Cross-Section of a 'Bubble': Stock Prices and Dividends during the British Railway Mania

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Abstract

Historical asset price 'bubbles' are often attributed to mispricing, but the empirical analysis of such episodes has been limited. This paper examines a notable but academically neglected period, known as the British Railway Mania, using a new dataset and a cross-sectional methodology which is unique to the study of historical asset price reversals. The main finding is that the cross-sectional variation in stock prices, in every week of the sample, is explained by the cross-sectional variation in dividends, growth and risk, with no significant differences between railways and non-railways. This implies that an economic bubble was not responsible for the rise and fall in the prices of railway stocks at this time. (JEL G01, G11, G12, N23)

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Asset price reversals have been a feature of financial markets for many centuries, with periods such as the Tulip Mania, the South Sea Bubble, and the Wall Street Crash being prominent examples. The 'Dot-Com Bubble' and 'Housing Bubble' have led to a renewed interest in such episodes, with popular commentary often associating them with irrationality and mispricing. The British Railway Mania of the 1840s has been amongst those periods which have attracted recent attention, with the *Economist* (2008) referring to it as 'arguably the greatest bubble in history'.

This paper argues that an analysis of the British Railway Mania rejects the hypothesis that an economic bubble existed during this period. Although the Railway Mania may have been a bubble in the popular sense of the word, in that there was a substantial rise and fall in stock prices, it was not a bubble in the economic sense. Railway assets did not have a significantly higher price than non-railway assets, even at the market peak, after controlling for fundamental factors such as dividends, growth, and risk.

A new dataset has been collected from primary sources for this analysis, and a unique approach to the study of historical asset price reversals has been used, with a focus on the cross-sectional variation between different assets. This new dataset consists of weekly stock price and dividend data for every railway that was listed and operating during this period, and a sample of non-railway companies. The extent of the data collection has produced a sample size which enables a greater depth of analysis than has been possible in the study of most other historical 'bubble' episodes.

The focus of the paper is on a series of 417 cross-sectional regressions, one for each week of the period between 1843 and 1850, relating the cross-sectional variation in stock prices to the variation in dividends, growth and risk. A dummy variable distinguishes the differences between railway stocks, which experienced a substantial price reversal, and non-railway assets, which did not. The results suggest that the cross-sectional variation in dividends had a significant relationship with the cross-sectional variation in stock prices throughout the sample. There is also an indication that there was a significant relationship between prices and dividend growth during most of the period, as companies with a relatively high share price generally went on to experience higher dividend growth.

When controlling for just current dividends and risk factors, the railways had significantly higher share prices than non-railways for between 31 and 110 weeks, depending on the functional form used. However, when several periods of future growth are also controlled for, the railways did not have a significantly higher price than the non-railways in any week of the sample period. These results imply that the prices of railway shares were determined by fundamental factors such as dividends, growth and risk throughout the period known as the Railway Mania, and that an economic bubble was not the reason for railway share price changes.

This paper contributes to our knowledge of the British Railway Mania specifically, to our understanding of historical asset price reversals in general, and to the debate regarding the identification of bubbles. The analysis in this paper expands our knowledge of an important period which has received little attention from academic economists, and provides econometric evidence against the argument of Odlyzko (2010) that the Railway Mania was driven by 'collective hallucinations and inefficient markets'.

More generally, the results provide further evidence against arguments that some historical asset price changes may have been due to irrationality (Dale et al., 2005). The conclusion that an economic bubble was not responsible for substantial price changes is consistent with research on the Tulip Mania of 1636 (Garber, 2001), the German stock market boom of 1927 (Voth, 2003), the Wall Street boom of the late 1920s (Donaldson and Kamstra, 1996), and the Nasdaq bull market of the 1990s (Pástor and Veronesi, 2006).

The use of a new methodology for studying historical episodes, which focuses on the cross-sectional variation in assets, illustrates that sustained time series price increases may be explained by changes in fundamental factors, rather than a bubble component. The evidence of consistency in cross-sectional pricing confirms that time series changes are not a conclusive indication of irrationality, and the importance of future growth illustrates the difficulty in detecting mispricing ex-ante. The results also suggest that a subsequent fall in prices may be due to a previously unexpected deterioration in fundamentals, and the finding that railway assets were not obviously mispriced at their peak implies that it may be difficult to forecast market crashes. This supports the argument of Bernanke (2002, 2010) and Mishkin (2008) that it is difficult to predict substantial price declines ex-ante.

This paper is organised as follows. Section 1 examines the related literature on the detection of bubbles, Section 2 provides a brief background to the Railway Mania, Section 3 discusses the data used, whilst Section 4 estimates the movement in stock prices and dividends during this period. Section 5 considers a panel cointegration analysis, Section 6 examines the cross-sectional relationship between stock prices, current dividends, and risk, Section 7 extends this analysis to account for dividend growth, Section 8 discusses robustness checks, with Section 9 being a brief conclusion.

1 Detecting Bubbles

As noted by O'Hara (2008), there has been some ambiguity about the meaning of the term 'bubble', with previous academic literature generally using two definitions. The popular usage of the term, per Kindleberger (2000, p.16), is an 'upward price movement over an extended range that then implodes', or what Bordo and Jeanne (2002) have described as an 'asset price reversal'. By using this first definition it is relatively easy to detect and label a bubble ex-post, simply by an observation of nominal prices. As will be demonstrated below, the Railway Mania can be classed as a bubble using this criteria, as there was a considerable stock price reversal during this period.

However, the economic definition of a bubble is a deviation from fundamental value (Flood and Hodrick, 1990, p.88). Using this second definition makes it much more difficult to definitively detect a bubble, as the concept of fundamental value is theoretical and not necessarily observed directly. Consequently, any apparent bubble component may be attributed to a mis-specification of the correct fundamental value by the researcher.

One approach to determining whether a certain period can be classified as an economic bubble has been to consider whether the expectations of growth or uncertainty implied by asset prices were unrealistic (see Pástor and Veronesi, 2006, and Voth, 2003). Various econometric tests have also been proposed for the detection of bubbles, including variance bound tests (Shiller, 1981), the comparison of the 'actual' relationship and a theoretical 'constructed' relationship between prices and dividends (West, 1987), co-integration tests which determine the orders of integration of prices and dividends (Diba and Grossman, 1988) and the relationship between the dividend yield and the level of dividends (Froot and Obstfeld, 1991).

Neither the implied expectations approach, nor time series analysis, focus on whether investors made rational decisions, given the cross-section of assets available for investment at a particular time. If investors were rational they should have ensured that at any time each asset reflected only the sum of discounted expected cash flows, with each asset priced consistently after controlling for factors such as dividends, growth and risk. By extension, assets in one industry should have been priced consistently with other industries, after accounting for such factors.

In the context of the Railway Mania, this would mean that if investors were rational and a bubble did not exist, the railways should have been priced consistently with the non-railways. Consistency of pricing would suggest that railway stock prices were determined by the same fundamental factors as non-railway stock prices, whilst inconsistency could suggest an irrational preference for the railways. This paper goes on to test the consistency of pricing during the Railway Mania by analysing whether railway stock prices were significantly different from other industries, after controlling for dividends, growth and risk.

2 Background to Railway Mania

The first modern passenger railway was the Liverpool and Manchester, which was promoted in 1824, authorised by Parliament in 1826, and opened in 1830. Over the subsequent decade about another sixty railways were constructed, with most of the lines projected during a minor promotion boom in 1836 and 1837. However, further promotion was subdued until the early 1840s. A period known as the Railway Mania then ensued, with share prices rising substantially from 1843 to 1845, and then falling steadily until 1850.

The initial phase of the Mania was associated with strong economic growth, and a low rate of interest, with 3 per cent Consols, government debt perpetuities, reaching par for the first time for over a century (*Economist*, April 13, 1844, p.674). A widespread reduction in fares, combined with the strong economic conditions, produced a rapid increase in passenger numbers and revenues for the railways. Between 1843 and 1846, first class traffic on the ten largest railways increased by 33 per cent, whilst second class and third class traffic increased by 68 per cent and 187 per cent respectively. This resulted in an overall increase in passenger receipts of 41 per cent, whilst receipts from goods traffic also increased, by 42 per cent (*Parliamentary Papers*, 1847). These increases in traffic and receipts were achieved with a relatively small increase of 25 per cent in the mileage open of the largest lines.

As the period progressed the promotion of new railway companies increased, reaching unprecedented levels in the autumn of 1845, just as railway share prices peaked. Some estimates suggested that over one thousand new railways were promoted at this time (*The Times*, November 17, 1845, p.4), although only a small number of these were ever constructed. These promotions exposed existing railways to the threat of competition, and encouraged amalgamations, often resulting in established lines purchasing newer lines which tended to earn lower returns on capital.

The downturn in asset prices, beginning in the autumn of 1845, also coincided with the discovery of a potato blight, and defective harvest, which led to an economic downturn and the Irish Famine. A financial crisis then followed in 1847, which involved distress amongst many banks and merchants, and led to a further reduction in economic growth (Evans, 1849). A feature of the downturn was the revelation of fraud amongst several large railways, but most of the allegations centred around companies controlled by just one chairman, George Hudson. Even amongst Hudson's companies, the mis-statements appear to have begun after the Mania had ended (*Railway Times*, 1849, pp. 441, 690, 1086). Receipts from traffic continued to grow during the latter half of the decade, but the mileage open on the railway network had expanded considerably, and the resulting increase in operating expenses and issue of equity reduced the returns available to investors.

Commentary throughout the period suggested that dividends were regarded as an important consideration in the valuation of railway stocks. For example, the *Economist* (November 8, 1845, p.1109) noted that 'with regard to the finished and dividend paying lines, they are of course calculated so as to yield a given rate of interest which must always have some reference to the rate which other securities yield, and so far the price of shares should fluctuate with other securities.' Similarly, an investment pamphlet entitled the *Short and Sure Guide to Railway Speculation* advised that 'as regards the purchase of shares in the established lines we have simply to compare the market price of the share with the dividend which it pays' (Anon., 1845, pp.5-6). It went on to note that 'taking the value of money at four per cent, the shares in a railway which pays six per cent per annum are worth £150 each; or in one which pays ten per cent they are worth £250 each. If bought below these prices, the purchaser is receiving, *pro tanto*, a better rate than four per cent, and he will accept this better rate, in proportion to any doubt he may have with respect to the dividend being maintained.'

3 Data

To improve our understanding of the Railway Mania, a unique and comprehensive dataset has been constructed, by inputting the original share price tables published in a weekly newspaper, the *Railway Times,* between 1843 and 1850. As this paper focuses entirely on those companies which were capable of paying dividends throughout this period, only the railways in operation at the beginning of the Mania, and the firms which resulted from mergers involving these lines, are included. The share price dataset was supplemented with data on dividends, collected from the *Course of the Exchange*, an official stockbroker list for the London stock market.

There were 64 railways listed in the *Railway Times* in the first week of 1843. However, the *Course of the Exchange* contained dividend data on only 41 of these railways. Due to a high number of mergers and acquisitions, the number of railway companies fell throughout the sample. If an established railway, in existence at the start of 1843, participated in a merger then the new company was also treated as an established railway and it was assumed that investors in the original company went on to receive the dividend of the merged firm. By the end of 1850 there were 27 established railways listed in the *Railway Times*, and dividend data was available from the *Course of the Exchange* for 24 of these railways.

Data on the twenty largest non-railway companies by market capitalisation was also obtained from the *Course of the Exchange*. These twenty companies represented 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. There are six banks, five insurance companies, three canals, three docks, two gas, light, and coke companies, and one waterworks company included. Bank of England stock and East India stock have been excluded from the non-railway sample as they were issued by companies with a strong relationship to the government.

The number of shares in issue *(N)*, the share price *(P)* and the par value *(Z)* of each of the securities was recorded for each of the 417 weeks in the sample period. The par value of a share was the total amount of equity which shareholders had paid to the company for that security. The share price/par ratio *(P/Z)* has been calculated for each security for each week, and is used to standardise prices in a manner which is similar to the market to book ratio. During this period dividends *(D)* were also generally expressed in terms of par value, with the dividend/par ratio *(D/Z)* providing an estimate of the shareholders' return on their equity investment. Dividend growth has been calculated as the change in the dividend/par ratio, $\Delta(D/Z)$ between different periods. To enable the analysis of dividend changes beyond the main sample period the dividend rates of companies until 1855 were included in the dataset. The dividend yield (*D/P*) has also been calculated for each security, for each week of the sample, by computing the dividend/price ratio.

Fama and French (1992) suggest that risk dimensions can be proxied by size and book-to-market variables. A proxy for the book-to-market variable (*P/Z*) will be used as the dependent variable in the following analysis, so it cannot also be included as an explanatory variable. However, size can be controlled for, and an estimate of the beta can also be made. The size *(S)* of the company has been measured as the market capitalisation of the firm, calculated as the number of shares in issue multiplied by the price of each share. The beta (*B*) of each firm has been estimated for each company for each year, by regressing the weekly returns of each asset 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-railways' market index, consistent with the approach of Pástor and Veronesi (2009) when calculating the beta of the early US railroads. The risk-free rate has been approximated by the yield on 3 per cent Consols. A railway dummy variable *(R)* has also been created, which equals one when the company was a railway, and zero otherwise.

Only those companies which had been traded, and had an observable share price, could be included in the analysis, which reduced the sample size mainly in the early months of 1843. For calculations involving the price/par ratio three outliers with extremely high dividend/par ratios, defined as being above 15 percent, were excluded as small changes in their price gives the appearance of shifts in the estimated coefficients, which is misleading with regards the rest of the sample. However, robustness tests described at the end of the paper illustrate that the key results remain the same when these outliers are included. For the calculations explaining variations in the dividend yield, these three companies have been included, as they did not have extreme dividend yields, but observations where a company had a zero dividend yield are excluded, as such observations do not reveal any information about pricing.

The average number of companies analysed each week in the regressions involving the share price/par ratio was 40.2, which over the 417 weeks of the sample results in 16,770 observations. For those regressions involving the dividend yield, there were an average of 39.6 companies included per week, which involved a total of 16,501 observations over the sample. When periods of future dividend growth are included, these figures are reduced slightly due to data availability.

4 Movement of Stock Prices and Dividends

Weekly market indices for the established railway companies and the non-railway companies, for which share price and dividend data are available, have been constructed and are plotted in Figure 1. In each case the market return has been calculated on a weekly basis by weighting the capital gains of each company by its market capitalisation at the end of the preceding week.

<<INSERT FIGURE 1>>

The index representing the established railways rose from a base of 1,000 in January 1843 to a peak of 1,718 on August 8, 1845, but the non-railways index had risen to just 1,152 by this time. The established railway index then fell substantially, declining by 18.5 per cent by the end of November 1845, whilst the non-railways fell by 5.9 per cent during the same period. The established railway index then stabilised throughout 1846, before beginning a steady decline from January 1847 onwards, with the sample ending in 1850 with the established railway index at 727, and the non-railway index at 1042.

Whilst the prices of railway shares changed dramatically, railway dividends also rose and fell substantially. As can be seen from Figure 2, the dividends, as a percentage of par value, paid by established railways at the beginning of 1843 averaged 4.3 per cent. They then increased steadily, reaching a peak of 7.2 per cent in July 1847, before falling to just 2.9 per cent by the end of 1850. Higher dividends were evident in almost every one of the major railways during the boom, and dividend declines were almost universal during the downturn. The dividends paid by the non-railways were much less volatile, beginning 1843 at an average of 6.4 per cent, and reaching 6.6 per cent by 1844, but they then fell slightly, ending 1850 at 6.1 per cent. It is interesting to note that the peak in railway share prices occurred almost two years before the peak in railway dividends, perhaps suggesting that investors were including estimates of future dividend changes into prices before the rates had actually changed.

<<INSERT FIGURE 2>>

The dividend/price ratios of the railway and non-railway industries are plotted in Figure 3. The railway industry dividend yield has been calculated as the total dividends paid by all the established railways as a fraction of the total market capitalisation of those railways, with the non-railways calculated in a similar manner. At the beginning of 1843 the dividend yields of the railway and non-railway industries were close, being 4.6 per cent and 4.8 per cent respectively. Although railway prices and dividends both rose and then fell during the sample period, prices seem to have moved in advance of dividends, resulting in a changing dividend yield. The railway industry dividend yield initially fell, reaching a minimum of 3.3 per cent in February 1844, but then rose substantially, reaching a peak of 7.3 per cent in October 1848. During the same period, the non-railway industry dividend yield remained between 4.2 and 5.2 per cent.

<<INSERT FIGURE 3>>

Total return indices have also been constructed, which combine both capital gains and dividends, and are shown in Figure 4. The established railways total return index reaches a peak of 1,897 in August 1845, and ends the sample at a level of 1,056, implying that even after dividends have been included the total return to investors in established railways was close to zero between 1843 and 1850. In contrast, the non-railways finish the sample period at 1,513, which was the peak for the sample period.

<<INSERT FIGURE 4>>

Descriptive statistics for each of the key variables included in the subsequent regression analysis have been reported in Table 1, by industry and by year. For the railways both the mean share price/par ratio and dividend/par ratio initially rise and then decline, whilst the non-railways show less movement over time. The non-railways consistently have both a higher price/par and dividend/par ratio throughout the period, but much of this is due to three non-railway outliers with very high ratios, which have been excluded from the price/par regressions. When these are removed the average price/par ratio of the non-railways falls from about 2.0 to 1.3, whilst the average dividend/par ratio falls from about 10.0 to 5.8 per cent for the whole period.

<<INSERT TABLE 1>>

The mean dividend yield of the railways also shows more change over time than that of the non-railways, with the railways initially having a relatively lower yield, before a dramatic rise gave them a relatively higher yield in 1847 and 1848. As a zero dividend yield does not reveal anything about prices, those companies with a zero yield are excluded from the dividend yield regressions. When these companies are removed the average yield for the whole period for the railways rises from 3.9 to 4.7 per cent, whilst the non-railways remain at 4.9 per cent.

The average beta of the railways rose and fell, but remained below one throughout the period, reflecting the weakness of the relationship between the movement in railway shares and the non-railways. Due to the possibility of errors-in-variables in the beta estimate, the subsequent regression analysis has been repeated without the inclusion of the beta variable and the key results remain the same, as discussed at the end of the paper.

The size variable reveals that the average market capitalisation of the railways was similar to that of the non-railways at the start of the period. However, the market capitalisation of the railways increased at a much faster rate during the early years of the boom, reflecting both higher prices and more shares being issued. This resulted in the railways being larger than the non-railways for most of the period.

5 Panel Cointegration

One approach to analysing the relationship between stock prices and dividends is to consider whether these variables cointegrate. Table 2 reports results of a panel cointegration analysis for railway assets during the sample period. To be included in the analysis each variable, for each company, must be integrated of order 1, and the value of the variable must have changed at least once during the sample period. Fisher-type ADF panel unit root tests, which can be conducted on unbalanced panels (Maddala and Wu, 1999), are reported for each variable and illustrate that the variables are I(1).

<<INSERT TABLE 2>>

Seven panel cointegration tests are reported, based on Pedroni (1999, 2004), each of which tests the null hypothesis of no cointegration. The first four tests, referred to as within-dimension panel statistics, have an alternative hypothesis H_1: $ã_i=ã<1$ for all *i*, presuming a common value for ã, the autoregressive coefficient. The first test is a nonparametric variance ratio statistic, the second and third are nonparametric statistics similar to the Phillips and Perron rho statistic and t-statistic respectively, whilst the fourth is similar to the Dickey-Fuller t-statistic. The latter three tests, referred to as between-dimension group statistics, have an alternative hypothesis H_1:ã$_i$=ã$_i$<1 for all *i*, which does not presume a common value for ã, the autoregressive coefficient. These tests are analogous to the Phillips and Perron rho statistic and t-statistics, and the Dickey-Fuller t-statistic respectively.

When only the price/par and dividend/par variables are analysed, just one of the seven test statistics rejects the null hypothesis of no cointegration at the 10 per cent level, as shown in Table 2. However, this lack of cointegration does not necessarily imply that investors were acting irrationally. If expectations move in advance of dividends then the relationship between prices and current dividends may not be stable. To account for the difference in timing, the analysis has been repeated with a variable for the future growth in dividends, calculated for each company as the change in the dividend/par ratio over the next two years. A time span of two years has been chosen as the peak in share prices occurred approximately two years before the peak in dividends. When the dividend growth variable is included in the cointegrating relationship, six of the seven test statistics rejects the null hypothesis of no cointegration at the 10 per cent level, as shown in Table 2. These results suggest that there may have been a relationship between prices, dividends and growth during the sample period, a finding which may challenge the popular characterisation of this period as a Mania.

6 Cross-Sectional Analysis with Current Dividends

Although the results discussed in the previous section suggest that there may be evidence of cointegration, a panel analysis may be regarded as insufficient for two reasons. Firstly, the power of the tests may be affected by the relatively short time span which is considered. Shiller and Perron (1985) have argued that it is the length of the period, rather than the frequency of the data, that matters for the power of tests involving time series. Additional analysis considering the cross-section of assets at particular times may provide further evidence of the relationship between prices and dividends.

Secondly, a panel analysis considers all entities and time periods together. Analysing each week individually can provide more detailed insights into how investors priced the cross-section of assets which were available at any given time. Examining the cross-section of assets at particular times can reveal whether railways were priced consistently with non-railways given their respective dividends, growth and risk at those times. The focus is on whether investors acted rationally given the cross-section of assets which were available to them for investment. Repeating this cross-sectional analysis across time periods can give an indication of how the pricing of the railways relative to the non-railways changed over time. This is particularly important for a sample which includes periods that may be loosely referred to as pre-Mania, Mania, and post-Mania.

The rest of this paper examines the pricing of assets during the Railway Mania using a cross-sectional methodology, with two functional forms being considered to ensure robustness. The first approach, shown in Equation 1, relates each asset's share price (P) with its dividend (D), both standardised by the par value (Z). Two risk factors are controlled for, namely the firm's beta (B), and size (S). A dummy for the railway industry (R) is included to determine whether the railways were priced differently from the non-railways.

For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 R_i + \beta_3 B_{i,t} + \beta_4 S_{i,t} + \varepsilon \tag{1}$$

The second approach, shown in Equation 2, expresses the share price and dividend as a dividend yield (*D/P*), and also controls for beta (*B*) and size (*S*). A dummy for the railway industry (*R*) is again included.

For week = t

$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 R_i + \beta_2 B_{i,t} + \beta_3 S_{i,t} + \varepsilon \tag{2}$$

A cross-sectional regression is estimated for each week. As each week's regression is independent of every other week, there are no multiple observations of any company in any regression. Table 3 reports the coefficients and standard errors for selected weeks, with one regression for the start of the period, the last week of each year and for the peak in prices on August 8, 1845. This analysis was repeated for each of the 417 weeks of the sample period, with the last column reporting the number of weeks during which each variable was significant.

<< INSERT TABLE 3 >>

It can be seen from Panel A of Table 3, that the coefficient of the dividend variable was significantly greater than zero on 399 out of the 417 weeks in the sample. Panel A of Figure 5 illustrates this finding, and charts the relationship between the standardised dividend and share price for each week, with a 95 per cent confidence interval constructed from each week's robust standard errors.

<< INSERT FIGURE 5 >>

Panel A of Table 3 suggests that using Equation 1, the railway dummy was significant on 192 weeks during the sample. This represents 31 weeks when the railway dummy was significantly greater than zero, implying that the railways may have had a significantly higher price, and 161 weeks when the railway dummy was significantly less than zero, implying a relatively lower price, given their current dividends and risk factors. Panel A of Figure 6 shows that the coefficient of the railway dummy rose throughout the first few years of the sample, and was significantly positive for periods between 1844 and 1846, before falling and becoming significantly negative for a sustained period between 1847 and 1850.

<< INSERT FIGURE 6 >>

Panel B of Table 3 reveals that when dividend yields are analysed using Equation 2, the railway dummy was significant on 148 weeks. This consists of 110 weeks when the railway dummy was significantly less than zero, which in this specification implies a relatively higher price, and 38 weeks when the railway dummy was significantly greater than zero, implying a relatively lower price. Panel A of Figure 7 shows that the railway dummy was significantly negative throughout most of 1844 and 1845, before rising during the latter half of the decade.

<< INSERT FIGURE 7 >>

The above results suggest that the current dividend rate was a highly significant factor in determining the prices of assets during the Railway Mania. Nevertheless, although changes in the current dividend rate may explain part of the increase in the nominal prices of railway shares, it cannot fully explain all of the changes. Railways appear to have had a significantly higher share price for a period during the boom, and a significantly lower share price for a period during the downturn, after accounting for current dividend rates. However, rather than reflecting mispricing, these differences may reflect expectations of dividend growth, which investors may also have considered in their valuations.

7 Cross-Sectional Analysis with Dividend Growth

One approach to considering the relationship between prices and future dividends has been to illustrate the association between the dividend yield and future dividend growth as per Campbell and Shiller (1998). Figure 8 plots the relationship between the dividend yield and the next period's dividend growth for each company in the sample, with one observation per company at the end of each of the sixteen half-years in the sample. The results suggest that there was a negative correlation which would imply that companies with a low dividend yield, meaning a relatively high price, went on to experience relatively higher growth.

<< INSERT FIGURE 8 >>

To estimate the extent of mispricing whenever future dividend growth has been accounted for, the cross-sectional regressions discussed in the previous section have been extended. By considering the possibility that investors' expectations of the next *n* half-years of dividend changes were accurate, it is possible to estimate whether railway shares were mispriced, given expectations of dividend growth.

The first approach, explaining the share price/par ratio per Equation 1, was extended to consider the impact of including the next *n* half-years of dividend changes. A railway dummy *(R)* was again included to estimate the proportion of the share price/par ratio *(P/Z)* of railway companies which could not be explained by the current dividend/par ratio *(D/Z)*, future changes in dividends, Δ*(D/Z)*, beta *(B)* and size *(S),* as shown in Equation 3. This approach was repeated with the inclusion of varying numbers of future changes in dividends.

For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 E_t \left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}} \right) + \beta_3 R_i + \beta_4 B_{i,t} + \beta_5 S_{i,t} + \varepsilon \tag{3}$$

The second approach, explaining the dividend yield per Equation 2, was also extended to consider the impact of the next *n* half-years of dividend changes. A railway dummy *(R)* was again included to estimate the proportion of the dividend yield *(D/P)* of railway companies which could not be explained by future changes in dividends, Δ*(D/Z)*, beta *(B)* and size *(S),* as shown in Equation 4. This approach was repeated with the inclusion of varying numbers of future changes in dividends.

For week = t

$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 E_t \left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}} \right) + \beta_2 R_i + \beta_3 B_{i,t} + \beta_4 S_{i,t} + \varepsilon \tag{4}$$

The number of weeks that each variable was significant in each specification is reported in Table 4. Panel A reports regressions explaining the share price/par ratio *(P/Z)*, and reveals that when future dividend changes are controlled for, the current dividend/par ratio was significant in all 417 weeks of the sample, regardless of the number of future dividend changes included. This can be seen from the graphical analysis in Panel B of Figure 5 which also suggests that the size of the dividend coefficient remained relatively steady once future growth is accounted for. The next half-year of dividend growth was significant for between 250 and 312 weeks, with the second half-year of dividend growth significant for between 136 and 210 weeks, depending on the number of other changes included. Dividend changes beyond this were significant in between 81 and 153 weeks. The number of weeks that the railway dummy was significant declines from 192 weeks to just 18 weeks as additional dividend growth is included.

<< INSERT TABLE 4 >>

In Panel B of Table 4 the number of weeks that each variable was significant when explaining the dividend yield is reported. The next half-year of dividend growth was significant for between 283 and 349 weeks, depending on the number of future changes included, with the second half-year of dividend growth significant for between 173 and 233 weeks. Further dividend changes were significant for between 144 and 193 weeks. The number of weeks that the railway dummy was significant declines from 148 weeks to between 11 and 12 weeks, when three or four future dividend changes were included.

Tables 5 and 6 analyse the number of weeks that the railway dummy was significant, by year, and considers whether the dummy implied that railways were overpriced or underpriced, given that the other variables had been controlled for. In Table 5, analysing the share price/par ratio regressions, the railways were defined as overpriced in a particular week if the railway dummy was significantly greater than zero during that particular week, and underpriced if the railway dummy was significantly less than zero during that week. The total weeks of overpricing and underpricing for each year were then calculated.

<< INSERT TABLES 5 AND 6 >>

When zero years of dividend growth are included, the railways appear to have been overpriced on 31 weeks of the sample, but when between three and six half-years of dividend growth are included this apparent overpricing is entirely eliminated. A period of underpricing remains, but this is relatively small in size and an unreported analysis suggests it would be completely eliminated if the extent of dividend declines after 1847 had been just one percentage point more than actually occurred. The graphical analysis in Panel B of Figure 6 shows that when four half-years of dividend growth are accounted for, the coefficient of the railway dummy remains close to zero throughout the period, and is never significantly greater than zero.

Using the second approach, of analysing differences in dividend yields, the railways were estimated to be overpriced during a particular week when the railway dummy was significantly less than zero, and underpriced when the dividend yield of the railways was significantly higher than the non-railways. Results are shown in Table 6 for the number of weeks of overpricing and underpricing when varying numbers of half-years of dividend growth was accounted for.

When no future dividend growth was accounted for, the railways appear to have been significantly overpriced for 110 weeks, but this is reduced to zero weeks when four half-years of dividend growth are accounted for. There is a small amount of underpricing remaining near the end of the sample, but this would also have been entirely eliminated if dividends had fallen by an additional one percentage point after 1847. Panel B of Figure 7 shows that when the next four half-years of dividend growth are considered, the coefficient of the railway dummy remains very close to zero throughout the boom in prices, and is only significantly different from zero for a brief period during the downturn.

8 Robustness

To ensure robustness, additional variations of the analysis have also been considered, although not tabulated separately. The share price/par regressions have been repeated with the inclusion of the three non-railway outliers which had extremely high dividend/par ratios. The key results remain the same, with the dividend variable significant during every week, and the railway dummy suggesting that the railways were not significantly overpriced in any week during the sample. The main difference is that the coefficients and standard errors are slightly more volatile over time, reflecting the impact that small changes in these outliers had.

Due to the possibility of errors-in-variables in the estimation of beta, the analysis has been repeated without this variable. In both the share price/par and the dividend yield regressions the key finding of zero weeks of overpricing remains when four periods of dividend growth are controlled for. An analysis was also carried out excluding four railways where allegations of fraud were made in the aftermath of the Mania. The results continue to suggest no overpricing for the share price/par regressions throughout the period. The dividend yield regressions continue to suggest no overpricing during the boom, but there may have been five weeks of overpricing during 1849, when the allegations of fraud were revealed.

When the dividend growth variables are expressed in terms of annual growth, rather than the semi-annual growth discussed above, the results when two years of growth are included suggest between 0 and 2 weeks of overpricing depending on the functional form. When the dividend growth during the next two years is expressed as a single variable the results suggest between 0 and 3 weeks of overpricing depending on the functional form.

When a large number of dividend growth variables are included there is a suggestion that the apparent overpricing of the railways begins to re-appear. For example, with five years of dividend growth expressed in semi-annual variables, there appears to between 9 and 17 weeks of overpricing depending on the functional form used. This may indicate that investors were able to successfully forecast short-term dividend changes, but did not expect the longer-term changes which occurred. This is consistent with the finding that the peak in prices occurred about two years before the peak in dividends.

9 Conclusion

This paper, which has examined the sustained rise and fall in stock prices during the British Railway Mania, has an important implication for the current debate on 'bubbles'. It suggests that even on occasions where there is a sustained increase in asset prices it may be that investors are acting rationally, as these high prices may reflect growth in fundamentals. A subsequent fall in asset prices may be caused by a previously unexpected decline in fundamentals.

Using a comprehensive dataset of share prices and dividends for established railways and non-railways, this paper has found that dividends remained extremely important to the valuation of shares throughout the period 1843 to 1850, which included the Railway Mania and the subsequent downturn. The cross-sectional variation in dividends had a positive and significant relationship with the cross-sectional variation in share prices in every week during this period. There was also a highly significant relationship between current prices and future dividend growth, suggesting that investors incorporated short-term future changes in dividends into their valuations.

When only the current dividend rate and risk factors were controlled for, the railways appear to have been overpriced for a considerable period during the boom, with estimates ranging from between 31 to 110 weeks depending on the functional form used in the estimation. However, when short-term future changes in dividends are included the apparent overpricing is entirely eliminated. This suggests that, given their fundamentals, railways were priced consistently with non-railways during this period, which could be interpreted to mean that the Railway Mania was not a bubble in the economic sense.

The importance of fundamentals during this episode illustrates that it may be inappropriate to suggest that asset price reversals can be attributed to irrationality, and highlights the difficulties of dealing with such periods in a modern context. Bernanke (2002) has argued, that ‘to declare that a bubble exists, the Fed must not only be able to accurately estimate the unobservable fundamentals underlying equity valuations, it must have confidence that it can do so better than the financial professionals whose collective information is reflected in asset-market prices.' If investors continue to act rationally during an asset price boom, as they seemed to have continued to do during the British Railway Mania, then it may be unrealistic to expect regulators to be able to forecast and prevent financial instability ex-ante, when investors cannot.

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Table 1: Descriptive Statistics of Companies by Industry on Selected Dates

			Jan 6, 1843	Dec 29, 1843	Dec 27, 1844	Aug 8, 1845	Dec 26, 1845	Dec 25, 1846	Dec 31, 1847	Dec 29, 1848	Dec 28, 1849	Dec 27, 1850
Number of Companies	Established Railways	N	22	26	24	25	24	22	19	23	22	23
	Non-Railways	N	20	20	20	20	20	20	20	20	20	20
Price/Par ratio (P/Z)	Established Railways	Mean	0.90	1.15	1.40	1.70	1.56	1.30	0.95	0.77	0.57	0.68
		St. Dev.	0.57	0.63	0.59	0.56	0.47	0.34	0.30	0.30	0.33	0.40
		Max	2.10	2.40	2.58	2.80	2.40	1.94	1.48	1.49	1.40	1.67
		Min	0.26	0.40	0.46	0.68	0.56	0.50	0.29	0.16	0.04	0.12
	Non-Railways	Mean	2.05	2.24	2.32	2.28	2.02	1.93	1.79	1.64	1.96	2.03
		St. Dev.	1.97	2.36	2.26	2.20	1.74	1.72	1.73	1.60	2.43	2.46
		Max	8.00	10.00	10.00	10.00	8.00	8.00	8.00	8.00	12.00	12.00
		Min	0.84	0.84	0.84	0.88	0.68	0.53	0.40	0.43	0.63	0.66
Dividend/Par ratio (D/Z)	Established Railways	Mean	4.11%	3.81%	4.66%	5.23%	5.35%	5.57%	5.58%	5.33%	2.95%	2.27%
		St. Dev.	3.16%	3.27%	3.19%	3.35%	3.42%	3.38%	2.77%	2.30%	2.94%	1.91%
		Max	10.00%	10.00%	10.00%	10.00%	10.00%	12.10%	10.00%	10.00%	10.00%	7.00%
		Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Non-Railways	Mean	10.16%	10.33%	10.35%	10.15%	10.20%	9.75%	9.40%	9.35%	9.94%	9.64%
		St. Dev.	10.76%	10.67%	10.66%	10.74%	10.71%	9.92%	10.14%	10.17%	11.30%	10.80%
		Max	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%	40.00%	50.00%	50.00%
		Min	3.00%	4.00%	4.50%	4.00%	4.50%	5.00%	0.00%	0.00%	3.00%	4.00%
Dividend Yield (D/P)	Established Railways	Mean	4.74%	3.02%	3.17%	2.78%	3.14%	4.02%	5.57%	6.89%	4.28%	2.85%
		St. Dev.	3.14%	1.80%	1.53%	1.57%	1.76%	2.03%	1.99%	3.06%	3.89%	1.74%
		Max	11.92%	7.00%	4.83%	4.88%	5.26%	7.96%	8.86%	16.84%	14.04%	5.19%
		Min	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Non-Railways	Mean	4.81%	4.69%	4.43%	4.30%	4.84%	5.17%	4.94%	5.36%	5.17%	4.95%
		St. Dev.	1.02%	1.03%	1.18%	1.08%	1.66%	2.27%	1.87%	2.34%	1.88%	1.65%
		Max	7.11%	7.14%	7.27%	6.86%	8.89%	11.43%	10.00%	10.97%	10.81%	10.81%
		Min	2.08%	2.98%	2.70%	2.66%	2.78%	2.53%	0.00%	0.00%	2.96%	2.84%
Beta (B)	Established Railways	Mean	0.27	0.37	0.62	0.68	0.60	0.75	0.12	-0.15	0.00	-0.14
		St. Dev.	0.83	0.73	2.19	2.53	2.55	1.16	0.47	2.22	1.08	1.17
		Max	2.17	2.17	5.75	5.46	5.46	3.62	1.19	7.07	1.39	0.96
		Min	-1.27	-0.88	-3.87	-9.34	-9.34	-0.83	-0.99	-7.03	-3.77	-4.11
	Non-Railways	Mean	1.22	1.22	1.06	1.01	1.01	1.28	1.24	1.06	1.10	1.11
		St. Dev.	2.92	2.92	1.23	1.22	1.22	2.86	2.60	2.25	2.13	4.11
		Max	12.77	12.77	4.73	4.03	4.03	12.57	8.25	10.17	9.59	18.32
		Min	-0.14	-0.14	-0.32	-0.65	-0.65	-0.35	-0.89	-0.50	-0.02	-0.90
Size in £000s (S)	Established Railways	Mean	1,488.9	1,790.5	2,380.5	3,502.7	3,339.1	3,460.3	4,304.8	3,887.2	3,234.0	3,899.5
		St. Dev.	2,117.1	2,585.8	2,778.2	3,673.1	3,085.8	3,919.4	5,328.4	4,629.7	4,252.9	5,264.7
		Max	9,527.3	13,065.4	12,524.5	14,922.1	12,379.1	17,268.2	22,602.4	17,577.1	15,580.6	22,942.2
		Min	64.0	88.0	73.0	94.9	290.9	162.9	426.0	203.0	84.0	112.1
	Non-Railways	Mean	1,123.5	1,228.8	1,351.2	1,324.7	1,231.2	1,205.9	1,075.4	1,015.1	1,182.0	1,227.5
		St. Dev.	595.5	682.8	791.0	757.3	738.0	782.0	663.1	698.1	894.0	911.5
		Max	2,849.7	3,238.3	3,886.0	3,853.6	3,626.9	3,659.3	3,173.5	3,367.8	4,329.6	4,366.0
		Min	600.0	600.0	720.0	787.5	607.5	357.2	357.2	339.3	330.4	330.4

Table 2: Panel Cointegration Tests for Railways

	All tests $H_0: \tilde{a}_i = 1$ (implies no cointegration) **Within-dimension panel tests** $H_1: \tilde{a}_i = \tilde{a} < 1$ for all i **Between-dimension group tests** $H_1: \tilde{a}_i = \tilde{a}_i < 1$ for all i Where $\tilde{a}$ is the autorgressive coefficient.	
	Statistic	**P-value**
Unit Root Tests (Fisher Chi-Square ADF Tests)		
Levels		
P/Z	35.912	0.956
D/Z	37.207	0.939
$\Delta(D/Z)_{2Year}$	45.169	0.738
First Difference		
P/Z	2630.070	0.000
D/Z	2905.580	0.000
$\Delta(D/Z)_{2Year}$	2891.260	0.000
Cointegration: P/Z, D/Z		
Within-dimension Panel tests		
V	0.157	0.438
Rho	-0.426	0.335
PP	0.151	0.560
ADF	0.569	0.715
Between-dimension Group tests		
Rho	-1.345	0.089
PP	-0.501	0.308
ADF	0.228	0.590
Cointegration: P/Z, D/Z, $\Delta(D/Z)_{2Year}$		
Within-dimension Panel tests		
V	1.134	0.129
Rho	-3.869	0.000
PP	-2.096	0.018
ADF	-1.286	0.099
Between-dimension Group tests		
Rho	-3.365	0.000
PP	-2.436	0.007
ADF	-1.598	0.055
Number of Cross-Sections	26	
Number of Observations	6,648	

Notes: Unit root tests based on Fisher type ADF statistics (Maddala and Wu, 1999). Each unit root test has null hypothesis of a unit root. Cointegration tests based on Pedroni (1999, 2004). Each cointegration test has the null hypothesis of no cointegration H_0: $\tilde{a}_i=1$. Within-dimension panel tests have an alternative hypothesis H_1: $\tilde{a}_i=\tilde{a}<1$ for all i, presuming a common value for ã, the autoregressive coefficient. Between-dimension group tests have an alternative hypothesis H_1: $\tilde{a}_i=\tilde{a}_i<1$ for all i, which does not presume a common value for ã, the autoregressive coefficient. v-statistic is a nonparametric variance ratio statistic, rho-statistic is analogous to the Phillips and Perron rho statistic, PP statistic is analogous to the Phillips and Perron t statistic, ADF statistic is analogous to the Dickey-Fuller t-statistic. Individual intercept included in estimation. Automatic lag selection based on Schwarz Information Criterion.

Table 3: Cross-sectional Regressions on Selected Weeks
Panel A: Price/Paid

	Jan 6, 1843	Dec 29, 1843	Dec 27, 1844	Aug 8, 1845	Dec 26, 1845	Dec 25, 1846	Dec 31, 1847	Dec 29, 1848	Dec 28, 1849	Dec 27, 1850	Total No. of Weeks Sig.
D/Z	0.113***	0.153***	0.106***	0.120***	0.125***	0.056*	0.113***	0.116***	0.102***	0.208***	399
	(0.030)	(0.020)	(0.032)	(0.021)	(0.018)	(0.032)	(0.015)	(0.016)	(0.020)	(0.018)	
R	-0.181	0.153*	0.051	0.252**	0.211**	-0.075	-0.284***	-0.387***	-0.435***	0.156	192
	(0.107)	(0.088)	(0.094)	(0.101)	(0.102)	(0.108)	(0.091)	(0.090)	(0.120)	(0.096)	
B	0.021	0.072*	0.024	0.027	-0.053***	-0.051	-0.013	0.009	0.030	0.039***	118
	(0.033)	(0.042)	(0.032)	(0.027)	(0.017)	(0.093)	(0.021)	(0.015)	(0.032)	(0.007)	
S	0.065**	0.029*	0.043**	0.024	0.008	0.020	-0.000	0.007	0.009	-0.008	78
	(0.025)	(0.017)	(0.017)	(0.018)	(0.015)	(0.015)	(0.009)	(0.009)	(0.008)	(0.006)	
Constant	0.518***	0.331**	0.732***	0.719***	0.681***	1.034***	0.603***	0.512***	0.679***	0.089	400
	(0.176)	(0.122)	(0.205)	(0.127)	(0.117)	(0.200)	(0.115)	(0.109)	(0.137)	(0.117)	
Obs.	39	43	41	42	41	39	36	40	39	40	16,770
R^2	0.643	0.683	0.446	0.617	0.594	0.329	0.659	0.663	0.739	0.871	0.598

Notes: A regression estimating Equation 1 is reported for selected weeks of the sample. Robust standard errors in parentheses. Significance given by *** p<0.01, ** p<0.05, * p<0.1. The total number of weeks that a variable is significant is shown in final column. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 R_i + \beta_3 B_i + \beta_4 S_{i,t} + \varepsilon \quad (1)$$

Panel B: Dividend Yield

	Jan 6, 1843	Dec 29, 1843	Dec 27, 1844	Aug 8, 1845	Dec 26, 1845	Dec 25, 1846	Dec 31, 1847	Dec 29, 1848	Dec 28, 1849	Dec 27, 1850	Total No. of Weeks Sig.
R	0.011*	-0.012***	-0.009**	-0.011***	-0.012**	-0.006	0.004	0.017*	0.014	-0.014***	148
	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.010)	(0.011)	(0.005)	
B	-0.000	-0.001	0.000	0.001	0.005**	0.001	-0.000	-0.000	-0.002	-0.001*	49
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	
S	-0.002	0.000	0.001	0.001	0.000	0.001	0.001	-0.001	-0.002	0.000	18
	(0.002)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	
Constant	0.051***	0.047***	0.043***	0.041***	0.043***	0.050***	0.051***	0.057***	0.056***	0.050***	417
	(0.004)	(0.003)	(0.004)	(0.002)	(0.003)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	
Obs.	38	42	41	41	40	39	37	41	35	38	16,501
R^2	0.116	0.214	0.139	0.219	0.324	0.040	0.089	0.106	0.111	0.227	0.057

Notes: A regression estimating Equation 2 is reported for selected weeks of the sample. Robust standard errors in parentheses. Significance given by *** p<0.01, ** p<0.05, * p<0.1. The total number of weeks that a variable is significant is shown in final column. P=Share Price, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 R_i + \beta_2 B_i + \beta_3 S_{i,t} + \varepsilon \quad (2)$$

Table 4: Number of Weeks during which Variables are Significant from Cross-Sectional Regressions

Panel A: Price/Paid

D	399	417	417	417	417	417	417
R	192	188	147	87	49	31	18
B	118	103	115	147	137	116	105
S	78	67	48	34	15	21	19
Δ(D/Z) t+1		250	312	290	283	271	296
Δ(D/Z) t+2			136	192	195	210	171
Δ(D/Z) t+3				113	117	140	153
Δ(D/Z) t+4					87	114	116
Δ(D/Z) t+5						86	127
Δ(D/Z) t+6							81
Cons.	400	383	324	277	217	137	95
Ave. Obs.	40.2	39.0	38.0	37.3	36.9	36.5	36.3
Obs.	16,770	16,258	15,830	15,571	15,374	15,219	15,133
Ave. Adj R^2	0.598	0.666	0.707	0.732	0.739	0.745	0.755

Notes: A regression estimating Equation 3 was calculated for each week of the sample, with varying numbers of half-years of dividend growth included. The total number of weeks that a variable is significant is shown for each specification. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 E_t\left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}}\right) + \beta_3 R_i + \beta_4 B_i + \beta_5 S_{i,t} + \varepsilon \quad (3)$$

Panel B: Dividend Yield

R	148	86	38	12	11	38	44
B	49	73	59	53	53	54	46
S	18	18	7	11	21	24	43
Δ(D/Z) t+1		283	318	335	349	341	333
Δ(D/Z) t+2			176	233	229	212	173
Δ(D/Z) t+3				150	193	167	162
Δ(D/Z) t+4					176	198	166
Δ(D/Z) t+5						204	220
Δ(D/Z) t+6							144
Cons.	417	417	417	417	417	417	417
Ave. Obs.	39.6	38.4	37.4	36.8	36.4	36.1	35.8
Obs.	16,501	16,002	15,586	15,356	15,193	15,038	14,932
Ave. Adj R^2	0.057	0.229	0.334	0.400	0.448	0.500	0.530

Notes: A regression estimating Equation 4 was calculated for each week of the sample, with varying numbers of half-years of dividend growth included. The total number of weeks that a variable is significant is shown for each specification. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

For week = t

$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 E_t\left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}}\right) + \beta_2 R_i + \beta_3 B_i + \beta_4 S_{i,t} + \varepsilon \quad (4)$$

Table 5: Estimates of the Number of Weeks of Over and Under Pricing of Railway Shares between 1843 and 1850 using Railway Dummy from Share Price/Par vs Dividend/Par regressions

No. of future changes in dividends included	Overpriced or Underpriced	1843	1844	1845	1846	1847	1848	1849	1850	Total	Relative to n=0	Total (% of sample)	Relative to n=0 (% of sample)
n = 0	Overpriced	0	6	20	5	0	0	0	0	31	-	7.4%	-
	Underpriced	0	0	0	0	22	52	52	35	161	-	38.6%	-
n = 1	Overpriced	0	8	12	5	0	0	0	0	25	-6	6.0%	-1.4%
	Underpriced	0	0	0	0	40	52	52	19	163	2	39.1%	0.5%
n = 2	Overpriced	0	5	8	0	0	0	0	0	13	-18	3.1%	-4.3%
	Underpriced	0	0	0	0	38	46	36	14	134	-27	32.1%	-6.5%
n = 3	Overpriced	0	0	0	0	0	0	0	0	0	-31	0.0%	-7.4%
	Underpriced	0	0	0	0	16	41	9	21	87	-74	20.9%	-17.7%
n = 4	Overpriced	0	0	0	0	0	0	0	0	0	-31	0.0%	-7.4%
	Underpriced	4	0	0	0	0	24	1	20	49	-112	11.8%	-26.9%
n = 5	Overpriced	0	0	0	0	0	0	0	0	0	-31	0.0%	-7.4%
	Underpriced	4	2	0	0	0	0	0	25	31	-130	7.4%	-31.2%
n = 6	Overpriced	0	0	0	0	0	0	0	0	0	-31	0.0%	-7.4%
	Underpriced	0	0	0	0	0	0	0	18	18	-143	4.3%	-34.3%

Notes: A regression estimating Equation 3 is calculated for each week of the sample. The railways were defined as overpriced in a particular week if the railway dummy (β_3) was significantly greater than zero during that particular week, as this suggested the railways had a significantly higher share price/par ratio than non-railways, given their current and future dividends, during that week. Conversely, they were defined as underpriced in a particular week if the railway dummy was significantly less than zero during that week. The total weeks of overpricing and underpricing for each year were then calculated. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

For week = t (3)

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 E_t\left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}}\right) + \beta_3 R_i + \beta_4 B_i + \beta_5 S_{i,t} + \varepsilon$$

Table 6: Estimates of the Number of Weeks of Over and Under Pricing of Railway Shares between 1843 and 1850 using Railway Dummy from Dividend Yield regressions

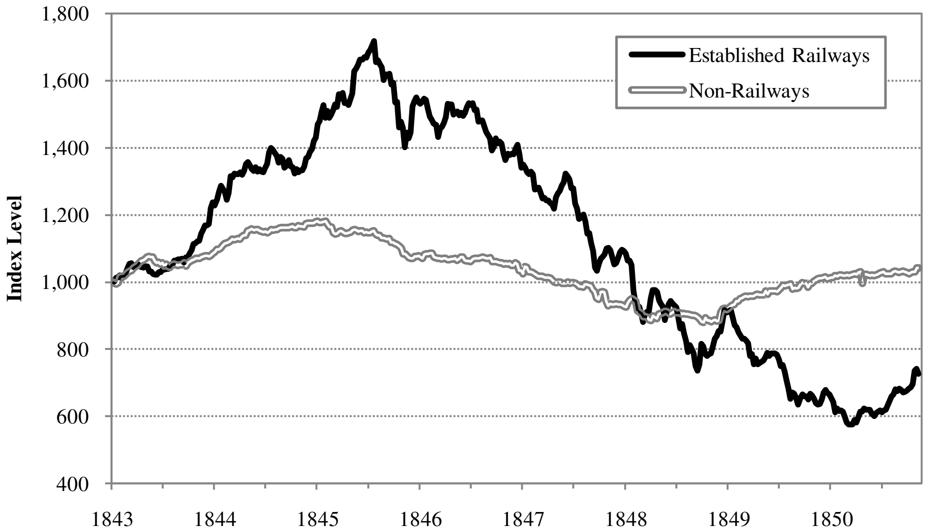
No. of future changes in dividends included	Overpriced or Underpriced	1843	1844	1845	1846	1847	1848	1849	1850	Total	Relative to n=0	Total (% of sample)	Relative to n=0 (% of sample)
n = 0	Overpriced	2	38	51	12	0	0	0	7	110	-	26.4%	-
	Underpriced	0	0	0	0	0	27	0	11	38	-	9.1%	-
n = 1	Overpriced	0	24	33	12	0	0	0	0	69	-41	16.5%	-9.8%
	Underpriced	0	0	0	0	0	17	0	0	17	-21	4.1%	-5.0%
n = 2	Overpriced	0	4	27	0	0	0	0	1	32	-78	7.7%	-18.7%
	Underpriced	0	0	0	0	0	6	0	0	6	-32	1.4%	-7.7%
n = 3	Overpriced	0	0	1	0	0	0	6	0	7	-103	1.7%	-24.7%
	Underpriced	0	0	0	0	0	5	0	0	5	-33	1.2%	-7.9%
n = 4	Overpriced	0	0	0	0	0	0	0	0	0	-110	0.0%	-26.4%
	Underpriced	1	0	0	0	0	2	3	5	11	-27	2.6%	-6.5%
n = 5	Overpriced	0	0	2	0	0	0	0	0	2	-108	0.5%	-25.9%
	Underpriced	7	1	0	0	0	5	16	7	36	-2	8.6%	-0.5%
n = 6	Overpriced	0	0	5	2	0	0	0	0	7	-103	1.7%	-24.7%
	Underpriced	7	0	0	0	0	11	12	7	37	-1	8.9%	-0.2%

Notes: A regression estimating Equation 4 is calculated for each week of the sample. The railways are estimated to be overpriced during a particular week when the railway dummy (β_2) is significantly less than zero, as this implies that railways had a significantly lower dividend yield than non-railways during that week, when future dividend growth is controlled for. Conversely they are estimated to be underpriced when the coefficient of the railways dummy was significantly higher than zero. The total weeks of overpricing and underpricing for each year were then calculated. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

For week = t

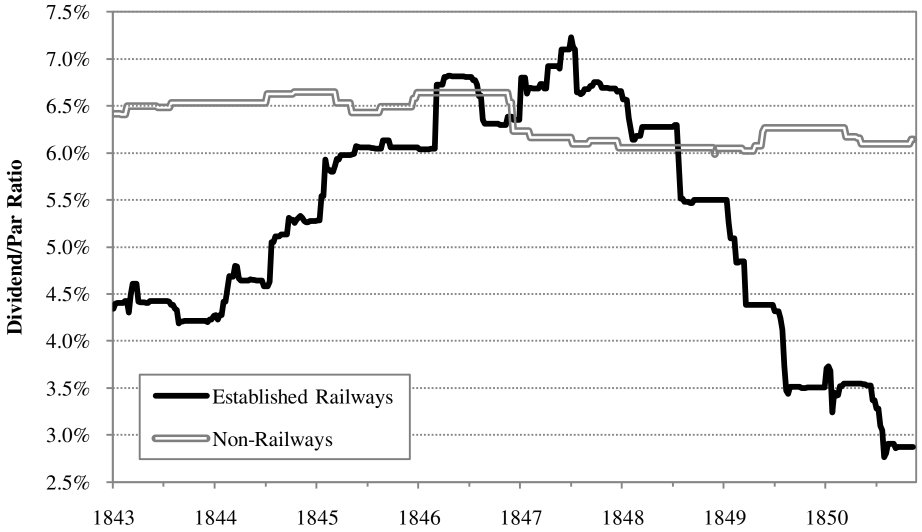
$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 E_t\left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}}\right) + \beta_2 R_i + \beta_3 B_i + \beta_4 S_{i,t} + \varepsilon \quad (4)$$

Figure 1: Capital Gains Indices for Established Railways and Non-Railways, 1843-50



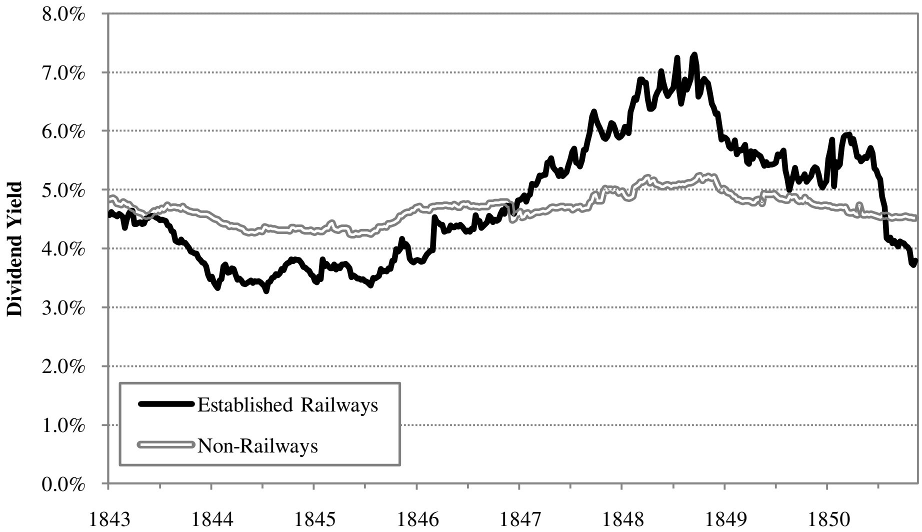
Notes: Source data for railway share prices from Railway Times (1843-50), and for non-railway share prices from Course of the Exchange (1843-50). Established railways index includes those railways which were operating before January 1843 for which share price and dividend data is available. Non-railways index includes the twenty largest non-railways by market capitalisation for which share price and dividend data is available. Capital gains for each company weighted by market capitalisation to produce market indices on a weekly basis.

Figure 2: Industry Dividend/Par Ratio Amongst Established Railways and Non-Railways, 1843-50



Notes: Source data for both railway and non-railway dividends from Course of the Exchange (1843-50). Par value data for railways obtained from Railway Times (1843-50), and for non-railways from Course of the Exchange (1843-50). Railway industry dividend/par ratio calculated as total dividends paid by established railway companies as a percentage of total par value of established railway companies for which share price and dividend data is available. Non-railway industry dividend/par ratio calculated as total dividends paid by non-railway companies as a percentage of total par value of non-railway companies for which share price and dividend data is available.

Figure 3: Industry Dividend Yield of Established Railways and Non-Railways, 1843-50



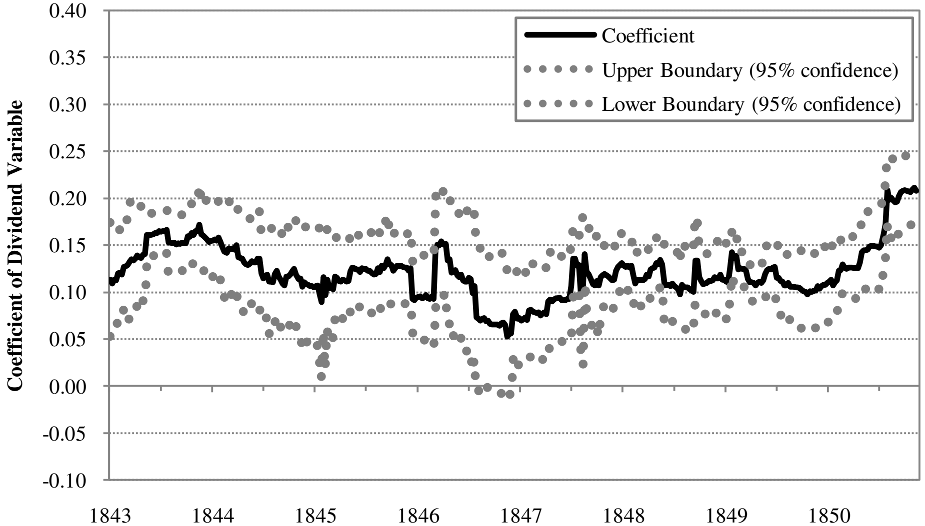
Notes: Source data for both railway and non-railway dividends from Course of the Exchange (1843-50). Share price data for railways obtained from Railway Times (1843-50), and for non-railways from Course of the Exchange (1843-50). Railway industry dividend/price ratio calculated as total dividends paid by established railway companies as a percentage of total market capitalisation of established railway companies for which share price and dividend data is available. Non-railway industry dividend/price ratio calculated as total dividends paid by non-railway companies as a percentage of total market capitalisation of non-railway companies for which share price and dividend data is available.

Figure 4: Total Return Indices for Established Railways and Non-Railways, 1843-50

Notes: Source data for both railway and non-railway dividends from Course of the Exchange (1843-50). Share price data for railways obtained from Railway Times (1843-50), and for non-railways from Course of the Exchange (1843-50). Half-yearly dividend assumed to be made in equal payments in each week. Total return, as measured by the sum of capital gains and dividends, for each company weighted by market capitalisation to produce market indices. Established railways index includes those railways which were operating before January 1843 for which share price and dividend data is available. Non-railways index includes the twenty largest non-railways by market capitalisation for which share price and dividend data is available.

Figure 5: Impact of Dividend Variable on Share Price Premium from Repeated Weekly Cross-sectional Regressions, 1843-50

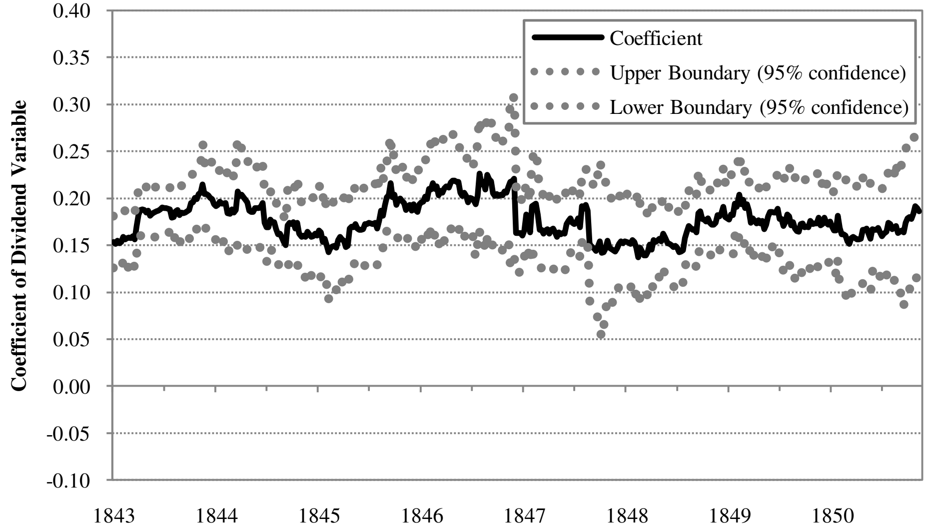
Panel A: Controlling for Beta, Size and Railway Dummy



Notes: A regression estimating Equation 1 is calculated for each week of the sample. Value of the coefficient represents the value of β_1 from Equation 1 in any given week, with a 95 per cent confidence interval constructed using robust standard errors. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.
For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 R_i + \beta_3 B_i + \beta_4 S_{i,t} + \varepsilon \quad (1)$$

Panel B: Controlling for Beta, Size, Railway Dummy and Two Years of Dividend Growth

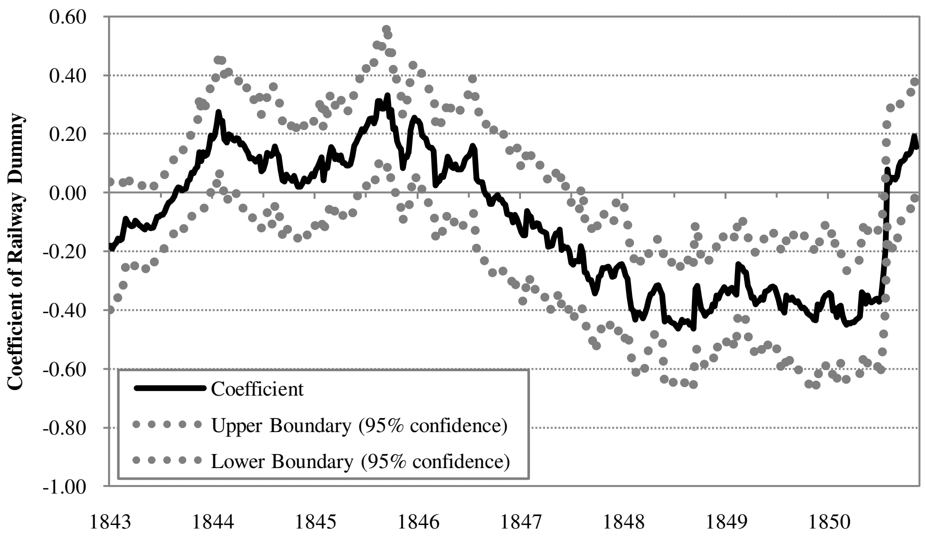


Notes: A regression estimating Equation 3 is calculated for each week of the sample. Value of the coefficient represents the value of β_1 from Equation 3 in any given week, with a 95 per cent confidence interval constructed using robust standard errors. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.
For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 E_t \left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}} \right) + \beta_3 R_i + \beta_4 B_i + \beta_5 S_{i,t} + \varepsilon \quad (3)$$

Figure 6: Impact of Railway Dummy on Share Price Premium from Repeated Weekly Cross-sectional Regressions, 1843-50

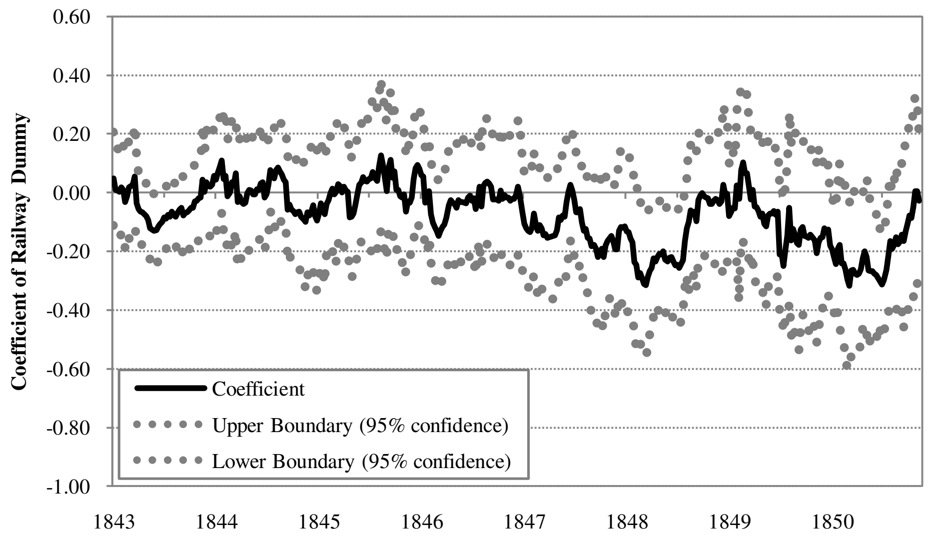
Panel A: Controlling for Current Dividend, Beta and Size



Notes: A regression estimating Equation 1 is calculated for each week of the sample. Value of the coefficient represents the value of β_2 from Equation 1 in any given week, with a 95 per cent confidence interval constructed using robust standard errors. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.
For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 R_i + \beta_3 B_i + \beta_4 S_{i,t} + \varepsilon \qquad (1)$$

Panel B: Controlling for Current Dividend, Two Years of Dividend Growth, Beta and Size

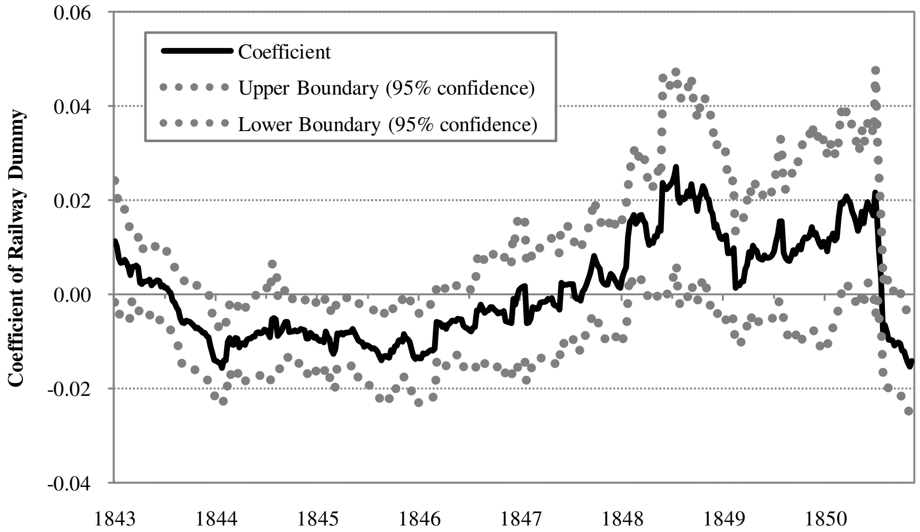


Notes: A regression estimating Equation 3 is calculated for each week of the sample. Value of the coefficient represents the value of β_3 from Equation 3 in any given week, with a 95 per cent confidence interval constructed using robust standard errors. P=Share Price, Z=Par Value, D=Dividend, R=Railway Dummy, B=Beta, S=Size.
For week = t

$$\frac{P_{i,t}}{Z_{i,t}} = \beta_0 + \beta_1 \frac{D_{i,t}}{Z_{i,t}} + \beta_2 E_t \left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}} \right) + \beta_3 R_i + \beta_4 B_i + \beta_5 S_{i,t} + \varepsilon \qquad (3)$$

Figure 7: Impact of Railway Dummy on Dividend Yield from Repeated Weekly Cross-sectional Regressions, 1843-50

Panel A: Controlling for Beta and Size

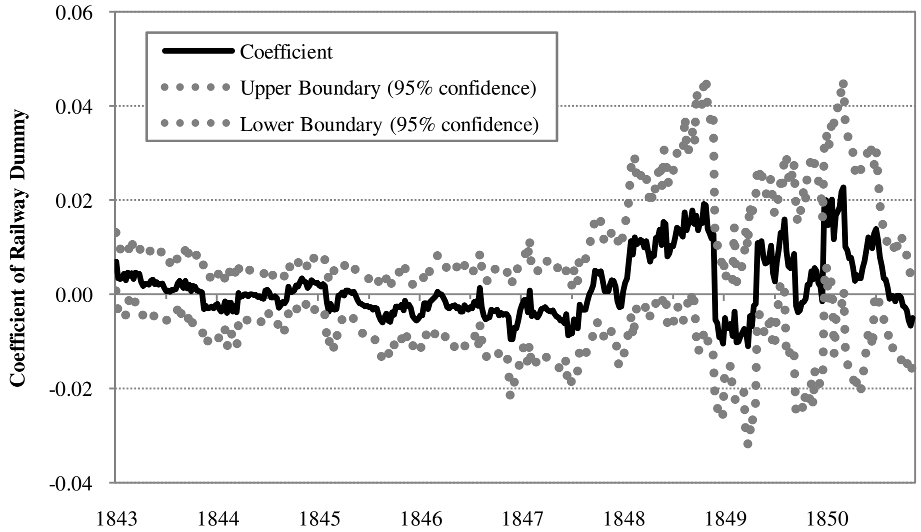


Notes: A regression estimating Equation 2 is calculated for each week of the sample. Value of the coefficient represents the value of β_1 from Equation 2 in any given week, with a 95 per cent confidence interval constructed using robust standard errors. P=Share Price, D=Dividend, R=Railway Dummy, B=Beta, S=Size.

For week = t

$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 R_i + \beta_2 B_i + \beta_3 S_{i,t} + \varepsilon \quad (2)$$

Panel B: Controlling for Two Years of Dividend Growth, Beta and Size

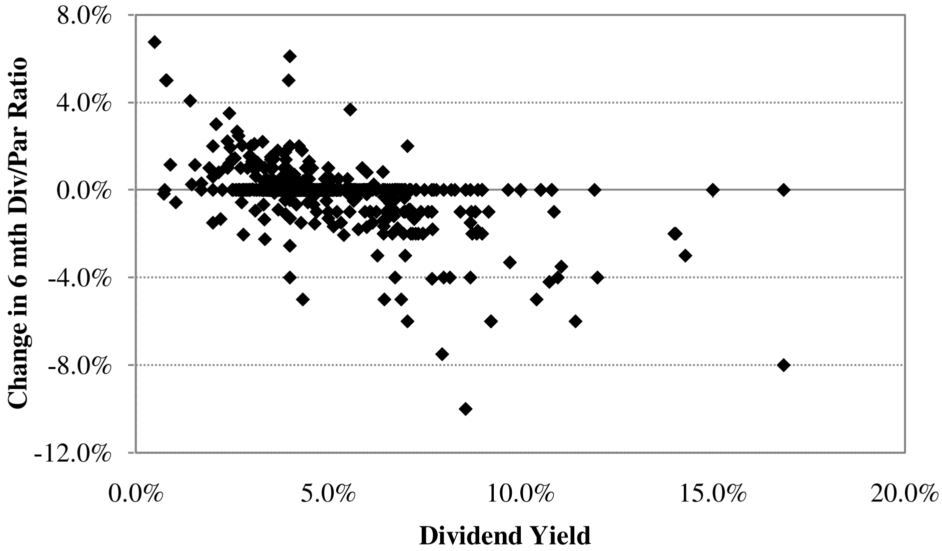


Notes: A regression estimating Equation 4 is calculated for each week of the sample. Value of the coefficient represents the value of β_2 from Equation 4 in any given week, with a 95 per cent confidence interval constructed using robust standard errors. P=Share Price, D=Dividend, Z=Par Value, R=Railway Dummy, B=Beta, S=Size.

For week = t

$$\frac{D_{i,t}}{P_{i,t}} = \beta_0 + \beta_1 E_t\left(\Delta \frac{D_{i,t+n}}{Z_{i,t+n}}\right) + \beta_2 R_i + \beta_3 B_i + \beta_4 S_{i,t} + \varepsilon \quad (4)$$

Figure 8: Correlation between Dividend Yield and Dividend Growth during the Next Six Months, using One Observation per Company Every Sixth Months



Notes: Correlation coefficient = -0.491. Source data for both railway and non-railway dividends from Course of the Exchange (1843-50). Share price data for railways obtained from Railway Times (1843-50), and for non-railways from Course of the Exchange (1843-50). One observation shown per company at end of June and end of December in each year between 1843 and 1850. Dividend Yield calculated as Dividend Per Share/Share Price. Change in 6 month Dividend/Par ratio calculated as difference between Dividend/Par ratio at time t and time t+6 months.