Frontier Farmers and the Atlantic Economy:
Another look at the causes of the American grain invasion of Britain in the nineteenth century

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Abstract: The usual explanation for the American grain invasion of Britain in the last decades of the nineteenth century is that falling transportation costs caused the price gap between the US and the UK to fall, causing US prices to rise, UK prices to fall, and thus causing US supply and UK demand to increase. This paper documents that this was not the case. Falling per mile transportation costs simply permitted an expansion of frontier farming in the US, while the total cost of transporting wheat from the US production areas to the UK, and the price received by the average farmer, remained constant. What this process did allow, however, was a massive increase in US output, which was then available to supply the booming demand in the UK. The grain invasion was therefore not a response to increasing prices by American farmers, who in reality offered a perfectly elastic supply at the going price as practically unlimited supplies of land in the west were populated by immigrants.

JEL Classifications: C5, F1, N7

Keywords: Grain invasion, wheat, globalization

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1. Introduction
The dominant explanation for the growth of an Atlantic Economy at the end of the nineteenth century, associated in particular with Knick Harley and Jeffrey Williamson, has stressed the importance of falling transportation costs, both across the Atlantic and within the United States. Improvements in transportation technology – with the movement from sail to steam and the extension of the rail network – allowed wheat in particular to flood into Europe from grain producers in America. Prices fell in Europe, stimulating demand, and increased in America, stimulating supply.

This paper challenges this interpretation of the so-called grain invasion and in so doing disputes what has until now been considered one of the key distinguishing features of the “first era of globalization” (see for example O’Rourke & Williamson 1999). Transportation costs from the main wheat production areas in the US to the UK did not decline during the crucial period of trade expansion (ca. 1870-1900). Moreover, the price received by the average farmer did not increase in real terms.

Falling per mile transportation costs did, however, permit an expansion of frontier farming in the US. This process thus allowed a massive increase in US output, which was then available to supply the booming demand in the UK. The grain invasion was therefore not a response to increasing prices by American farmers, who in reality offered a perfectly elastic supply at the going price as practically unlimited supplies of land in the west were populated by immigrants.

2. The grain invasion and the expansion of the American frontier
Before attempting to explain the grain phenomenon as an historical phenomenon, it is worth standing back for a moment and reflect on what it actually entailed. As figure 1 demonstrates, this was a truly dramatic event. Although America had been an important supplier of wheat since colonial times, and was to play a significant role during the Napoleonic Wars (Galpin 1922, 1925) and periodically thereafter, it was not until the after the Civil War that American imports were to reach a more permanently high and significant level.
Prior to this, trade fluctuated wildly. The rise and fall of wheat imports after 1815 was determined by trade policy and in particular the unusual mechanisms for regulating imports contained in the Corn Laws (see Sharp 2006). Before the grain invasion, British imports were mainly from Europe, in particular Prussia and “Germany”. All this changed, however, with the movement to repeal of the Corn Laws, which were relaxed in 1842, 1846 and 1849; and were finally abolished in 1869. As figure 2 demonstrates, in the second half of the nineteenth century the UK became more dependent on distant sources of supply, in particular the US, although in the twentieth century the US lost ground to new producers in particular from Canada, Argentina, India and Australia. In this sense, the US grain invasion was soon followed by a more general “new world” invasion. Nevertheless, something changed after the 1860s, and the United States led this change.
Sources: BPP (various), Mitchell & Deane (1953). Hundredweight converted to quarters at 4.4 cwt per quarter.

The period of the grain invasion coincided with another key event in the history of American agriculture: the westward movement of the frontier. Over the course of the nineteenth century the centre of wheat production moved from New York State, Virginia and Pennsylvania to the Midwest states which dominated around the Civil War with states such as Illinois, Iowa, Michigan and Wisconsin. But by the end of the nineteenth century the major new wheat producing states were Nebraska, Kansas and North and South Dakota. This westward movement led to huge increases in production: fuel for the grain invasion. Figure 3 illustrates this.
Figure 3: Wheat production in 1839 and 1909

**Figure 2a**
WHEAT PRODUCTION, 1839

*Note: Each dot represent 100,000 bushels.*
*Source: Paullin, Atlas, plate 143P, used by permission.*

**Figure 2b**
WHEAT PRODUCTION, 1909

*Note: Each dot represents 50,000 bushels.*

Source: Olmstead & Rhode (2002)
This expansion of production was at least in part made possible by a dramatic decline in domestic transportation costs, which slashed the per mile cost of transporting wheat. Figure 4 is taken from Federico & Persson (2007), and shows the “freight factor” (the cost of transporting a unit of wheat divided by the price of a unit of wheat) for the transportation of wheat from Chicago to New York and from New York to London. As the authors note, the striking lesson to be learned from this is that the transatlantic freight factor remained almost constant over the period, although with large fluctuations. The domestic freight factor, on the other hand, declined until the First World War, most probably largely due to a change in market organization, rather than technological developments.

**Figure 4: Freight factors, 1850-1990 (1884 = 1)**

This picture of falling transportation costs, frontier movement and increasing exports has led to the compelling story of the grain invasion, first suggested by Knick Harley in the 1980s.

3. The Harley hypothesis
Harley (1986) provides some of the original work on the reasons for the expansion of the transatlantic grain trade. His hypothesis is simple and relies on two elements. First, a model of the world market, and second, a model of the movement of the frontier.

3.1 Harley’s model of the world market for wheat
Harley’s model for the impact of falling transportation costs is usually summarized as in figure 5 (see for example O’Rourke & Williamson 1999). A fuller account of his original model is given in appendix A.

Figure 5: A simple model for explaining the increase in trade

The MM schedule is the UK’s home import demand function (i.e. UK demand minus UK supply). It is falling with the home market price, \( p \). SS is the US export supply schedule (US supply minus US demand) and is increasing in the price abroad, \( p^* \). The law of one price states that, in the absence of any sort of barriers to trade, then \( p \) should equal \( p^* \) in equilibrium. Any difference in prices would lead to short-term arbitrage, which would return the economy to its equilibrium state. However, with barriers to trade, for example tariffs and transportation costs, a wedge, \( t \), is driven between export and import prices – the higher the barriers to trade, the larger the wedge.
Harley’s hypothesis can be understood by imagining an inward shift of the transport cost “wedge” in figure 4. The old import price, \( p \), now corresponds to a higher price (minus transport costs) for the exporting region. This implies that the quantity supplied by the exporting region will increase. *Ceteris paribus* this will result in excess supply in the importing region leading to a decline in price. At the same time, the old price, \( p^* \), in the exporting region now corresponds to a lower price in the importing region, thus leading to excess demand and pushing up the price in the exporting region. Import prices have thus fallen, and export prices have risen. Supply in the exporting region will increase and domestic supply in the importing region will decrease.

### 3.2 Harley’s model of the movement of the frontier

The basis of this part of the model is Ricardo’s extensive margin, which here is determined by transportation costs. At the margin, or frontier, transportation costs exhaust any surplus over the variable costs of production, so no revenue is left as a rent on land. No production will therefore take place beyond the margin.

Figure 6 illustrates this. The horizontal axis gives the distance from Europe, and the local price and costs of production are on the vertical axis. It is assumed that the transportation costs are a linear function of distance. The transportation costs at each location can be read as the vertical distance between the PP and CC schedules. They cross at the frontier.

A fall in transportation costs makes the PP schedule flatter to \( P'P' \) and, as shown in figure 4, causes the price in Europe to fall. Farmers at the old frontier will see an increase in the price they can sell their wheat for.
3.3 A brief criticism

Harley presents a simple but powerful story, which has provided a useful way for scholars to understand the grain invasion over the years. We might, however, be inclined to criticize this account on two counts.

First, in Harley’s model, the reason for the expansion of trade was a decline in the wedge caused by a fall in transportation costs. This ignores an important point. Although per mile transportation costs within the US were undoubtedly falling, the distance grain was being transported was also increasing. Simply looking at the cost of transporting grain from one particular location (Chicago) to the East Coast as in figure 4 might then hide the true cost of domestic transportation from the main production areas.

In addition, this account completely ignores the fact that shifts in the curves in figure 5 will also lead to an expansion of trade. And yet the United States was experiencing rapid growth of population through immigration and simultaneously the westward expansion of agriculture - an outward shift of SS. Simultaneously, UK population was also expanding, implying an outward shift of DD.

These criticisms are now considered one at a time.
4. A closer look at the role of transportation costs

The relevant measure of the barrier to trade implied by domestic transportation costs is the cost of transporting a unit of wheat from the main area of production to the UK. Unfortunately, however, data on transportation costs from locations west of Chicago is lacking.

Nevertheless, it is possible to get an idea as to the cost of shipping wheat using information on price differentials between the production area, and the East Coast (New York). As figure 6 makes clear, given trade the price differential between each state and New York must be equal to the cost of transporting wheat from that state to New York. By calculating the differential between the price in the main area of production and the price in New York, we get an estimate of the price of shipping wheat.

The relevant price differential is, however, changing each year with the movement of the frontier. A price series, \( p_t^{COG} \), for the centre of gravity of wheat production is thus constructed, by calculating a weighted average of the farm gate price of wheat using the prices, \( p_t^i \), given for each of the 1 to \( I \) states included in the sample\(^2\), weighted by the production in each state, \( q_t^i \), i.e.

\[
p_t^{COG} = \frac{p_t^1 \cdot q_t^1 + p_t^2 \cdot q_t^2 + p_t^3 \cdot q_t^3 + \cdots + p_t^I \cdot q_t^I}{q_t^1 + q_t^2 + q_t^3 + \cdots + q_t^I}
\]

\(^2\) In fact, the number of states with data is not constant each year, so \( I \) is also dependent on time.
Using the difference between the price at the centre of gravity of production, and that in New York, it should be possible therefore to get some idea as to the cost of transporting wheat within the US. Might the price differences simply be due to quality differences between the states, however? Of course, this is a possibility, but in fact there are theoretical reasons to believe that the wheat furthest from the East Coast should have had the highest quality, and thus the highest price ceteris paribus. A.A. Alchian and W.R. Allen (1967) noted long ago that there is good reason to ‘ship the best apples out’ since transport costs do not differ for good and bad apples making the low quality apple relatively more expensive in foreign markets. Transport is thus simply a specific price increase which lowers the relative price of the higher-quality produce in the distant market. East Coast and European demand will therefore shift to the high quality variety of the commodity. Producers might have been expected to meet that demand by improving the quality of the product. The price differential for a comparable quality of wheat might therefore be underestimated using this method.

Figure 7 illustrates the farm gate price in various locations and the farm gate price at the centre of gravity of production, $p_{t}^{COG}$. Clearly, these data support the model in figure 6,
since the further west, the lower the price received by the farmer – but this is just a consequence of the law of one price when markets are integrated, as the US market clearly was. At the same time, the movement of the frontier is clearly discernable, since the centre of gravity price lies between the New York and Illinois prices at the beginning of the period, but by 1900 it is below that in Illinois.

Figure 8 illustrates the price gaps between the centre of gravity and New York is in terms of freight factors, with the UK price used as the deflator, i.e. \( \frac{\text{transport cost from COG to NY}}{p_{UK}^{t}} = \frac{p_{NY}^{t} - p_{COG}^{t}}{p_{UK}^{t}} \).

Also included are the international freight factor and the \textit{ad valorem equivalent} (AVE) of the UK duties on wheat.

\[ \text{Figure 8: Transport costs and tariff protection} \]

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{Transport costs and tariff protection}
\end{figure}

\textbf{Sources:} The AVEs are from Sharp (2006). From 1884 the transatlantic freight factor series is that described by Federico & Persson (2006) and is for New York to London. Prior to 1884 the series is based on my estimates (which follow Federico & Persson’s closely for most years, but have less missing observations). The wheat is valued using the US price. From 1866 to 1883 the transport costs for New York to Liverpool are taken from United States (1901). These are reported as (UK) pence per (presumably US) bushel. These have been converted to shillings per quarter. Freight rates for the years 1829-32 and 1844-65 can be found using North’s (1958, pp. 550-1) “(East Coast) American Factor” for wheat, by multiplying this with the Gazette price for each year. I have not been able to find freight rates for 1833-43. I have thus estimated these by assuming that the freight rate for wheat followed the same pattern as North’s (p. 549) “American Export Freight Rate Index” after 1832, an assumption which is not too far from the truth for most years. The US freight factor is calculated using the data compiled by Cooley, DeCanio & Matthews (1977).

The AVEs are taken from Sharp (2006). They are calculated as the tariff revenue on wheat in each year divided by the value of wheat imports. The transatlantic freight factor for wheat is defined as the transport cost per unit of wheat divided by the value of a unit of wheat. The
estimates of the internal transportation costs are only included from 1866, when data information on farm gate prices becomes available. The idea is thus to express both protection and transportation costs as ad valorem barriers to trade.

The total height of the shaded area in each year is not an exact measure of the wedge in figure 5, which ideally should be the price difference between wheat in the two countries. However, wheat is by no means a homogeneous good, and qualities and types of wheat differ considerably both between the wheat produced in each country, and within each country’s own output. Even if it was possible to construct a UK and a US price series for an identical variety of wheat, it is by no means clear that this price gap would be representative of the entire wheat trade, and it would certainly not capture the westward movement in wheat production, as discussed above.

Interestingly, although it is well known that US domestic transportation costs were falling over this period, the estimated US freight factor does not. Clearly, since the centre of gravity of production was moving westward, this counteracted the impact of falling per mile transportation costs. In fact, it is clear that that the role of falling transportation costs for the story of the grain invasion appears to be limited. In fact, the econometric analysis in section 6 reveals that the sum of the domestic and international freight factors, and the AVEs for the period 1866-1900 is stationary (i.e. has constant mean and variance). Since the volume of imports is found to be non-stationary, falling barriers to trade can thus have no role to play in determining this variable.

The series of prices for the centre of gravity of production also has other implications. It is well known (at least since North 1974) that the price of wheat at individual locations in the US was increasing in the last years of the nineteenth century, in line with the simple analysis of the effect of falling transportation costs above: Harley’s model implies that the gains from falling transportation costs were shared between the producing and consuming regions. It is simple to verify this with the data used here.

In the UK, the price of American wheat fell by 2.35 per cent per year while producers’ prices fell by 1.72 per cent per year using a typical measure from one location (Chicago) when calculated as the slope coefficient of a linear regression of the log of prices. However, the grain invasion era was a period of a general and substantial deflation which means that we
need to compute the change in wheat prices relative to the price level. The US wholesale price index fell by 2.0 per cent per year in the period indicating that the real change in the producer price of wheat, that is the price deflated by the price index, is \(-1.7 \cdot (-2.0) = 0.3\) per cent. Producers thus gained in real terms. A similar calculation for consumers but using the UK wholesale price index as a deflator reveals a fall in the relative price of wheat of -0.58 per year. By these standards consumers and producers seem both to have been treated well, with a small advantage to British consumers. This is completely in line with Harley’s predictions.

When looking at the regional pattern of prices, however, it is clear that the farmers further west were getting a significantly lower price for their produce and that the centre of gravity price fell faster than the price at individual locations. The gains for American producers calculated above were thus principally accruing to eastern producers, whilst the frontier farmers got next to nothing. In fact, at the centre of gravity of production, prices fell by 2.12% per year, i.e. at approximately the same level as the fall in the general price level, and this fall would of course have been greater at the frontier. The frontier price was, therefore, not constant as in figure 6, although the price at the centre of gravity was.

5. The role of shifts in the curves
In the simple version of Harley’s model illustrated in figure 5, there are two ways, apart from declines in the wedge, which can lead to an expansion of trade. These are a shift in the import demand or export supply schedules. These are examined in turn. Both rely on knowledge of the level of wheat production in each country, since export supply is defined as US production minus US demand and import demand is defined as UK demand – UK supply. I have thus attempted to reconstruct wheat production data for both countries for the century from 1829 to 1913 (see appendix B). Please note, however, that the US production data prior to 1866 is for illustrative purposes only, and cannot be relied on for econometric analyses.

Figure 9 reports the production series for the US and the UK, and makes for fascinating reading in itself. The story of the American supply is one of increase throughout the period, rapidly overtaking that of the UK. Rothstein (1965, pp. 62-63) attributes the expansion of American agriculture after 1850 to the completion of the acquisition of easily exploitable
new territories with victory in the Mexican War and technological innovations in agriculture and transportation, a point already noted by Anon (1934, p. 293) for the period after 1870. Parker & Klein (1966) found that productivity in US wheat farming increased 4.17 times between 1840 and 1910, and that mechanization accounted for most of this increase. More recent work has stressed biological innovations. (Olmstead & Rhode, 2002) Indeed, the last year when UK production exceeded that of the US is 1855.

The data for UK production are no less interesting: British agriculture certainly does not give up immediately. The largest crop is recorded for 1845 with over 18 million quarters, but a similar level is also reached in 1864. Even by the early 1870s, UK crops are not noticeably below their long-term average level, but a noticeable decline sets in soon after, falling to about half their historical average by the end of the period. By the 1920s, the UK was producing only about 6 million quarters per year, whilst the US was producing regularly in excess of 100 million quarters.

![Figure 9: UK and US Wheat Production](image)

Source: See appendix B.

UK production as a proportion of UK consumption is illustrated in figure 10. Consumption is assumed to be equal to total UK production plus total imports (from Mitchell & Deane, 1962, pp. 97-99). The increase in population from 1829-1913 is also shown. (Mitchell &
Deane, 1962, pp. 8-10) It is clear that even if UK wheat output had not been falling, the import demand curve in figure 2 was shifting outwards.

Figure 10: UK production and imports of wheat, and population 1829-1913

Source: Mitchell & Deane (1962), own calculations

6. What caused the invasion? An empirical test
It is clear what is changing during this period. There was a massive increase in the British demand for wheat, largely fuelled by an increasing population, and American supply was increasing to meet this demand. The role of falling transportation costs, however, was very limited. It is rewarding, however, to attempt a more formal test of Harley’s model.

Harley’s theory motivates the inclusion of several explanatory variables for an econometric test: in particular, a test of the theory must include ways of measuring the relative importance of demand factors, supply factors as well, of course, as the gap between British and American wheat prices.

Unfortunately, the model cannot be tested directly, since it is impossible to see the American grain invasion in isolation. More generally, this was a story of increasing wheat imports, only some of which were supplied by the United States. It is therefore not only the British/American price gap that is relevant for analysis, but a multitude of price gaps
between the competing suppliers. Moreover, by no means all the wheat consumed in the UK came from abroad. Substantial quantities are still grown today for domestic consumption and were throughout the period. The state of domestic supply is undoubtedly also an important part of the grain invasion story. The econometric model thus makes use of the data that are available in as general a framework as possible.

6.1 The variables
It is of course necessary to start with the theory model in order to suggest what variables to include in our analysis. Obviously, the imports of wheat from the United States to the United Kingdom must be one of the variables in our analysis. This is the “trade” variable in figure 5, and the variable(s) which explains this will explain the grain invasion. The volume of UK imports is called \( m_t \) and is taken in logarithms.

For the price gap, a simple measure, \( z \), is defined as

\[
Z_t = \log(\text{ave}_t + ff_t)
\]

where \( \text{ave} \) is the *Ad Valorem Equivalent* of the UK tariffs and \( ff \) is the sum of the international and American domestic freight factors. \( z \) is thus a measure of the “explainable” gap between the prices of British and American wheat.

Also included are the logs of UK production, \( q_{t}^{UK} \), which is a component of import demand, and of US production, \( q_{t}^{US} \), which is a component of export supply. These are of course again not perfect substitutes for the desired variables, but they are what is available. A full measure of import demand would require total demand in the UK, but this can only be estimated, as in figure 10, as the sum of total UK production and total imports. Since the former is the other component of import demand and the latter is what we are trying to explain, this does not get us very far. Likewise, export supply can only be approximated by using an estimate of US demand, which in turn could only be approximated using the sum of the difference between US production (the other component of export supply) and US exports (what we are trying to explain).

6.2 The choice of econometric model
The analysis here uses the cointegrated VAR model and the methodology described by Juselius (2006). To model the long-run relationships the following model is estimated:
\[ \Delta X_t = \alpha \beta' x_{t-1} + \Gamma \Delta X_{t-1} + \mu + \alpha \beta' t + \varepsilon_t \]

where \( X_t = (m_t, z_t, q_t^{UK}, q_t^{US})' \) as described in the previous section, and \( t \) is the trend.

This model assumes that the \( p = 4 \) variables in \( X_t \) are related through \( r \) equilibrium relationships with deviation from equilibrium \( u_t = \beta' Z_t \), and \( \alpha \) characterizes the equilibrium correction. It holds that \( \alpha \) and \( \beta \) are \( p \times r \) matrices and the rank of \( \Pi = \alpha \beta' \) is \( r \leq p \). The autoregressive parameter, \( \Gamma \), models the short-run dynamics, and throughout it is assumed that \( \varepsilon_t \sim iid.N_p(0, \Omega) \).

This approach enjoys many advantages. In particular, all the variables are considered in a very general model in which they are all initially treated as endogenous. This means that any potential relationship between the variables can be modelled, in contrast to other modelling techniques which usually assume a theoretical model and attempt to fit the data into this structure. The relationships found between the variables can thus be considered “sophisticated stylized facts” (Juselius & Franchi, 2007) which the theory model has to replicate before it can claim empirical relevance. Another advantage is that the cointegrating equilibrium relationships between the variables are by definition invariant to the addition of other variables to the model. This implies that, although other relevant variables might be considered to be of importance for the econometric analysis, their omission will not impact on the interpretation of the equilibrium relations that are uncovered: this is a very convenient property for many econometric analyses using historical data.

6.3 The expected results

It is expected that the imports of wheat are determined by three relationships: exogenous (i.e. not determined by the price gap) import demand and export supply shifts, and the wedge. This would imply reduced rank of the \( \Pi \) matrix, i.e. \( r = 3 \).

\( z \) is expected to be stationary, and thus form a cointegrating relationship with itself. Apart from this, the import demand schedule implies a negative cointegrating relationship of the form \( m_t = m_t(q_t^{UK}) \) and the export supply schedule would imply a positive cointegrating relationship of the form \( m_t = m_t(q_t^{US}) \).
6.4 The results

The results presented here were obtained using CATS in RATS, version 2\(^3\). The period used for estimation is 1866 to 1900, which is the period during which the grain invasion is usually considered to have taken place. It is tempting to extend the analysis to the years prior to 1866, but reliable estimates for the US production of wheat are impossible to come by prior to 1866.

The model is well specified under the assumption that the residuals are iid. and normally distributed. Checks for normality and no autocorrelation of the residuals do not reveal major problems with the model.\(^4\)

Importantly, and as expected, for any choice of \(r\), \(z\) is found to be stationary, using the CATS test for stationarity. A crucial step in the analysis is to determine the number of equilibrium relationships. \(r = 3\) is found sufficient\(^5\), one of which is for \(z\) which, as a stationary variable, cointegrates with itself.

It is expected that three equilibrium relationships will be found: one for import demand, and one for export supply, and one for \(z\). It is therefore obvious to normalize two relationships on \(m\) and the last on \(z\). Imposing this, the results presented in table 1 under H0 are found. Imposing stationarity of \(z\), and considering the first relationship to be that for export supply, and the second for import demand implies the restrictions imposed under H1. Finally, further tests were made to check the assumptions of the model such as parameter constancy, which did not give reason to question the validity of the estimation results.

Note that the restrictions are accepted with a large p-value, all beta coefficients are highly significant, and that all relationships error correct significantly in the variable which has

\(^3\) See Appendix C for the CATS output.

\(^4\) The Doornik & Hansen (1994) test for normality is accepted with a p-value of 0.312. Tests for no autocorrelation of different orders are likewise accepted with large p-values (Godfrey 1988).

\(^5\) Although the LR rank test suggests \(r = 1\) or \(r = 2\) is accepted, the short sample length will have a tendency to bias the rank test towards too low a low rank. Examination of the graphs of the cointegrating relations, and recursive estimation of the trace test statistics reveals that the less restrictive specification of \(r = 3\) is more reasonable.
been normalized on (i.e. significant negative alpha coefficients for \( m \) in the first two relations, and for \( z \) in the final relation. \( q^{UK} \) is also adjusting to the second relation (i.e. it has a highly significant alpha coefficient), but this is not surprising, since it is clearly also going to be impacted on in the long run by the increase in imports. As shown above, British wheat production did indeed drop in the wake of the grain invasion.

Since all variables are in logarithms, the coefficients in the \( \beta \) matrix can be interpreted as elasticities. The first relation reveals that, in equilibrium, a 1 percentage point increase in \( q^{US} \) implied a 2.56 per cent increase in imports. The second relation shows that, in equilibrium, a 1 percentage point increase in \( q^{UK} \) caused a 4.97 per cent decrease in imports. Imports are thus determined by exogenous import supply and export demand shifts in the ways suggested by the model. They are not, however, determined by the price gap.

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P-value for test of restricted model: 0.783
7. **A re-examination of the Harley hypothesis**
As discussed above, the big change during the course of the nineteenth century was the massive expansion of US wheat supply, which then flooded into Europe.

7.1 **Model for the impact of falling transportation costs on the location of production**

Figure 11 is a modified version of Harley’s original model for the movement of the frontier. The following empirical facts are used:

1. The price of domestic transportation fell on a per mile basis (figure 5). The PP curve thus becomes flatter.
2. The price in the UK decreased in real terms (section 4.2). The intercept of the PP curve with the vertical axis thus falls.
3. The price at Chicago increased in real terms (section 4.2). Chicago must therefore have been located to the right of location X.
4. The price at the new centre of gravity is approximately equal to that in the former centre of gravity (section 4.2).

**Figure 11: The movement of wheat production**

Instead of costs, it is assumed that the horizontal line illustrates some target level for the reservation income of a farmer at the centre of gravity of wheat production. Since this level
is above costs, it is possible for the frontier to be located to the right (west) of the centre of gravity without this implying that farmers receive a negative income.

Note that, in this model, there are both short run and long run effects of a decrease in transportation costs. In the short run, the price at the centre of gravity of production will increase. In the long run, however, the centre of gravity will move west and will eventually return to the target level of reservation income. This distinction between the short and long runs is important, and forms the basis of the revised model for the world wheat market.

7.2 Model for the world wheat market
The model in this section is inspired by that described by Shepherd & Walton (1972) to understand the colonial economy. As in their model, a distinction is made between the short and the long run. The model is illustrated in figure 12.

Figure 12: Model of the world wheat economy

Initially, the world price is determined by the intersection of the short run supply curve, S, and the demand curve, D. The short run supply curve is upward sloping, reflecting the costs of extending the frontier, and the fact that immigrants took time to arrive. The long run supply curve, on the other hand, is horizontal, since in the long run immigrants would arrive and force income down to the reservation level again.
Consider a fall in transportation costs, or the move to repeal the Corn Laws. This initially causes the effects in figure 6: the price in the UK falls, and the price in the US increases. As immigrants start to arrive and push the frontier westward, however, the short run supply curve will start to move outwards to $S'$. At this point, the price of wheat in the US is again at its long run level, and farmers are receiving their reservation income. Importantly, and in contrast to Harley’s original analysis, American producers would then not gain from falling transportation costs, unlike UK consumers, in line with the empirical evidence presented in section 4.2.

The empirical evidence suggests, however, that (at least after the repeal of the Corn Laws), the main reason for the expansion of trade were endogenous shifts of the supply and demand curves, for example to $S''$ and $D''$. Note also that an increase in productivity, such as that described by Olmstead & Rhode (2002), would have the effect of a downward shift in the long run supply curve, as it would reduce farmers’ production costs. It can easily be shown that this would also increase trade.

8. Conclusion
This paper provides empirical and theoretical support for the hypothesis that the increase in trade associated with the grain invasion was the result of transportation cost reductions which allowed the extension of the frontier without increasing the price for producers. This contrasts with Harley’s interpretation: that trade increased because US farmers were paid more due to the reduction in transportation costs. As such, the hypothesis first suggested by Persson (2004), that the growth in world trade expanded due to the elastic supply of nations where “practically unlimited supplies of land were populated by immigrants”, has been given empirical and theoretical support. These results have a number of interesting implications.

The fact that farm gate prices did not increase for the representative producer, and might even have been falling on the frontier, ties into an extensive literature on the reasons for the agricultural discontent in America over this period, which until now have been difficult to understand given the real price increases documented by amongst others Douglass North. This is explored briefly in Appendix D.
Just as intriguingly, this paper seems to imply that the grain invasion was, at least in part, not due to “globalization”, as defined by O’Rourke & Williamson (2002a, p. 25), which for them is market integration, or a decline in the “wedge” illustrated in figure 4. The “first era of globalization” might therefore have more in common with the “overseas trade boom” of 1500-1800 (O’Rourke & Williamson, 2002b), than has previously been suggested.

Domestic transportation improvements were, however, a factor in permitting the westward expansion of agriculture and thus the increase in supply. But what is quite clear is that the enormous increase in production in the US could not have taken place without the substantial immigration she enjoyed throughout this period. Interestingly, this means that we can perhaps again conclude that globalization played an important role for the expansion of trade, but through the integration of labour markets, rather than of commodity markets.
Appendix A: Harley’s original model of the world market for wheat

This is a model for trade between two locations: an exporting country (the US), and an importing country (Europe, or the UK). The intersection of demand and supply in the two locations is illustrated in figure 4. The model relies on the observation that, if trade actually occurs, then the price of wheat can only differ between regions by an amount equal to the trading costs between the two locations.

**Figure 4: Harley’s model for the world market for wheat**

In figure 4, it is assumed that in the absence of trade, the price would be high in the importing region and low in the exporting region. This will be the case if the price differential is smaller than the transaction costs – then the price in each location is determined by supply and demand in the individual locations.
At importing price \( P_{\alpha} \), the supply can be read from the importing region’s supply curve \( (Q_{m,\alpha}) \). At this price in the importing region, the price in the exporting region is \( P_{\alpha} \) minus transportation costs \( (P_{x,\alpha}) \) and the quantity supplied is \( Q_{x,\alpha} \). The sum of the quantities is the world quantity supplied, \( Q_{\alpha} \). The world demand curve can be found in a similar way.

The important point is this: when transportation costs fall, the world market must find a new equilibrium. The old price in the importing region now corresponds to a higher price in the exporting region. This means that the quantity supplied at that price in the exporting region will increase and the quantity demanded in the exporting region will fall. This leads to an excess supply of wheat, and the price will fall to \( P_{\beta} \). In the exporting region, the old equilibrium price corresponds to a lower price in the importing region, and thus excess demand and a price increase. Prices thus fall in the importing region and increase in the exporting region. In addition, the quantity supplied increases.
Appendix B: Data sources for the production estimates

Although official estimates for the UK are only available from 1884 (Mitchell & Deane 1962, pp. 86-7; see Coppock 1956 for a background on these estimates), unofficial estimates are given by Gilbert & Lawes (1893, appendix table II) for the years 1853-83. They report their estimates in “harvest years” e.g. 1852-3 – I have used the second of the pair in each case. Contemporary estimates are not available for earlier years, but are given by Fairlee (1969, p. 114) for 1829-52. She does not give an estimate for 1842, since her estimates are based on multiplying the quantity of wheat sold in “inspected markets” under the Corn Laws by a constant fraction, which changes from 4 to 14/5 in 1842, since the number of inspected markets increased from 150 to 290 on April 29, 1842. It is not too hard to use Fairlee’s method to get a rough estimate of wheat output in 1842. Using BPP (1842, p. 177) we find that 970 thousand quarters of wheat were sold in inspected markets until April 29. Multiplying this by Fairlee’s factor of four gives 3,880 thousand quarters. After April 29, 8,739 thousand quarters were sold. Multiplying this by Fairlee’s factor of 14/5 gives 8,740 thousand quarters. Adding the two together gives an estimate of 12,620 thousand quarters produced in 1842.

Prior to 1866 the only official estimates for the US are those from the decennial census. These estimates from 1839 can be found in United States (1975, pp. 511-2). Other (sometimes contradictory) estimates exist from various sources for other years. The most complete of these is from Guetter & Mckinley (1924, p. 29), which has data for some years back to 1790. (For background information and a discussion on the reliability of the early US estimates, see Benedict (1939), Ebling (1939) and Gallman (1963).) I have used their estimates for the years 1841-49, 1851-58 and 1862-65. This still leaves missing observations for 1829, 1831-38 and 1861. Thorp (1926, pp. 113-145) gives descriptions of the state of the wheat harvest for most years from 1790 to 1925. Wheat crops are given various descriptions such as “failure”, “poor”, “abundant”, “record” to name a few. His descriptions seem to follow the data from Guetter & Mckinley very closely, e.g. his description of a “record” crop corresponds to historical highs. The levels for these years have been based on these descriptions. For 1860 and 1861 his description is “good”, which as the same as for 1859, which had a production of 173 million bushels. I have thus chosen a level of 173 for 1860 and 1861. I have assumed production in 1830 was the same as that in 1829, and I have
then assigned levels to 1831-8 using linear interpolation between 1830 and 1839. When the description is “failure”, “short” or “shortage”, I have subtracted 15% from the interpolated series. When the description is “good”, “large” or “excellent”, I have added 15%. Other descriptions result in the use of the standard interpolated series. The 1840 production has been assumed to be the same as in 1839.
Appendix C: CATS Output

Residual analysis

RESIDUAL ANALYSIS

Residual S.E. and Cross-Correlations

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<th>DLXUS</th>
<th>DLZ</th>
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LOG(|Sigma|) = -15.515

Information Criteria: SC = -11.277

H-Q = -12.480

Trace Correlation = 0.590

Tests for Autocorrelation

Ljung-Box(8): ChiSqr(96) = 175.306 [0.000]

LM(1): ChiSqr(16) = 14.477 [0.563]

LM(2): ChiSqr(16) = 15.179 [0.512]

LM(3): ChiSqr(16) = 19.042 [0.267]

LM(4): ChiSqr(16) = 17.283 [0.368]

Test for Normality: ChiSqr(8) = 9.376 [0.312]

Test for ARCH:

LM(1): ChiSqr(100) = 102.755 [0.405]
**Test for stationarity**

**TEST OF STATIONARITY**

LR-test, Chi-Square(4-r), P-values in brackets.

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Restricted Trend included

in the cointegrating relation(s)
Appendix D: Some reflections on the implications of the new price series

Long ago, Douglass North (1974) found that the last decades of the nineteenth century saw a period when the real price of farm products increased and transportation costs fell. In Europe, farmers protested against the invasion of cheap grain. This of course fitted well into the story told by Harley (see above).

The agricultural distress and protest in the Old World in the wake of the grain invasion was both predictable and understandable. Countries either chose to shield themselves through protectionism, as in the cases of Sweden, Germany and France, or allowed their economies to adjust. The UK saw a large decline in agriculture (Ejrnæs, Persson & Rich 2008) whereas Denmark - a particularly interesting case – changed from being a net exporter of grain in the 1850s and 1860s to become a net importer in the 1880s of wheat as well as fodder for an agricultural sector switching to bacon and dairy products. (Henriksen 1993)

However, although the last decades of the nineteenth century are perhaps principally associated with agricultural discontent for the European economic historian, somewhat paradoxically the historian of American agriculture would associate this period with the same. In the United States, from the 1860s, a succession of protest movements flourished, culminating with the Presidential campaign of the Populist William Jennings Bryan in 1896. However, it has been difficult to find a wholly convincing argument as to why farmers were angry. The problem rests on evidence that the real incomes of farmers actually increased over this period.

The story of the agrarian protest movement in the United States during the latter part of the nineteenth century is well known. A succession of protest movements emerged starting with Oliver Kelly’s ‘National Grange of the Patrons of Husbandry’ in 1867, followed by the Greenback party, the Farmers’ Alliance and finally the Populist movement of the 1890s. The farmers’ concerns are typically summarized as ‘falling commodity prices, increased entry costs to farming, rising tenancy, farm foreclosure, and uncertainties generated by harvests in another hemisphere and reliance upon markets an ocean away’. (Atack, Bateman & Parker 2000)
However, the reasons for the discontent have long been disputed and putting it into the context of the emergence of the United States as the leading agricultural exporter can only appear to add to the confusion. Indeed, the reaction of American farmers was sharply at odds with the standard interpretation of the Grain Invasion as first suggested by Harley (1980, 1986). He demonstrated within a simple theoretical framework that the gains from falling transport costs should have been shared by producers in the US and consumers in Europe with the establishment of a transatlantic grain market. The lower transport costs caused the price gap between American and European grain to narrow, resulting in a price decrease in Europe (good for consumers) and a price increase in the United States (good for producers).

The Harley hypothesis fitted well into earlier research by North (1974), who argued that the real price of farm products increased and transport costs fell. However, this made it difficult to relate the agrarian protest movement to deteriorating economic conditions. The consensus view\(^6\) was therefore that the economic plight of farmers seemed to have been exaggerated or misrepresented in earlier research when farmers were taken on their own word. As Frieden (1997, p. 372) points out, ‘there is a puzzling weakness of evidence’ for a relationship between economic conditions and farm protest.

Accepting this, other researchers have looked elsewhere. One line of argument suggests that income uncertainty increased or was particularly high in regions with strong farm reform movements. The logic here is that there are welfare losses associated with price volatility if farmers were risk averse. (McGuire 1981) Another line of argument looks at the particular problems of indebted farmers in a period of deflation. Since the general price level fell by half or more in the Grain Invasion period, debt as a proportion of current income might increase when nominal prices fall because the nominal debt for a farmer remains unaffected by the fall in prices. The risk of foreclosures increased and fuelled unrest. (Stock 1983) The problem with this interpretation is that foreclosures were not very frequent, but Stock argues that even so most farmers would have known someone who was

\(^6\) This was shared for example by W. Parker and R. Higgs.
affected which fuelled a fear of being the next victim. States with a higher frequency of foreclosures were fertile ground for the protest movement.

Interesting as these explanations are they do not seem to have convinced the profession of economic historians. As Mayhew (1972, p. 466) points out, it is ‘puzzling that farmers began complaining about railroad rates, interest rates, and problems of obtaining credit in a period when freight rates and interest rates were falling rapidly and when... credit was easily available’. She continues that it ‘is also puzzling that earlier fluctuations in prices did not provoke farmer protest’. Thus, in a recent survey, Whaples (1995) reports that only 22 per cent of economists in the Economic History Association agreed with the proposition that ‘The Agrarian protest movement in the Middle West from 1870 to 1900 was a reaction to the deteriorating economic status of farmers’. 52 per cent disagreed. Did farmers then have nominal illusions, mistaking a nominal fall in income for a real fall? This seems unlikely given that if farmers were aware of the prices of their own produce they must surely also have been informed about the prices of the goods they purchased.7

In fact, we ought to be concerned about any argument which implies that people protest for the wrong reasons. Economists usually believe that man acts fairly rationally on the basis of knowledge which is accurate or at least not systematically misleading or biased. Indeed, Cooley & DeCanio (1977) convincingly argued that American farmers responded rationally to price signals during the period of discontent. However, in the dominant explanation for the unrest farmers were simply wrong or seriously misinformed.8

In fact, the favoured explanation for the unrest according to Whaples’ survey is almost aggressively non-economic. Mayhew (1972) argued that farmers were simply upset by ‘commercialization’, ‘the increasing importance of prices’ and their being forced into an economic system in which money was all important. Although we will attempt to reveal an economic basis for the farmers’ concerns, our explanation is in fact compatible in a sense

7 Although see Friedman (1990, p. 1171) for a dissenting view.

8 This idea was also apparent in the statements of contemporaries, for example the President of the Boston Manufacturers’ Mutual Fire Insurance Company in evidence before the British Royal Commission on Agriculture in 1879 (1881, C. 7400): “You do not think that the [agrarian protest] movement then has any real economic basis?—No...”
with Mayhew’s. From a study of the contemporary political debate there is no doubt that farmers themselves were clearly under the impression that their economic condition was deteriorating. And there is also no doubt that the objects of their frustration were those identified by Mayhew: the owners of railroads, moneylenders, manufacturers, banks etc. All these were perhaps a sign of the increasing commercialization of agriculture but more generally they were just one aspect of the increasing internationalization of agriculture, and indeed economic life in general, which occurred in the second half of the nineteenth century.

What the farmers were then really experiencing was their submergence in the new Atlantic Economy. This gave rise to concerns which were entirely economic in nature. Exposure to distant export markets had differential effects on producers in America. The farmers’ concerns were thus entirely consistent with those of rational economic agents.

Farmers in the United States saw something that economists and economic historians have not seen. Those who complained got next to nothing from the export boom despite falling transport costs and despite the surging overseas demand. It was consumers in Europe who got all or almost all the benefits as long as domestic farmers did not succeed in protecting their markets.

There is a W.A. Lewis flavour to the argument in that the US labour supply to agriculture and, by implication, grain supply is believed to be very if not perfectly elastic. This also implies that technological progress in the farming sector did not translate into higher wages but rather resulted in lower prices. There is an expectation here that the farm protest had a particular geographical pattern being concentrated in areas of the frontier where recently settled farmers gained access to the world market made possible by falling transport costs but at the going farm income.
References


BPP (various), HCPP


