Infrastructure Finance and the London Capital Market:
New evidence on the integration of British Domestic Capital Markets, 1700-1840

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Abstract

When did the London capital market become integrated with the financing of transport improvements in Britain? This paper uses unknown structural break tests to analyze the stability of the relationship between transportation improvement acts and real yields on long-term government debt traded in London between 1701 and 1840. The results reveal that integration differed across transport modes. Road financing appears to have been integrated with the London capital market from the early 1700s, whereas the financing of inland waterways became integrated with the London capital market after the 1790s and harbors after the early 1800s. Bridge financing was never integrated with the London market before 1840. The results have implications for the apparently weak link between finance and the real economy during the early stages of the Industrial Revolution.

I. Introduction

British financial markets evolved tremendously from the early eighteenth century to the late nineteenth century. The state of financial markets at the two end-points of this period are well known. In the early 1700s a substantial market for government debt emerged in London and along with it interest rates on long-term government bonds decreased and the amount of government debt soared. By the late 1800s the London capital market was the largest in the world, providing financial services to a whole range of governments and firms.

What is less clear is how and when the London capital market came to play a crucial role in the financing of private investment. There is a famous quote from Postan that during the Industrial Revolution "the reservoirs of savings were full enough but conduits to connect them with the wheels of industry were few and meager" (1935, p. 2). Their absence is puzzling at first glance because a variety of 'conduits' emerged to help finance government borrowing in the early 1700s (Dickson 1967, Neal 1990). It appears that early innovations in the market for government debt did not have an effect on private investment until much later. This realization has led to much debate about the reasons for the apparently weak link between finance and the real economy during the early stages of the Industrial Revolution.[1]

The financing of transport projects provides an excellent opportunity to study such issues. In Britain the government did not finance transport investments. Instead it passed acts of parliament which gave individual trusts or companies that right to undertake specific projects. The financing needs of these transport improvement authorities were substantial. Building or improving roads, bridges, rivers, canals, and harbors required fixed investments that were usually beyond the means of an individual or a small group. Most transport authorities paid for

[1] There is a very large literature on this topic. A sampling of relevant works includes Pressnell (1956), Neal (1990), Quinn (2001), Yishay and Sussman (2006), Trew (2007), and Temin and Voth (2008).

investments by issuing bonds secured on the income of the tolls or by issuing shares. In addition to their demand for long-term finance, transport authorities needed short-term loans to pay for operational expenses during economic downturns. Many also resorted to short-term loans when long-term lenders were not forthcoming.

The predominant view in the literature is that the market for transport financing in Britain was local in nature well into the nineteenth century. Many scholars have found that investors were generally local landowners, merchants, and industrialists with a direct financial interest in the success of the project (see Willan 1965, Albert 1972, Ward 1974). Scholars have also found that the geographic and professional scope of investors broadened over time. In particular, they note the growing involvement of London financiers or intermediaries connected to the London market. It remains an open question, however, when and how the London capital market came to be integrated with transport financing in Britain or other parts of the U.K. like Ireland.

We address this issue by combining data on the real yields of British government bonds with the number of acts to improve roads, bridges, inland waterways, and harbors from 1701 to 1840. Another paper documents a strong negative correlation between real yields on British government bonds and all transport improvement acts (see Bogart and Richardson 2008). We interpret this result as evidence that Britain had a flexible property rights system in that individuals could obtain rights to implement investments whenever it was economically beneficial to them. In this paper we focus on when, if ever, there was a structural break in the relationship between transport improvement acts and real yields on British government bonds. The analysis is based on unknown structural break tests developed by Andrews (1993) and Bai and Perron (1999, 2003). They identify whether and in what year there was a significant change in the relationship between the number of transport improvement acts and real yields. The latter serves as a proxy for the real interest rare in London where government bonds were actively traded. If after some date there is a stronger negative relationship between real yields and transport improvement acts then this would provide evidence of greater integration between transport financing and the London capital market.

The tests show there is no evidence for a structural break in the relationship between real yields and either the number of road improvement acts or the number of bridge improvement acts. However the baseline analysis shows that real yields were negatively and significantly correlated with road improvement acts over the whole sample period from 1701 to 1840. In the case of inland waterways and harbors, the tests provide evidence for a single structural break in the years 1790 and 1803 respectively. Moreover, after 1790 real yields exhibit a negative and significant relationship with inland waterway acts and after 1803 real yields are negatively and significantly related to harbor acts. These results suggest that integration differed across transport modes. Road financing appears to have been integrated with the London market from a very early date. Bridge financing never became integrated. Inland waterway and harbor financing became integrated with the London capital market only after the 1790s and early 1800s.

We also consider some of the causes of market integration. Our preliminary analysis suggests that legal and financial innovations were the key factors. The timing of the structural break for inland waterway acts coincided with the emergence of brokers, close relationships between banks and canal companies, and the emergence of new securities like interest-bearing notes which could be converted into stock at the option of the holder. The timing of the structural break for harbors coincided with the emergence of the joint-stock harbor company. In the case of road financing, market integration seems to have been maintained by financial innovations like the practice of obtaining bond subscriptions prior to obtaining the act. The legal system was also conducive here because it made subscribers liable if they failed to provide funds when called.

The findings in this paper relate to a large literature on British financial markets. A closely related paper in terms of its conclusions is the work by Mosche Bushinsky and Ben Polak (1993). They use a series on property deeds in Middlesex and Yorkshire to argue that the London capital market was strongly linked with local capital markets only after the late eighteenth century. As a caveat they point out that their evidence cannot identify whether the 'modern' industries of the Industrial Revolution utilized the London capital market starting in the late eighteenth century. In this regard we would argue that our evidence adds to the literature because it shows that at least some modern industries—like canal transportation—utilized the London market during the Industrial Revolution.

Another related paper is by Trew (2007) who develops a theoretical framework to explain the slow integration of the London capital market with the real economy. Trew's model assumes that London financiers are more efficient in financing large investment than local financiers but they face an informational disadvantage because of their distance from projects. Over time the information disadvantage of London financiers diminishes because they learn from the implementation of local projects. As soon as their informational disadvantages become smaller than their efficiency advantage in raising capital then London financiers take over the market and they finance a higher equilibrium level of investment. The structural breaks identified for inland waterways and harbors could be interpreted as the tipping point in Trew's model. From this perspective the early innovations of the London capital market may have been slow to reach the real economy, because it was first necessary for more narrow financial innovations to erode the informational disadvantages of distant investors.

More generally the findings point to importance of financial innovation in British economic growth during the eighteenth and nineteenth century. Productivity growth in financial services is hard to measure and as a result this important sector has been given less attention in most of the macro-analyses (e.g. Crafts and Harley 1992). The integration of markets is one indicator of productivity growth in financial services because it indicates a lowering of the transaction costs required for matching entrepreneurs with investors. Such advances led to savings in the financial sector and the development of an extensive transport system.

II. Background

Britain had a unique system for financing transport investment in the eighteenth and early nineteenth century. Local groups would approach Parliament and petition for an act to build or improve specific infrastructure projects, like roads, bridges, rivers, ports, canals, and railways. The act would include the authority to purchase land, collect tolls, issue debts secured on the income of the tolls, and possibly the right to issue shares. With respect to financing, Parliament sometimes set the maximum interest rate that could be paid on bonds or it might regulate the amount of debt or stock that could be issued.

A variety of business organizations were created through transport improvement acts. Road and bridge acts usually created a body of trustees composed of landowners, merchants, industrialists, and local officials. The road trusts became known as turnpike trusts because they erected turnpikes to collect tolls on highways. Turnpike and bridge trustees did not have an ownership stake in the organization, and generally served without direct compensation. River improvement authorities could either be non-profit trusts or they could be for-profit partnerships or joint-stock companies. Most of the river improvement authorities in the late 1600s and early 1700s were operated as partnerships with assignable rights or they were under the direct authority of a municipal corporation. The first private, joint stock company to improve a river was created in 1730 and was called the Company of proprietors of the navigation of the River Dunn. After it was created joint-stock companies became increasingly common for river improvements.

Harbor improvement authorities also exhibited much variety in their business organization. In the early 1700s they operated as trusts or extensions of municipal corporations. For example, most of the docks in Liverpool in the 1770s operated as trusts, some with a close affiliation to the corporation of Liverpool. Joint stock companies emerged most clearly in London in the early 1800s. Several dock companies were created with monopoly rights to particular branches of trade. The West Indian dock company opened in 1803 with monopoly rights to the West Indian trade. The London dock company opened in 1805 with rights to trade in tobacco, rice, wine, and brandy. The East India dock opened in 1806 with rights to the trade of the East India company (Jackson 1983, p. 203).

Canal acts came later and were different from the rest because they almost exclusively created joint stock companies. Local landowners and merchants were typical investors in canals, but unlike road and bridge trusts, they purchased shares rather than long-term bonds. With the canal boom of the 1790s they were increasingly joined by other types of investors both local and in London (Ward 1974). Joint stock canal companies were the first speculative transport venture in British and perhaps world history.

A substantial amount was invested in transport through statutory authorities even before the arrival of railways in the 1830s and 1840s. The source materials do not allow for precise figures to be given, but some estimates have been made. Bogart (2008) estimates that £6.5 million was invested in roads in England and Wales by 1820 and that less than £1 million was invested in rivers by 1750. Ward (1974) estimates that £17 million was raised for river and canal investments in England by 1815. Jackson (1983, p. 203) estimates that £7 million was invested in London's ports by 1830. It is not yet possible to quantify the total amount of transport investment at any date, but it is clear that it represented a substantial share of the net capital stock in the early nineteenth century.[2]

The identity of investors and their location has been a major topic in the literature on British transport finance. The predominant view is that most investors were local property owners, but over time other investors increasingly participated. The literature has placed particular focus on the role of London financiers, although the term is a little ambiguous. There were some investors who resided solely in London and who made their income from trading in govt. debt, bank of England stock, East Indian company stock, and making loans to Londoners. There were also large landowners that resided partly in London and partly on their country estate. These investors had portfolios consisting of British government debt and other London-based investments, but they also held local securities like the bonds or shares of transport authorities. Albert (1972, p. 105) describes how the Duke of Norfolk, the Duke of Devonshire, the Marquis of Hereford, the Earl of Guildford, the Duchess of Argyll, and the earl of Dartmoor were all major investors in various turnpike trusts in the eighteen and nineteenth century. Most,

[2] See Harris (2000) for an estimation along these lines.

if not all, of these nobles would have had portfolios that included government bonds or other investments in London.

The increasing presence of London financiers provides one indication that London capital market and local capital markets were becoming increasingly integrated by the early nineteenth century. The absence of large direct investment by Londoners does not necessarily imply that capital markets were disintegrated. If there are no arbitrage opportunities then investment flows from London to the provinces may be minimal, but the market could still be integrated.

More evidence is needed to establish when the London capital market began to have an influence on transport projects throughout Britain. The most common approach in the literature is to analyze the relationship between interest rates in London and the timing of transport investment. This study follows in this tradition but it analyzes the relationship using structural break tests. The following section discusses the data for this analysis.

III. Data

III.1 Time series data on transport acts

Data on the timing of transport investment throughout Britain would be ideal for studying the relationship with the London market. Unfortunately, as yet, there is no annual time-series on investment in roads, bridges, inland waterways, and harbors. Instead authors have used the number of road, bridge, inland waterway, and harbor acts passed by Parliament as a proxy for the timing of investment in each mode. The vast majority of transport acts originated with a petition submitted to the House of Commons. Through the petition promoters asked for the authority to establish rights of way, set or alter tolls, and define or redefine capitalization. The petition would be assigned to a committee which wrote the bill and read it to the Commons three times.

If it passed the bill went to the Lords where a similar procedure was performed. If it passed the Lords the bill would then be approved by King and became a law.

Numerous scholars have collected and published the time-series for individual transport modes (e.g. Albert 1972 for roads, Ward 1974 for harbors, rivers, and canals). However, the data are not always presented annually and they include some selection by the authors based on the content of the acts. Bogart and Richardson (2008) have put together an annual data series on all statutory authority acts from 1600 to 1830. The time series includes all acts that created or amended the rights of specific road, bridge, inland waterway, and harbor authorities in Britain. In other words, the data consist of all acts that authorized new transport projects and acts that amended the rights of existing organizations that were granted rights through an earlier act. For example in 1794, Parliament passed

> An Act for making and maintaining a Navigable Canal from and out of the Canal Navigation from Manchester to or near Ashton under Lyne and Oldham in the County Palatine of Lancaster, at the intended Aqueduct Bridge in Dukinfield in the County of Chester, at or near to Chapel Milton in the County of Derby; and a Communication by Rail Ways or Stone Roads from thence to Load's Knowl, within Peak Forest in the said County of Derby; and a Branch from and out of the said intended Canal to Whaley Bridge in the said County of Chester.

In 1800, Parliament passed

> An Act for altering and amending an Act passed in the thirty fourth Year of the Reign of His present Majesty, for making and maintaining the Peak Forest Canal; and for granting to the Company of Proprietors of the said Canal further and other Powers.

The first Act authorized the construction of a navigable canal. The second Act amended the previous act, providing “further and other powers” to the proprietors. In some of the earlier research scholars attempted to separate acts that authorized new improvements and acts that simply amended earlier rights. The two types of acts are not separated in this study. The main reason is that amendment acts often included changes in capitalization or corporate organization.

These changes in financial structure were sometimes just as important for the completion of projects as the original act which created a new trust or company. Secondly, it is difficult to identify which amendment acts were aimed to affect investment from other activities.

The time-series on transport improvement acts are separated into acts affecting specific roads, bridges, inland waterways, and harbors. Each of these modes has a different economic and financial history and thus for the present purposes it is most revealing to analyze them separately. The data include transport projects located in England, Wales, Scotland, and Ireland. The broad geographic scope, including Great Britain and Ireland, is advantage of the data because it provides information on transport projects for a larger area.

Lastly, it is important to recognize that transport acts represent successful attempts to initiate a project or successful attempts to modify the rules facing transport organizations. They are not the same as petitions for transport acts because Parliament rejected some proposals to improve transport. The failure rate for transport petitions was quite high in the early 1700s but it stabilized at around 15% after the 1720s (Hoppit 1996). Failures are potentially problematic for this study because they might bias the relationship between the number of transport acts and interest rates in a particular period. Failures could be viewed in at least three ways. First, they could be viewed as proposals which were rejected by Parliament because they were not financially viable or they had few indirect benefits. Second, they could represent a systematic political bias against projects that were not favored by Members of Parliament. Third, failure might be viewed as a random event caused by shortened sessions or other exogenous factors. There is no definitive evidence as yet on which way to view failure, but there are some indications that failure was essentially random as time went on. The randomness suggests there will be little bias from using acts instead of petitions.

III.2: Real interest rates in London

Yields on long-term government debt are the typical measure of interest rates in the London capital market. The three-percent consol was the most heavily traded British government bond in London. Annual (as well as monthly) yields are available starting in the 1750s and continue beyond 1840 (Neal 1990). For earlier periods scholars typically use the real yield on Bank of England stock or the yield on East India Company stock because they were closely connected with long-term government borrowing. The series are available starting in 1701 and run continuously through the eighteenth century. This paper uses a compilation of yields on these securities provided by the Global financial database.[3]

The real yield on government bonds in London is calculated by subtracting a three-year moving average of the inflation rate from the nominal yield on government bonds. Inflation was calculated using Clark's (2001) annual consumer price index. The consumer price index is a representation of national prices based on a basket of goods consumed by workers.

III.3 Preliminary Analysis of the Data

The basic trends in the series on transport acts are shown in figures 1 through 4. Road improvement acts increased in the 1750s and continued to grow up to the 1830s when the number falls off substantially. The decline in the 1830s occurred because the arrival of railways captured the attention of investors and promoters (Albert 1972). What is also noticeable is the greater variance in road acts after 1750 with some periods experiencing large numbers of acts followed by other periods when few were passed. Bridge improvement acts increased in the 1750s and again in the early 1800s. The variance in bridge acts is also noticeably larger after 1750. There was a steady flow of acts to improve inland waterways until the 1790s when the canal mania drove a large surge in acts. Afterwards the number of inland waterway acts

[3] See https://www.globalfinancialdata.com/

decreases, although it does not appear to return to its earlier level. Harbor improvement acts increased starting in the early 1800s. After a decline in the 1820s there was another increase in the 1830s.

Figure 5 shows the real yield on British government bonds from 1701 to 1840. The most noticeable feature is the fluctuation in the series. The standard deviation for the real yield series is 5.4. The standard deviation for the nominal yield is 1.5 and the standard deviation for the inflation rate is 5.3. The other noticeable feature is that real yields show little trend over time, except for the early eighteenth century when there is a slight decrease from the 1700s to the 1720s.

In order to analyze the stability of the relationship between real yields and transport acts it is first necessary to establish whether the series are non-stationary. Table 1 reports Dickey-Fuller tests for unit roots in all the variables. The results show that the unit-root hypothesis can be rejected for all the variables. This implies that the relationship between transport improvement acts and real yields on govt. bonds can be analyzed in levels rather than differences.

The analysis will focus on the simplest possible model. Equation (1) shows an auto-regressive model of road, bridge, inland waterway, or harbor improvement acts y_{it} with K lags. It also includes a constant and x_{it-1} the real yield on government bonds in t-1.

$$y_{it} = \alpha + \sum_{k=1}^{K} \rho_k y_{it-k} + \beta x_{it-1} + \varepsilon_{it} \qquad (1)$$

The number of lags K can be determined using lag-order selection statistics for VARs. Table 2 reports the lags selected by a variety of tests. The likelihood ration (LR), the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC) lag-order selection statistics are all imply 2 lags for roads and 4 lags for bridge improvement acts. Four of the five tests imply 3 lags for inland waterways and 3 lags harbor improvement acts. Overall the tests suggest different lags for each transport mode. Two lags were used for road improvement acts, four for bridge acts, and three lags for inland waterway and harbor acts because only the SBIC test statistic suggested 2 lags.

Before turning to the stability analysis it is useful to examine the parameter estimates for the full sample of observations from 1701 to 1840. Table 3 shows the coefficient estimates for each transport mode. The most important coefficient for our purposes is the real yield on govt. bonds. In all specifications the coefficient for the real yield is negative, indicating that higher (lower) interest rates in London reduced (increased) the initiation of infrastructure projects. However, the coefficient it is statistically significant for road acts and inland waterway acts only. The finding suggests a number of possibilities in the stability analysis. First, there may be some year t after which real yields on government bonds had a stronger negative relationship with harbor and bridge improvement acts, but this relationship is obscured in the whole sample. Second, there may be some year t after which real yields on government bonds had an even stronger negative relationship with road and inland waterway improvement acts. Third, there may be no structural changes. In this latter case, road and inland waterway finance may have always been integrated with the London capital market, while bridge and harbor acts were never integrated, at least over the sample years from 1701 to 1840.

IV. Methodology: Unknown Structural break tests.

Over the past 15 years econometricians have developed a number of techniques to identify an unknown number of structural break dates in time-series models. These tests have become very popular in applied work because the significance of a particular year is not assumed in advance. In other words, they are designed to let the data speak.[4] This section outlines how these procedures can be used to identify a structural break in the relationship between real interest rates in London and the number of transport improvement acts passed by Parliament from 1701 to 1840.

Recall that equation (1) assumes an auto-regressive model of transport improvement acts y_{it} with *k* lags. A single structural break in the relationship between interest rates and transport improvement acts exists if for some year t_1, $\beta = \beta_0$ for $t = 1,,,t_1 - 1$ and $\beta = \beta_1$ for $t = t_1,,,T$. Multiple structure breaks would exist if there are a set of years $t_1, t_2, ...t_M$ such that the coefficient $\beta = \beta_m$ for $t \in (t_{m-1}, t_m]$ and $\beta \neq \beta_m$ otherwise. A structural break could also be defined for the constant term α and the interest rate coefficient β if for some year t_1, $(\alpha, \beta) = (\alpha_0, \beta_0)$ for $t = 1,,,t_1 - 1$ and $(\alpha, \beta) = (\alpha_1, \beta_1)$ for $t = t_1,,,T$.

In this application we are particularly interested in structural breaks where $0 < \alpha_0 < \alpha_1$ and $\beta_1 < \beta_0 < 0$ after year t_1. The structural change in β would be consistent with the hypothesis that higher (lower) interest rates in London reduced (increased) the initiation of infrastructure projects by a greater amount after the break year. The structural change in the constant implies there was an overall increase in the number of projects initiated following the

[4] See Hansen (2001) for a recent summary.

break year. The two breaks should be jointly tested because the ultimate causes of capital market integration are likely to have broad effects, including an increased demand for transport projects. The broad changes would be captured by a shift in the constant term.

The first step in most stability analyses is to identify whether a single structural break exists. Quandt (1960) and Andrews (1993) developed an approach based on the Chow Statistic which identifies structural breaks at a known date. In this procedure the Wald-form of the chow statistic is calculated for every year excluding the years close to the beginning or end of the sample. Usually 7.5% of the dates at the beginning and end are not considered. If any of the Chow statistics for the intervening years exceeds the critical values provided by Andrews (1993) then there is evidence that a single structural break exists. The most likely break-date would be the year in which the chow-statistic attains its maximum value—the so-called Sup-F statistic.

Bai and Perron (1999 and 2003) have developed additional methods to test whether multiple structural breaks exist and to identify the break dates. Their procedure first specifies a maximum number of potential breaks (usually 5). Second, their global minimizing procedure identifies structural break dates assuming that $m=5$ breaks exist. Third, they develop a hypothesis test of 0 breaks instead of 1, 2, 3, 4, or 5 breaks. Fourth, they develop a hypothesis test of 1 instead of 2 breaks, 2 instead of 3 breaks, 3 instead of 4 breaks, and 4 instead of 5 breaks. In their methodology one structural break would exist if the hypothesis of 0 versus 1 break is rejected and the hypothesis of 2 versus 1 breaks fails to be rejected. Two structural breaks would exist if the hypothesis of 0 instead of 2 breaks is rejected and the hypothesis of 2 instead of 3 breaks fails to be rejected. A similar algorithm is used for 3, 4, and 5 breaks. In each case the break dates $t_1, t_2, \ldots t_m$ are identified using the global minimizing procedure. The coefficients (α_m, β_m) for the break dates can be estimated as well.

The Bai and Perron procedure can be compared with the number of breaks identified by the sequential procedure developed by Bai (1997), the Bayesian Information Criterion, and the Modified Schwarz Criterion from Liu et. al. (1997). Unfortunately, the three methodologies do not always yield the same conclusions for the number of breaks.

V. Results

When, if ever, did the London capital market become integrated with markets for local infrastructure financing in Great Britain and Ireland? This section provides some answers using structural break analysis. We begin by plotting the Chow statistics for each candidate break year assuming there is one structural break in the constant and the coefficient on the real yield variable. Figures 6 through 9 show the Chow statistics for each transport mode. The Chow statistics for road improvement acts are below the Andrews (1993) 5% critical level for all candidate break years (see figure 6). In other words there is no evidence of a structural break in the relationship between real yields and road improvement acts. The same conclusion holds for bridge acts. The Chow statistics are below the 5% critical level for all candidate break years (see figure 7). The largest Chow statistic for bridge acts is in 1808. It exceeds Andrews 10% critical value suggesting there is weak evidence for a structural break in the relationship between real yields on govt. bonds and bridge acts during the early 19th century.

In the case of inland waterways there is stronger evidence for at least one structural break. The largest Chow statistic is in 1790 and exceeds Andrews 5% critical value (see figure 8). This finding suggests there may have been a structural break in the relationship between acts to improve rivers and canals and real yields on government bonds in the early 1790s. The strongest evidence for a structural break applies to harbor acts. The largest Chow statistic is in

1803 and exceeds the Andrews 5% critical value by a substantial margin. Once again this suggests there is a structural break in the relationship between harbor improvement acts and real yields on government bonds in the early 1800s.

Table 4 shows a summary of the results for the Quandt-Andrews test of a single structural break in the constant and the coefficient on the real yields. The trimming parameter was assumed to be 15%. The results from the top panel show there was a structural break in 1790 for inland waterways and 1803 for harbors. The bottom panel shows the change in the coefficient on real yields before and after the identified break date. The coefficient is three and half times larger after the break date for both inland waterways and harbors. The results for roads imply no break and the results for bridges suggest there may have been a break in 1808, but it had little effect on the coefficient for real yields.

The Bai and Perron's procedure provides an alternative method for identifying the number of breaks and the timing of breaks. Moreover their approach allows the error terms in equation (1) to be heteroskedastic rather than homoskedastic. The results for road and bridge acts are not reported. Like before, the Bai and Perron procedure shows little evidence of any structural break between road or bridge improvement acts and real yields on government bonds. Table 5 shows Bai and Perron's multiple unknown structural breaks for inland waterways and harbors assuming five breaks and a trimming of 0.15. The results from the Bai and Perron global minimizing procedure are less conclusive than before. They both show the SupF(1) and SupF(2) tests are insignificant. In other words one cannot reject the hypothesis of zero breaks instead of 1 or 2 breaks. The SupF(3), SupF(4), and SupF(5) tests are all significant, suggesting that the hypothesis of zero breaks instead of 3, 4, or 5 breaks can be rejected. However the SupF (2|1), SupF(3|2), SupF(4|3), and SupF(5|4) are all insignificant, suggesting that the hypothesis of 1 instead of 2 breaks, 2 instead of 3 breaks, 3 instead of 4 breaks, and 4 instead of 5 breaks all cannot be rejected. The UD Max and WD Max statistics suggest that we can reject the hypothesis of zero breaks in favor of an unkown number of breaks not exceeding 5. Thus the Bai and Perron procedure does not provide clear evidence on the number of breaks in the relationship between real yields and either harbor acts or inland waterway acts.

Table 5 also reports the number of breaks identified by other procedures like the Sequential, LWZ, and BIC. The first two also show no structural breaks, but the BIC does indicate a structural break in 1789 for inland waterways and 1802 for harbors. As we saw earlier these are essentially the same dates identified by the Andrews-Quandt procedure. The changes in the coefficient on real yields before and after the breaks dates are also the same. This finding would appear to support the argument that break existed for inland waterways in the early 1790s and break existed for harbors in the early 1800s.

VI. Discussion and Interpretation

One of the conclusions from the structural break tests is that integration differed across modes. Roads appear to have been integrated with the London capital market from very early. There was a stable negative relationship between real yields on government bonds in London and road improvement acts as early as the 1720s. The literature has tended to downplay the role of the London market in turnpike development, stressing other factors like trade expansion and demonstration effects (Albert 1972, Pawson 1977, Bogart 2007). However the results here suggest that conditions in the London market did play a role. One reason is that most turnpike roads before 1750 were near London or they were on major highways that led to London. Thus London financiers had intimate knowledge of these projects and would have been more willing to finance them. Moreover the investors along roads near London were probably already investing in the London market and so the opportunity cost of investing in government bonds was a relevant consideration when considering whether to invest in turnpike bonds.

As the turnpike network expanded to northern and western England and eventually to Wales, Scotland, and Ireland it was not obvious that road financing would continue to be integrated with the London market. The estimation suggests that integration was sustained nevertheless. In this case, financial and legal innovation may have played some role. Starting in the 1750s promoters began obtaining subscriptions of capital prior to petitioning Parliament. Previously promoters would obtain the act and then they would solicit capital. In 1773 it became a law that if an individual subscribed to a trust they were legally liable to provide the capital when called upon by the trustees. If they failed to do so they could be sued in common law courts (Albert 1972, pp. 100-101).

The introduction of legally enforcement subscriptions was significant because it reduced the potential for opportunism in the market. Promoters could obtain financing commitments from Londoners and elsewhere with less concern that the investor would renege on their commitment. By strengthening the rights of trustees it was more likely that road financing would remain integrated with the London market even as projects moved away from London.

The financing of bridges appears to have been different from roads. The baseline estimation suggests there was not a significant relationship between bridge acts and real yields in London at any point before 1840. If anything the London capital market became less integrated with local bridge financing. Why? There are several potential explanations. One is that bridge financing never reached a large enough scale for integration to occur. Integration requires some fixed investments in gathering information about the technology as well as local market conditions. The profit potential from bridges may not have been sufficient to justify these investments. This explanation has some problems, particularly because it does appear that Londoners financed much bridge development around the city in the early eighteenth century. They must have become familiar with the economics of bridges based on this experience. An alternative explanation is the absence of financial and legal innovation specific to bridges. Bridge construction spread to all parts of England, Wales, Scotland, and Ireland in the late nineteenth century. London financiers would have had little information about local conditions and would have been hesitant about investing without increasing flows of information and contractual arrangements which limited opportunism. More research is needed to verify whether these or other explanations can explain the lack of integration in bridge financing.

The evidence suggests that harbor financing became integrated with the London capital market only in the early 1800s. One explanation follows the earlier analysis for roads and bridges as well as the theoretical work of Trew (2007). According to this argument, the London financial market was more efficient than local capital markets in financing large capital investments, but local financiers had a comparative advantage in local projects because they had better information. Their comparative advantage eroded over time as the number of harbor projects increased and Londoners learned more about harbor improvements. At the some point, the comparative advantage of local financiers disappeared and Londoners began to finance harbor improvements because they were more efficient in financing large investments. Perhaps the tipping just described occurred in the early 1800s when harbor financing became integrated with the London capital market.

The learning hypothesis is certainly part of the story, but there are other explanations as well. In the early 1800s harbor financing took on a new form with the arrival of the joint stock harbor company. Many of the harbor improvements before 1800 were implemented by municipal corporations or trusts closely connected with them. The organization of harbor improvements in Liverpool in the 1770s is one important example (Jackson 1983, p. 203). Several joint stock companies built harbors in London during the early 1800s. The first was the West Indian dock which opened in 1803, precisely the year which has been identified as a structural break. Several more joint stock companies were formed in other parts of England in the early 1800s as well, most notably in Bristol, Hull, Grimsby, and Goole all of which were among the top ten ports in the mid-19th century. The emergence of joint stock companies may have indirectly contributed to integration by fostering speculation of London financiers. The joint stock form may have also strengthened property rights, thereby encouraging long-distance investment. More research on joint stock harbor companies is clearly needed, but it cannot be an inconsequential fact that harbor financing became integrated with the London capital market at the same time that the joint-stock form became increasingly common.

The structural break tests suggest that the financing of inland waterways became integrated with the London capital market earlier than harbors in the 1790. After that date there is negative and significant relationship between inland waterway acts and real yields on government bonds. The lack of integration in the early eighteenth century might be attributed to the limited scale of financing. The typical inland waterway project cost around £10,000 before 1750 (Ward 1974, p. 165). This amount is larger than the average turnpike road project in the mid-eighteenth century, but there were far fewer river projects than road projects. Therefore, unlike road projects at the time, one of the limiting factors to market integration may have been the small scale of river projects. Local financiers and promoters had a comparative advantage in information and its scale was within their financing limits. Londoners had little incentive to incur the fixed cost of entry into these local markets.

The finding that inland waterway finance became integrated with the London market in 1790 is significant because there was a canal mania in the 1790s. The canal mania witnessed the creation of numerous canal companies. Some of these companies survived and completed their lines while others did not. The result was a simultaneously expansion of the canal network and consequential financial losses for some investors. The results from the structural break analysis raise the intriguing possibility that the integration of inland waterway finance with the London capital market may have contributed to the canal mania. This hypothesis might be questioned on the grounds that most speculators were local (Ward 1974). However it is possible that local investors borrowed on the London capital market to pay for their stock subscriptions and thus the opportunity cost of capital in the London market had an influence.

Putting aside the issue of whether market integration influenced the canal mania, it is interesting to consider what caused the emergence of market integration in 1790. The emergence of the joint-stock form does not appear to be the explanation for inland waterway financing because it was already employed in some river navigations and canals in the 1760s and 1770s. In this case, other types of financial innovations appear to have played a role in causing market integration. One innovation was the emergence of intermediaries like brokers. In several provincial cities, like Oxford and Leicester, brokers helped transfer shares in newly formed companies (Ward, 1974, pp. 106-107). The role of these brokers appears to have diminished in the early nineteenth century, but they might have fostered some of the initial investments by lowering search costs.

Another innovation in canal financing was the interest-bearing optional note. Optional notes were first issued by the Grand Junction canal in the late 1790s, around the time when the structural break was identified for inland waterways. It gave the holder the right to convert the bond into a share at face value. Optional notes were increasingly used by canal companies in the early 1800s. They were particularly popular among London investors (Ward 1974, p. 71). The introduction of optional notes could have contributed to market integration because they gave less informed investors greater assurances, while at the same time providing them with the option to become an equity holder in the canal once they learned whether its prospects were favorable or not.

Yet another innovation in the financing of inland waterways was the emerging relationship between banks and canal companies. Ward documents several cases where banks extended credit to canal companies in the 1790s (p. 112). He also notes that bankers were typically treasurers for canal companies. By the late nineteenth century banks had emerged as one of the key conduits of commercial finance in Britain (Presnell 1956). Their knowledge of the London capital market might have been imparted on the directors of canal companies who generally had more expertise in local affairs or engineering. Moreover bankers likely conveyed information about canals to investors in London, which would further reduce search costs between companies and investors.

VII. Conclusion

In this paper, we examine when the London capital market became integrated with the financing of different types of transport improvements in Britain. It uses unknown structural break tests to analyze the stability of the relationship between transportation improvement acts and real yields on long-term government debt traded in London between 1701 and 1840. The results suggest that the timing of integration with the London market differed across transport modes. Road financing appears to have been integrated with the London capital market from the early 1700s, whereas inland waterways became integrated with the London capital market after the 1790s and harbors after the early 1800s. Bridge financing was never integrated with the London market before 1840.

The results are thus partly consistent with the view that the London capital market did not become integrated with local real capital markets until the late eighteenth and early nineteenth centuries (the major exception being road finance). They are also consistent with the view that early innovations in the market for government debt did not have an effect on the financing of private investment until more narrow financial innovations eroded the informational disadvantages of distant investors.

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Table 1: Unit Root Tests

Variable	Dickey fuller test statistic
real yield on govt. bonds	-6.095*
road improvement acts	-3.543*
bridge improvement acts	-5.67*
inland waterway improvement acts	-4.897*
harbor improvement acts	-5.535*

sources: see text.
notes: * indicates significance at the 1% critical level.

Table 2: Lag-order selection statistics

Variable	LR	FPE	AIC	HQIC	SBIC	Chosen Order
road improvement acts	2	2	2	2	2	2
bridge improvement acts	4	4	4	4	4	4
inland waterway improvement acts	3	3	3	3	2	3
harbor improvement acts	3	3	3	3	2	3

sources: see text.

Table 3: Baseline Auto-Regressive Models explaining Transport Improvement Acts

variable	road acts	bridge acts	inland waterway	harbor acts
constant	4.5	0.47	1.35	0.591
	1.69*	0.24*	0.422*	0.314*
real yield govt. bonds, t-1	-0.34	-0.014	-0.115	-0.012
	0.18*	0.029	0.05*	0.036
lag 1	0.491	0.342	0.485	0.286
	0.078*	0.085*	0.085*	0.085*
lag 2	0.39	0.187	0.123	0.366
	0.07*	0.09*	0.094	0.083*
lag 3		0.043	0.179	0.182
		0.095	0.085*	0.086*
lag 4		0.259		
		0.088*		
n	138	136	137	137
r-square	0.75	0.49	0.54	0.52

sources: see text.
notes: * indicates significance at the 10% critical level or below.

Table 4: Andrews-Quandt Tests for a Single Unknown Structural Break

Variable	year	Maximum Chow Statistic	p-value
road acts	1753	4.57	0.63
bridge acts	1808	10.67	0.07
inland waterway acts	1790	12.07	0.04*
harbor acts	1803	14.34	0.015*
Variable		coeff real yields before break	coeff real yields after break
inland waterway acts	1790	-0.053	-0.194*
harbor acts	1803	-0.048	-0.176*
bridge acts	1808	-0.047	0.013

sources: see text.
notes: * indicates significance at the 5% critical level or below.

Table 5: Bai and Perron tests for Multiple Unknown Structural Breaks

Inland waterways

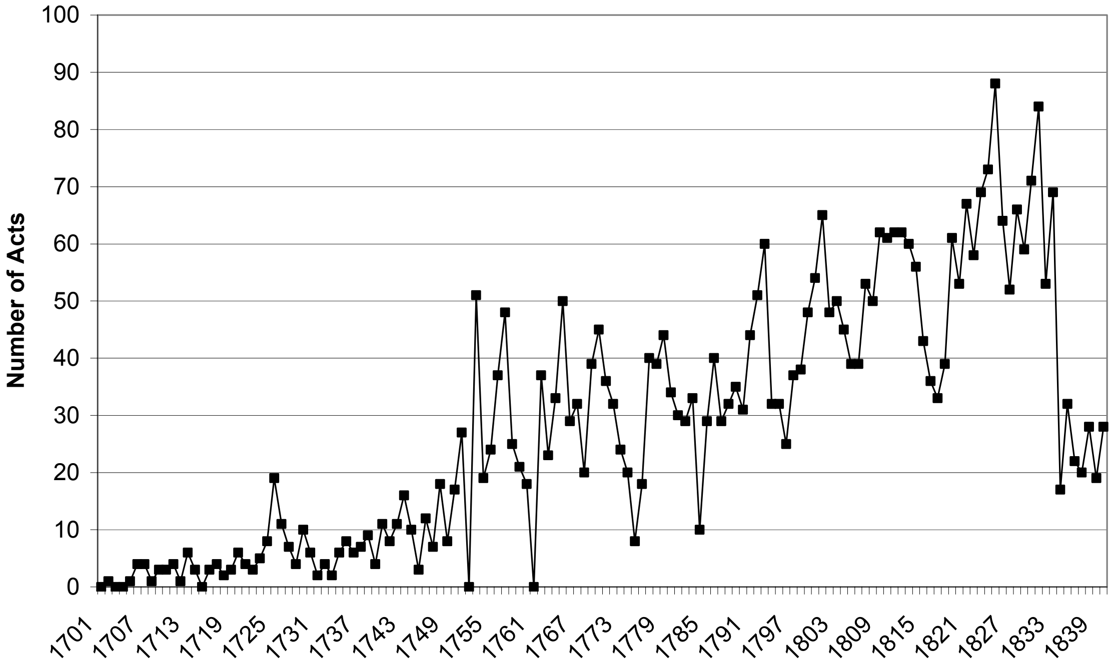
tests					
	Sup F(1)	Sup F(2)	Sup F(3)	Sup F(4)	Sup F(5)
	0.85	5.04	19.83	34.84	32.91
	Sup F(2|1)	Sup F(3|2)	Sup F(4|3)	Sup F(5|4)	
	2.64	0.36	0.36	0	
	UD max	WD max (10%)	WD Max (5%)		
	34.84	61.27	64.53		
Alternative procedures		number of breaks selected	year selected		
sequential		0			
LWZ		0			
BIC		1	1789		
coeff real yields before break		coeff real yields after break			
	-0.05	-0.19*			

Harbors

tests					
	Sup F(1)	Sup F(2)	Sup F(3)	Sup F(4)	Sup F(5)
	1.33	7.14	16.46	189.07	55.26
	Sup F(2|1)	Sup F(3|2)	Sup F(4|3)	Sup F(5|4)	
	2.69	0.26	0.01	0	
	UD max	WD max (10%)	WD Max (5%)		
	189.07	284.91	301.61		
Alternative procedures		number of breaks selected	year selected		
sequential		0			
LWZ		0			
BIC		1	1802		
coeff real yields before break		coeff real yields after break			
	-0.04	-0.17*			

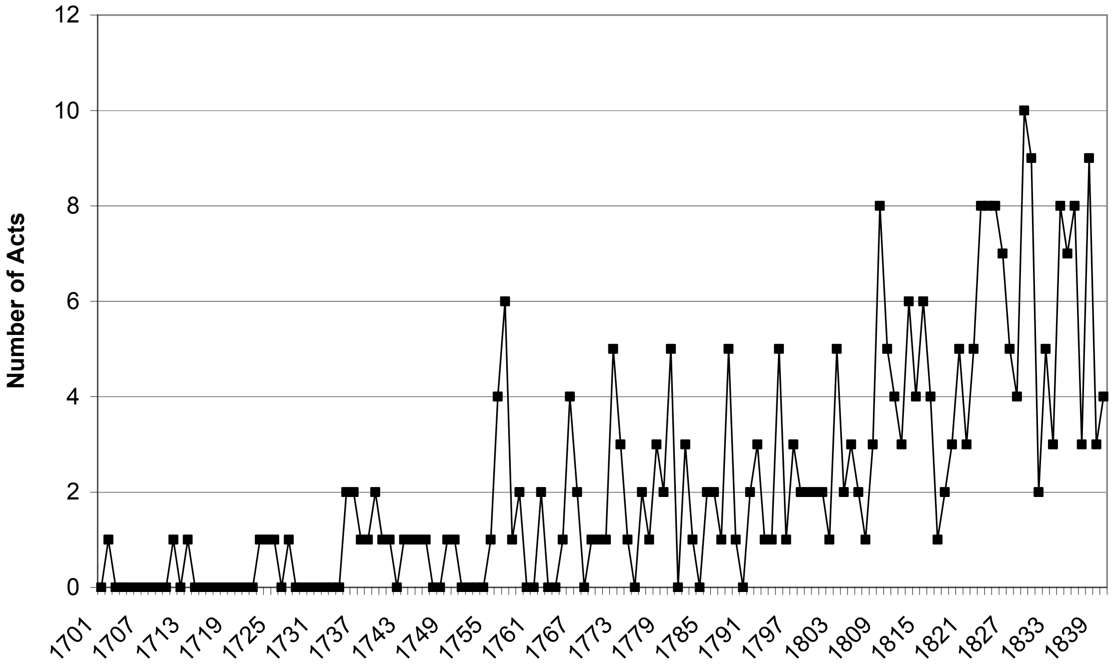
sources: see text.
notes: * indicates significance at the 5% critical level or below.

Figure 1: Road Improvement Acts, 1701-1840



Sources: see text.

Figure 2: Bridge Improvement Acts, 1701-1840



Sources: see text.

Figure 3: Inland Waterway Improvement Acts, 1701-1840

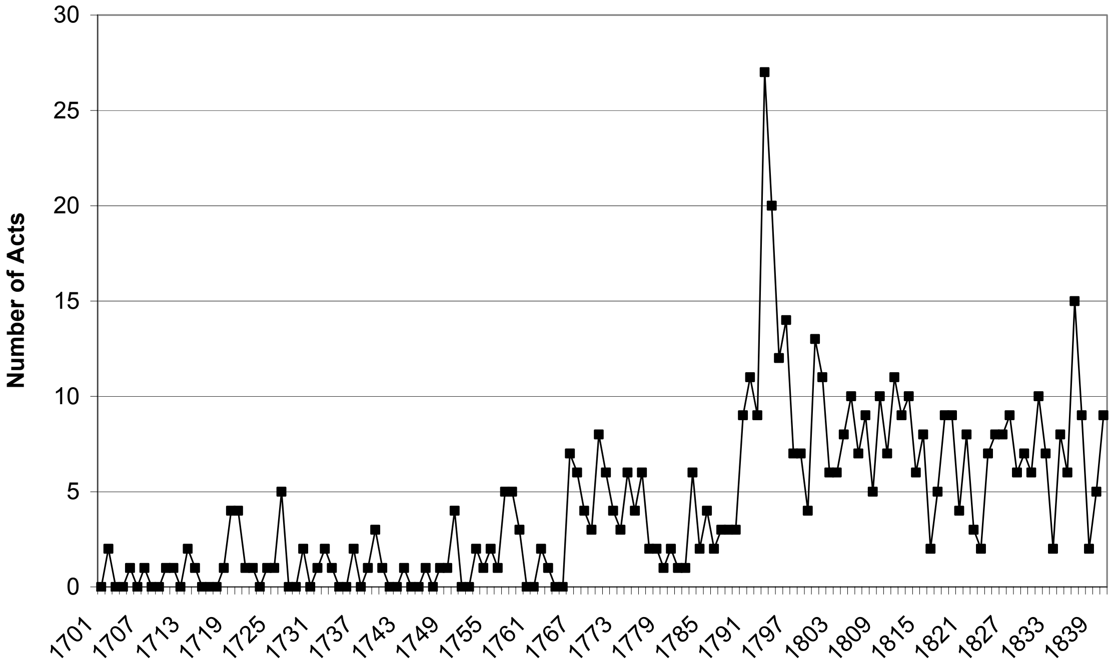


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Figure 4: Harbor Improvement Acts, 1701-1840

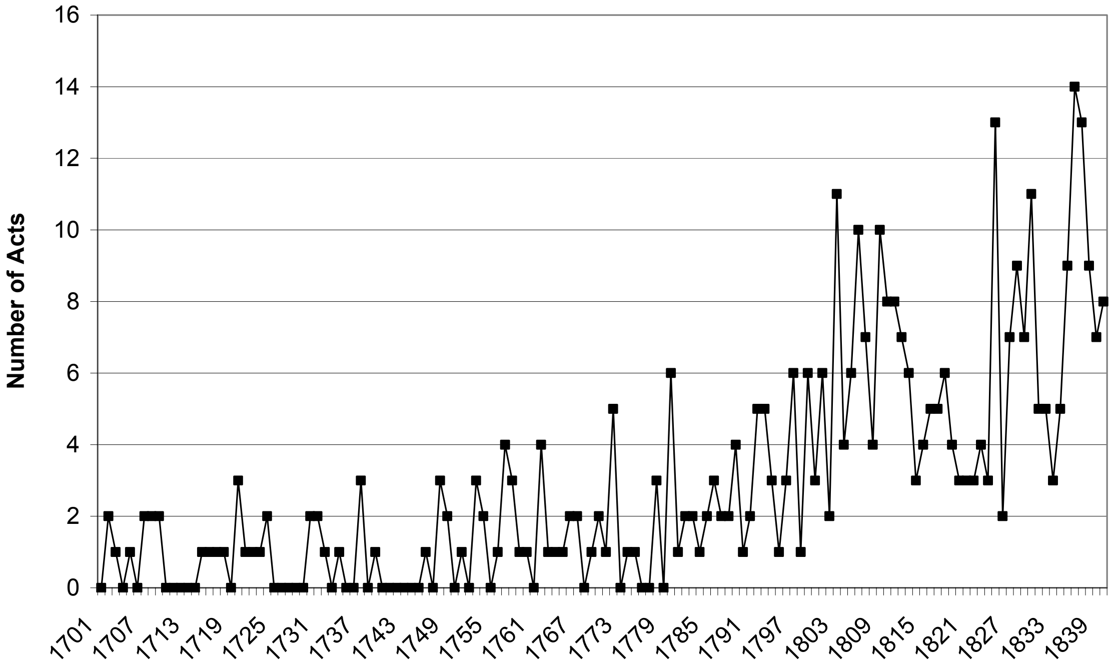

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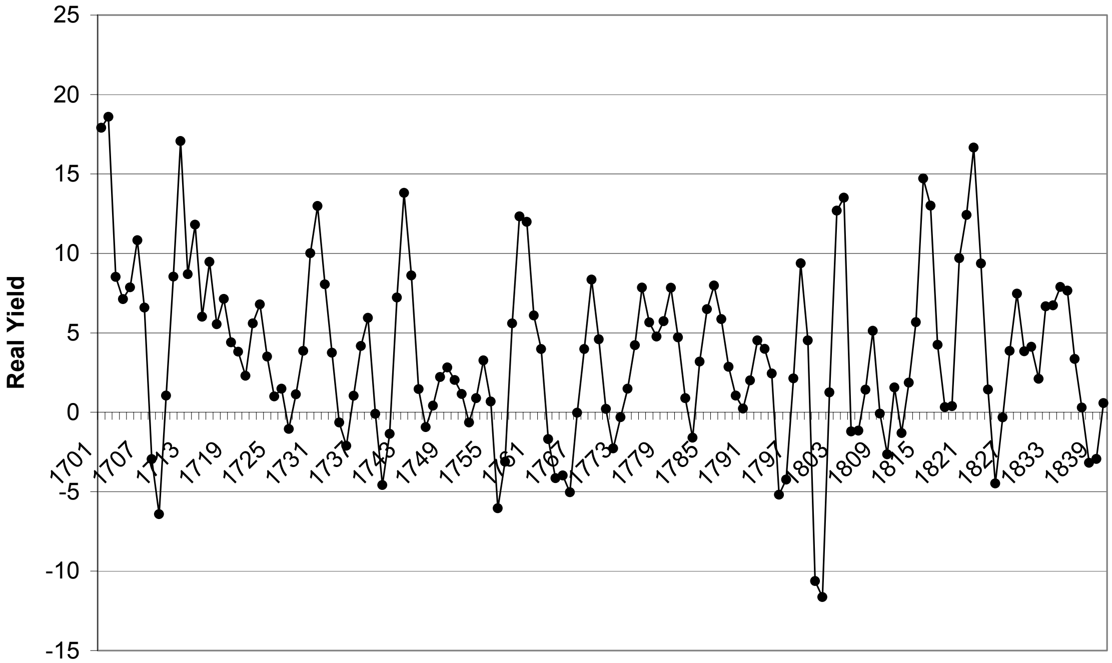
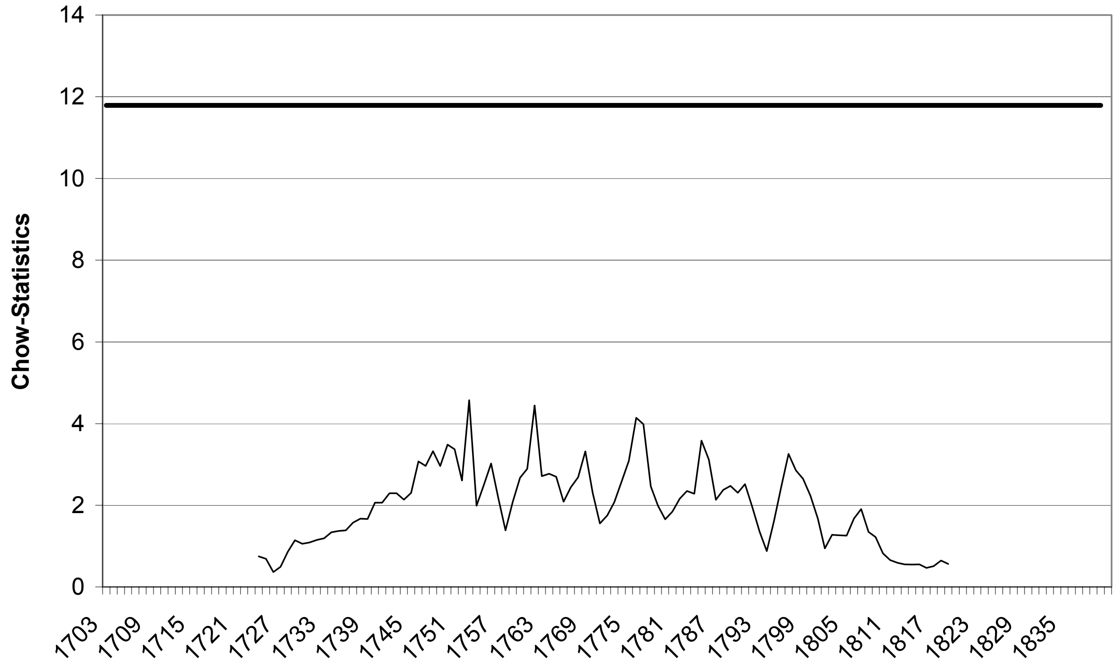
Figure 5: Real Yields on British Govt. Bonds, 1701-1840



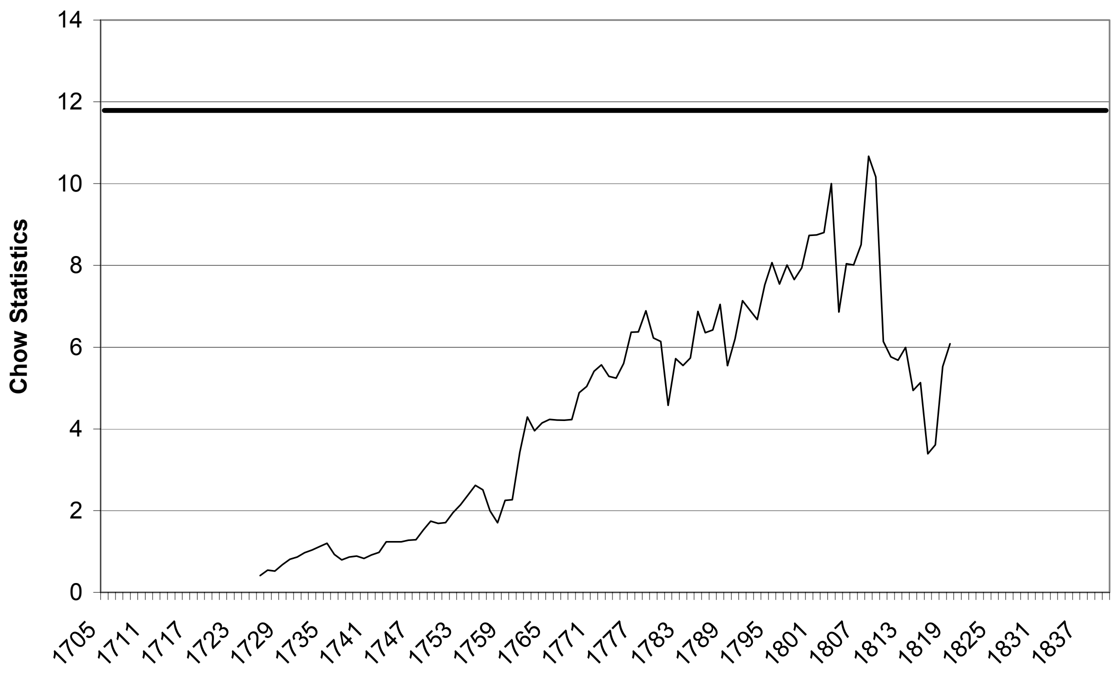
Sources: see text.

Figure 6: Road Acts: Chow-Statistics for Candidate Break years



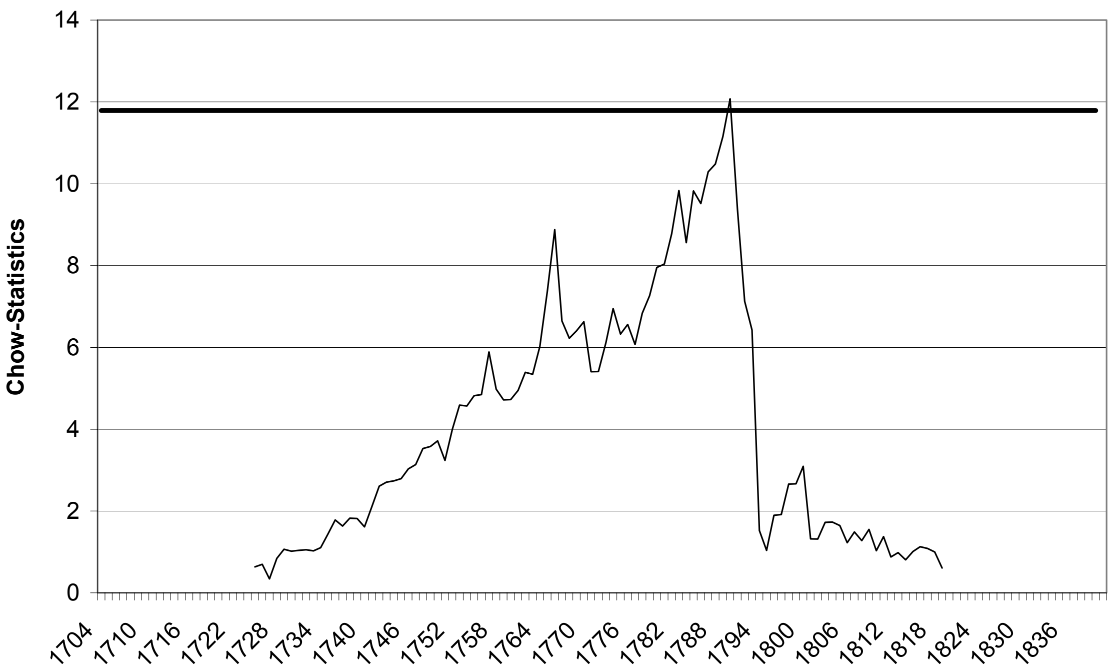
sources: see text.

Figure 7: Bridge Acts: Chow Statistics for Candidate Break Years



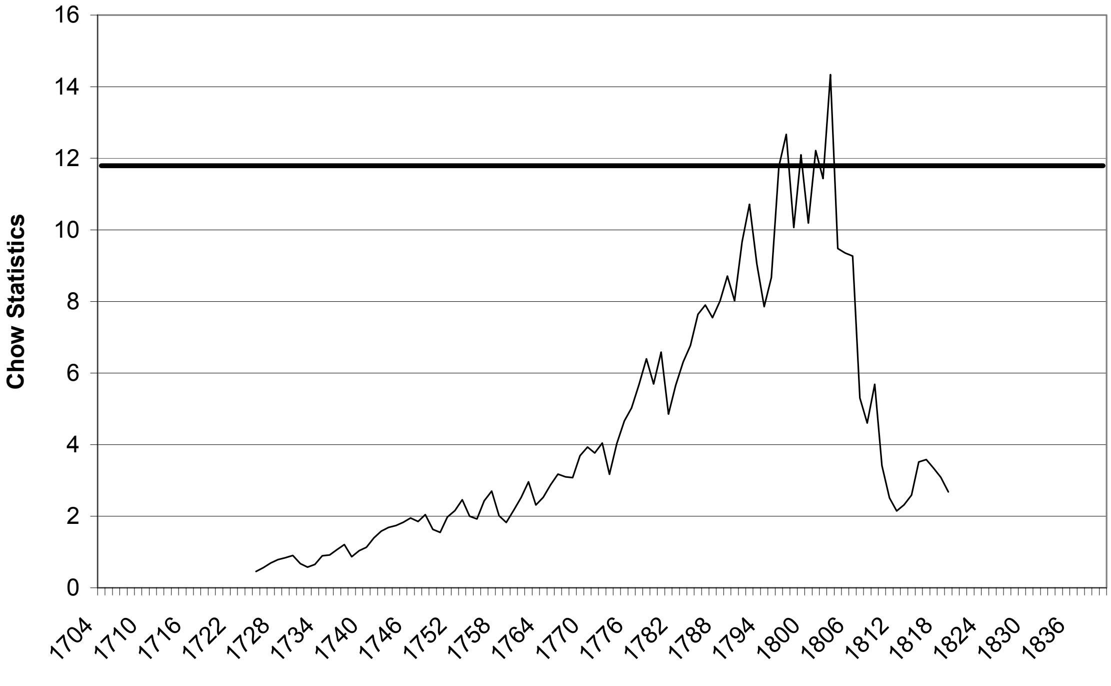
Sources: see text.

Figure 8: Inland Waterways: Chow Statistics for Candidate Break Years



Sources: see text.

Figure 9: Harbor Acts: Chow Statistics for Candidate Break Years



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