'The Greatest Bubble in History': Stock Prices during the British Railway Mania

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Abstract

Although the British Railway Mania has been described as one of the greatest bubbles in history, it has been largely neglected by academics. This paper attempts to redress this neglect by creating a daily stock price index for the 1843-50 period and by assessing the contribution of the many newly-created railways to the bubble-like pattern in stock prices. The paper then examines whether this bubble-like pattern was due to an increase in the stochastic discount factor arising from an increase in the probability of large-scale adoption of railway technology. We find little evidence to support this hypothesis.

INTRODUCTION

Recent asset price reversals in the technology and housing markets have stimulated an interest in historical financial crashes.[1] The contemporary academic literature on 'bubbles' has examined periods such as the Tulip Mania, the Mississippi Scheme, the South Sea Bubble, and the stock market crashes of the late 1920s in Germany and the USA.[2] In contrast, what *The Economist* has recently termed 'arguably the greatest bubble in history'[3], the British Railway Mania of the mid-1840s, has been relatively neglected in the academic literature. It has been mentioned in studies of the early railways,[4] in works considering manias and crashes[5], and by academics focussing on the historical development of accounting practices[6], but there has been little quantitative analysis produced.

We know very little about how railway share prices changed during this period. Any previous discussion of stock price movements during the Railway Mania has relied on Gayer *et al.*'s monthly index of railway stocks, which contains just 10 stocks of companies which had been established well before the mania period.[7] Given that over 400 railway companies had their shares traded on the stock market during this period, there are major concerns over how representative this index is of stock price performance during the mania. It has also meant that a detailed analysis of the period in terms of how the many small or newly-listed companies contributed to the

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[1] See, for example, Reinhart and Rogoff, *This Time is Different*.
[2] Garber, "Tulipmania", *Famous First Bubbles*; Neal, *Financial Capitalism*, chapters 4-5; White, "Stock Market Boom"; Rappoport and White, "Was there a Bubble"; Donaldson and Kamstra, "New Dividend Forecasting"; Dale *et al.*, "Financial Markets"; Donaldson and Kamstra, "New Dividend Forecasting"; Carlos *et al.*, "Royal African"; Voth, "With a Bang"; Shea, "Understanding", "Financial Market"; Temin and Voth, "Riding"; Thompson "The Tulipmania"; Velde, "John Law's System" Nicholas, "Innovation".
[3] Anon., "The Beauty of Bubbles", p.115.
[4] See, for example, Lewin, *Railway Mania,* Mitchell, "The Coming"; Jackman, *Development of Transportation*; Mitchell, Kenwood, "Railway"; Reed, "Railways"; Simmons, *The Railway*, *Victorian Railway*; Gourvish, "Railways"; Kostal, *Law.*
[5] Nairn, *Engines*; Odlyzko, *Collective Hallucinations*; Miller, *Railway.Com.*
[6] Bryer, "Accounting"; Arnold and McCartney, "It May Be Earlier"; McCartney and Arnold, "The Railway Mania".
[7] Gayer *et al.*, *Growth and Fluctuation*, vol. I, p.361.

mania has not been possible. To overcome this difficulty, we have collected daily stock prices and capitalization data for the 442 railway companies which were listed during the period 1843 to 1850 and have constructed daily stock price indices using this data.

These indices of railway stock prices permit us to analyse the following. First, we can measure the extent of the Railway Mania with confidence as essentially all railway stocks are included. Second, we can differentiate between the contribution of railways established prior to the mania and those established during the mania. Third, our data also enables us to analyse the impact of first-day returns of these new railway companies as a common view amongst contemporaries was that they played a large role in attracting investors to railway stocks.

Our results suggest that there was a rapid rise and fall in asset prices for both the established and new railways, with the index of railway stock prices doubling between 1st January 1843 and 9th August 1845, and then falling over 67 per cent by the end of 1850. We also find that investors in new railways earned substantial first-day returns. However, even after removing these returns from the indices or simply by looking at the stocks of railways which had established prior to the Railway Mania, we still observe a substantial bubble-like pattern in our data.

As well as augmenting the literature on historical asset price bubbles, our paper also contributes to the debate on the relationship between technological revolutions and stock market bubbles. Recent literature has suggested that new technology and technological innovations can partially explain bubble-like patterns in stock prices such as those observed with the introduction of railroads in the US, the 1920s stock market runup in the US, and the rise and collapse of Internet-based

technology stocks in the late 1990s.[8] We analyse whether the Railway Mania can be explained by a technological revolution, by comparing the stock prices, the risk, and the volatility of railway shares with other equity securities. Our results are largely inconsistent with the technological revolution hypothesis.

The paper is structured as follows. The next section gives a brief historical sketch of the episode which has become known as the Railway Mania. The third section describes the data sources and methodology used for constructing indices of returns. The fourth section discusses the indices of railway stock returns. The fifth section examines the contribution of new railways and first-day returns to the bubble-like pattern. The sixth section analyses the view that the bubble-like pattern in railway stock prices can be attributed to a technological revolution.

A BRIEF OVERVIEW OF THE MANIA

Although the railway was a private venture, it still required Parliamentary authorisation, mainly because of the need to force landowners to sell the land along the route that the railway was to take.[9] As a result, railways were incorporated enterprises with shareholders enjoying limited liability. The first major railway company was the Stockton and Darlington railway, which obtained Parliamentary authorisation in 1821. Although it transported passengers, most of its revenue was derived from coal transportation.[10] The first modern passenger railway therefore was the Liverpool and Manchester railway, which was authorised in 1826, and opened in 1830. Subsequently, during the mid-1830s, many new railway companies were

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[8] Pástor and Veronesi, "Technological Revolutions"; Nicholas, "Innovation". The view that new technology inevitably results in bubble-like stock market patterns also has currency in more popular writings. See, for example, Anon., "Internet Economics"; Anon., "A Hard Landing"; Anon., "The Beauty of Bubbles".

[9] Jackman, *Development of Transportation*, p.522.

[10] Francis, *History of English Railway*, vol. 1, p.55; Jackman, *Development of Transportation*, p.479.

promoted, with Parliament authorising 59 new railways, having about £36.4m of capital.[11] Railway share prices subsequently rose by 118 per cent in the twelve months to May 1836, then fell by 23 per cent in the seven months to December 1836, and continued to fall for several years, being 37 per cent below their cyclical peak by October 1841.[12] The next phase of railway development (the episode known as the Railway Mania) occurred during the mid-1840s.

The Railway Mania differed from the earlier 'minor railway mania' of 1836 in at least two ways. First, during the Railway Mania, there were substantially more railway companies promoted and formed. By the end of 1843, there were 63 petitions to Parliament,[13] by the end of 1844 there were a further 199 petitions,[14] and by the end of 1845 there were another 562 petitions.[15] There were also many other projected companies which never reached the stage of applying for Parliamentary authorisation, with *The Times* estimating that there were 1,263 new projects in 1845 alone.[16]

Second, many individuals from the increasingly-prosperous middle classes invested in the equity market for the very first time during the Railway Mania.[17] Parliamentary returns list 33,959 individuals who subscribed for shares in new railways considered in the 1845 and 1846 sessions of Parliament,[18] which was well above the estimated 11,500 who subscribed to railway projects in the mid-1830s mania.[19]

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[11] *The Economist*, October 4, 1845, p.949

[12] Gayer *et al.*, *Growth and Fluctuation*, vol. I, p.375.

[13] *Railway Times*, November 9, 1844, p.1309.

[14] *Railway Times*, August 16, 1845, p.1288.

[15] *Railway Times*, April 25, 1846, p.578.

[16] *The Times*, November 17, 1845, p.4 This figure underestimates the extent of promotion as 335 companies not on this list went on to petition Parliament (*The Times*, January 14, 1846, p.6).

[17] Broadbridge, "Railway Share Capital"; Gayer *et al*, *Growth and fluctuation*, pp.380, 410; 'Reed, "Railways", p.182; Reed, *Investment in Railways*.

[18] *Parliamentary Papers*, 1845, XL, p.1 and *Parliamentary Papers*, 1846, XXXVIII, p.1. This figure substantially underestimates the full number of subscribers as no records were kept of subscribers in the 1846 session who applied for shares with a nominal value under £2,000.

[19] *Parliamentary Papers*, 1837, XLVIII.

The runup phase of the Railway Mania was associated with strong economic growth, with GDP estimates suggesting that the economy grew in real terms by 3.1, 5.4, and 5.3 per cent in 1843, 1844 and 1845 respectively.[20] Output was boosted by a productivity shock to agriculture from a period of good weather which resulted in abundant harvests at the end of 1842, 1843 and 1844.[21] In addition to high economic growth, interest rates were also at historic lows during this period. For example, the 3 per cent Consols, government debt perpetuities, reached par for the first time for nearly a century[22] and the Bank Rate reached a new historical low of 2.5 per cent between September 1844 and October 1845.[23] The runup phase was also associated with most established railway companies increasing their dividends substantially.[24]

The turning point of the Railway Mania in the autumn of 1845 corresponded with a poor harvest and the failure of the potato crop in Ireland, which commentators at the time predicted would result in a famine in Ireland and great scarcity in Britain.[25] The subsequent increase in grain imports resulted in a decrease in the Bank of England's gold reserves, which resulted in it raising the Bank Rate by 0.5 per cent in both October and November 1845.

The initial declines in stock prices were also associated with concerns about the extent of new railway promotions, and substantial calls on shareholders for capital. *The Economist* on October 4th 1845 commenced publication of a supplement entitled the 'Railway Monitor'[26], in which they began an extensive and detailed critique of the negative effects which the new railways would have.[27] Similarly, *The*

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[20] Mitchell, *British Historical Statistics*, p.837.
[21] Barnes, *History of Corn Laws*, p.253.
[22] *The Economist*, April 13, 1844, p.674
[23] Clapham, Bank of England, vol. 2, pp. 391 and 429.
[24] See Campbell, "Cross-section of a 'Bubble'"
[25] *The Economist*, October 18, 1845, p.997 and October 25, 1845, p.1029.
[26] *The Economist*, April 5, 1845, p.310,
[27] *The Economist*, October 4, 1845, p.950-953

Times in a series of articles from July 1st onwards raised the alarm about the effects of the new proposed railways.[28] Those new companies which had been promoted in 1844 finally obtained Parliamentary sanction in July and August 1845, and began the construction of their lines, resulting in substantial calls for capital from their shareholders. Whereas between January 1843 and the end of September 1845, an average of £0.3m had been called up each month, between October and December 1845 a total of £4.4m was called up. *The Times* commented that 'it was the first calls for new lines in progress that immediately precipitated the November panic'.[29] Meanwhile the 1,000 plus proposals for new railways, which were to be considered in the 1846 session, were attempting to meet the November 30th deadline for the submission of their proposals to Parliament, which involved them raising a 10 per cent deposit from subscribers.

From this point onwards, railway stocks were depressed for the rest of the decade. The railways which were projected at the height of the boom were constructed during the downturn, requiring continual calls for capital to finance their construction. *The Economist* suggested that 'every fresh call that was made upon exhausted shareholders was attended by one of two effects – either the shares themselves upon which the call had been made were sold in order to avoid payment, or some other shares were sold in order to raise the money for that purpose.'[30] In addition, many of the long-established railways cut their dividends during this time, adding further to the misery of railway investors.

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[28] *The Times*, July 1, 1845, p.4; July 30, 1845, p.4 As the deadline for new promotions drew near *The Times* asked "if six millions a year has been difficult," which was their estimate of the annual cost of constructing the early railways, "and twenty-two millions a year is almost a four times greater difficulty", the estimated annual cost of railways which had been authorised but not constructed, "what can we say to the enormous – the stupendous – the infinite sums that would be required for the projected schemes" (*The Times*, November 17, 1845, p.4).

[29] *The Times*, April 17, 1846, p.4

[30] *The Economist*, October 21, 1848, p.1187. In a similar vein, *The Times* likened railway shares to a "fine Bengal tiger that devours a leg of mutton a day" (*The Times*, June 2, 1846, p.4).

DATA AND METHODOLOGY

Having sketched the main features of the Railway Mania, the next step is to determine the extent of asset price movements at this time. The data used in this analysis was obtained from weekly share price tables in the *Railway Times* from 1843 to 1850. The *Railway Times* was launched in 1837, and it was the first railway periodical to focus on investing, quickly becoming the periodical of choice for railway investors.[31] The share price tables published in the *Railway Times* contain the price at which trades took place on the London stock exchange on a daily basis from Monday to Saturday; they also contain data on the number of shares issued and the nominal and par value of each share.[32] Shares issued by the railways during this period were generally issued on an instalment basis, whereby investors were required to pay a small deposit and then make a series of regular payments when the company made 'calls for capital'. The amount which shareholders had paid in to the company was referred to as the par value of the share, with the difference between the nominal and par value being the amount that a shareholder was still liable to pay.

Each weekly share price table, containing an average of 242.1 securities for each of the 417 weeks in the sample, was collected and entered.[33] After excluding 88 securities which were not ordinary equity, 84 securities issued by railways based outside Great Britain and Ireland, and 150 securities where data on either the number

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[31] Reed, *Investment in Railways*, p.171. In 1843, its circulation was more than double that of its nearest competitor (*Railway Times*, January 14, 1843, p.37).

[32] When some companies were first listed some of the data on the number of shares, nominal value or par value were not reported. In these cases the next reported data was assumed to be correct for the missing period. If this data was not reported at any future period, Tuck, *Railway Shareholders' Manual* for 1845 and 1848 was used to obtain the missing details. Information on 81 securities was found in this way.

[33] The difference between the market price and the par value of the share was referred to as the premium. In some instances, the premium was reported rather than the stock price. In these cases, which are clearly marked in the *Railway Times*, the price was calculated by adding the premium to the current par value of the shares.

of shares or par value could not be ascertained, we were left with 591 ordinary shares belonging to 332 companies. As a result, we have 449,165 observations in our dataset. However, as many railway stocks were not traded every day, there are only 108,444 daily price observations over the 1843 to 1850 period.[34]

The return for railway stock i at time t was calculated as follows:

$$R_{i,t} = \frac{(Price_{i,t} - Price_{i,t-1}) - (Par_{i,t} - Par_{i,t-1})}{Price_{i,t-1} + (Par_{i,t} - Par_{i,t-1})}$$

where $Price_{i,t}$ and $Par_{i,t}$ are the price and par value of stock i at time t. If a stock was not traded on a particular day, we assume that the return was zero, and if a stock was traded, but had not been traded on the previous day, the return was calculated based on the last quoted price. If the par value of a share increased, but the share was not traded immediately, the return was calculated the next time the share traded, using the last quoted price and the par value at that time as the inputs to the previous price and par value. If the number of shares issued changed, or the nominal value of a share changed, or the par value decreased, the next return was set equal to zero.

To construct market indices, the market return has been calculated by weighting the returns of the component companies by their market capitalization at the start of the day. This weighting factor is calculated as follows:

$$w_{i,t} = \frac{NumShares_i(Price_{i,t-1} + Par_{i,t} - Par_{i,t-1})}{\sum_{i=1}^{n} NumShares_i(Price_{i,t-1} + Par_{i,t} - Par_{i,t-1})}$$

where $NumShares_i$ is the is the total number of issued shares of stock i, and n is the total number of stocks in existence at any one time. The market return is simply the sum of the weighted returns:

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[34] The number of railway securities listed on the stock market at the peak of the mania underestimates the extent of promotion as only a small proportion ever achieved a listing.

$$R_{m,t} = \sum_{i=1}^{n} w_{i,t} R_{i,t}$$

This market return is then used to calculate the following market index as follows:

$$Index_t = Index_{t-1}(1 + R_{m,t})$$

In our baseline index, the first-day return of new companies has been included based on the assumption that the investor subscribed to the share at its par value. Subscriptions to new railways were often advertised in newspapers, and individuals could apply for shares by completing a form on the advertisement and sending it back to the company. In every advertisment observed in the *Railway Times* from 1843 to 1845, the amount which investors were asked to subscribe was the par value. This implies that the first day return for railway stock *i* is given by

$$R_{i,t} = \frac{Price_{i,t} - Par_{i,t}}{Par_{i,t}}$$

If a share was not traded on the first day it was listed, the first day return was calculated when it was first traded.[35]

RAILWAY STOCK RETURNS DURING THE MANIA

Sample size and capitalization

Table 1 shows that the average number of securities included in the index rose from 94.6 in 1843 to 270.4 in 1846, but then declined, reaching 154.3 in 1850. Although the minimum number of securities in 1850 was less than half that of the peak in 1846, it was still almost 45 per cent above the 1843 figure. Similarly, as can also be seen from Table 1, the annual number of observations of listed companies in the dataset rose in line with the number of securities listed between 1843 and 1846, and then

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[35] If a new company was listed which was the result of a merger or if a share delisted and then reappeared in the share list at a subsequent period, the first-day return of that stock was set equal to zero.

subsequently fell to 1850. The annual number of observations where stocks traded on a particular day also rose and fell in a similar fashion. The ratio of traded to listed observations increased from 18.9 per cent in 1843 to 33.5 per cent in 1845, but then fell sharply to 22.7 per cent in 1846, and remained close to this level between 1847 and 1850. This suggests that trading in listed companies increased during the period of rising prices, but then fell during the downturn.

<< INSERT TABLE 1 >>

It can be seen from Figure 1 that both total market par value and market capitalization rose dramatically between 1843 and 1850. The rise in par value was relentless between July 1844 and October 1849. In contrast, market capitalization rose at a faster rate than par value until October 1845, and then, despite the large increases in par value, failed to increase substantially thereafter, finishing 1850 at almost the same level as it was at five years earlier. These differences largely reflect changes in the premium on railway share prices during this period. At the beginning of 1843, railway shares were trading at a small premium, with a price to par ratio of 1.08. This ratio reached a peak of 2.01 on 8th August 1845, but by 9th October 1847 the ratio had fallen below parity, with market capitalization being slightly less than total par value. By the end of 1848, the price to par ratio had fallen to 0.77, and reached a trough of 0.55 on 16th April 1850.

<< INSERT FIGURE 1 >>

The market index and returns

The market index in Figure 2 and Table 1 clearly reveals the path of railway stock prices during the period from 1843 to 1850. Prices increased slowly during the first

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half of 1843, with the index rising from 1,000 in January to 1,036 by July 1843. It then began to increase more rapidly, rising to 1,215 by the end of 1843, and to 1,450 by the end of 1844. The index peaked at 2,017 on 9th August 1845, and stayed close to that level for two months, being at 2,016 on 6th October 1845. The rise in prices during these years was incremental, with the maximum market return on any given day within this period being 2.46 per cent, with a mean return of 0.08 per cent. The index then fell to a temporary trough of 1,650 on 28th November 1845; and it ended 1845 at 1,883. It subsequently fell steadily over the following four years, reaching a low of 672 on 16th April 1850. Overall, the index fell by 14.3 per cent between January 1843 and December 1850, and from peak to trough, prices fell by 66.7 per cent.

<< INSERT FIGURE 2 >>

Table 1 reveals that the average daily market return was positive from 1843 to 1845, and negative from 1846 to 1849. The maximum return of 5.35 per cent and the minimum return of -4.93 per cent both occurred in 1848. We can see from Figure 3 that there were six occasions when the daily market return was less than -2.5 per cent. The first occurred on October 25, 1845, and is generally associated with the market crash which ended the boom in railway shares.[36] The next two occurred on 2nd and 19th October 1847, during what has become known as the Commercial Crisis.[37] The two largest daily declines occurred on 26th and 28th February 1848, when news about the French Revolution was received.[38] There was also a sharp decline on 9th October 1848, which corresponds with the publication of an article by the compilers of the

[36] Evans, *Commercial Crisis*, p.18.
[37] Evans, *Commercial Crisis*, pp.75-83.
[38] Evans, *Commercial Crisis*, p.110.

Stock Exchange list which raised fears about the extent of future construction that the railways had committed to undertake.[39]

<< INSERT FIGURE 3 >>

There were also six occasions when the daily market return exceeded 2.5 per cent during the sample period. None of these occurred during the boom, with the first being on 26th October 1847, on the day after the publication of the government letter which suspended the Bank Charter Act in order to relieve the growing financial crisis.[40] This level was also breached on three days within one week, on 26th, 28th, and 30th October 1848, in the aftermath of the suspension of much of the projected construction by the major lines, with the single largest rise of 5.4 per cent on 28th October 1848.[41] The market return also exceeded 2.5 per cent on 2nd May 1848, which may have been related to comments at the Great Western Railway general meeting suggesting a limit to the promotion of new lines,[42] and 18th December 1848, in the aftermath of the election of Louis-Napoleon Bonaparte in France, which it was hoped would settle political events on the Continent.[43]

Delisting scenarios

There were a considerable number of delistings of companies during the sample period. The reasons for delisting have been obtained for many companies from H. Tuck's railway shareholder manual and Henry G. Lewin.[44] For the 100 companies which delisted due to amalgamation, or because they were purchased or leased, the

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[39] Evans, *Commercial Crisis*, p.124.
[40] Evans, *Commercial Crisis*, p.87.
[41] Evans, *Commercial Crisis*, p.125.
[42] *Railway Times*, May 6, 1848.
[43] Evans, *Commercial Crisis*, p.126.
[44] Tuck, *Railway Shareholders' Manual*; Lewin, *Railway Mania*.

last day return was set to zero, implying that the shareholders received the market price of the shares. If the company delisted and reappeared at a future time during the sample period, the last day return was also set to zero. If one share class of a company delisted but others did not, then the last day return of the delisted security was also set to zero.

For the 155 securities, representing 144 companies, where the reasons for delisting are unknown, or when it is known that the company did not obtain authority, or did not exercise its authority to construct a railway, various possible scenarios are analysed. Figure 4 illustrates the effects of alternative assumptions about how much investors received when a company with an unknown or unexercised outcome delisted. The baseline index assumes that investors received the market price of the share upon delisting, the second scenario assumes investors received 50 per cent of the market price, and the third scenario assumes they received 0 per cent of the market price. It is theoretically possible that investors not only received nothing but would also be liable for unpaid debts up to the amount of uncalled capital which was outstanding. However, for the very small number of companies where the details of the winding up procedure was reported, there was always a positive sum returned to shareholders. [45]

<< INSERT FIGURE 4 >>

The maximum for all three scenarios was reached on the same day (9th August 1845), at levels of 2,017, 1,992 and 1,967 respectively. As the period progressed the divergence widens slightly, with the indices closing 1847 at 1,260, 1,190, and 1,123 respectively. By the end of 1850, the indices stood at 857, 793, and 733 respectively. Under the various scenarios, prices ended 1850 at 57.5 per cent, 60.2 per cent, and

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[45] See for example *Railway Times*, 1846, pp.522, 550, 599.

62.7 per cent below their peak level. Although these figures show slight variation, there is no change in the conclusion about the trend in prices during this period.

NEW RAILWAYS AND FIRST-DAY RETURNS

Table 2 compares established railways (i.e. those constructed prior to 1843) and new railways (i.e. those established from 1844 onwards) by presenting key characteristics of the median company within each group at the end of each year. The number of established railway companies declined over the period as a result of amalgamations. There were no new railways listed on the London Stock Exchange during 1843, but 48 listed during 1844, and by the end of 1845, there were 221 new railway companies listed, over five times as many as the number of established railways. However, many of these new companies subsequently delisted due to either failing to obtain Parliamentary authorisation or because they were purchased or leased by another company, and by 1850, only 60 of these new railways were listed on the London market. Consequently, it is interesting to analyze the contribution of these new railways to the bubble-like pattern we observe in this episode.

<< INSERT TABLE 2 >>

As can be seen from Table 2, the par value of the median established railway in 1843 was £0.780m. This rose to £1.160m by 1845 and stood at £2.349m at the end of 1850. The par value of the median new railway was just £0.065m in 1844, but this increased rapidly, to £0.682m in 1849, reflecting the calls on capital made by the new railways during their construction phase. The new railways initially issued shares with a very small percentage of capital paid up, with the median company having 6.0 per cent paid up in 1844 and 1845 and 13.1 per cent in 1846. The beginning of construction

saw this rise, to 39.1 per cent in 1847, 67.2 per cent in 1848, 86.0 per cent in 1849 and 92.4 per cent in 1850.

The price/par ratio reflects the differences between the market price of shares and the amount that investors had already paid up. The median established railway's price/par ratio was 0.72 in 1843, and this increased sharply to 1.63 in 1845. It then showed a steady decline, falling to 0.89 in 1847, and reaching 0.60 in 1849. The median new railway in 1845 was trading at a price/par ratio of 1.22, but this then declined dramatically, reaching 0.54 by the end of 1850.

The notional price/par ratio, which assumes that all uncalled capital is fully paid and that the price rises by exactly the rise in par value, provides an estimate of what the price/par ratio would have been if the effect of uncalled capital had been removed. The trends are similar to those for the actual price/par ratio, but are closer to parity as neither premiums nor discounts were leveraged. The price/par ratio for the median established railway increases from 0.76 in 1843 to 1.47 in 1845, falling to 0.75 by 1850. However, the impact is greatest for the new railways due to the extent of uncalled capital, with the median new railway trading at a premium of just 1.02 in 1845, compared to the actual price/par ratio of 1.22.

Given the above, it is useful to analyse the effect that the first-day return of new listings had on the overall market index. Indeed, a contemporary investment expert highlighted the effect of first-day returns when he remarked that 'it will be obvious that the party who has had certain shares allotted to him, which rise to a premium (as they almost invariably do, at least for a time) has the whole of that premium for his profit. By this means, persons possessing only sufficient capital to pay the deposit, may more than double it in a day'.[46]

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[46] Anon., *The Railway Investment Guide*, p. 10.

Figure 5 compares the all-railway market index which includes first-day returns, the all-railway index excluding first-day returns, and an index consisting only of established railways (i.e. those constructed prior to 1843). It can be seen that when first-day returns are included, the overall price index is substantially higher than when those returns are excluded. The peak of prices occurred on 9th August 1845, at a level of 2,017, when the first day return is included, and at 1,722, when they are excluded. The peak in prices of the railways established before 1843 occurred on 8th August 1845, at a level of 1,670. This evidence suggests that the new railways made a substantial contribution to the positive returns experienced during the boom, but most of this impact was derived from the first day they traded on the market, implying that it was the initial subscribers who captured these returns. Figure 5, however, shows that although the new railways accentuated the bubble-like pattern, it is still there when we just consider the railways constructed prior to 1843.

<< INSERT FIGURE 5 >>

DOES NEW TECHNOLOGY EXPLAIN THE BUBBLE-LIKE PATTERN DURING THE RAILWAY MANIA?

Technological revolutions and bubbles

Having conducted a detailed analysis of asset price movements during the Railway Mania, we are now left with a question: why did the Railway Mania occur? To date, two principal explanations for the Railway Mania have been advanced.[47] First, ever since contemporaries coined the term 'railway mania' to describe this episode, its occurrence has been subsequently explained by mania, delusion and irrational

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[47] Kostal, *Law*, chapter 1 suggests that the legal profession took advantage of and maybe even perpetuated the mania, but he does not suggest that they were the primary cause of the Railway Mania.

behaviour on the part of investors.[48] The second explanation which has been advanced to date is that the railway mania was a swindle perpetrated by the London financial and political elite upon the unsuspecting provincial middle classes.[49]

A further potential explanation for the Railway Mania could be Luboš Pástor and Pietro Veronesi's technological revolution model. They have recently suggested that stock price reversals that are usually referred to as bubbles can be explained by an *ex post* selection bias in that academics studying bubbles know that a technological revolution took place, but investors living through the revolution were uncertain as to the eventual impact of the new technologies.[50] Initially, due to uncertainty about technology adoption, new-technology stocks have a lot of idiosyncratic risk attached to them, and consequently earn higher returns. However, as the probability of the technology being adopted increases, the idiosyncratic risk changes to systematic risk. This results in an increase in the stochastic discount rate, which consequently depresses stock prices, particularly new-technology stocks.

From the perspective of the Railway Mania, Pástor and Veronesi's model leads to at least five testable hypotheses.[51] First, the bubble in railway stocks should be much greater than in non-railway stocks, and stock prices of both railways and non-railways should reach the bottom when large-scale adoption of railway technology occurs. Second, the beta of railway stocks should rise sharply before large-scale adoption. Third, the volatility of railway stocks should rise sharply before

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[48] Writing in 1851, Francis, *History of English Railway*, vol. 1, p.vii-viii describes the development of the railways in the mid-1840s as "a delusion as popular as any chronicled in Dr. Mackay's interesting work". Subsequently the following have viewed the Railway Mania as being attributable to irrational behaviour on the part of investors: Hyndman, *Commercial Crises*, p.55; Lewin, *Railway Mania*; Gayer *et al.*, *Growth and Fluctuation*, vol. I, p.380; Simmons, *The Railway*, chap. 2; Kindleberger, *Financial History*, p.201; McCartney and Arnold, "The Railway Mania"; Eatwell, "Useful Bubbles"; Odlyzko, *Collective Hallucinations*.

[49] Bryer, "Accounting". For a challenge to this view see McCartney and Arnold, "The Railway Mania".

[50] Pástor and Veronesi, "Technological Revolutions".

[51] Pástor and Veronesi, "Technological Revolutions", p.1453.

large-scale adoption and it should exceed the volatility of non-railway stocks. Fourth, the volatility of non-railway stocks should rise, but by less than the volatility of railway stocks. Fifth, the beta of railway stocks and the volatility of both railway and non-railway stocks should all peak when there is a large-scale adoption of new technology.

A bubble in non-railway stocks?

As extant stock market indices for this period are calculated on a monthly basis, a market index of non-railway shares consisting of the twenty largest non-railway companies ranked by market capitalization was constructed using the same method as outlined above.[52] As only weekly stock price data is available from the *Course of the Exchange*, a stockbroker list for the London stock exchange, a weekly index of non-railway stocks was constructed for the period 1843-50. This index contains six banks, five insurance companies, three canals, three docks, two gas, light, and coke companies, and one waterworks company.[53] These twenty companies represent 45.2 per cent of total non-railway market capitalization at the beginning of 1843, suggesting that they give a good representation of the overall market. As non-railway share prices have been collected on a weekly basis, the all-railway indices have been re-calculated on a weekly basis to ensure that the frequency of data did not affect the comparison between indices.[54]

The weekly all-railway, new-railway and non-railway indices are shown in Figure 6. During early 1843, the non-railway index increased in line with the all-railway index, with both reaching a level of 1,050 on 1st September 1843. The non-

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[52] See Acheson *et al.*, "Rule Britannia".

[53] Bank of England stock and East India stock have been excluded from the non-railway index as they were issued by companies with a strong relationship to the government.

[54] Such a precaution was unnecessary as there is a 99.99 per cent correlation between the end-of-week value of the daily index and the re-calculated weekly index.

railway index continued to rise until 17th January 1845, reaching a level of 1,182, but the growth was much slower than that of the all-railway index, which reached 1,509 at this time. The non-railway index then began to fall in value, just as the all-railway index began its most rapid increase. By 8th August 1845, the non-railway index stood at just 1,152, compared to the all-railway index of 1,984.[55]

<< INSERT FIGURE 6 >>

During the collapse of railway share prices, which fell by 16.4 per cent in the six weeks from mid-October to the end of November 1845, the non-railway index also fell, but by just 3.0 per cent. The non-railway index continued to fall during the next few years, but by a lesser degree than the railways, and the all-railway and non-railway indices met in October 1848 and April 1849. After this time, the non-railway index remained above the all-railway index, finishing at a level of 1,042 in December 1850.

Beta and volatility

The betas of the all-railway and the established-railway portfolios, reported in Figure 7, have been constructed, using a rolling window of 52 weeks, by regressing the weekly returns of each index minus the risk-free rate against the weekly returns of the market portfolio minus the risk-free rate. The market portfolio has been approximated by the non-railway index, and the risk-free rate has been approximated by the yield on 3 per cent Consols, which was obtained from the *Course of the Exchange*.

<< INSERT FIGURE 7 >>

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[55] Despite the extremely high correlation between the daily and weekly market indices the peak value of the weekly index is 1.6 per cent lower than the peak of the daily index.

As can be seen from Figure 7, the betas for both railway portfolios rose and peaked in the autumn of 1845. However, they were generally below one throughout the period, and were only significantly different from zero for a brief period around the peak.

Panel A of Figure 8 shows the volatility of each index using a rolling window of 52 weeks, whereas Table 3 reports the standard deviations of weekly returns for each index in each year, as well as the results of variance ratio tests. From Figure 8 it can be seen that the all-railway and established-railway portfolios had a higher volatility than the non-railways throughout the period. The results of the variance ratio tests in Table 3 suggest that the volatility of both the all-railway and established-railway portfolios were significantly higher than that of the non-railways in each year of the sample. However, this difference in volatility may partially reflect the poor marketability of other stocks compared to railway stocks.[56] As can be seen from Panel A of Figure 8, volatility peaked in 1845 and 1848. Panel B of Figure 8 reports the predicted conditional variance of each index using a GARCH(1,1) model of weekly returns, and this also suggests that volatility peaked in 1845 and 1848. As can also be seen from Figure 8, the volatility of the non-railway index increased during 1847 and peaked in the spring of 1848.

<< INSERT TABLE 3 AND FIGURE 8 >>

Discussion

Consistent with the predictions of Pástor and Veronesi, there is a bubble-like pattern in the prices of railway shares, and there are increases in the betas and volatility of railway stocks during the period. In addition, there is a minor bubble-like pattern in non-railway stocks. However, a key question which needs to be addressed before we can proceed to check how well their model explains the Railway Mania is: when did

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[56] On this, see Acheson and Turner, "Secondary market".

large-scale adoption of railway technology take place? Pástor and Veronesi, when applying their model to mid-nineteenth-century US railroads, use actual railway construction to date the large-scale adoption of railway technology.[57] As can be seen from Figure 9, capital formation by UK railways peaked at a massive high in 1847, suggesting that large-scale adoption of railway technology occurred around this year.[58]

<< INSERT FIGURE 9 >>

If it is assumed that large-scale adoption occurred in 1847, there are several pieces of evidence going against the technological-revolution hypothesis. First, although the non-railway index bottoms out in early 1848, the railway indices keep on falling until 1850, well after the large-scale adoption of railway technology. Second, the peak of the beta estimates is in the autumn of 1845, which is at least two years prior to the date at which large-scale technology adoption occurred. Third, the timing of the peaks (autumn 1845 and late 1848) in volatility are inconsistent with the technological revolution hypothesis.

Taken together, the evidence above provides little support for the technological revolution hypothesis if it is assumed that large-scale adoption occurred in 1847. However, an argument could be made that late 1845 was the date at which the large-scale adoption occurred. For example, *The Times* estimated in November 1845 that an unprecedented 1,263 railways, representing £563.2m of capital, were seeking authorization at this time.[59] However, the evidence presented above is still

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[57] Pástor and Veronesi, "Technological Revolutions", pp.1471-2.
[58] Mitchell, "The Coming of the Railway", pp.315-6 notes that, in the case of the UK, the technological revolution occurred with greater alacrity than that in the US. Indeed, the system which endured into the twentieth century was almost complete by 1852.
[59] *The Times*, November 17, 1845, p.4 This figure underestimates the extent of promotion as 335 companies not on this list went on to petition Parliament (*The Times*, January 14, 1846, p.6).

not consistent with the technological revolution hypothesis as stock prices do not reach the bottom until at least four years after this date, there is also no rise in the volatility of the non-railway stocks at this time, and the volatility of railway stocks is higher three to four years after this date.

The above, however, raises questions as to why railway stocks declined until the middle of 1850, why the beta estimates of the railways peaked in 1845, and why the volatility of railway stocks peaked in 1845 and 1848. Railway stocks declined during the latter half of the decade for at least two reasons: (a) railways made lots of calls for capital which depressed prices as investors sold their stocks to avoid calls,[60] and (b) the established railways made substantial cuts to their dividends.[61]

The beta estimates increase in 1845 simply because railway stock prices changed more than non-railway stocks in this the most frenetic year of the Railway Mania, when an unprecedented number of new railways were promoted and economic conditions began to deteriorate. The first peak in volatility corresponds to the collapse of railway stocks prices at this time. The beta also rose slightly in 1847, and volatility increased during 1847 and 1848, probably due to the severe financial and commercial difficulties arising from the Commercial Crisis in late 1847, the uncertainties created by the French revolution, and a stock exchange report highly critical of the railways.

CONCLUSION

The creation of a daily price index for the episode known as the Railway Mania has enabled us to measure with great accuracy the extent of the price reversal of railway stocks during this period. Using this newly-assembled dataset, we have shown that the railways created during the Mania contributed significantly to the extent of the

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[60] *The Economist*, October 21, 1848, p.1187.
[61] See Campbell, "Cross-section of a 'Bubble'" on this.

asset price reversal. In addition, investors in the railways established in 1844 and 1845 enjoyed substantial first-day returns, which greatly accentuated the bubble-like pattern in stock prices. However, there was also a substantial asset price reversal in the railways which were established well before the Mania.

Using an index of non-railway stocks, we find that the bubble-like pattern is railway specific. Our evidence also suggests that the timing of changes in beta and volatility are inconsistent with the technological revolution hypothesis of Pástor and Veronesi. This does not imply, however, that the revolution in technology was inconsequential. For example, the main influence of large-scale adoption of railway technology may have been on expected cash flows as widespread adoption may have brought decreasing returns to scale or increased competition.[62] Indeed, the rapid decline in the dividends paid by railway firms during the downturn suggests that changes in cash flows may have been influential in the price falls.[63]

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[62] The increased promotion of new projects at the end of 1845 may have affected investor expectations of cash flows for the railways as it was believed that "railway rivalry and railway ruin were terms nearly synonymous" (Railway Times, March 9, 1844, p.285).

[63] For more on this, see Campbell, "Cross-Section of a 'Bubble'".

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FIGURE 1

MARKET CAPITALIZATION AND PAR VALUE OF RAILWAY
SHARES 1843-50
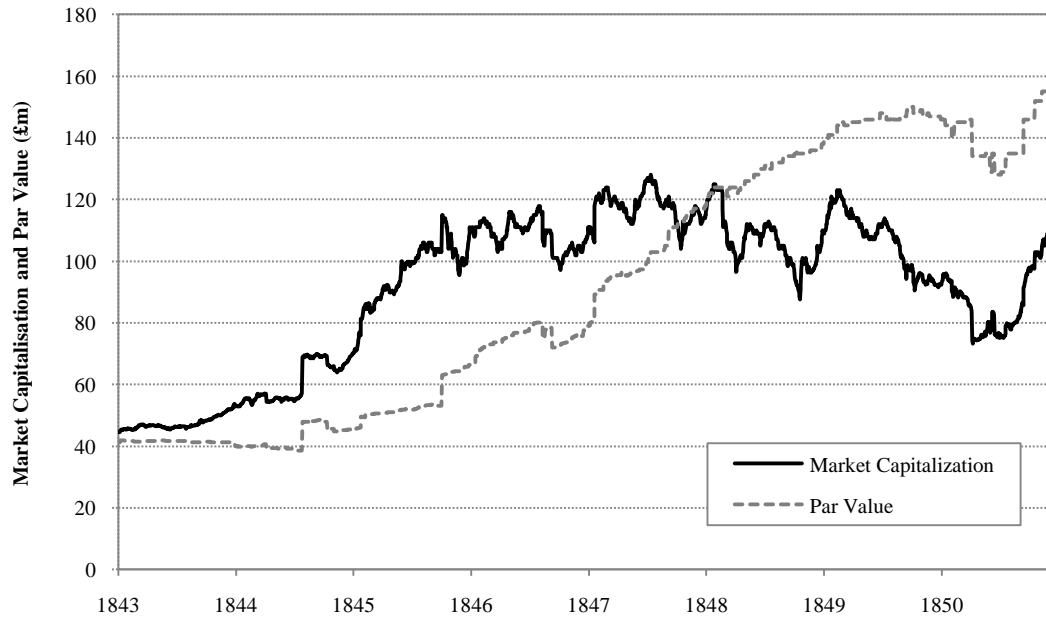
Sources: Calculated from weekly share price tables in *Railway Times* (1843-50).
Notes: The market capitalization of each security is calculated as the product of the share price and the number of shares issued, with industry market capitalization calculated as the sum of the market capitalization for each security. Industry par value is calculated in a similar manner.
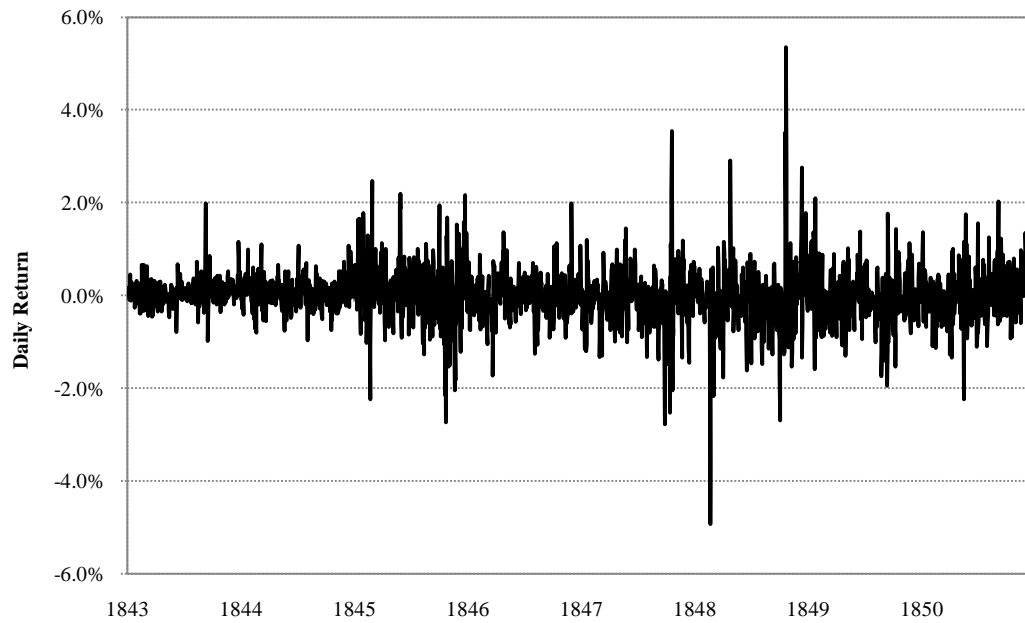
FIGURE 2
DAILY MARKET INDEX OF RAILWAY SHARES, 1843-50

Sources: Railway share index calculated from weekly share price tables in *Railway Times* (1843-50).
Notes: Capital gains for each company are weighted by market capitalization to produce a daily market index. All ordinary equity securities are included.
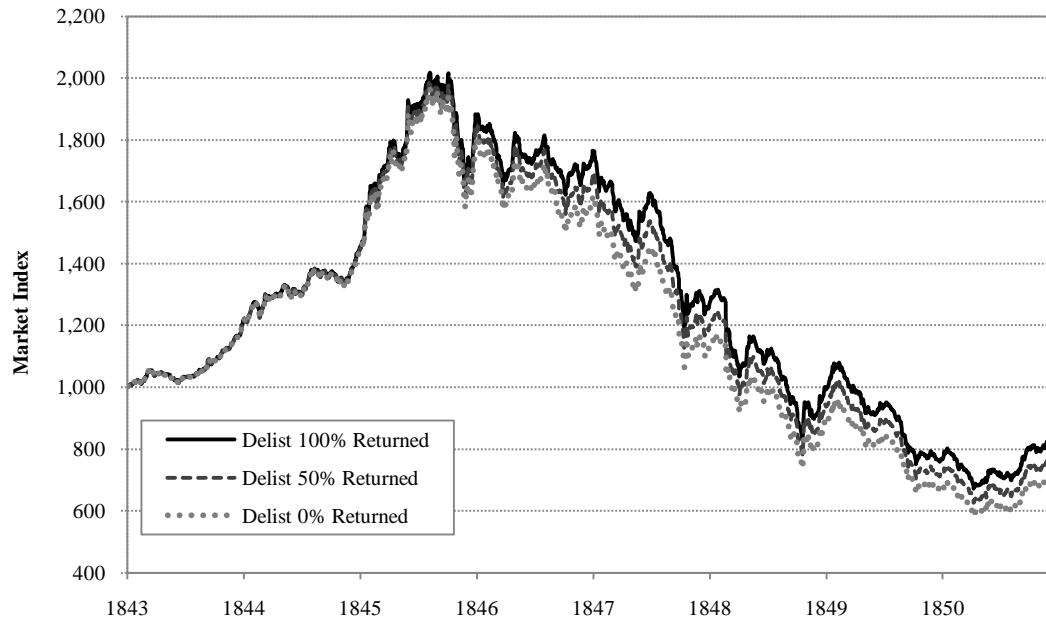
FIGURE 3
DAILY MARKET RETURNS OF RAILWAY SHARES 1843-50

Sources: Railway share index calculated from weekly share price tables in *Railway Times* (1843-50).
Notes: Capital gains for each company are weighted by market capitalization to produce daily market returns. All ordinary equity securities are included.
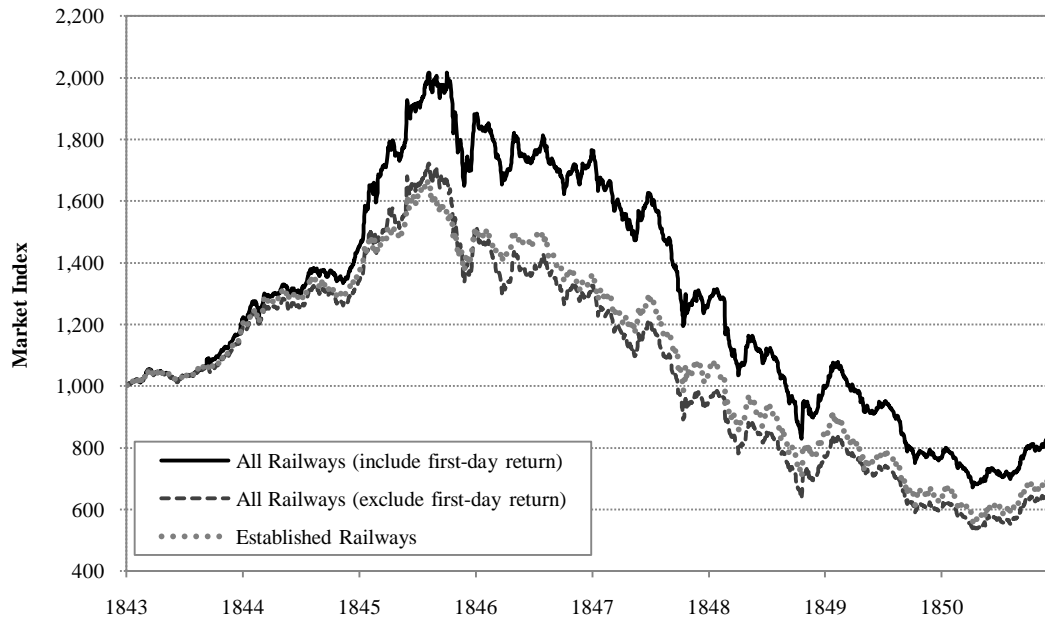
FIGURE 4
MARKET INDICES OF RAILWAY SHARES USING ALTERNATIVE
DELISTING SCENARIOS , 1843-50

Sources: Railway share index calculated from weekly share price tables in *Railway Times* (1843-50).
Notes: Each index includes all ordinary equity railway securities. Capital gains for each company are weighted by market capitalization to produce daily market indices. The three alternative scenarios assume that either 100, 50 or 0 per cent of the market price prior to delisting was returned to shareholders when a security delisted for a reason which is unknown.

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FIGURE 5

MARKET INDICES OF ALL RAILWAYS AND ESTABLISHED RAILWAYS,
1843-50

Sources: Railway share index calculated from weekly share price tables in *Railway Times* (1843-50).
Notes: The All-Railway index includes all railway securities, whereas the Established-Railway index includes those railways which were operating before January 1843. Capital gains for each company are weighted by market capitalization to produce daily market indices.

FIGURE 6
WEEKLY MARKET INDICES OF ALL RAILWAYS, ESTABLISHED
RAILWAYS AND NON-RAILWAYS, 1843-50
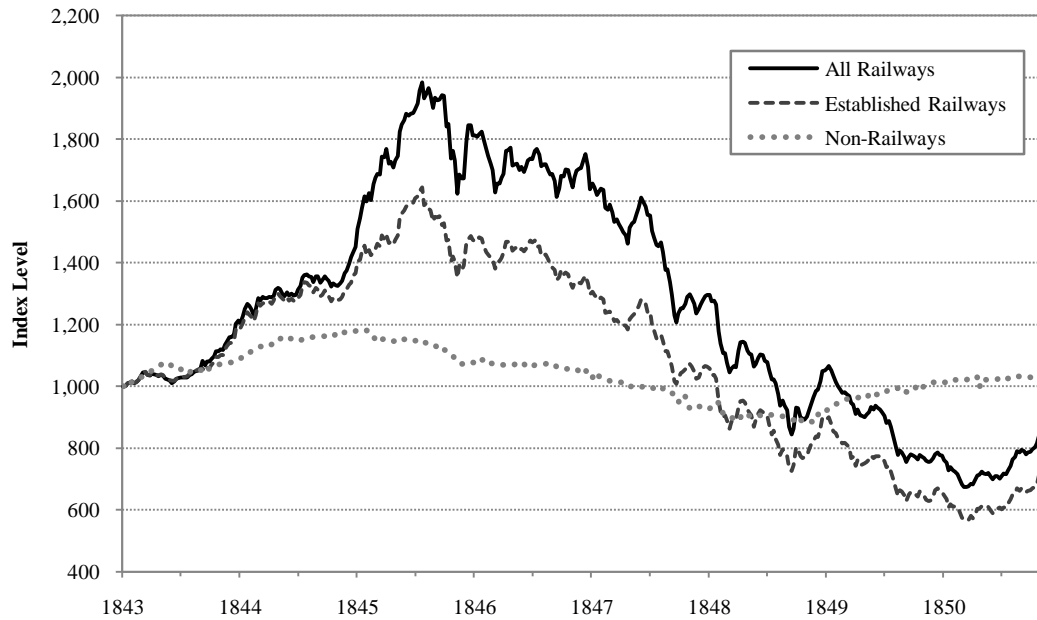
Sources: Railway share indices calculated from weekly share price tables in *Railway Times* (1843-50). Non-Railway share index calculated from weekly share price tables in *Course of the Exchange* (1843-50).
Notes: The All-Railway index includes all railway securities, whereas the Established-Railway index includes those railways which were operating before January 1843. The Non-Railway index includes the twenty largest non-railways by market capitalization. Capital gains for each company are weighted by market capitalization to produce weekly market indices.

FIGURE 7
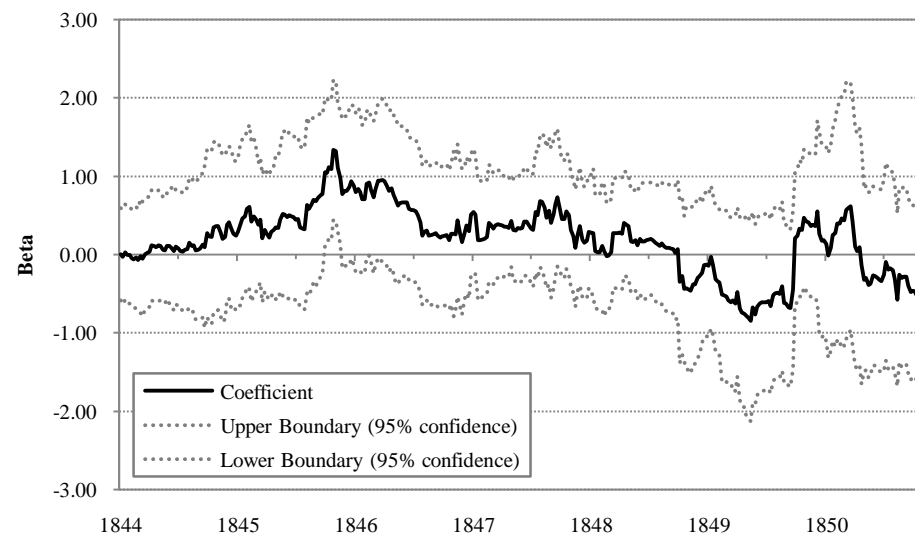ROLLING BETA FOR ALL RAILWAYS AND ESTABLISHED RAILWAYS, 1843-50

PANEL A: ROLLING BETA FOR ALL RAILWAYS
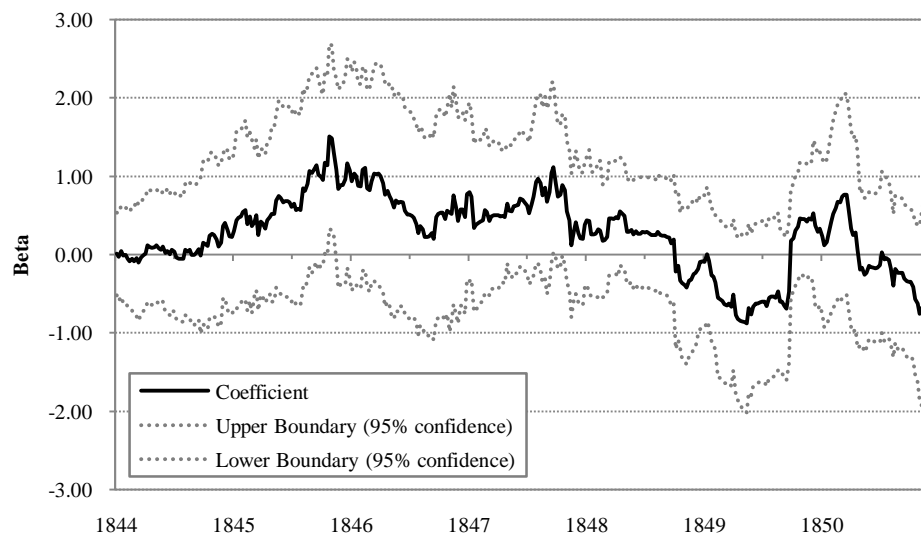
PANEL B: ROLLING BETA FOR ESTABLISHED RAILWAYS

Notes: Constructed, using a rolling window of 52 weeks, by regressing the weekly returns of all-railway index minus the risk-free rate, against the weekly returns of the market portfolio minus the risk-free rate. The market portfolio has been approximated by the non-railway market index, and the risk-free rate has been approximated by the yield on 3 per cent Consols.
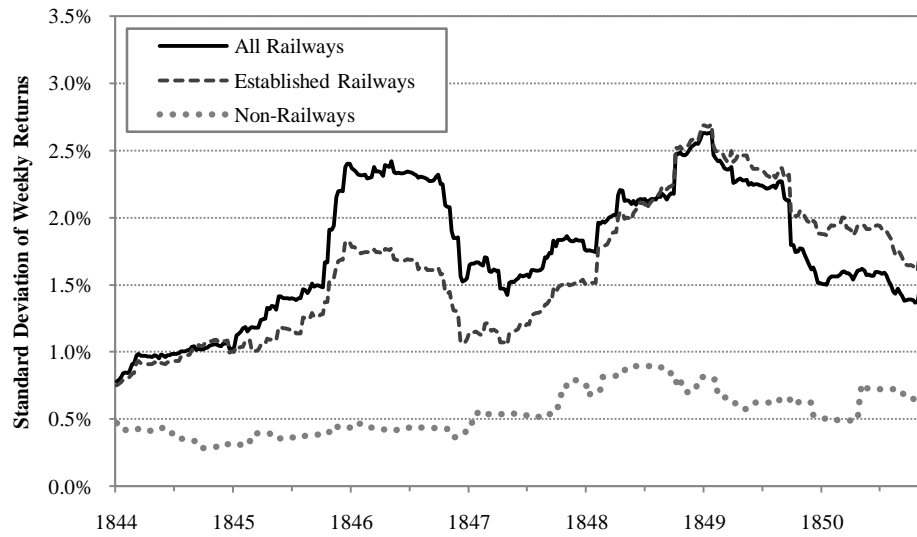
Notes: Constructed, using a rolling window of 52 weeks, by regressing the weekly returns of established-railway index minus the risk-free rate, against the weekly returns of the market portfolio minus the risk-free rate. The market portfolio has been approximated by the non-railway market index, and the risk-free rate has been approximated by the yield on 3 per cent Consols.

FIGURE 8
VOLATILITY OF INDICES, 1843-50

PANEL A: ROLLING VOLATILITY

PANEL B: GARCH(1,1) CONDITIONAL VARIANCE
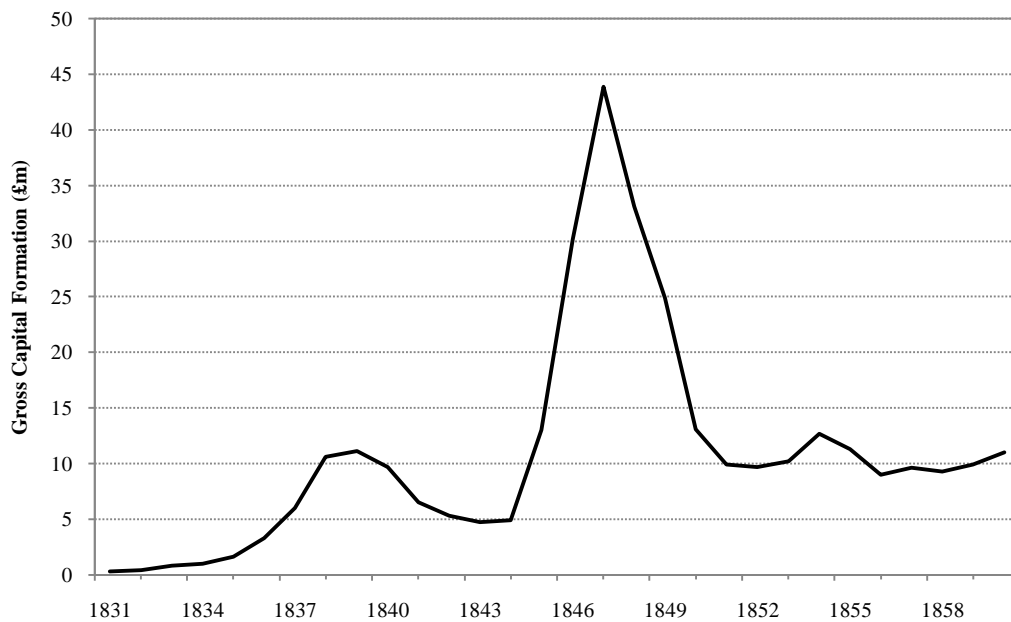

Notes: Volatility of each index calculated as standard deviation of weekly returns using a rolling window of 52 weeks.
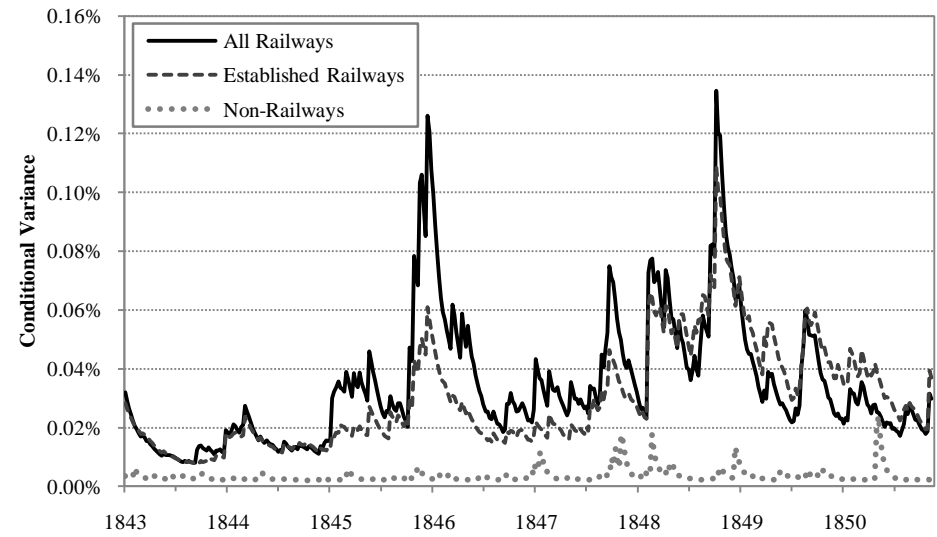
Notes: Predicted conditional variance from a GARCH(1,1) model of weekly returns for each index.

FIGURE 9

GROSS UK CAPITAL FORMATION BY RAILWAY COMPANIES, 1831-1860

Source: Mitchell, "The Coming of the Railway", p.335.

TABLE 1
DESCRIPTIVE STATISTICS OF ALL RAILWAYS' MARKET INDEX BY YEAR 1843-50

	1843	1844	1845	1846	1847	1848	1849	1850	Overall
No. Of Securities Listed									
Mean	94.6	110.2	191.5	270.4	216.8	205.2	193.5	154.3	179.6
Max	97.0	140.0	290.0	295.0	225.0	219.0	197.0	188.0	295.0
Min	92.0	87.0	138.0	218.0	208.0	194.0	188.0	133.0	87.0
St. Dev	1.1	22.1	54.4	31.8	5.0	7.7	3.2	20.4	59.5
Observations									
Listed	29,509	34,594	59,942	84,638	67,856	64,228	60,552	47,846	449,165
Traded	5,573	10,018	20,109	19,178	17,598	13,744	11,920	10,304	108,444
Ratio of Traded/Listed	18.9%	29.0%	33.5%	22.7%	25.9%	21.4%	19.7%	21.5%	24.1%
Total Market Capitalization (£ m)									
Mean	£47.4	£60.6	£96.0	£108.0	£117.0	£107.0	£107.0	£88.3	£91.5
Max	£53.8	£70.1	£115.0	£118.0	£128.0	£125.0	£123.0	£113.0	£128.0
Min	£44.5	£52.8	£70.1	£97.2	£104.0	£87.6	£90.4	£73.2	£44.5
St. Dev	£2.0	£6.4	£10.1	£4.8	£5.1	£8.4	£9.2	£11.1	£24.6
Total Market Par Value (£ m)									
Mean	£41.5	£42.6	£54.4	£74.9	£101.0	£129.0	£146.0	£141.0	£91.3
Max	£41.9	£48.5	£66.3	£80.2	£117.0	£138.0	£150.0	£155.0	£155.0
Min	£40.0	£38.5	£45.6	£66.3	£77.8	£118.0	£138.0	£128.0	£38.5
St. Dev	£0.2	£3.7	£6.0	£3.2	£10.1	£5.3	£2.7	£7.9	£41.4
Index (Jan 1, 1843 = 1000)									
Year-end	1215.1	1449.5	1883.0	1736.0	1260.4	975.9	761.4	857.4	857.4
Mean	1062.4	1324.4	1803.5	1743.9	1492.0	1075.3	911.2	752.9	1271.4
Max	1215.1	1449.5	2017.4	1884.0	1765.1	1315.4	1079.1	881.8	2017.4
Min	1001.4	1211.5	1450.1	1623.1	1194.1	829.2	750.0	672.1	672.1
St. Dev	47.8	50.6	144.0	57.0	149.8	125.7	98.3	49.0	373.6
Daily Index Returns									
Mean	0.06%	0.06%	0.09%	-0.03%	-0.10%	-0.08%	-0.08%	0.04%	0.00%
Max	1.99%	1.10%	2.46%	1.99%	3.54%	5.35%	2.09%	2.03%	5.35%
Min	-0.98%	-0.97%	-2.73%	-1.74%	-2.78%	-4.93%	-1.96%	-2.24%	-4.93%
St. Dev	0.26%	0.31%	0.72%	0.42%	0.62%	0.82%	0.55%	0.55%	0.57%

Sources: See text.

TABLE 2

KEY CHARACTERISTICS OF MEDIAN RAILWAY COMPANIES, BY COMPANY TYPE AND BY YEAR, 1843-50

	Jan 1, 1843	Dec 29, 1843	Dec 31, 1844	Dec 31, 1845	Dec 31, 1846	Dec 31, 1847	Dec 30, 1848	Dec 31, 1849	Dec 27, 1850
Number of Companies Listed									
Established Railways	64	55	51	38	29	27	28	28	27
New Railways			48	221	116	83	69	67	60
Number of Companies with Full Data Available									
Established Railways	22	33	32	26	24	20	24	25	24
New Railways			39	115	102	75	58	56	44
Number of Securities per Company (median)									
Established Railways	2	2	2	3.5	3	4	4.5	4	3
New Railways			1	1	1	1	1	1	1
Company Capitalization in £000s (median)									
Established Railways	550.8	758.5	1,038.1	2,429.7	1,582.1	1,961.2	1,461.0	1,059.5	1,292.0
New Railways			64.8	77.9	99.8	205.0	304.9	381.6	529.4
Company Par Value in £000s (median)									
Established Railways	779.6	835.5	785.9	1,159.8	1,269.5	2,211.1	2,082.6	1,828.1	2,348.7
New Railways			65.0	60.0	147.6	259.0	530.9	681.5	817.6
Percentage of Capital Paid-up (median)									
Established Railways	100.0%	95.0%	84.0%	78.6%	65.1%	79.1%	87.1%	96.0%	93.7%
New Railways			6.0%	6.0%	13.1%	39.1%	67.2%	86.0%	92.4%
Price / Paid-up (median)									
Established Railways	0.72	0.92	1.24	1.63	1.36	0.89	0.79	0.60	0.70
New Railways			1.20	1.22	0.95	0.69	0.61	0.60	0.54
Price / Paid-up if shares fully paid-up (median)*									
Established Railways	0.76	0.94	1.24	1.47	1.18	0.92	0.85	0.71	0.75
New Railways			1.02	1.02	0.99	0.94	0.84	0.80	0.75

Source: See text.

Notes: The median is based on those companies for which full data is available, meaning that their shares had to have traded to record a share price, and their par value, nominal value and number of shares in issue must also have been reported.Notional price/paid up ratio if all uncalled capital was paid up immediately and price rose by exactly the rise in par value

TABLE 3
STANDARD DEVIATION OF WEEKLY RETURNS AND VARIANCE RATIO TESTS, 1843-50

	Standard Deviation Of Weekly Returns				Variance Ratio Tests (Probability that Standard Deviations are Equal)		
	All Railways	Established Railways	Non-Railways		All Railways = Non-Railways	Established Railways = Non-Railways	All Railways = Established Railways
1843	0.78%	0.75%	0.47%		0.001	0.001	0.800
1844	1.02%	0.99%	0.31%		0.000	0.000	0.836
1845	2.38%	1.82%	0.43%		0.000	0.000	0.059
1846	1.56%	1.07%	0.37%		0.000	0.000	0.007
1847	1.84%	1.51%	0.79%		0.000	0.000	0.162
1848	2.54%	2.58%	0.70%		0.000	0.000	0.899
1849	1.65%	1.97%	0.62%		0.000	0.000	0.217
1850	1.48%	1.75%	0.65%		0.000	0.000	0.228
Total	1.78%	1.67%	0.59%		0.000	0.000	0.211

Notes: Standard deviation of weekly returns calculated for each index for each year. Variance ratio test reports probability that the standard deviations of given indices are equal.