Wheat: Why Supply Mattered for the American Grain Invasion of Britain in the Nineteenth Century*. Mimeo

SHEFFIELD, J. (17xx). *Observations on the Commerce of the American States.* London: J. Debrett

SHEPHERD, J.F. & WALTON, G.M. (1972). *Shipping, Maritime Trade, and the Economic Development of Colonial North America.* Cambridge: Cambridge University Press

UNITED STATES (1975). *Historical Statistics of the United States*. Washington: Government Printing Office

WILLIAMSON, J.G. (2008). Globalization and the Great Divergence: Terms of Trade Booms and Volatility in the Poor Periphery 1782-1913. *NBER Working Paper No. W13841*

Appendix

A1: The DOLS analysis without dummies

```
EQ( 1) Modelling LPUK by OLS (using data.xls)
       The estimation sample is: 1702 to 1900

                  Coefficient  Std.Error  t-value  t-prob Part.R^2
LPUK_1               0.767806    0.06819     11.3   0.000   0.3977
LPUK_2              -0.279665    0.06629    -4.22   0.000   0.0848
Constant             0.403091     0.1130     3.57   0.000   0.0622
LPUS                 0.517381    0.06353     8.14   0.000   0.2567
LPUS_1              -0.292568    0.09260    -3.16   0.002   0.0494
LPUS_2               0.249064    0.07296     3.41   0.001   0.0572
Trend             -0.00108843  0.0002601    -4.18   0.000   0.0836

sigma                0.152377  RSS                4.45800764
R^2                  0.851496  F(6,192) =    183.5 [0.000]**
log-likelihood        95.5922  DW                     1.97
no. of observations       199  no. of parameters         7
mean(LPUK)            3.78847  var(LPUK)           0.150851

AR 1-2 test:      F(2,190) =  0.50014 [0.6072]
ARCH 1-1 test:    F(1,190) =   5.5104 [0.0199]*
Normality test:   Chi^2(2) =   24.124 [0.0000]**
hetero test:      F(12,179)=   2.4099 [0.0065]**
hetero-X test:    F(27,164)=   2.6480 [0.0001]**
RESET test:       F(1,191) =   1.8846 [0.1714]
```

A2: The DOLS analysis with dummies

```
EQ( 5) Modelling LPUK by OLS (using data.xls)
       The estimation sample is: 1702 to 1900

                  Coefficient  Std.Error  t-value  t-prob Part.R^2
LPUK_1               0.911237    0.05909     15.4   0.000   0.5611
LPUK_2              -0.369837    0.05702    -6.49   0.000   0.1845
Constant             0.365570    0.09445     3.87   0.000   0.0745
LPUS                 0.577708    0.05369     10.8   0.000   0.3837
LPUS_1              -0.387827    0.07847    -4.94   0.000   0.1161
LPUS_2               0.234673    0.06143     3.82   0.000   0.0728
Trend             -0.00100755  0.0002201    -4.58   0.000   0.1013
DUM1741             -0.677971     0.1326    -5.11   0.000   0.1232
DUM1704             -0.515863     0.1299    -3.97   0.000   0.0781
DUM1715              0.551174     0.1310     4.21   0.000   0.0869
DUM1714             -0.432781     0.1291    -3.35   0.001   0.0570
DUM1727              0.493401     0.1283     3.85   0.000   0.0737
DUM1756              0.416586     0.1278     3.26   0.001   0.0540

sigma                0.126531  RSS                2.97789233
R^2                  0.900801  F(12,186) =   140.8 [0.000]**
log-likelihood        135.739  DW                     1.86
no. of observations       199  no. of parameters        13
mean(LPUK)            3.78847  var(LPUK)           0.150851

AR 1-2 test:      F(2,184) =   1.8452 [0.1609]
ARCH 1-1 test:    F(1,184) =  0.15822 [0.6913]
Normality test:   Chi^2(2) =   6.2016 [0.0450]*
hetero test:      F(18,167)=   1.1098 [0.3467]
hetero-X test:    F(33,152)=  0.94899 [0.5528]
RESET test:       F(1,185) =  0.36735 [0.5452]
```

A3: The static long-run equation for *puk*

```
Solved static long-run equation for LPUK
                  Coefficient  Std.Error  t-value  t-prob
Constant             0.797144     0.1839     4.33   0.000
LPUS                 0.925760    0.05947     15.6   0.000
Trend             -0.00219702  0.0004457    -4.93   0.000
DUM1741              -1.47835     0.3553    -4.16   0.000
```

```
DUM1704              -1.12486     0.3006    -3.74   0.000
DUM1715               1.20186     0.3164     3.80   0.000
DUM1714             -0.943700     0.3023    -3.12   0.002
DUM1727               1.07589     0.3035     3.54   0.000
DUM1756              0.908386     0.3012     3.02   0.003
Long-run sigma = 0.275908

ECM = LPUK - 0.797144 - 0.92576*LPUS + 0.00219702*Trend + 1.47835*DUM1741
       + 1.12486*DUM1704 - 1.20186*DUM1715 + 0.9437*DUM1714 - 1.07589*DUM1727
       - 0.908386*DUM1756;
WALD test: Chi^2(8) = 319.222 [0.0000] **

Analysis of lag structure, coefficients:
            Lag 0    Lag 1    Lag 2      Sum  SE(Sum)
LPUK           -1    0.911    -0.37   -0.459   0.0494
Constant    0.366        0        0    0.366   0.0945
LPUS        0.578   -0.388    0.235    0.425   0.0517
Trend    -0.00101        0        0 -0.00101  0.00022
DUM1741    -0.678        0        0   -0.678    0.133
DUM1704    -0.516        0        0   -0.516     0.13
DUM1715     0.551        0        0    0.551    0.131
DUM1714    -0.433        0        0   -0.433    0.129
DUM1727     0.493        0        0    0.493    0.128
DUM1756     0.417        0        0    0.417    0.128

Tests on the significance of each variable
Variable     F-test        Value [  Prob]     Unit-root t-test
LPUK         F(2,186) =   128.50 [0.0000]**        -9.2915**
Constant     F(1,186) =   14.979 [0.0002]**
LPUS         F(3,186) =   48.829 [0.0000]**         8.2059
Trend        F(1,186) =   20.955 [0.0000]**
DUM1741      F(1,186) =   26.131 [0.0000]**        -5.1119
DUM1704      F(1,186) =   15.768 [0.0001]**        -3.9709
DUM1715      F(1,186) =   17.691 [0.0000]**          4.206
DUM1714      F(1,186) =   11.234 [0.0010]**        -3.3517
DUM1727      F(1,186) =   14.790 [0.0002]**         3.8458
DUM1756      F(1,186) =   10.623 [0.0013]**         3.2592

Tests on the significance of each lag
Lag 2        F(2,186) =   21.556 [0.0000]**
Lag 1        F(2,186) =   119.05 [0.0000]**

Tests on the significance of all lags up to 2
Lag 2 - 2    F(2,186) =   21.556 [0.0000]**
Lag 1 - 2    F(4,186) =   77.095 [0.0000]**
```

A4: Analysis on eighteenth century only

```
EQ( 7) Modelling LPUK by OLS (using data.xls)
       The estimation sample is: 1702 to 1800

                 Coefficient  Std.Error  t-value  t-prob Part.R^2
LPUK_1              0.850874    0.08160     10.4   0.000   0.5584
LPUK_2             -0.483580    0.08115    -5.96   0.000   0.2922
Constant            0.744067     0.2089     3.56   0.001   0.1285
LPUS                0.611467    0.09579     6.38   0.000   0.3215
LPUS_1             -0.393217     0.1271    -3.09   0.003   0.1001
LPUS_2              0.273629    0.09540     2.87   0.005   0.0873
Trend           -0.000610206  0.0007637   -0.799   0.426   0.0074
DUM1741            -0.623864     0.1516    -4.12   0.000   0.1646
DUM1704            -0.514174     0.1471    -3.50   0.001   0.1245
DUM1715             0.607341     0.1493     4.07   0.000   0.1614
DUM1714            -0.388030     0.1471    -2.64   0.010   0.0749
DUM1727             0.520639     0.1422     3.66   0.000   0.1348
DUM1756             0.385914     0.1418     2.72   0.008   0.0793

sigma               0.139355  RSS               1.67010933
R^2                  0.84453  F(12,86) =    38.93 [0.000]**
log-likelihood       61.5955  DW                      1.91
no. of observations       99  no. of parameters         13
mean(LPUK)           3.61125  var(LPUK)           0.108508
```

```
AR 1-2 test:      F(2,84)  =  0.26803 [0.7655]
ARCH 1-1 test:    F(1,84)  =  0.40356 [0.5270]
Normality test:   Chi^2(2) =   7.2839 [0.0262]*
hetero test:      F(18,67) =  0.56939 [0.9091]
Hetero-X test: not enough observations
RESET test:       F(1,85)  =  0.81352 [0.3696]

Solved static long-run equation for LPUK
                 Coefficient  Std.Error  t-value  t-prob
Constant             1.17601     0.2689     4.37   0.000
LPUS                0.777422    0.09790     7.94   0.000
Trend           -0.000964437   0.001219   -0.791   0.431
DUM1741            -0.986025     0.2938    -3.36   0.001
DUM1704            -0.812658     0.2516    -3.23   0.002
DUM1715             0.959909     0.2598     3.69   0.000
DUM1714            -0.613286     0.2515    -2.44   0.017
DUM1727             0.822876     0.2456     3.35   0.001
DUM1756             0.609941     0.2447     2.49   0.015
Long-run sigma = 0.220253

ECM = LPUK - 1.17601 - 0.777422*LPUS + 0.000964437*Trend + 0.986025*DUM1741
       + 0.812658*DUM1704 - 0.959909*DUM1715 + 0.613286*DUM1714 - 0.822876*DUM1727
       - 0.609941*DUM1756;
WALD test: Chi^2(8) = 144.533 [0.0000] **

Analysis of lag structure, coefficients:
           Lag 0    Lag 1    Lag 2      Sum  SE(Sum)
LPUK          -1    0.851   -0.484   -0.633    0.081
Constant   0.744        0        0    0.744    0.209
LPUS       0.611   -0.393    0.274    0.492   0.0796
Trend    -0.00061        0        0 -0.00061 0.000764
DUM1741    -0.624        0        0   -0.624    0.152
DUM1704    -0.514        0        0   -0.514    0.147
DUM1715     0.607        0        0    0.607    0.149
DUM1714    -0.388        0        0   -0.388    0.147
DUM1727     0.521        0        0    0.521    0.142
DUM1756     0.386        0        0    0.386    0.142

Tests on the significance of each variable
Variable     F-test        Value [  Prob]     Unit-root t-test
LPUK         F(2,86)  =   54.695 [0.0000]**        -7.8111**
Constant     F(1,86)  =   12.684 [0.0006]**
LPUS         F(3,86)  =   20.289 [0.0000]**         6.1809
Trend        F(1,86)  =  0.63849 [0.4265]
DUM1741      F(1,86)  =   16.940 [0.0001]**        -4.1158
DUM1704      F(1,86)  =   12.225 [0.0007]**        -3.4965
DUM1715      F(1,86)  =   16.555 [0.0001]**         4.0688
DUM1714      F(1,86)  =   6.9599 [0.0099]**        -2.6382
DUM1727      F(1,86)  =   13.398 [0.0004]**         3.6603
DUM1756      F(1,86)  =   7.4043 [0.0079]**         2.7211

Tests on the significance of each lag
Lag 2        F(2,86)  =   18.850 [0.0000]**
Lag 1        F(2,86)  =   55.826 [0.0000]**

Tests on the significance of all lags up to 2
Lag 2 - 2    F(2,86)  =   18.850 [0.0000]**
Lag 1 - 2    F(4,86)  =   28.919 [0.0000]**
```