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Bubbles and Leverage

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Bubbles and Leverage

This paper analyses the relationship between leverage and asset price 'bubbles'. During an important historical bubble there was a substantial expansion in the number of railways promoted, most of which were financed by shares which could be purchased on an instalment basis. An analysis of a new and comprehensive dataset suggests that these assets can be modelled as futures or options, implying that investors were purchasing highly leveraged derivatives. The leverage embedded in these assets amplified returns and made it possible to obtain exposure to an asset for a small deposit. However, during the downturn negative returns were also magnified and investors had difficulties paying further instalments. Although leverage may have initially increased demand for these assets, they did not become overpriced, possibly due to a substantial increase in their supply.

JEL codes: G01, G11, G12, N23

The prominent role of mortgages and derivatives in the recent 'Housing Bubble' has led to the suggestion that there may be some relationship between asset price 'bubbles' and the use of leverage. For example, Geithner (2010) has remarked that prior to the Credit Crunch 'we let leverage build up on a massive scale.' This paper analyses the effects of leverage by examining an historical period known as the British Railway Mania.

During this period the prices of railway shares increased dramatically, but the market then crashed and share prices fell considerably. The boom was associated with a substantial increase in the promotion of new railway companies, with at least 1,000 new railway lines being projected at this time. Most of these new companies issued shares with uncalled capital, which meant that investors could acquire the asset by paying a small initial deposit, and by agreeing to make a series of regular payments in the future.

To enable a comprehensive analysis of this episode, which the *Economist* (2008) has described as 'arguably the greatest bubble in history', a new dataset, consisting of daily share prices for all railway securities listed on the London Stock Exchange between 1843 and 1850, has been collected from original newspaper tables. The analysis in this paper begins with a cointegration analysis relating fully-paid shares and partially-paid instalment plan shares, which suggests that there was a spot-future relationship between these assets, implying that the partially-paid shares could be modelled as futures. There is also some evidence of partially-paid shares being treated as call options, with a significantly higher default rate on payments when the price of a share was below the implied exercise price. If partially-paid shares were analogous to derivatives, then it implies that the leverage which results from the use of derivatives was available to investors during the Railway Mania.

An important consequence of leverage was to amplify the returns which investors experienced. An analysis of first-day returns suggests that subscribers to the IPOs of new

railway companies, on average, could have doubled their investment if they sold their shares on the first-day that they were listed on the market. Throughout the boom the market price of railway shares was, on average, more than double the amount that investors had paid up in capital. However, this was largely due to the structure of the assets which gave investors exposure to price changes for only a small deposit. If investors had been required to pay the full cost of the asset immediately, their returns would have been fairly modest. The structure of the assets meant that during the downturn the losses experienced were also magnified.

Another feature of leverage was to affect the timing with which investors had to make their payments. During the boom shareholders had to initially deposit an average of less than 10 per cent of their total liability. At the market peak almost two hundred new railways were listed on the stock market, but enough capital had been deposited to fully finance less than twenty of these companies. During the construction phase there were a large number of calls for capital, which meant that investors had to make further payments to the companies. This resulted in deleveraging, and there is evidence of substantial price declines in the weeks when these calls were made.

The potential for higher returns, and the ability to pay for assets on an instalment plan, may have increased the demand for highly leveraged assets. This would tend to increase the price of partially-paid shares relative to other assets. However, the increased risk, and the considerable increase in the supply of assets, may have meant that the equilibrium price was not particularly high. A comparison between the prices of the highly leveraged shares of the new railways, and a sample of non-railways, suggests that the new railways were not overpriced.

This analysis contributes to our understanding of the link between asset price reversals and leverage. It suggests that leverage may not necessarily affect the prices of assets, but it may

have an impact on the financial position of investors. Leverage may be employed during the boom, as it amplifies positive returns and reduces the amount of capital which must be deposited, but it could produce difficulties during a downturn, by magnifying negative returns and enforcing deleveraging when payments are required.

This paper adds to other research into the relationship between leverage and asset price reversals, such as that of Kindleberger (2000, p.14) who has suggested that a boom can be fed by an expansion of bank credit. Allen and Gale (2001) have argued that using borrowed money to invest in risky assets is relatively attractive because it is possible to avoid losses by defaulting on the loan, which leads to investors bidding up asset prices. Bernanke and Gertler (2001) have discussed how an initial increase in asset prices can improve the collateral of investors, which increases borrowing, which can increase demand and prices further. Aoki et al. (2002) have examined the links between house prices, collateral and borrowing in the United Kingdom. Detken and Smets (2004) have found that real credit and money growth have been relatively strong before and during booms in 18 countries since the 1970s.

This paper is organised as follows. The next two sections give a brief overview of the Railway Mania, and of the data which has been used. The third section considers whether partially-paid shares can be viewed as futures or options. The fourth section discusses the relationship between leverage and returns, the fifth section considers the impact of leverage on the timing of payments, the sixth section considers the effect on pricing, with the final section being a brief conclusion.

1 Expansion during the British Railway Mania

The first modern railway, the Liverpool and Manchester, was promoted in 1824 and opened in 1830. Within the next decade about sixty other railways obtained Parliamentary authorisation, with most of these projects being promoted in a minor boom during 1836 and

1837. Whilst the economy was weak, and these railways were being constructed, share prices remained low and the promotion of new lines was subdued. However, between 1843 and August 1845, railway share prices rose rapidly in a period which has become known as the Railway Mania. Figure 1 shows several market indices, constructed by Campbell and Turner (2010), which illustrate a pronounced rise in prices amongst all railway companies, and in the subset of railway companies which had already been established before the Mania began.

<< INSERT FIGURE 1 >>

Several suggestions have been offered for the cause of the price changes which were experienced at this time. Bryer (1991) has argued that the Mania could have been an attempt to 'swindle' investors, but this view has been challenged by McCartney and Arnold (2003). Odlyzko (2010) has suggested that 'collective hallucinations' were responsible for the Mania, whilst Campbell (2010) has argued that changes in the dividends paid by the established railways were the main cause of the price changes which occurred during this period. Despite this research, there has been little detail provided on the new companies promoted at this time, or on the assets which they issued.

As with some other periods of rapid asset price growth, such as the South Sea Bubble of 1720, the boom of 1825, and the Dot-Com Bubble of the 1990s, there was a substantial increase in the promotion of new companies during the Railway Mania. The number of railway securities listed on the London Stock Exchange underestimates the extent of promotion, as only a small proportion ever achieved a listing, but the number of listed securities follows the pattern in prices with a lag, as shown in Figure 2.

<< INSERT FIGURE 2 >>

Most of the new schemes issued partially-paid shares with uncalled capital, which meant that investors paid a small deposit and would then make future payments when the process of construction required it. Shares issued during the Railway Mania, and throughout much of the eighteenth and nineteenth century, were quoted with a nominal value, a par value and the market price. The nominal value of the share was the total amount that original shareholders were initially liable to pay to the company. The par value of the share was the amount that shareholders had already paid to the company.

The difference between the nominal and par value reflected uncalled capital, which was the amount that shareholders were still liable to pay to the company. Uncalled capital could be used in several ways, with banks and insurance companies generally retaining it as a reserve, but the railways tended to call it up in regular instalments to finance the construction of their lines. Figure 3 illustrates the rapid increase in nominal value during the boom in railway shares, compared to a more gradual rise in par value. This reflects the issuance of the new securities which had only a small proportion of capital initially paid up.

<< INSERT FIGURE 3 >>

Railway share prices peaked in August 1845, but fell by 18 per cent during the next three months, just as the promotion of new railway schemes reached unprecedented levels. Many of the railways promoted at the height of the boom never received Parliamentary authorisation, and others faced difficulties when they began to lay their line, but the extent of railway construction was still impressive. Estimates by Mitchell (1964) suggest that railway investment represented 5.7 per cent of GDP in 1846, 6.7 per cent in 1847, and 4.7 per cent in 1848. However, the magnitude of railway expansion proved to be unsustainable, with the size of investment being amongst a range of factors blamed by a Parliamentary Committee for the Commercial Crisis of 1847 (*Parliamentary Papers*, 1847-48, VIII, Pt. I, p.4). Concerns about

overexpansion led several of the leading railways to announce they would not proceed with much of the planned construction in October 1848 (*Economist*, November 4, 1848, p.1241). It was not until near the end of the decade that most of the remaining construction had been completed, and the new railways began to operate.

2 Data

Data on the number of shares in issue, the nominal value, the par value, and the market price of every railway security listed on the London Stock Exchange between 1843 and 1850 was obtained on a daily basis from the *Railway Times*, the leading railway newspaper during this period. Data from each table, containing an average of 242.1 securities for each of the 417 weeks in the sample, was computerised and each table was then merged to produce a comprehensive dataset. Due to the high number of listings and delistings the total number of securities included in the dataset is 868, representing 442 railway companies.

Preference shares (88 securities) and assets issued by railways outside Great Britain and Ireland (84 securities) were excluded. 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, the *Railway Shareholders' Manual* (Tuck, 1845) was used to obtain the missing details. There were 150 securities where data on either the number of shares or par value could not be ascertained.

Several additional variables were also included. The value of uncalled capital for each asset was calculated as the difference between the nominal value and the par value of that asset. Data on dividends, for the subset of companies which were also reported in the *Course of the Exchange* (a share list produced by a stockbroker) were also recorded. The risk-free rate was

approximated as the yield on Consols, government debt perpetuities, which was also obtained from the *Course of the Exchange*.

3 Embedded Leverage

The partially-paid shares issued during the Railway Mania were paid for in instalments. This meant that investors subscribed to the shares for a small deposit, and then paid a fixed amount at future dates. This feature makes them resemble future contracts, assuming that investors could not default on their payments, or option contracts, assuming that default was possible. One of the characteristics of these types of derivatives is the leverage which results from their structure. Investors effectively borrow the funds from the counterparty, and obtain exposure to the movements of the underlying asset by paying only a small initial amount. If partially-paid shares can be modelled as derivative-like assets, then it suggests that the leverage which results from these asset classes was available to investors during this period.

3.1 Partially-paid Shares as Futures

The relationship between fully-paid and partially-paid shares can be illustrated by a no arbitrage argument. Investors should receive the same return from purchasing a fully-paid up share, or from purchasing a partially-paid up share and paying the remaining liability. Assuming that investors could not default on their liability, a partially-paid share can be modelled as a future contract with a fixed payment in the future, and the fully-paid share can be regarded as the underlying security, as suggested by Dale et al. (2005). Equation 1 adapts the standard future pricing relationship, as stated by Hull (2003, p.50), to this situation and accounts for dividends which can be expressed as a percentage of the future payment.

$$S = f + Ke^{(-r+q)t} \tag{1}$$

where: S = Price of fully-paid share, f = Price of partially-paid share,

K = Size of future payment, r = Risk-free interest rate, q = Dividend rate

To illustrate the implications of uncalled capital on the market price of an asset an example will be used of the relationship between the fully-paid and partially-paid shares issued by the Great Western Railway (GWR), before a more comprehensive analysis of other companies. When only the market prices of the assets are compared, the difference in prices appears to change over time, as suggested in Panel A of Figure 4. However, a fairer comparison would be between the fully-paid 'GWR Half Shares' and the implied price of an equivalent fully-paid 'GWR Original Share'. This implied price can be estimated using Equation 1, by adjusting the price of the partially-paid 'GWR Original Share' to take account of uncalled capital. Once these adjustments have been made, for each day of the sample between 1843 and 1850, there appears to be a close relationship between the implied prices of the fully-paid shares, as shown in Panel B of Figure 4.

<< INSERT FIGURE 4 >>

It is possible to introduce a more systematic analysis, which can be used to examine a wider sample of companies, by testing for cointegration. By using the Engle-Granger 2-step approach (Engle and Granger, 1987) it is possible to test if the residual from a regression between two time series is stationary. This test for cointegration has been carried out for the pair of GWR assets discussed above, and then repeated for all other companies which had partially and fully paid shares listed simultaneously. To be included in the analysis a pair of assets had to be issued by the same company, have the same *pro rata* dividend rights, and both be listed on the stock market for at least one year, and be traded on average at least once per week. Any assets which delisted and were then relisted with a different nominal or par value were excluded. The size of the Augmented Dickey Fuller (ADF) statistic, and its significance, for each cointegration test is shown in Table 1.

<< INSERT TABLE 1 >>

The results suggest that when uncalled capital is accounted for, either as a separate variable or to produce a notional fully-paid share, there is evidence of cointegration for almost every pair of assets. This implies that investors were pricing partially-paid shares as if they were future contracts, which means that investors who purchased these assets were effectively purchasing assets with embedded leverage.

3.2 Partially-paid Shares as Options

The discussion has thus far assumed that the contract which subscribers entered into to pay future instalments was a binding obligation. However, Shea (2007b) has suggested that it may be better to treat these assets as options, as the holder may have had the right, but not the obligation, to pay a future amount and obtain a fully-paid share.

During the Railway Mania the legal framework for this issue was set down in the Companies' Clauses Consolidation Act (*Parliamentary Papers*, 1845, II, p.226-227). If a shareholder had failed to pay a call two months after it was due, the company could sue the shareholder and attempt to recover the amount due with interest, or the directors could declare the share forfeited. At least another two months had to pass before the declaration of forfeiture could be confirmed at a general meeting, which would allow the company to sell the forfeited shares.

By suing shareholders the company could hope to obtain the full amount due, but they would have to pay legal expenses. By forfeiting the share these expenses could be avoided, and the company could sell the share in the secondary market. During the construction of the early railways (pre-1843), the practice of forfeiting shares seems to have been preferred by at least some of the companies. For example, the Cheltenham and Great Western Railway had originally issued 7,500 shares, but by 1843 only 5,693 remained in issue, with the rest having been forfeited for non-payment of calls (MacDermot, 1964, p.83).

It should have been in the best interests of an investor to forfeit a share if the amount which the investor was required to pay was greater than the value of that share after that payment had been made. The default condition should therefore have been given by Equation 2.

$$S - K < 0 \qquad (2)$$

where: S = Price of asset after payment of instalment

K = Size of instalment

By analysing data on the arrears outstanding on the instalments due on the shares of various railway companies, taken from *Parliamentary Papers* (1848, LXIII, p.275-442), it is possible to estimate whether investors chose to forfeit a partially-paid share based on the criteria given in Equation 2. The arrears data states the amount that investors had paid on that instalment and the amount which was still outstanding in August 1848, when the data was collected. Alternative scenarios are considered which consider whether companies enforced forfeiture if payment was not made after either two months, four months, one year or two years. Table 2 shows how many times the default condition was met under the various scenarios.

<< INSERT TABLE 2 >>

The results for the timeframe of four months, one year and two years suggest that there was a significantly higher default rate when it was in the best interests of investors to default. Although it may be inappropriate to assume that partially-paid shares were pure call options, the difference in default rates depending on the default criteria suggests that some investors did treat them this way.

4 Amplifying Returns

The discussion in the previous section has suggested that there is evidence that the partially-paid shares listed during the Railway Mania were considered by investors as either futures or options. This implies that the leverage associated with derivatives was available to investors

during this period. This section will consider the impact that this leverage had on returns, initially examining first-day returns before considering returns throughout the period.

4.1 First-day Returns

Investors who subscribed to railway IPOs were asked to pay the par value of the share as a deposit. They would then be liable to pay calls up to the amount of the nominal value of the shares when the company requested it. An investor who subscribed to IPOs in the primary market and then sold those shares on the first-day that they traded on the secondary market would receive a return given by Equation 3. The abnormal return has been calculated by subtracting the return on that day from an index of all railway shares which has been constructed by Campbell and Turner (2010).

$$r_{partial} = \frac{P_{partial} - Z_{partial}}{Z_{partial}} \tag{3}$$

where: r = Return, P = Price, Z = Par Value

Table 3 shows that the size of the return which subscribers to new schemes could obtain during the boom was substantial, with a mean abnormal first-day return of 76.2 per cent in 1844, and 106.7 per cent in 1845. This is consistent with commentary during the period, such as the remark by the *Railway Investment Guide* (1845, p.10) 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'.

<< INSERT TABLE 3 >>

If investors had been required to pay the total cost of the asset immediately, rather than in instalments, their return would be given by Equation 4. The cost of the fully-paid share can

be implied by adjusting the par value to include the discounted sum of future calls. The price of the fully-paid share can be implied by adjusting the price of a partially-paid share according to the futures pricing relationship, if it is assumed default is not possible. For this analysis a discount rate of three per cent is used, which was close to the yield on Government Consols, but unreported analysis suggests that similar results are obtained when other rates are used.

$$r_{full} = \frac{P_{full} - \left[Z_{partial} + K_{partial}\, e^{(-r+q)t}\right]}{Z_{partial} + K_{partial}\, e^{(-r+q)t}} \tag{4}$$

where: r = Return, P = Price, Z = Par Value,

K = Size of future payment, r = Risk-free interest rate, q = Dividend rate

When considering the scenario that default was possible, the price of a fully-paid share can be implied by using an options pricing formula. Shea (2007a) has suggested modelling these assets as n-fold compound call options. To facilitate computation for such an extensive dataset, this paper considers them as 2-fold compound call options, and uses the closed form formula proposed by Geske (1979). This implies that investors were initially purchasing assets which gave them the right on the first exercise date to pay the first instalment K_1, and receive a call option which gave them the right on the second exercise date to pay the remaining liability, K_2, and receive the underlying asset. A volatility of 30 per cent has been used for this analysis, which is close to the median volatility of 28 per cent for fully-paid shares in the sample. Other volatilities have also been considered, although not reported, and produce similar results.

Table 3 shows that the average returns which would have been experienced if only fully-paid shares had been issued were just 5.5 per cent in 1844 and 7.1 per cent in 1845 if the partially-paid share was regarded as a future contract, or 5.0 per cent in 1844 and 3.4 per cent in 1845

if the partially-paid share was regarded as an option contract. The difference between the returns for partially-paid shares and fully-paid shares was substantial and significant during these years.

These results suggest that the first-day returns for underlying ordinary shares were not particularly high, but the return which was experienced was considerable because the full premium was embedded in an asset on which only a small deposit was required. The impact of uncalled capital was to magnify the first-day returns experienced by investors in new companies. Thus the dramatic returns which investors experienced at this time from investing in new companies were at least partially due to the effects of leverage.

4.2 Returns throughout Mania

To estimate the impact on shareholder returns throughout the Mania a similar analysis can be repeated for each day of the sample period. If an investor subscribed to all new railway IPOs, and then paid all subsequent calls when they were due, their cost at any particular time can be calculated as the sum of the par values of all new companies. The market capitalisation at any particular time reflected the price at which investors could sell their shares. Consequently, a simple measure for estimating the return to investors was the price/par ratio. A price/par ratio of 1 suggested that the current market price equalled the amount which had already been invested. A price/par ratio of 2 suggested that the original investors had made a 100 per cent return, whilst a price/par ratio of 0.5 suggested investors had lost 50 per cent of their original investment.

The average price/par ratios for the established railways and new railways were calculated for each day between 1844 and 1850, and are illustrated in Figure 5. The price/par ratio of the new companies reached a peak of 2.74, which meant that an investor who had subscribed to all the new companies would have earned a return of 174 per cent. The price for each

equivalent fully-paid share, when the partially-paid share is considered as a future contract, has been calculated for each day of the sample. Alternative scenarios for the discount rate have been employed, being -10 per cent, 0 per cent and +10 per cent. The implied price of each equivalent fully-paid share, when the partially-paid share is treated as an option contract, has been calculated using the approach of Geske (1979). To obtain a range of scenarios volatilities of 20 per cent, 30 per cent and 40 per cent were analysed. The implied total market capitalisation and the total par value for all of the new railways have been used to calculate the implied price/par ratio for the industry, for each day, which is shown in Figure 5.

<< INSERT FIGURE 5 >>

When partially-paid shares are treated as a future contract the average price/par ratio of the equivalent fully-paid shares of new railways reached a peak of between 1.12 and 1.18 depending on what assumptions are made about the discount rate. When partially-paid shares are treated as option contracts, a peak of between 0.98 and 1.11 was reached, depending on the assumptions regarding volatility. In each instance the results suggest that the returns which investors would have experienced from investing in fully-paid shares would have been relatively low, but due to the leveraged nature of the partially-paid shares the returns which they actually experienced were substantial.

5 Instalment Payments

The use of leveraged derivatives also affects when investors must provide payment. Rather than paying the full amount initially, the use of leverage makes it possible to obtain an asset for a small initial deposit. The ability to obtain exposure to the price movements of assets without having to immediately find the total capital required may have contributed to the number of new railways promoted at this time, and to the enthusiasm with which investors

subscribed to the new schemes. The *Economist* (April 5, 1845, p.310) noted that 'it is one of their peculiar characteristics but yet not less ultimately dangerous and deceptive on that account, that from the delay of procuring the act and getting it into operation the period when the main bulk of capital is required is remote from that when the greatest excitement and speculation exists, and no immediate check is therefore experienced by calls of capital.'

The substantial difference between the amount that investors were liable to pay (the nominal value), and the amount which they had paid so far (the par value), is reported in Table 4 for the end of each year. Only companies where the details of both the nominal and par values are available are included in the analysis.

<< INSERT TABLE 4 >>

It can be seen from Table 4 that the total nominal value of new railways at the end of 1844 was £39.6m, and at the end of 1845 was £158.0m. In contrast, the total par value of these new railways was just £3.7m in 1844, and £15.6m in 1845, which means that during the boom in prices and promotions investors had been asked to pay up less than 10 per cent of their total liability. This implies that although 44 new railway companies had been listed by the end of 1844, investors had only provided enough capital to fully finance 4.1 companies. By the end of 1845, when 186 new railway companies were listed, investors had provided enough capital to entirely finance just 18.5 companies.

When payments were eventually demanded, the resulting deleveraging may have contributed to a decline in prices. Investors were required to make regular and sizeable payments on their partially-paid shares during the construction phase, especially between 1846 and 1848, as shown in Figure 6.

<< INSERT FIGURE 6 >>

The Times (July 30, 1845, p.4) had issued warnings at the height of the Mania about the extent and impact of future calls for capital. They said 'soon or late the day will come when an untold proportion of this year's scripholders will be doubly pressed, no longer able to suffer the sums they have already paid to remain buried in the earthworks of an unfinished line, much less to pay up the quick recurring calls of the company'. The *Economist* (October 21, 1848, p.1187) noted 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. There was constantly an increasing number of sellers, and a constantly diminishing number of buyers.' This led to the result that 'lines in course of construction in place of increasing in price as more and more capital became invested in them, have after each new call fallen about as much as they should have risen.'

To estimate the impact which these calls for capital had on prices, 971 changes in capital were analysed as shown in Table 5. When a company issued a call, its return during that week was calculated, with the abnormal return being calculated as the company return minus the return on an index of all railway shares which has been constructed by Campbell and Turner (2010). If an asset was not traded in the week during which the call was made the calculation was carried out for the week that it was next traded.

<< INSERT TABLE 5 >>

An analysis of all 971 calls for capital between 1843 and 1850 suggests that a share had an average abnormal return of -9.7 per cent in the week that a call was made on it, as shown in Table 5. The most likely reason for the falls in prices was investors selling some shares to pay the instalments on others. If a three week period is analysed, there was an average abnormal return of -8.4 per cent, and if a five week period is considered, there was an average abnormal

return of -4.7 per cent. The results from these longer windows suggest that part of the decline was temporary, reflecting the short-term difficulties which investors had in meeting the demand for further payments. Nevertheless, there is still evidence of substantial declines which, combined with the number of calls which were made, would suggest that this exercised a considerable downward pressure on prices during this period. This implies that the process of deleveraging contributed to the decline in prices during the downturn.

6 Impact on Pricing

It is possible that leverage may initially increase the demand for an asset by raising expected returns, and by providing easier payment terms. This would suggest that the price of the asset could be higher than it would have been if leverage was not available. However, this increase in demand may be at least partially offset by the increased risk of the asset. It is also possible that an increase in the price of assets could be followed by an increase in the supply of assets, reducing the equilibrium price. The net impact of leverage on the price of an asset is thus ambiguous.

The impact of leverage on pricing during the Railway Mania can be assessed by comparing the prices of highly leveraged assets, namely those issued by the new railways, with other assets. A basic approach to assessing the relative price of an asset is to compare its dividend yield with other assets. As the new railways promoted at this time could not pay a dividend until they had finished construction and began operation, a current dividend yield cannot be calculated for their early stages. However, it is possible to use an approximation to calculate what dividend they would eventually have to achieve to produce a similar return to the non-railways and established railways. The dividend yield can be expressed in terms of the dividend/par ratio and price/par ratio, as shown in Equation 5.

$$Dividend\ Yield = \frac{Dividend/Par}{Price/Par} \quad (5)$$

The highest price/par ratio of the new railways from the various scenarios discussed above was 1.18, assuming a partially paid share can be treated as a future contract, and using a discount rate of 10 per cent. During 1845 a sample of non-railway companies were trading at an average dividend yield of 4.5 per cent (Campbell, 2010), so to achieve a similar yield the new railways should have been producing a dividend/par ratio of 5.3 per cent. This is a lower bound estimate, as it does not take account of the much greater uncertainty surrounding the new railways, or the foregone dividends during the construction phase, but it provides an approximation for required performance.

The dividend/par ratio of the established railways peaked at 7.2 per cent during the Mania (Campbell, 2010). An analysis of the prospectuses of 85 new railways collected from advertisements in the *Railway Times* (1843-45) suggests that the promoters of these new railways encouraged investors to expect an average dividend/par ratio of 7.9 per cent. The lower bound estimate of the required dividend/par ratio to justify the price of the new railways was therefore much lower than either the established railways or the prospectuses of the new railways suggested was possible.

These calculations have been performed using the highest price/par ratio of any scenario which has been discussed above. If a more reasonable discount rate is used, or partially paid shares were options, then the implied dividend rate would have been even lower, suggesting that the prices of new railway shares were not particularly high during the Railway Mania, even at the market peak.

7 Conclusion

Using an extensive dataset, this paper has analysed the pricing of assets with uncalled capital during the British Railway Mania. It has provided evidence that the partially-paid assets listed

on the market at this time may be modelled as either futures or options, which implies that investors who purchased these assets were effectively purchasing highly leveraged derivatives.

The evidence presented above suggests that the first impact of this leverage was to amplify the returns to investors. First-day returns for partially-paid shares were significantly higher than the returns which investors would have received if they had only been able to purchase fully-paid shares. The returns, throughout the boom, which were accumulated by investors in new railways were substantially increased by the effects of leverage, but during the downturn negative returns were also magnified.

The second impact of leverage was to allow investors to purchase assets on an instalment payment plan. Investors could subscribe to shares in new companies for a small deposit. This meant that although almost two hundred new railways had been listed on the market at its peak, enough capital had been provided to finance only about twenty of them. When payments were subsequently required, the resulting deleveraging was associated with price declines.

The combined effects of higher expected returns, and easier payment terms, may have increased the demand for the assets issued by the new railways. However, possibly due to the increased risk, and the substantial increase in the supply of assets, the new railways did not have a much higher price than the non-railways at this time.

These results suggest that leverage may play an important role in ‘bubbles’. Although its influence on prices may be limited, it affects the returns experienced by investors, and the timing of flows of capital. The use of leverage may initially appear to be attractive to investors, as it amplifies positive returns and reduces the amount of capital required for

investment, but it can lead to problems in a downturn, when negative returns are magnified, and deleveraging occurs.

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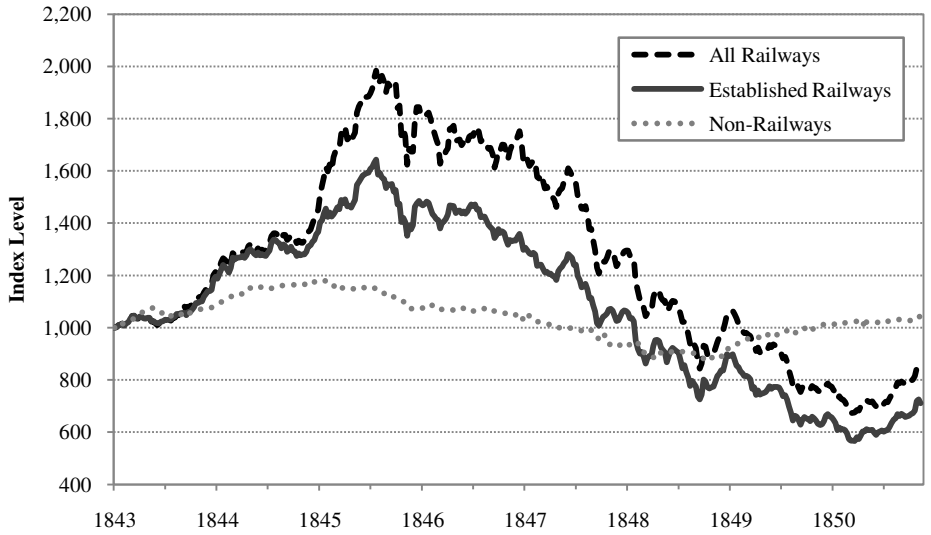
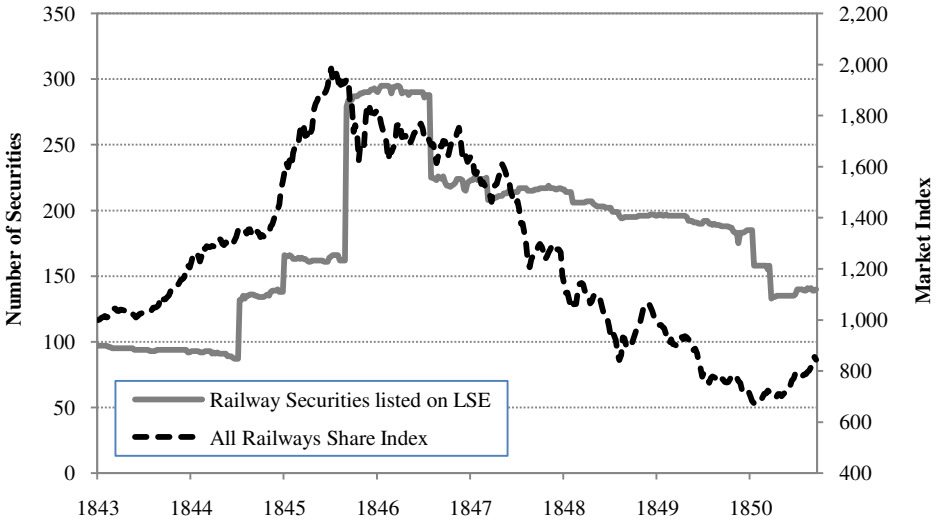
Figure 1: Weekly Market Indices of All Railways, Established Railways and Non-Railways, 1843-50



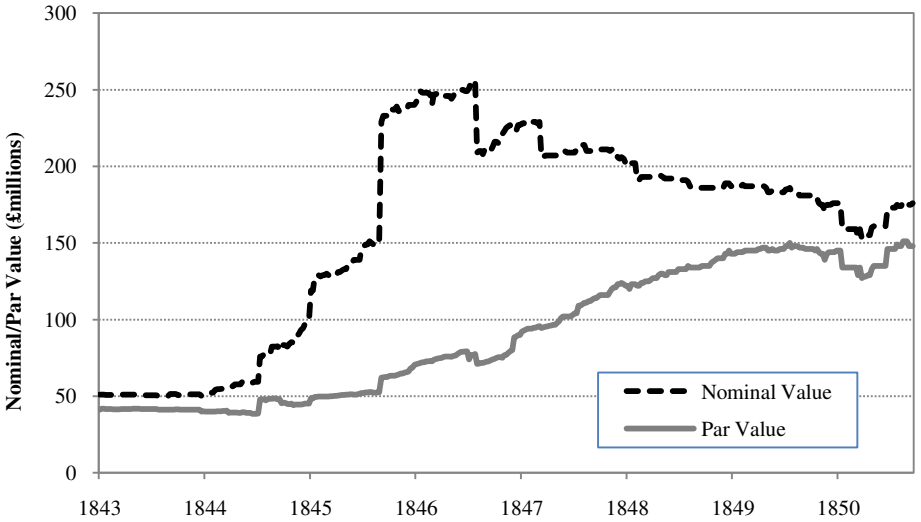
Source: Campbell and Turner (2010).
Notes: Railway share indices calculated from weekly share price tables in *Railway Times* (1843-50). Non-Railway share index calculated from weekly share price tables in *Course of the Exchange* (1843-50). The All-Railway index includes all railway securities, whereas 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 2: Number of Railway Securities Listed on London Stock Exchange, and Railway Share Index 1843-50



Notes: Railway share index and number of securities listed on London Stock Exchange calculated from weekly share price tables in *Railway Times* (1843-50). Market index constructed from market returns, which have been calculated by weighting the returns of the component companies by their market capitalisation at the start of the day.

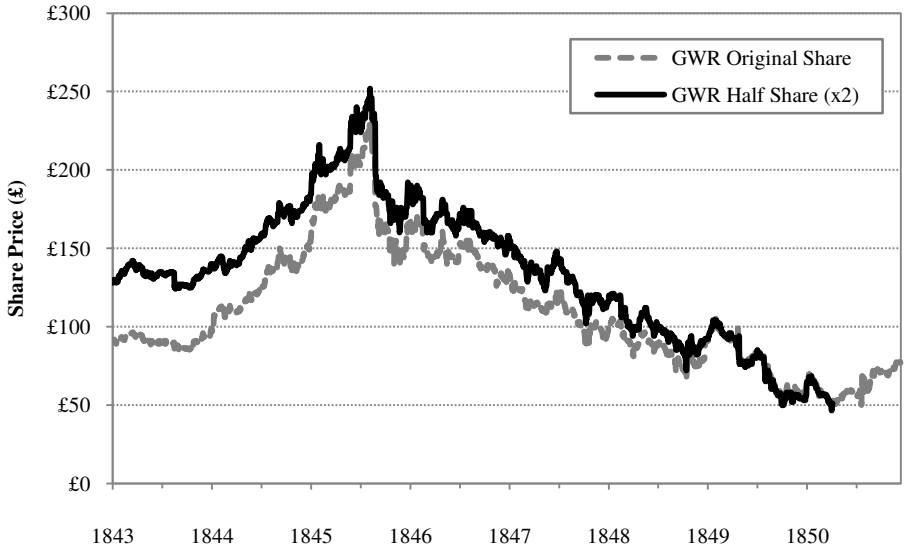
Figure 3: Total Par Value and Nominal Value of Railway Shares Listed on London Stock Exchange, 1843-50



Notes: Nominal Value and Par Value for each company listed on London Stock Exchange obtained from weekly share price tables in *Railway Times* (1843-50). Industry Nominal and Par Values calculated by summing individual companies.

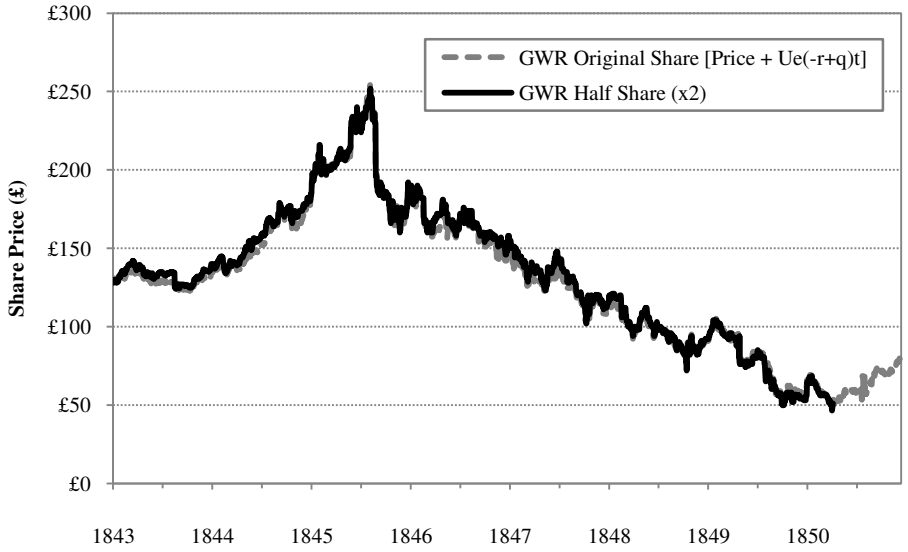
Figure 4: Daily Share Prices of a GWR Full Share and Two Half Shares, 1843-50

Panel A: Prices Observed in Market



Notes: Share prices obtained on a daily basis from weekly share price tables in *Railway Times* (1843-50).

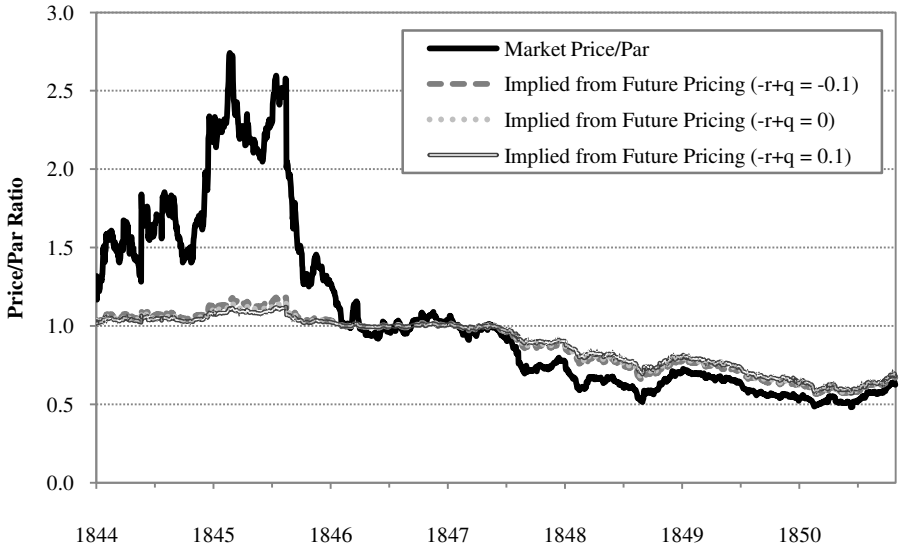
Panel B: Prices Adjusted for Uncalled Capital Discounted at Actual Risk-Free and Dividend Rates



Notes: Share prices and par values obtained from weekly share price tables in *Railway Times* (1843-50). Implied price of a GWR original share calculated using Equation 1.

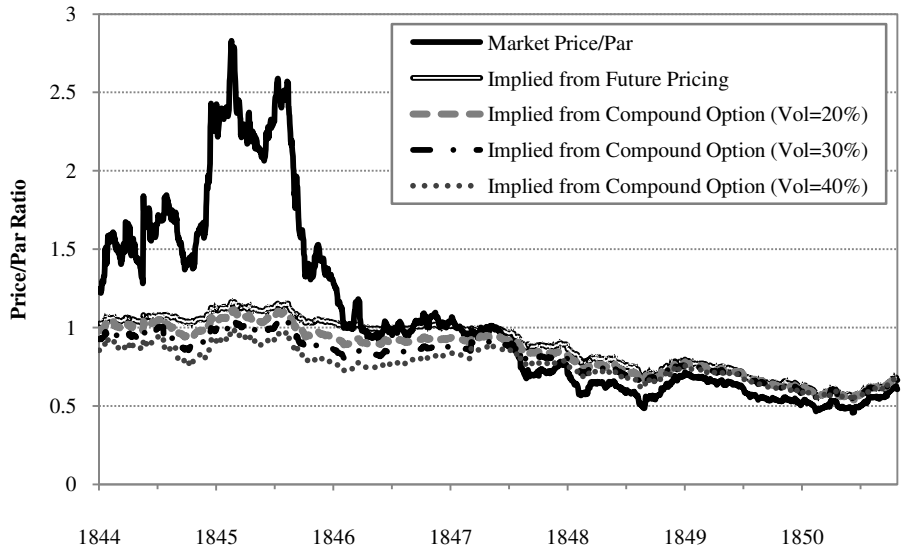
Figure 5: Price/Par Ratio of New Railways, 1844-50

Panel A: Shares Treated as Futures, using Alternative Scenarios of Discount Rate



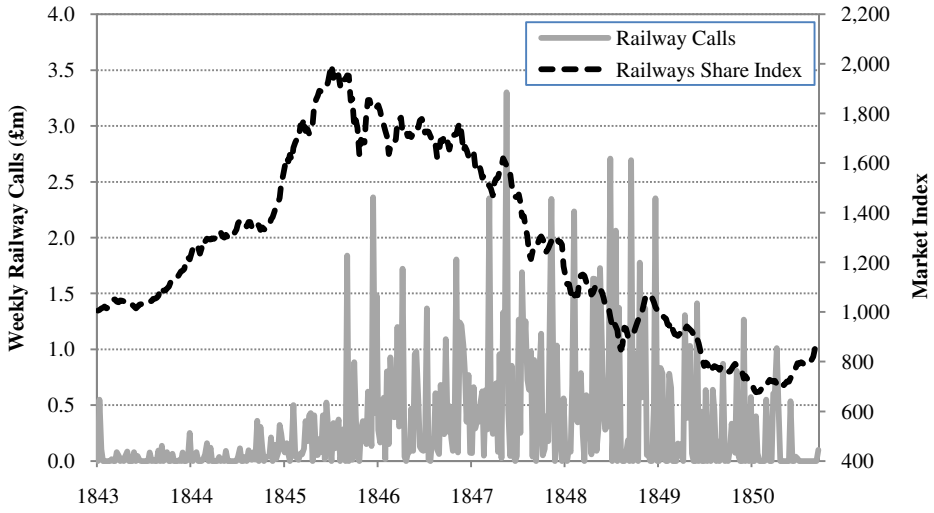
Notes: Implied market capitalisation and par value calculated for individual new railways, promoted after 1843, using alternative scenarios of the interest and dividend rates. Implied price/par ratio of all new railways calculated as implied total market price/total cost.

Panel B: Shares Treated as Compound Call Options, using Alternative Scenarios of Volatility



Notes: When treated as a future the implied price/par ratio calculated as total price/total cost using an interest rate of 3 per cent and dividend rate of 0 per cent to discount uncalled capital. When treated as an option the price of a partially-paid share is assumed to be the price of a compound call option, using alternative assumptions about volatility. The pricing formula for a compound call option (Geske, 1979) was used to imply the price of an underlying fully-paid share for each company.

Figure 6: Weekly Railways Calls and Railway Share Index 1843-50



Notes: Railway share index and volume of calls calculated from weekly share price tables in *Railway Times* (1843-50).

Table 1: Augmented Dickey-Fuller (ADF) Tests of Residual from Estimated Cointegrating Relationships between Fully-paid and Partially-paid Shares of Established Railway Companies

		Variables Included in Cointegrating Relationship																	
		$Y = Price_F$ $X_1 = Price_P$		$Y = Price_F$ $X_1 = Price_P$ $X_2 = Uncalled_P$		$Y = Price_F$ $X_1 = Price_P$ $X_2 = Uncalled_P$ $X_3 = R_f$ $X_4 = Div$		$Y = Price_F$ $X_1 = Price_P + Ue^{(-r+q)t}$, where (-r+q) is equal to:											
Fully-paid Share ($Y = Price_F$)	**Partially-paid Share ($X = Price_P$)**							**Actual**		**-10%**		**0%**		**10%**		**Obs**			
Edinburgh and Glasgow	Half Shares	-1.60		-4.78	***	-5.33	***	-4.33	***	-3.59	**	-4.13	***	-4.72	***	1,186			
Great Western Half Share	Full Shares	-3.82	**	-16.36	***	-16.82	***	-14.50	***	-8.67	***	-13.21	***	-12.04	***	2,284			
Great Western Half Share	Fifth Shares	-3.79	**	-17.83	***	-18.26	***	-15.93	***	-10.09	***	-14.21	***	-17.20	***	2,270			
Great Western Half Share	Sixth Shares	-1.13		-9.83	***	-10.18	***	-8.90	***	-6.78	***	-8.29	***	-9.75	***	1,119			
Great Western Half Share	Quarter Shares	-2.38		-13.28	***	-13.18	***	-11.91	***	-9.31	***	-11.61	***	-11.23	***	1,379			
London and North Western	New Shares	-0.87		-7.52	***	-8.64	***	-8.17	***	-2.94		-6.18	***	-6.11	***	1,050			
London and North Western	Fifth Shares	-1.27		-9.07	***	-10.79	***	-6.11	***	-5.69	***	-7.07	***	-4.07	***	1,359			
London and North Western	Quarter Shares	-1.47		-6.25	***	-6.55	***	-5.03	***	-4.74	***	-4.91	***	-5.04	***	537			
Midland	Half Shares	-1.43		-5.03	***	-5.72	***	-4.34	***	-3.35	*	-4.23	***	-4.02	***	1,284			
Midland	New Shares	-2.02		-8.84	***	-9.24	***	-8.45	***	-5.67	***	-8.27	***	-6.65	***	989			
York and Newcastle	New Shares	-2.70		-6.85	***	-6.79	***	-6.37	***	-6.65	***	-6.65	***	-6.07	***	327			
York, Newcastle and Berwick	Extension No. 1 Shares	-2.51		-12.00	***	-12.04	***	-9.92	***	-7.04	***	-9.04	***	-10.55	***	1,008			
York, Newcastle and Berwick	Extension No. 2 Shares	-1.93		-6.90	***	-7.58	***	-5.19	***	-3.47	**	-4.70	***	-5.23	***	438			
York and North Midland	Half Shares	-4.95	***	-14.35	***	-14.51	***	-12.30	***	-10.86	***	-11.67	***	-12.59	***	1,279			
York and North Midland	E&W Riding Shares	-0.89		-5.94	***	-7.86	***	-3.82	**	-2.95		-3.31	*	-4.20	***	1,035			
York and North Midland	Extension Shares	-1.54		-4.97	***	-7.40	***	-2.61		-1.42		-2.00		-2.95		886			
York and North Midland	Scarborough Branch Shares	-3.31	*	-4.27	**	-4.31	*	-2.90		-2.96		-2.92		-2.90		870			

Notes: Daily share prices and par values obtained from weekly share price tables in *Railway Times* (1843-50). Engle-Granger 2-step procedure (Engle and Granger, 1987) used to test for cointegration between a partially-paid share and equivalent fully-paid share for a particular established railway. Significance shown by *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Forfeiture Rates on Railway Share Instalments, using Alternative Scenarios for Deadline on Payment

Time between Instalment Due Date and Deadline for Payment	N	Criteria Met		Forfeiture Rate		Difference in Forfeiture Rates		SE of Difference
		S-K>=0	S-K<0	S-K>=0	S-K<0			
2 Months	225	214	11	10.5%	13.6%	3.2%		(4.1%)
4 Months	221	197	24	8.5%	19.0%	10.5%	***	(2.4%)
1 Year	163	132	31	5.5%	14.8%	9.3%	***	(1.8%)
2 Years	74	52	22	2.7%	6.3%	3.5%	**	(1.7%)

Notes: Forfeiture rates calculated from data on arrears on calls for capital published in *Parliamentary Papers* (1848, LXIII, p.275-442), assuming that any arrears which were still outstanding after the deadline had been forfeited.

Table 3: New Railways' First-day Abnormal Returns

			Return on Partially-paid Shares			Return on Fully-paid Shares if Partially-paid Shares Treated as Futures						Return on Fully-paid Shares if Partially-paid Shares Treated as Compound Options					
Year	N	Average Paid up (%)	Mean	SE of mean		Mean	SE of mean		Mean Difference between Partial and Full	SE of Mean Difference between Partial and Full		Mean	SE of mean		Mean Difference between Partial and Full	SE of Mean Difference between Partial and Full	
1844	38	10.2%	76.2%	(17.4%)	***	5.5%	(1.9%)	***	70.8%	(15.7%)	***	5.0%	(2.9%)	*	71.2%	(15.0%)	***
1845	79	6.2%	106.7%	(13.1%)	***	7.1%	(0.9%)	***	99.6%	(12.3%)	***	3.4%	(1.8%)	*	103.4%	(11.7%)	***
1846	40	15.8%	1.9%	(9.9%)		3.4%	(2.2%)		-1.4%	(8.7%)		1.6%	(3.3%)		0.3%	(7.8%)	
1847	9	20.0%	8.3%	(20.7%)		1.3%	(4.9%)		7.0%	(17.0%)		4.1%	(6.7%)		4.2%	(15.8%)	
1848	1	10.0%	37.3%	.		3.8%	.		33.5%	.		-0.2%	.		37.5%	.	
Total	167	10.2%	69.0%	(8.5%)	***	5.5%	(0.9%)	***	63.5%	(7.9%)	***	3.3%	(1.4%)		65.6%	(7.6%)	

Notes: Significance shown by *** p<0.01, ** p<0.05, * p<0.1. When treated as a future a discount rate is assumed of 3 per cent. When treated as an option the price of a partially-paid share is assumed to be the price of a compound call option, using assumption of 30 per cent volatility.

Table 4: Total Nominal and Par Values of New Railways, 1844-50

	Dec 27, 1844	Dec 26, 1845	Dec 25, 1846	Dec 31, 1847	Dec 29, 1848	Dec 28, 1849	Dec 27, 1850
Total for All New Railways							
Nominal Value (£m)	39.6	158.0	129.0	94.4	79.0	78.8	69.4
Par Value (£m)	3.7	15.6	24.8	36.0	48.5	57.0	53.9
Average for New Railways							
Nominal Value (£m)	0.9	0.8	1.1	1.2	1.1	1.2	1.2
Par Value (£m)	0.1	0.1	0.2	0.4	0.7	0.8	0.9
Number of New Railway Companies							
Listed on London Stock Exchange	44.0	186.0	112.0	81.0	69.0	68.0	60.0
Which could have been fully financed by the invested capital	4.1	18.5	21.6	30.9	42.4	49.2	46.6
Par/Nominal Ratio	9.2%	9.9%	19.2%	38.1%	61.4%	72.3%	77.7%

Notes: Nominal Value and Par Value for each company listed on London Stock Exchange obtained from weekly share price tables in *Railway Times* (1843-50).

Table 5: Event Study on Company Returns when Calls for Capital Were Issued

		One Week			Three Weeks			Five Weeks		
Year	**Number of calls**	**Mean**	**SE of mean**		**Mean**	**SE of mean**		**Mean**	**SE of mean**	
1843	22	-4.2%	(2.5%)		-0.7%	(3.5%)		2.4%	(3.0%)	
1844	36	-4.6%	(2.1%)	**	-2.5%	(3.5%)		4.8%	(4.8%)	
1845	110	-4.1%	(1.6%)	**	-2.4%	(1.7%)		-1.3%	(2.2%)	
1846	197	-7.4%	(1.9%)	***	-6.0%	(2.1%)	***	-3.9%	(2.2%)	*
1847	218	-9.1%	(1.2%)	***	-7.9%	(1.5%)	***	-6.2%	(1.7%)	***
1848	182	-16.1%	(1.8%)	***	-14.3%	(2.1%)	***	-6.5%	(3.4%)	*
1849	149	-11.9%	(2.3%)	***	-11.4%	(2.3%)	***	-6.9%	(2.6%)	***
1850	57	-10.9%	(3.8%)	***	-10.4%	(3.6%)	***	-6.1%	(6.1%)	
Overall	971	-9.7%	(0.7%)	***	-8.4%	(0.8%)	***	-4.7%	(1.1%)	***

Notes: Share prices and par values obtained from weekly share price tables in *Railway Times* (1843-1850). Time of call defined as the week on which paid up value of the share changes in the share list. Significance shown by *** p<0.01, ** p<0.05, * p<0.1, testing if the mean return is significantly different from 0.