Systematic risk of QR Network

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1. Executive summary

1.1 Objective

SFG Consulting has been engaged to advise QR Network on an estimate of equity beta, for the purposes of setting the regulated rate of return by the Queensland Competition Authority ("the QCA" or "the Authority"). In its 2010 determination the Authority adopted an equity beta estimate of 0.80 (QCA, 2010). This is consistent with an asset beta estimate of 0.45 if we assume a debt beta estimate of 0.12, 60% leverage and a corporate tax rate of 30% as the Authority has previously adopted.[1]

1.2 Method

Our estimates rely upon the relationship between excess stock returns and excess market returns for listed firms, computed using ordinary least squares ("OLS") regression. All our calculations are based upon four-weekly returns and are the result of performing the analysis 20 times, and computing average values. The 20 sets of analysis correspond to 20 different start points at which we can compute four-weekly returns. We observe substantial fluctuations in beta estimates depending upon start dates, so minimise estimation error by repeating the analysis in this manner. This calls into question the reliability of beta estimation which does not account for alternative start points.

We also consider whether firm characteristics other than industry sectors – market capitalisation, book-to-market ratio and debt-to-equity ratio – provide additional information about the empirical relationship between stock returns and market returns. In this analysis, the percentile ranks of these characteristics for each firm itself are incorporated into the regression. We observe that, incorporating these characteristics directly into the regression analysis reduces the dispersion of beta estimates across 40 industry sectors by around 5 to 9%, compared to simply taking the mean of the OLS estimates for each firm within the industry.[2] This is a pooled regression which relies upon an average 323,061 returns observations, an average of approximately 10 years' worth of four-weekly returns for each firm.[3]

An alternative technique to account for firm characteristics in beta estimation is to first compute OLS beta estimates on a firm-specific basis, and then regress these beta estimates against variables which measure these characteristics. If we take the predicted beta estimates for each firm from this regression, and then compute the mean beta estimates for each industry, this reduces the dispersion of beta estimates across industry sectors even further, by around 19 to 55% compared to taking the mean of industry sector estimates.[4]

In short, we compile beta estimates using three alternative techniques to account for firm characteristics – *OLS estimates* by firm, *pooled* estimates which account for firm characteristics in the returns regression itself, and *fitted* regression estimates in which we compile the OLS beta estimates which are predicted by firm characteristics.

It is important to emphasise that this analysis of characteristics relies upon what relationships are present in the data itself. We do not impose a relationship between these characteristics and returns or

[1] The equation which represents the relationship between asset and equity betas is presented in Sub-section 2.5.

[2] Across the 40 industry sectors, the standard deviation of beta estimates is 0.45 if we compute the mean beta estimate for firms within each sector. When we incorporate firm characteristics directly into the regression analysis, the standard deviation of beta estimates across the sectors is 0.43, a reduction of 5%. There is one sector, Food & Drink Retailers, with an extreme beta estimate of –1.41. Excluding this sector, the standard deviation of beta estimates across the sectors is 0.25 when we take the mean OLS estimate, and 0.23 when we incorporate firm characteristics into the pooled regression. This is a reduction of 9%.

[3] There is an "average" of 323,061 observations because we repeat our analysis 20 times.

[4] Across the 40 industry sectors the standard deviation of average predicted beta estimates is 0.21 if we include Food & Drink Retailers and 0.20 if we exclude this sector. These figures represent reductions in beta estimates of 55% and 19%, respectively, compared to simply taking the mean OLS beta estimate from each sector.

beta estimates. If firm characteristics are independent of systematic risk, then incorporating these characteristics into the analysis should not impact on the conclusions. In small samples we could observe relationships due to random chance. But we have a large sample of firms. In fact, this analysis relies upon a sample of firms which is far greater than typically analysed when only a narrowly-defined industry is taken into consideration.

In addition, we analyse four plausible sets of comparator firms. We have considered the evidence for (1) QR National Limited itself; (2) nine Australian-listed energy network firms which have previously been relied upon by the Australian Energy Regulator ("the AER") and which underpinned the previous determination of the Authority; (3) 29 Australian-listed firms classified as Industry Classification Benchmark ("ICB") Sector 2770 Industrial Transportation, which includes QR National; and (4) nine United States ("US")-listed firms classified as ICB Sub-Sector 2775 Railroads.

1.3 Equity beta estimates

The equity beta estimates resulting from this analysis are summarised below. These beta estimates have not been adjusted for differences in leverage between QR Network and listed firms. We consider the impacts of leverage in Sub-section 1.4.

- **QR National Limited.** The OLS beta estimate for QR National Limited is 0.58, the predicted value from the pooled regression is 0.86 and the fitted estimate is also 0.86. These estimates for QR National have been presented for completeness and should be given little weight in isolation, as there is substantial estimation error for an individual stock. Across the 20 OLS beta estimates computed, the minimum estimate was 0.25 and the maximum estimate was 0.97, based entirely upon the random start point with which to compute four-weekly returns across the estimation period.

- **Australian-listed energy networks.** The mean OLS beta estimate for nine energy network firms is 0.54, the mean predicted value from the pooled regression is 0.87 and the mean fitted estimate is 0.82. The beta estimates from the pooled and fitted analysis are higher for two main reasons. First, firms with higher debt-to-equity ratios have lower OLS beta estimates, but the OLS beta estimates for the listed energy networks are much lower than other firms with the same amount of leverage. Second, other firms classified according to the same industry sub-sectors have higher beta estimates.

  If we incorporate only the accounting and market-based characteristics into the fitted estimates the mean estimate for these firms is 0.85; if we incorporate only the industry sub-sector classifications into the fitted beta estimates the mean estimate for these firms is 0.83; and as noted above if we incorporate both sets of information into the analysis the mean fitted estimate is 0.82.

- **Australian-listed Industrial Transportation.** The mean OLS beta estimate for 29 firms in the ICB Sector 2770 Industrial Transportation is 0.82, the mean predicted value from the pooled regression is 0.78 and the mean fitted estimate is 0.80. In the US-data, there is no material difference in the beta estimates of nine Railroads and 183 other Industrial Transportation firms.[5] This provides support for examining this broader class of Australian-listed firms.

- **United States-listed Railroads.** The mean OLS beta estimate for 9 firms in the ICB Sub-Sector 2775 Railroads is 0.99, the mean predicted value from the pooled regression is 0.96 and the mean fitted estimate is 0.99.

[5] Specifically, the mean OLS estimates for the nine Railroads was 0.99 and the mean OLS estimate for the other 183 Industrial Transportation firms was 1.12. The corresponding figures for the pooled estimates are 0.96 for Railroads and1.06 for the other Industrial Transportation firms and the figures for the fitted estimates are 0.99 for Railroads and 1.08 for the other Industrial Transportation firms.

These figures suggest that the weights placed on different samples of "comparable" firms and the weights placed upon alternative estimation techniques, will be crucial in compiling a beta estimate for QR Network. If we were to rely exclusively on OLS estimation, the data is consistent with a beta estimate of 0.54 for Australian-listed energy networks, 0.82 for Australian-listed Industrial Transportation firms and 0.99 for US-listed Railroads. Recall that these estimates have not been adjusted for gearing. If we were to adjust for gearing, the disparity in the estimates would be even greater, because the sub-samples with the lowest beta estimates have the highest gearing. This is considered below.

If we account for firm characteristics in the analysis, and taking average values for the pooled and fitted analysis, the data is consistent with a beta estimate of 0.85 for Australian-listed energy networks, 0.79 for Australian-listed Industrial Transportation firms and 0.98 for US-listed Railroads.

In aggregate, what the data implies is that the OLS beta estimates for Australian-listed energy networks are unusual, in comparison to their characteristics. It is debatable just how much weight the OLS estimates from these firms should be given in the Authority's consideration. A more appropriate equity beta estimate from analysis of comparable firm stock returns, and before considering relative gearing, would be an equity beta estimate of 0.90, as the data is consistent with an equity beta estimate of around 0.80 to 1.00.

1.4 Leverage impacts

Our analysis highlights a limitation of the conventional un-levering/re-levering approach to equity beta estimation for the purposes of regulation. In the data, it is the firms with high leverage that have the relatively lower OLS beta estimates. To illustrate, the sample of Australian-listed energy network firms has mean leverage of 55%, the Australian-listed Industrial Transportation firms have mean leverage of 33% and the US-listed Railroads have mean leverage of 29%. This means that, when the effects of leverage are removed, in order to compute asset beta estimates, the differences are exacerbated. Assuming a debt beta of 0.12, a corporate tax rate of 30% and 60% benchmark gearing, we have the following estimates for asset betas and re-levered equity betas:

- The mean OLS asset beta estimate is 0.35 for Australian-listed energy network firms, 0.67 for Australian-listed Industrial Transportation firms and 0.78 for US-listed Railroads. In turn, these values imply re-levered beta estimates of 0.59, 1.25 and 1.47.

- The mean pooled asset beta estimates are 0.52 for Australian-listed energy network firms, 0.65 for Australian-listed Industrial Transportation firms and 0.75 for US-listed Railroads. In turn, these values imply re-levered beta estimates of 0.93, 1.21 and 1.42.

- The fitted asset beta estimates are 0.49 for Australian-listed energy network firms, 0.66 for Australian-listed Industrial Transportation firms and 0.78 for US-listed Railroads. In turn, these values imply re-levered beta estimates of 0.88, 1.23 and 1.48, respectively.

After considering these leverage impacts, we can summarise the beta estimates in the following table.

QR Network shares a characteristic of the energy network businesses, in that it is a single operator of a network business subject to a similar regulatory regime. But revenue for these comparator firms is driven by an entirely different customer segment. It also shares a characteristic of the transportation firms, namely a *broadly* similar customer base and product, but is not exposed to the risks associated with the unregulated segments of the listed businesses. The substantially different capital structures of these industry sectors suggests that their underlying risks are, in fact, different. What is unclear is just how similar the systematic risk of QR Network is to either sector.

Table 1. Summary of beta estimates

Sample	Equity beta			Asset beta			Re-levered to 60%		
	OLS	Pooled	Fitted	OLS	Pooled	Fitted	OLS	Pooled	Fitted
Aust. energy networks	0.54	0.87	0.82	0.35	0.52	0.49	0.59	0.93	0.88
Aust. Industrial Transportation	0.82	0.78	0.80	0.67	0.65	0.66	1.25	1.21	1.23
US Railroads	0.99	0.96	0.99	0.78	0.75	0.78	1.47	1.42	1.48

What we can conclude is that the joint assumption of an equity beta estimate of 0.80 and an asset beta estimate of 0.45 can only be sustained if almost all weight is placed on the OLS beta estimates for Australian-listed energy networks. Some implied asset betas and equity betas under alternative weights are as follows:

- If **100%** weight is placed on the OLS beta estimates for Australian-listed energy networks, the asset beta estimate is **0.35** and the re-levered equity beta estimate is **0.59**.

- If **100%** weight is placed on the OLS estimation technique, and **50%** weight is placed on the sample of Australian-listed energy network firms (with the remaining 50% sample weight allocated equally to Australian-listed Industrial Transportation firms and US-listed Railroads) the asset beta estimate is **0.54** and the re-levered equity beta estimate is **0.98**.

- If **50%** weight is placed on the OLS estimation technique, and **50%** weight is placed on the sample of Australian-listed energy network firms (with the remaining 50% sample weight allocated equally to Australian-listed Industrial Transportation firms and US-listed Railroads) the asset beta estimate is **0.57** and the re-levered equity beta estimate is **1.05**.

In the table below, we present the asset beta estimates, and corresponding re-levered equity beta estimates, under alternative weights placed on OLS estimation (versus incorporating firm characteristics) and alternative weights placed on Australian-listed energy network businesses (versus weights placed on the two transportation sub-samples). The table shows that an asset beta/equity beta assumption of less than 0.45/0.80 can only be sustained if high weight is placed on OLS estimates (ignoring firm characteristics) or if high weight is placed on Australian-listed energy networks (ignoring the information in Australian- and US-listed transportation firms). These combination of weights are presented in the lower right-hand sections of the panels.

In our view, a more appropriate assumption would be an asset beta/equity beta combination of 0.55/1.00. If at least half of the sample weight is placed on firms which are part of the transportation industry sectors, then the equity beta estimate is at least 0.98, regardless of the estimation technique (the middle row of Panel B). Furthermore, if at least half of the weight is placed on estimation techniques which account for firm characteristics, the equity beta estimate only falls below 0.99 if less than 40% weight is placed on firms which are part of the transportation industry sectors (the middle column of Panel B).

Table 2. Beta estimates under alternative weights

Panel A Asset beta estimates

Weight on energy networks (%)	Weight on OLS estimates (%): 0	10	20	30	40	50	60	70	80	90	100
0	0.71	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
10	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
20	0.67	0.67	0.67	0.66	0.66	0.66	0.66	0.66	0.65	0.65	0.65
30	0.65	0.65	0.64	0.64	0.64	0.63	0.63	0.62	0.62	0.62	0.61
40	0.63	0.62	0.62	0.61	0.61	0.60	0.60	0.59	0.59	0.58	0.58
50	0.61	0.60	0.59	0.59	0.58	0.57	0.57	0.56	0.55	0.55	0.54
60	0.59	0.58	0.57	0.56	0.55	0.54	0.54	0.53	0.52	0.51	0.50
70	0.57	0.56	0.55	0.54	0.53	0.52	0.50	0.49	0.48	0.47	0.46
80	0.55	0.53	0.52	0.51	0.50	0.49	0.47	0.46	0.45	0.44	0.43
90	0.53	0.51	0.50	0.48	0.47	0.46	0.44	0.43	0.42	0.40	0.39
100	0.50	0.49	0.47	0.46	0.44	0.43	0.41	0.40	0.38	0.37	0.35

Panel B: Equity beta estimates

Weight on energy networks (%)	Weight on OLS estimates (%): 0	10	20	30	40	50	60	70	80	90	100
0	1.33	1.34	1.34	1.34	1.34	1.35	1.35	1.35	1.36	1.36	1.36
10	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.28	1.28
20	1.25	1.25	1.24	1.24	1.23	1.23	1.22	1.22	1.22	1.21	1.21
30	1.21	1.20	1.19	1.18	1.18	1.17	1.16	1.15	1.15	1.14	1.13
40	1.16	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.06	1.05
50	1.12	1.11	1.09	1.08	1.06	1.05	1.03	1.02	1.01	0.99	0.98
60	1.08	1.06	1.04	1.03	1.01	0.99	0.97	0.95	0.94	0.92	0.90
70	1.04	1.01	0.99	0.97	0.95	0.93	0.91	0.89	0.87	0.84	0.82
80	0.99	0.97	0.94	0.92	0.89	0.87	0.85	0.82	0.80	0.77	0.75
90	0.95	0.92	0.89	0.87	0.84	0.81	0.78	0.75	0.73	0.70	0.67
100	0.91	0.88	0.85	0.81	0.78	0.75	0.72	0.69	0.66	0.62	0.59

1.5 Conclusion

In deriving an equity beta estimate for QR Network from listed firm information we have attempted to overcome an important sample limitation – there are no pure-play listed rail networks in Australia. The Authority has previously relied upon analysis of listed energy networks, which has the obvious limitation of having a different product and customer base to a rail network. Hence, in addition to analysing this sample, we have considered Australian-listed Industrial Transportation firms, and US-listed rail firms. Again, there are obvious limitations of comparability. In one case the firms are not rail businesses, in another case the firms form part of an overseas market, and in neither case is it clear just how much the business can be considered a pure-play network. In addition, the standard technique of computing industry means ignores important firm-specific information relating to market capitalisation, book-to-market ratio and leverage, which are associated with stock returns and allow us to mitigate against firm-specific estimation error.

All of this information, from different samples and estimation techniques, is informative about the appropriate beta estimate for QR Network. There is no reason to place sole reliance on one particular sample or estimation technique. The only question is just how much relative weight should be placed on particular samples and estimation techniques.

Our conclusion is that an asset beta/equity beta combination of 0.55/1.00 is appropriate. To deviate from this position requires placing high reliance on a sample which has questionable comparability to QR Network *and* which ignores information about firm characteristics which provide relevant information.

2. Methodology

2.1 Introduction

We compile beta estimates according to three estimation techniques. First, we compile OLS beta estimates by firm, and report mean estimates across firms for three sub-samples – Australian-listed energy networks, Australian-listed Industrial Transportation firms and US-listed Railroads. Second, we incorporate firm characteristics directly into a pooled regression.. There are three accounting and market-base characteristics – market capitalisation, book-to-market ratio and debt-to-equity ratio – along with industry classifications. Thus, we compile predicted beta estimates from the regression. Third, we regress OLS estimates against these same firm characteristics, where each firm comprises one observations. We compile fitted beta estimates from this cross-sectional regression.

2.2 Ordinary least squares regression

We compiled OLS beta estimates for individual firms and an equal-weighted index according to two regression equations on four-weekly excess returns, where excess returns refers to stock or market returns minus the risk-free rate. Our analysis is repeated 20 times using different start points for four-weekly returns, and we take average values from the 20 sets of analysis.

The first equation assumes a constant relationship between excess stock and market returns:

$$r_{i,t} - r_{f,t} = \alpha + \beta\left(r_{m,t} - r_{f,t}\right) + \varepsilon_{i,t}$$

where:

$r_{i,t}$, $r_{m,t}$ and $r_{f,t}$ = return on stock *i,* the return on the equity market and the risk-free rate, respectively in period *t*; and
$\varepsilon_{i,t}$ = an error term for stock *i* during period *t*.

The second equation allows the association between excess stock and market returns to vary according to whether excess market returns are positive or negative:

$$r_{i,t} - r_{f,t} = \alpha + \beta_{up}\left(r_{m,t} - r_{f,t} - th\right)I + \beta_{down}\left(r_{m,t} - r_{f,t} - th\right)(1 - I) + \varepsilon_{i,t}$$

where:

I = an indicator variable which takes on a value of 1 when excess market returns exceed a threshold of *th* (set equal to zero in this case) and 0 otherwise.

The differential exposure to systematic risk is illustrated in Figure 1 which is extracted from Mitchell and Pulvino (2001, p.2143). They investigated whether there was differential exposure to market risk from buying stocks for which takeover offers had been announced, a trading strategy known as merger arbitrage. The same regression equation is used to examine the risk of this trading strategy in the Australian market (Maheswaran and Yeoh, 2005; Hall, Pinnuck and Thorne, 2012). The figure is presented to aid understanding of the beta estimates which follow. Whether or not asymmetric risk is present in merger arbitrage is independent of whether asymmetric risk is present in any particular sample we analyse.

Figure 1. Asymmetric relationship between stock returns and market returns

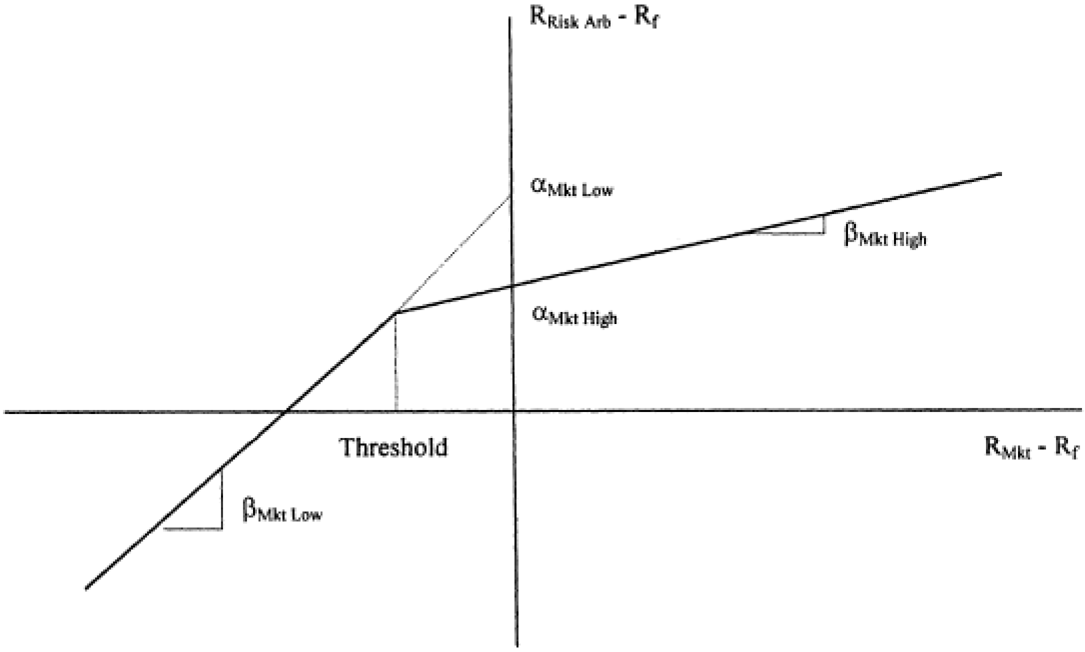

Figure 2. This figure depicts the piecewise linear model specified in equations (2) and (3). $R_{Risk\ Arb}$ is the monthly return obtained from the risk arbitrage portfolio, R_f is the monthly risk-free rate, and R_{Mkt} is the monthly return obtained from the CRSP value-weighted index. The market beta is allowed to vary depending on market returns. $\beta_{Mkt\ Low}$ is the slope coefficient when the difference between the market return and the risk-free rate is less than the threshold. $\beta_{Mkt\ High}$ is the slope coefficient when the difference between the market return and the risk-free rate is greater than the threshold.

The presentation of the equations in the papers listed above is different to the presentation of our equation, but the actual computations are the same. In those papers the authors estimate two different slope coefficients (that is, beta estimates) and two different intercept terms, but restrict the equation so that there is continuity at the point labelled "Threshold" in the figure. In our case we have a constant value (α) at this point and incorporate the threshold for excess market returns into the independent variables. The result is the same – at the threshold for excess market returns is an estimated value for excess stock returns, which then increases or decreases depending upon the up and down market beta estimates.

2.3 Incorporating firm characteristics directly into beta estimates

The beta estimates from this regression technique result from what are termed "interactive" variables, in the sense that we interact (that is, multiply) the firm characteristics with the excess market returns. We convert these firm characteristics to percentile ranks in order to mitigate against the influence of extreme observations. Our regression equation is presented below. There is a corresponding regression equation in which we have separate coefficients for up and down market beta estimates.

$$r_{i,t} - r_{f,t} = \alpha + \gamma_1 MC_i \times (r_{m,t} - r_{f,t}) + \gamma_2 B/M_i \times (r_{m,t} - r_{f,t}) + \gamma_3 D/E_i \times (r_{m,t} - r_{f,t})$$
$$+ \sum_{n=1}^{40} \delta_n Industry_i \times (r_{m,t} - r_{f,t}) + \varepsilon_{i,t}$$

where:

MC_i = the percentile rank of the average market capitalisation for firm i minus 0.5;
B/M_i = the percentile rank of the average book-to-market equity ratio for firm i minus 0.5;

D/E_i = the percentile rank of the average book-to-market equity ratio for firm *i* minus 0.5;
$Industry_i$ = an indicator variable (that is, 1 or 0) according to 40 different ICB sector classifications (referred to as industry fixed effects in the paper); and
$\varepsilon_{i,t}$ = an error term.

As mentioned above, this is a pooled regression in which each four-weekly return for each firm is an observation. The analysis is performed on a pooled basis because the firm characteristics will be relatively stable over time. In other words, each firm will have a relatively stable value for market capitalisation, book-to-market ratio, debt-to-equity ratio and industry classification over time. So it is not feasible to run the regression for each firm. This would be basically multiplying the excess market returns by a series of constant values.

The important issue to understand is that, if industry is the only characteristic which has information for beta estimations, the coefficients on market capitalisation, book-to-market ratio and debt-to-equity ratio will be zero. The beta estimate for each industry will be the same as if we ran a pooled regression of excess stock returns on excess market returns for separately for each industry. But if the three accounting and market based characteristics do have information which is relevant for beta estimation, then this will mitigate against some of the estimation error associated with consideration only of industry.

We can interpret the coefficients as follows. For each industry the coefficient on the industry variable (delta or δ) is the beta estimate for a firm in that industry with median values across the entire sample for market capitalisation, book-to-market ratio and debt-to-equity ratio. The coefficients on the other variables represent the incremental contribution to the beta estimate for the firm with the smallest value to the firm with the largest value. For example, the coefficient on market capitalisation percentile (gamma 1 or γ_1) represents how much the beta estimate would differ for the largest market capitalisation firm compared to the smallest market capitalisation firm.

2.4 Fitting regression-based beta estimates according to firm characteristics

In this analysis, we first estimate the beta for each firm using all available stock returns for that firm. These beta estimates then become the dependent variable in a regression on firm characteristics. The assumption underlying this analysis is that there is random estimation error in the beta estimate for each firm, but that, on average, the regression-based estimates appropriately measure the systematic risk for a firm with specified firm characteristics.

A simplified version of this analysis would be to partition the sample into a number of sub-samples according to cut-offs for the accounting and market-based characteristics and the industry groupings, and then simply compute the mean or median beta estimates within those sub-samples. All that the regression analysis does is perform the same task but with continuous variables rather than partitioning the sample into cohorts.

We report results in which the dependent variable is the regression-based beta estimate and in which the dependent variable is its percentile rank. Hence our regression equation is as follows.

$$\beta_i = \alpha + \gamma_1 MC_i + \gamma_2 B/M_i + \gamma_3 D/E_i + \sum_{n=1}^{40} \delta_n Industry_i + \varepsilon_i$$

where:

β_i = either the OLS beta estimate, the up market beta estimate, the down market beta estimate (or their corresponding percentile ranks)or the difference in the up market beta estimate and the down market beta estimate; and
other variables are as defined in the previous equation.

2.5 Leverage

For the purposes of computing asset betas and re-levered equity betas we use the following equation, consistent with the Authority:

$$\beta_e = \beta_a \times \left[1 + \frac{D}{E} \times (1 - \tau)\right] - \beta_d \times \frac{D}{E} \times (1 - \tau)$$

where:

β_e, β_a, and β_d = the equity beta, asset beta and debt beta respectively;
D/E = the market value debt-to-equity ratio; and
τ = the corporate tax rate.

3. Data

3.1 Introduction

We analyse data for Australian-listed firms and United States-listed firms. Ideally, we would analyse data for a large sample of Australian-listed rail networks. However, there are no pure-play Australian-listed rail networks, let alone a large sample of such firms. So we analyse data for 2400 Australian-listed firms (one of which, QR National Limited, is classified as ICB Sub-sector 2775 Railroads and 29 of which are classified more broadly as ICB Sector 2770 Industrial Transportation); and a sample of 192 US-listed firms classified as Industrial Transportation (nine of which are classified as Railroads).

We use firm characteristics to mitigate against estimation error in OLS beta estimation, namely market capitalisation, book-to-market ratio, debt-to-equity ratio and 40 ICB Sub-sector classifications. In short, we use alternative statistical techniques to estimate the systematic risk of each firm according to the beta estimates of all firms with similar firm characteristics.

3.2 Australian-listed firms

We analysed four-weekly returns on 2400 Australian-listed firms from January 1976 to May 2012, a period of 39 years and four months. The analysis begins in January 1976 because this is the first period in which required data is available for analysis. We restrict our analysis to firms in which at least 13 four-week periods of returns are available for analysis. On average each firm contributes 134 four-weekly returns to the sample, which is equivalent to 10 years of returns.

We do not require market capitalisation and accounting data for the entire period for which returns are available. Accounting information is only available from 1980 onwards so we estimate mean leverage and book-to-market equity ratios for each firm using data from this year onwards. Market capitalisation figures have been converted to March 2012 dollars using the Consumer Pricing Index as reported by the Reserve Bank of Australia. Accounting and market information is from Datastream. From June 1992 the index used to compute beta estimates is the All Ordinaries Index. Total returns are not available on this index prior to this date, so from January 1976 to May 1992, we use the Datastream Total Market Index for Australia.

In Table 3 we present descriptive statistics. The mean OLS beta estimate is 1.09 with a standard deviation of 0.84 and 90% of estimates lie within the range of 0.17 to 2.22. As we discuss later, small firms are characterised by relatively higher beta estimates. If the beta estimates are weighted by average market capitalisation, the mean OLS beta estimate is 0.95. The median firm has market capitalisation of $47 million, book-to-market equity ratio of 0.68 and debt/equity of 0.07. We excluded firms with book value of equity less than or equal to zero.

QR National Limited ("QRN") has an OLS beta estimate of 0.58, an up market beta estimate of 0.41 and a down market beta estimate of 0.64. The QR National beta estimate illustrates the benefit of taking an average estimate across 20 different starting points over the four-week returns period. The 20 OLS beta estimates for QRN range from 0.30 to 0.97. If only one beta estimate was computed, we would observe vastly different results purely on the basis of the randomly-selected start point. QRN has means for market capitalisation of $7.9 billion, book-to-market equity ratio of 0.90 and debt-to-equity of 0.09.

Table 3. Descriptive statistics for Australian-listed firms

Rate	Mean	Median	Std Dev	Min	5th perc	95th perc	Max
Beta	1.09	1.04	0.84	-16.04	0.17	2.22	12.46
Betaup	0.85	0.70	1.24	-4.88	-0.63	2.70	23.94
Betadn	1.28	1.23	1.31	-41.48	0.18	2.72	5.46
Betadn – Betaup	0.43	0.39	1.92	-52.75	-1.68	2.63	-10.20
Market cap (A$m)	506	47	2673	1.19	5	1905	74299
Book/Market	0.89	0.68	1.25	0.002	0.16	1.95	33.89
Debt/Equity	0.34	0.07	1.25	0.000	0.00	1.22	39.49

3.3 United States-listed firms

In the United States we analysed a sample of 192 firms classified in as Sector 2770 Industrial Transportation. Given the larger number of firms within this sector in the US market, we expect there to be sufficient cross-sectional variation in market capitalisation, book-to-market ratio and debt-to-equity ratio for the impact of these characteristics on systematic risk to show up in our results. Descriptive information for these firms is presented in Table 4.

These firms have a mean OLS beta estimate of 1.12 with a standard deviation of 0.54 and 90% of estimates lie within the range of 0.44 to 2.16. The median firm has market capitalisation of US$379 million, book-to-market ratio of 0.77 and debt-to-equity ratio of 0.56.

Table 4. Descriptive statistics for United States-listed firms

Rate	Mean	Median	StdDev	Min	5th perc	95th perc	Max
Beta	1.12	1.08	0.54	-0.23	0.44	2.16	3.18
Betaup	0.94	0.87	0.76	-0.54	-0.07	2.21	5.62
Betadn	1.29	1.20	0.58	0.11	0.41	2.37	3.29
Betadn – Betaup	0.35	0.33	0.76	-3.95	-0.67	1.60	3.36
Market cap (US$m)	1,266	379	3,821	8	24	3,669	41,546
Book/Market	0.91	0.77	0.54	0.06	0.29	2.06	2.92
Debt/Equity	0.91	0.56	1.17	0.00	0.01	3.30	9.64

4. Results

4.1 Introduction

There is considerable estimation error associated with the conventional technique used to estimate the systematic risk of equity in a given firm. There is a small sample problem, both in terms of the number of firms available for analysis and the time period over which we can observe their returns. In the case of QR Network, this limitation is so extreme that prior decisions of the Authority have relied upon analysis of a small sample of listed energy network businesses. Hence, there is a high probability that the OLS beta estimates are not representative of the systematic risk we would expect to be incorporated into the required returns to equity holders for the firms analysed. Furthermore, even if the risk of those firms could be analysed with precision, there is a high probability that the firms analysed are not representative of the risk of QR Network.

The most troubling aspect of the industry analysis is that it ignores firm characteristics which empirical evidence and theory implies are associated with equity returns. The two most commonly-used firm characteristics used to benchmark firms according to risk are market capitalisation and the book-to-market ratio. On average, small firms and high book-to-market firms earn higher returns than large firms and firms with low book-to-market ratios. This result is not specific to any individual market.

A third characteristic, the debt-to-equity ratio, is directly addressed in cost of capital estimation. This is done by assuming that each firm analysed has the same systematic risk in its underlying assets (an asset beta is estimated by "unlevering" the equity beta estimate of listed firms) and the risk to equity holders is estimated under the assumption of benchmark gearing (the equity beta of the firm of interest is determined by "relevering" the asset beta). So the standard technique relies upon a relationship between leverage and equity risk. But if this is true, we can minimise estimation error by examining the relationship between leverage and equity beta for a large number of firms.

So in our analysis we take into consideration not just industry, but market capitalisation, book-to-market ratio and debt-to-equity ratio in equity beta estimation. This is done using two forms of regression analysis. First, we incorporate these four characteristics directly into the regression estimate of beta itself. It is a pooled analysis in which each four-week return is an individual observation. It will generate a beta estimate for each firm with any specified industry, market capitalisation, book-to-market ratio and debt-to-equity ratio.

Second, we measure regression-based estimates for each firm and then compile fitted estimates for firms with the same characteristics. This is analogous to the standard technique in which the fitted estimate is the same value for firms within the same industry. The incremental difference is that our fitted estimate is the same value for firms within the same industry *and* with the same market capitalisation, book-to-market ratio and debt-to-equity ratio.

4.2 Australian-listed firms

4.2.1 Regression incorporating firm characteristics

In Table 5 we present pooled regression results for Australian-listed firms. The coefficients, adjusted r-squared figures and number of observations represent mean values resulting from performing the regression 20 times.

Table 5. Regression analysis incorporating firm characteristics into beta estimates

	Coefficient			Standard error			Two-tailed *p*-value		
	OLS	Up	Dn	OLS	Up	Dn	OLS	Up	Dn
Intercept	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Market capitalisation	0.04	0.12	-0.02	0.07	0.08	0.10	0.59	0.14	0.87
Book-to-market	-0.05	-0.17	0.06	0.10	0.08	0.16	0.59	0.04	0.70
Debt-to-equity	-0.29	-0.40	-0.19	0.09	0.09	0.14	0.00	0.00	0.00
530 Oil & gas producers	1.29	1.13	1.42	0.05	0.09	0.05	0.00	0.18	0.00
570 Oil equipment, services & dist.	**1.21**	**1.03**	**1.35**	**0.19**	**0.21**	**0.20**	**0.27**	**0.90**	**0.08**
580 Alternative energy	1.31	0.90	1.64	0.18	0.23	0.19	0.08	0.66	0.00
1350 Chemicals	0.73	0.47	0.95	0.09	0.10	0.10	0.00	0.00	0.61
1730 Forestry & paper	0.86	0.49	1.20	0.11	0.12	0.13	0.22	0.00	0.13
1750 Industrial metals & mining	1.49	1.24	1.69	0.06	0.08	0.06	0.00	0.00	0.00
1770 Mining	1.28	1.15	1.39	0.03	0.04	0.04	0.00	0.00	0.00
2350 Construction & materials	0.89	0.68	1.06	0.07	0.09	0.07	0.09	0.00	0.35
2710 Aerospace & defence	1.13	0.98	1.23	0.30	0.41	0.25	0.67	0.97	0.37
2720 General industrials	0.62	0.38	0.82	0.08	0.08	0.08	0.00	0.00	0.03
2730 Electronic & electrical equipment	0.93	0.61	1.23	0.09	0.11	0.10	0.40	0.00	0.02
2750 Industrial engineering	0.88	0.67	1.06	0.11	0.12	0.12	0.26	0.01	0.63
2770 Industrial transportation	**0.85**	**0.59**	**1.08**	**0.09**	**0.10**	**0.10**	**0.09**	**0.00**	**0.40**
2790 Support services	1.00	0.69	1.25	0.05	0.07	0.06	0.97	0.00	0.00
3350 Automobiles & parts	0.79	0.45	1.10	0.15	0.18	0.18	0.17	0.00	0.58
3530 Beverages	0.58	0.35	0.79	0.09	0.12	0.09	0.00	0.00	0.02
3570 Food producers	0.65	0.34	0.92	0.06	0.06	0.07	0.00	0.00	0.24
3720 Household goods & home const.	0.85	0.61	1.04	0.10	0.11	0.12	0.14	0.00	0.71
3740 Leisure goods	0.73	0.44	0.97	0.16	0.14	0.21	0.09	0.00	0.87
3760 Personal goods	0.66	0.41	0.86	0.13	0.13	0.15	0.01	0.00	0.34
3780 Tobacco	0.47	0.26	0.66	0.05	0.06	0.06	0.00	0.00	0.00
4530 Health care equip. and services	0.81	0.48	1.07	0.07	0.09	0.08	0.00	0.00	0.35
4570 Pharmaceutical and biotechnology	1.11	0.89	1.28	0.10	0.13	0.10	0.27	0.40	0.01
5330 Food & drug retailers	-1.41	0.20	-2.96	1.96	0.17	3.73	0.22	0.00	0.29
5370 General retailers	0.77	0.51	0.99	0.06	0.07	0.08	0.00	0.00	0.90
5550 Media	0.91	0.68	1.10	0.11	0.12	0.13	0.41	0.01	0.45
5750 Travel & leisure	0.78	0.61	0.92	0.08	0.11	0.12	0.01	0.00	0.49
6530 Fixed line communications	1.15	0.96	1.30	0.13	0.19	0.16	0.22	0.84	0.05
6570 Mobile communications	1.08	0.88	1.23	0.16	0.20	0.18	0.62	0.56	0.19
7530 Electricity	**1.08**	**0.79**	**1.30**	**0.12**	**0.21**	**0.11**	**0.53**	**0.32**	**0.01**
7570 Gas, water & multi-utilities	**0.74**	**0.53**	**0.91**	**0.06**	**0.08**	**0.07**	**0.00**	**0.00**	**0.19**
8350 Banks	0.89	0.68	1.07	0.06	0.08	0.07	0.05	0.00	0.33
8530 Nonline insurance	0.70	0.35	1.03	0.08	0.08	0.14	0.00	0.00	0.83
8570 Life insurance	0.77	0.37	1.13	0.23	0.28	0.18	0.32	0.02	0.46
8630 Real estate investment & services	0.90	0.68	1.09	0.08	0.10	0.08	0.17	0.00	0.28
8670 Real estate investment trusts	0.99	0.66	1.25	0.08	0.09	0.09	0.89	0.00	0.01
8770 Financial services	0.88	0.64	1.06	0.06	0.08	0.06	0.03	0.00	0.33
8980 Equity investment instruments	0.65	0.41	0.86	0.08	0.10	0.10	0.00	0.00	0.14
9530 Software & computer services	1.10	0.90	1.25	0.08	0.12	0.07	0.20	0.43	0.00
9570 Technology hardware & equip.	1.05	0.94	1.14	0.13	0.19	0.16	0.70	0.73	0.38
Observations		323,061							
Adjusted R-squared	2.9		3.0						

There are two sectors of interest. First, we consider the sector 2770 Industrial Transportation which includes 29 firms across Delivery Services (1 firm), Marine Transportation (3 firms), Railroads (1 firm), Transportation Services (16 firms) and Trucking (8 firms). The regression coefficient is 0.85 with a standard error of 0.09, which implies a 90% confidence interval of 0.71 to 0.99. This is the estimated equity beta for a firm in this sector with median market capitalisation, book-to-market and debt-to-equity (across all sample firms). Of the 40 sectors, this sector has the 23rd highest beta estimate and the median beta estimate across the sectors is 0.88. The implication of this analysis is that there is no evidence that the Industrial Transportation sector is more or less exposed to systematic risk than the typical sector. In subsequent analysis we summarise the beta estimates for all 29 firms within this Sector, compiled according to our three estimation techniques.

Expressed as an equation, according to the regression estimates the expected excess return for an Industrial Transportation firm would be given according to the equation below (recalling that MC, B/M and D/E are percentile ranks scaled within the range of –0.5 to +0.5 with ranks computed across the entire sample):

$$r_{i,t} - r_{f,t} = 0.01 + 0.04 \times MC_i \times (r_{m,t} - r_{f,t}) - 0.05 \times \frac{B}{M_i} \times (r_{m,t} - r_{f,t}) - 0.29 \times \frac{D}{E_i} \times (r_{m,t} - r_{f,t}) + 0.85 \times (r_{m,t} - r_{f,t})$$

Second, we consider the sectors which span the nine listed energy network businesses which have been previously relied upon by the Authority in its analysis of QR Network. The sectors are 7530 Electricity (25 firms including Spark Infrastructure and SP Ausnet), 7570 Gas, water & multi-utilities (9 firms including Alinta and Duet Group), and 570 Oil equipment, services & distribution (11 firms including Gasnet, APA Group and Hastings Diversified Utilities Fund). Of these three sectors, there is one with a sector beta estimate significantly below one. The Gas, water & multi-utilities sector has a beta estimate of 0.74, within a 90% confidence interval of 0.64 to 0.85 based upon its standard error of 0.06. This sector has the 30th highest beta estimate. The other two sectors have beta estimates of 1.08 and 1.21, respectively, both of which are close to one in a statistical sense. The implication of this analysis is that, all else being equal, a firm assigned to the Gas, water & multi-utilities sector has an equity beta estimate below one.

We reiterate the importance of performing the analysis 20 times and reporting mean values. For the Industrial Transportation sector, across the 20 sets of analysis the minimum beta estimate was 0.76 and the maximum beta estimate was 0.93. For the Gas, water & multi-utilities sector, the minimum beta estimate was 0.62 and the maximum beta estimate was 0.90. These differences result purely from the selection of the day at which the four-weekly returns are computed, and there is no reason to believe that one start point will be more reliable than another start point.

4.2.2 Regressions with OLS estimates as the dependent variable

The alternative way to account for the association between firm characteristics and systematic risk is to first estimate OLS beta estimates, and then to estimate fitted OLS values according to those characteristics. We present these regression results in Table 6. The dependent variable is the percentile rank of the OLS beta estimates, because this mitigates against the noise associated with extreme beta estimates. We compile fitted percentile ranks and then convert these to beta estimates in the final step. We repeated our analysis using OLS beta estimates as the dependent variable. There is a reduction in explanatory power but the directional results are consistent.

We also present results including and excluding the industry fixed effects, and include the other firm characteristics separately as dependent variables. This is presented to show how the inter-relationships between the firm characteristics impact upon the analysis.

Table 6. Regression analysis with OLS estimates as the dependent variable

	Coefficient				Standard error				Two-tailed *t*-test *p*-value				A-Rsq
	Int	MC	B/M	D/E	Int	MC	B/M	D/E	Int	MC	B/M	D/E	(%)
Panel A: No industry fixed effects													
OLS	0.54	-0.07			0.01	0.02			0.00	0.00			0.5
	0.57		-0.13		0.01		0.02		0.00		0.00		1.6
	0.63			-0.27	0.01			0.02	0.00			0.00	6.9
	0.65	0.00	-0.07	-0.25	0.02	0.02	0.02	0.02	0.00	0.88	0.00	0.00	7.2
Up	0.48	0.04			0.01	0.02			0.00	0.03			0.2
	0.55		-0.09		0.01		0.02		0.00		0.00		0.7
	0.56			-0.12	0.01			0.02	0.00			0.00	1.3
	0.55	0.08	-0.05	-0.13	0.02	0.02	0.02	0.02	0.00	0.00	0.02	0.00	2.2
Down	0.56	-0.12			0.01	0.02			0.00	0.00			1.4
	0.56		-0.11		0.01		0.02		0.00		0.00		1.2
	0.62			-0.26	0.01			0.02	0.00			0.00	6.5
	0.66	-0.05	-0.06	-0.23	0.02	0.02	0.02	0.02	0.00	0.01	0.01	0.00	6.9
Dn – Up	0.08	-0.17			0.02	0.03			0.00	0.00			1.5
	0.01		-0.02		0.02		0.03		0.55		0.37		0.0
	0.06			-0.14	0.02			0.03	0.00			0.00	1.0
	0.11	-0.14	-0.01	-0.09	0.02	0.03	0.03	0.03	0.00	0.00	0.84	0.00	1.9
Panel B: Industry fixed effects													
OLS		0.04				0.02				0.04			80.0
			-0.05				0.02				0.03		80.0
				-0.07				0.02				0.00	80.1
		0.05	-0.03	-0.07		0.02	0.02	0.03		0.02	0.22	0.00	80.1
Up		0.11				0.02				0.00			76.6
			-0.03				0.02				0.16		76.3
				-0.01				0.03				0.60	76.3
		0.12	-0.01	-0.04		0.02	0.03	0.03		0.00	0.66	0.14	76.6
Down		-0.02				0.02				0.32			80.0
			-0.05				0.02				0.03		80.0
				-0.07				0.02				0.00	80.1
		-0.01	-0.04	-0.06		0.02	0.02	0.03		0.51	0.09	0.01	80.1
Dn – Up		-0.13				0.03				0.00			5.3
			-0.01				0.03				0.69		4.4
				-0.06				0.03				0.06	4.5
		-0.13	-0.03	-0.02		0.03	0.03	0.04		0.00	0.41	0.51	5.3

The regression results show, in the absence of industry fixed effects, firm characteristics are able to explain approximately 7% of the variation in the percentile ranks of beta estimates (see the last column in the fourth row of Panel A). This is primarily attributable to a statistically significant inverse relationship between the debt-to-equity ratio and the beta estimates. In a given sample, it is unclear whether we would expect to observe a positive or negative relationship between leverage and the beta estimate. If two firms have the same systematic risk at an operational level (that is, the same asset beta), we would expect an increase in financial risk to be associated with higher beta estimates. However, if firms with low operational risk use relatively more debt to finance their operations, but the low operational risk and high financing risk are not entirely offsetting, then we will observe an inverse relationship between beta estimates and gearing.

In the multiple regression analysis, there is a statistically significant positive relationship between market capitalisation and OLS beta estimates (see the fourth row of Panel B). When the percentile rank of market capitalisation is used as the sole independent variable in the analysis, we observe a statistically significant inverse relationship between size and beta estimates (see the first row of Panel A). However, larger firms take on more leverage (the correlation between the percentile ranks of market capitalisation and the debt-to-equity ratio is 0.32) which offsets the relationship between market capitalisation and the beta estimate. All three coefficients on accounting and market-based characteristics are in the same direction as for the pooled regression analysis.

The industry coefficients are not presented in the table. But the corresponding coefficients for the industries of interest are 0.40 for 2770 Industrial Transportation, 0.49 fo4 570 Oil equipment, services & distribution, 0.54 for 7530 Electricity and 0.28 for 7570 Gas, water & multi-utilities. Recall that these represent percentile ranks. The corresponding beta estimates associated with these percentile ranks are 0.87 for 7530 Electricity, 1.03 for 570 Oil equipment, services & distribution, 1.10 for 7530 Electricity and 0.68 for 7570 Gas, water & multi-utilities.

4.2.3 Beta estimates

In this sub-section we present all three sets of beta estimates – OLS estimates, pooled estimates from the returns regression and fitted estimates from the beta regression. In Table 7 we present estimates for the nine energy network businesses and in Table 8 we present estimates for the 29 Industrial Transportation businesses. In the latter table, firms are sorted in descending order of fitted estimates.

Table 7. Beta estimates for listed energy networks

	Means			Percentiles			OLS estimates			Pooled estimates			Fitted estimates		
Firm	MC	B/M	D/E	MC	B/M	D/E	Beta	Up	Down	Beta	Up	Down	Beta	Up	Down
Spark	1632	0.46	0.93	0.95	0.30	0.92	0.43	0.02	0.71	0.98	0.71	1.20	1.05	0.72	1.20
SPAus	2717	1.06	1.62	0.97	0.78	0.96	0.23	0.20	0.25	0.95	0.61	1.22	1.03	0.71	1.16
APA	1418	0.72	1.26	0.94	0.55	0.95	0.60	0.46	0.70	1.10	0.89	1.26	0.95	0.87	1.07
HDUF	594	0.86	0.90	0.88	0.65	0.92	0.91	0.62	1.11	1.10	0.88	1.28	0.94	0.85	1.06
Gasnet	432	0.64	1.96	0.85	0.48	0.97	0.28	0.18	0.38	1.09	0.88	1.26	0.94	0.84	1.07
AGL	7182	0.88	0.25	0.99	0.67	0.69	0.68	0.66	0.71	0.70	0.49	0.87	0.64	0.64	0.70
Alinta	6475	0.53	0.92	0.99	0.37	0.92	0.54	0.16	0.91	0.64	0.45	0.81	0.63	0.62	0.69
Envestra	807	0.37	2.93	0.90	0.22	0.98	0.56	0.35	0.72	0.63	0.44	0.79	0.62	0.60	0.70
Duet	1571	0.78	3.21	0.94	0.60	0.98	0.62	0.48	0.71	0.61	0.38	0.81	0.60	0.60	0.67
Mean	2536	0.70	1.55	0.93	0.51	0.92	0.54	0.35	0.69	0.87	0.64	1.06	0.82	0.72	0.92
Median	1601	0.71	1.41	0.94	0.53	0.93	0.55	0.35	0.71	0.91	0.62	1.13	0.88	0.71	0.99

For the energy network businesses, the table shows that the mean OLS beta estimate is 0.54. However, the estimates are considerably higher if we condition upon firm characteristics. This sub-sample of firms is relatively large, with high gearing and typical book-to-market ratio, as exhibited by average percentile ranks of 93% and 92% for market capitalisation and debt-to-equity ratio, and 51% for book-to-market ratio. According to firm and industry characteristics, the mean pooled estimate is 0.87 and the mean fitted estimate is 0.82.

For the Industrial Transportation businesses, the mean OLS beta estimate is 0.82, the pooled estimate is 0.78 and the fitted estimate is 0.80. These firms are relatively large, with high book-to-market ratios and high leverage (the mean percentiles are 0.69, 0.64 and 0.76, respectively). The OLS estimate for QR National itself is 0.58, but its pooled and fitted estimates are 0.86 and 0.86, respectively. This illustrates the impact of accounting for firm characteristics. QR National has an OLS beta estimate which is unusually low for a firm of its size, book-to-market ratio, debt-to-equity ratio and industry sector. In contrast, Asciano has an OLS beta estimate of 2.23 but it has a pooled estimate of 0.74 and a fitted estimate of 0.81.

One interpretation of this information is that QR National has systematic risk of approximately half the market, and Asciano has risk of approximately double the market. A more plausible interpretation is that the firms have roughly equal risk to the market and that the OLS beta estimates diverge purely because of random fluctuations in the data.

Table 8. Beta estimates for firms classified as ICB Sector 2770 Industrial Transportation

	Means			Percentiles			OLS estimates			Pooled estimates			Fitted estimates		
Firm	MC	B/M	D/E	MC	B/M	D/E	Beta	Up	Down	Beta	Up	Down	Beta	Up	Down
QR National	7867	0.90	0.09	0.99	0.68	0.51	0.58	0.41	0.64	0.86	0.61	1.08	0.86	0.62	1.08
Comb. Comm	156	0.56	0.08	0.72	0.41	0.51	0.28	-1.35	1.57	0.86	0.62	1.07	0.85	0.56	1.12
Patrick	3636	0.54	0.25	0.97	0.39	0.69	0.93	1.02	0.82	0.82	0.59	1.03	0.85	0.61	1.08
Toll	3209	0.52	0.29	0.97	0.37	0.72	0.95	0.70	1.17	0.81	0.58	1.02	0.84	0.60	1.08
Nevada Iron	12	0.89	0.00	0.20	0.67	0.09	1.93	1.72	2.04	0.95	0.68	1.17	0.84	0.47	1.16
Aus. Infr. Fd.	702	1.22	0.09	0.89	0.85	0.52	0.89	0.66	1.08	0.84	0.56	1.09	0.84	0.59	1.07
Hills M'way	1444	0.36	0.53	0.94	0.21	0.84	0.32	0.17	0.46	0.78	0.55	0.99	0.83	0.59	1.08
Intoll Group	5288	0.95	0.27	0.98	0.72	0.71	0.83	0.72	0.91	0.80	0.52	1.05	0.82	0.60	1.05
QUBE Log.	398	1.18	0.14	0.84	0.83	0.59	1.01	0.79	1.16	0.82	0.53	1.08	0.82	0.57	1.07
Transurban	4679	0.51	0.67	0.98	0.36	0.88	0.50	0.39	0.59	0.77	0.52	0.99	0.82	0.59	1.06
Viking Ind.	102	0.46	0.23	0.65	0.31	0.67	0.80	0.73	0.88	0.82	0.57	1.03	0.82	0.53	1.11
Adst. & Mar.	567	0.54	0.60	0.88	0.39	0.86	0.84	0.67	1.01	0.77	0.51	1.00	0.82	0.57	1.07
Fin. Hldg.	140	0.77	0.23	0.70	0.59	0.67	0.87	0.79	0.97	0.80	0.53	1.05	0.82	0.54	1.08
Asciano	4200	0.79	1.03	0.98	0.60	0.93	2.23	2.63	1.95	0.74	0.45	1.00	0.81	0.58	1.04
Syd. Airport	4971	1.01	0.76	0.98	0.75	0.89	0.97	0.65	1.19	0.74	0.44	1.01	0.80	0.58	1.03
K & S	153	0.79	0.42	0.72	0.60	0.80	0.40	0.03	0.74	0.77	0.47	1.03	0.80	0.53	1.06
Mermaid Mar.	234	0.82	0.51	0.78	0.62	0.84	0.96	0.80	1.08	0.76	0.46	1.02	0.80	0.54	1.05
IAMA	214	0.63	0.82	0.77	0.47	0.91	0.49	0.24	0.81	0.74	0.46	1.00	0.80	0.54	1.05
Richfield Intl.	3	3.13	0.00	0.01	0.98	0.22	0.11	-1.14	1.08	0.89	0.56	1.17	0.80	0.41	1.13
Chall. Infr.	687	0.82	2.70	0.89	0.62	0.98	0.60	0.12	0.93	0.72	0.42	0.99	0.79	0.55	1.03
Safe. Hldgs	34	1.06	0.32	0.45	0.78	0.74	1.26	1.20	1.29	0.76	0.43	1.05	0.78	0.47	1.06
Holyman	118	1.05	1.13	0.67	0.78	0.94	0.38	-1.07	2.06	0.72	0.38	1.01	0.77	0.51	1.03
Engenco	115	1.31	0.90	0.67	0.87	0.92	1.87	1.58	2.06	0.72	0.38	1.02	0.77	0.51	1.03
TDG Logistics	53	1.15	0.88	0.53	0.82	0.91	0.84	1.27	0.35	0.72	0.37	1.02	0.77	0.48	1.04
CTI Logistics	29	1.30	0.82	0.42	0.87	0.90	0.63	0.24	0.98	0.71	0.35	1.03	0.76	0.46	1.04
Scott Corp.	23	0.91	1.13	0.36	0.69	0.94	0.65	0.52	0.76	0.71	0.36	1.01	0.76	0.45	1.05
Lindsay Aust.	31	1.10	1.44	0.43	0.80	0.95	0.43	0.19	0.64	0.70	0.35	1.01	0.76	0.46	1.04
Pru. Inv. Co.	14	0.69	1.43	0.24	0.53	0.95	1.00	-1.81	4.03	0.71	0.37	1.00	0.75	0.42	1.06
Chalmers	18	1.48	0.65	0.30	0.90	0.87	0.22	0.21	0.22	0.71	0.34	1.04	0.75	0.43	1.04
Mean	1348	0.95	0.64	0.69	0.64	0.76	0.82	0.45	1.15	0.78	0.48	1.04	0.80	0.53	1.07
Median	156	0.89	0.53	0.72	0.67	0.84	0.83	0.65	0.98	0.77	0.47	1.02	0.80	0.54	1.06

4.3 United States-listed firms

4.3.1 Regression incorporating firm characteristics

In Table 9 we present pooled regression results for US-listed firms in the Sector 2770 Industrial Transportation. This includes 32 Delivery Services firms, 56 Marine Transportation firms, 9 Railroads, 24 Transportation Services firms and 71 Trucking firms. For Railroads, the regression coefficient is 0.77 with a standard error of 0.08, which implies a 90% confidence interval of 0.63 to 0.91. This is the estimated equity beta for a firm in this sector with median market capitalisation, book-to-market and debt-to-equity (across all sample firms).

Expressed as an equation, according to the regression estimates the expected excess return for a Railroad firm would be given according to the equation below (recalling that MC, B/M and D/E are percentile ranks scaled within the range of –0.5 to +0.5 with ranks computed across the sample of US-listed Industrial Transportation firms):

$$r_{i,t} - r_{f,t} = 0.00 + 0.72 \times MC_i \times (r_{m,t} - r_{f,t}) + 0.26 \times \frac{B}{M_i} \times (r_{m,t} - r_{f,t}) + 0.27 \times \frac{D}{E_i} \times (r_{m,t} - r_{f,t}) + 0.77 \times (r_{m,t} - r_{f,t})$$

Table 9. Regression analysis incorporating firm characteristics into beta estimates

	Coefficient			Standard error			Two-tailed *p*-value		
	OLS	Up	Dn	OLS	Up	Dn	OLS	Up	Dn
Intercept	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Market capitalisation	0.72	0.79	0.64	0.14	0.16	0.15	0.00	0.00	0.00
Book-to-market	0.26	0.18	0.33	0.20	0.24	0.20	0.20	0.46	0.11
Debt-to-equity	0.27	0.16	0.40	0.15	0.15	0.16	0.00	0.00	0.00
2771 Delivery Services	1.10	0.96	1.23	0.09	0.13	0.08	0.28	0.73	0.01
2773 Marine Transportation	1.10	0.81	1.33	0.09	0.09	0.09	0.24	0.04	0.00
2775 Railroads	**0.77**	**0.60**	**0.93**	**0.08**	**0.09**	**0.09**	**0.01**	**0.00**	**0.41**
2777 Transportation Services	1.15	1.07	1.19	0.09	0.13	0.08	0.09	0.59	0.02
2779 Trucking	0.97	0.77	1.15	0.04	0.05	0.05	0.43	0.00	0.00
Observations		31,923							
Adjusted R-squared	12.9	13.1							

4.3.2 Regressions with OLS estimates as the dependent variable

In Table 10 we present the regression analysis where the dependent variable is the percentile rank of the OLS beta estimates.

In the multiple regression analysis, there is a statistically significant positive relationship between market capitalisation and OLS beta estimates (see the fourth row of Panel B). When the percentile rank of market capitalisation is used as the sole independent variable in the analysis, we observe a statistically significant inverse relationship between size and beta estimates (see the first row of Panel A). However, larger firms take on more leverage (the correlation between the percentile ranks of market capitalisation and the debt-to-equity ratio is 0.32) which offsets the relationship between market capitalisation and the beta estimate. All three coefficients on accounting and market-based characteristics are in the same direction as for the pooled regression analysis.

The industry coefficients are not presented in the table. But the corresponding coefficients for the industries of interest are 0.40 for 2770 Industrial Transportation, 0.49 fo4 570 Oil equipment, services & distribution, 0.54 for 7530 Electricity and 0.28 for 7570 Gas, water & multi-utilities. Recall that these represent percentile ranks. The corresponding beta estimates associated with these percentile ranks are 0.87 for 7530 Electricity, 1.03 for 570 Oil equipment, services & distribution, 1.10 for 7530 Electricity and 0.68 for 7570 Gas, water & multi-utilities.

Table 10. Regression analysis with OLS estimates as the dependent variable

	Coefficient				Standard error				Two-tailed *t*-test *p*-value				A-Rsq
	Int	MC	B/M	D/E	Int	MC	B/M	D/E	Int	MC	B/M	D/E	(%)
Panel A: No industry fixed effects													
OLS	0.32	0.37			0.04	0.06			0.00	0.00			12.9
	0.49		0.02		0.04		0.08		0.00		0.81		-0.5
	0.41			0.19	0.04			0.07	0.00			0.01	3.1
	0.12	0.45	0.14	0.17	0.06	0.07	0.10	0.08	0.05	0.00	0.15	0.04	18.8
Up	0.32	0.37			0.04	0.07			0.00	0.00			13.2
	0.51		-0.03		0.04		0.08		0.00		0.72		-0.5
	0.47			0.06	0.04			0.07	0.00			0.44	-0.2
	0.17	0.46	0.19	0.01	0.06	0.07	0.10	0.09	0.01	0.00	0.05	0.92	15.3
Down	0.37	0.26			0.04	0.07			0.00	0.00			6.5
	0.49		0.01		0.04		0.08		0.00		0.87		-0.5
	0.38			0.25	0.04			0.07	0.00			0.00	5.6
	0.21	0.30	-0.02	0.29	0.07	0.07	0.10	0.08	0.00	0.00	0.87	0.00	13.7
Dn – Up	-0.05	0.11			0.05	0.08			0.27	0.19			0.4
	0.02		-0.04		0.05		0.08		0.66		0.61		-0.4
	0.09			-0.19	0.05			0.08	0.04			0.02	2.5
	-0.04	0.17	0.20	-0.29	0.08	0.08	0.10	0.09	0.57	0.05	0.04	0.00	3.7
Panel B: Industry fixed effects													
OLS		0.39				0.06				0.00			79.8
			-0.08				0.08				0.33		76.3
				0.11				0.08				0.19	76.4
		0.46	0.12	0.11		0.07	0.10	0.09		0.00	0.23	0.22	80.4
Up		0.39				0.07				0.00			78.7
			-0.09				0.08				0.24		75.1
				-0.01				0.08				0.94	74.9
		0.49	0.20	-0.04		0.07	0.10	0.09		0.00	0.05	0.65	79.0
Down		0.28				0.07				0.00			78.1
			-0.08				0.08				0.31		76.3
				0.08				0.08				0.31	76.9
		0.29	-0.04	0.24		0.07	0.10	0.09		0.00	0.65	0.01	79.0
Dn – Up		0.11				0.08				0.18			0.2
			-0.01				0.08				0.90		-0.8
				-0.19				0.09				0.04	1.7
		0.20	0.24	-0.29		0.09	0.10	0.10		0.03	0.02	0.01	3.5

4.3.3 Beta estimates

As with the data for Australian-listed firms, in this sub-section we present all three sets of beta estimates – OLS estimates, pooled estimates from the returns regression and fitted estimates from the beta regression. In Table 11 we present estimates for each individual US-listed Railroad, plus mean and median estimates for each industry sector.

For the Railroads, the mean OLS beta estimate is 0.99, the mean pooled estimate is 0.96 and the mean fitted estimate is 0.99. The mean estimates for the remaining 183 Industrial Transportation firms are only slightly higher, at 1.12 for OLS estimation, 0.96 for the pooled estimate and 0.99 for the fitted estimate. This provides support for the analysis of Australian-listed Industrial Transportation firms. In the US, there is no material difference in the beta estimates across the sub-sectors within this overall industry sector.

Table 11. Beta estimates for US-listed firms classified as ICB Sector 2770 Industrial Transportation

		Means			Percentiles			OLS estimates			Pooled estimates			Fitted estimates		
Firm	N	MC	B/M	D/E	MC	B/M	D/E	Beta	Up	Dn	Beta	Up	Dn	Beta	Up	Dn
CSX		11,554	0.84	0.67	0.97	0.56	0.58	1.09	1.00	1.16	1.15	0.99	1.28	1.13	0.93	1.25
Burlington		13,975	0.66	0.54	0.98	0.38	0.49	0.96	0.90	1.01	1.08	0.95	1.19	1.10	0.89	1.24
Norfolk		14,063	0.72	0.36	0.99	0.45	0.37	0.93	0.89	0.97	1.07	0.95	1.17	1.10	0.93	1.17
Union Pac.		19,684	0.62	0.44	0.99	0.32	0.41	0.90	0.88	0.91	1.06	0.94	1.15	1.09	0.89	1.21
Kansas City		2,344	0.71	0.56	0.94	0.45	0.50	1.31	1.08	1.52	1.07	0.93	1.19	1.09	0.89	1.21
Rail America		709	1.04	0.87	0.65	0.68	0.64	1.18	0.36	1.82	0.97	0.77	1.14	0.96	0.74	1.14
Genesee & Wy.		733	0.70	0.51	0.67	0.44	0.46	1.01	0.82	1.17	0.86	0.71	1.00	0.90	0.69	1.09
Florida Ea.		1,071	0.78	0.08	0.80	0.51	0.14	0.89	0.70	1.08	0.88	0.77	0.97	0.94	0.84	1.05
Prov. & Worc.		60	1.44	0.07	0.10	0.85	0.12	0.64	0.54	0.73	0.47	0.29	0.64	0.62	0.38	0.78
Mean		7,133	0.83	0.46	0.79	0.51	0.41	0.99	0.80	1.15	0.96	0.81	1.08	0.99	0.80	1.13
Median		2,344	0.72	0.51	0.94	0.45	0.46	0.96	0.88	1.08	1.06	0.93	1.15	1.09	0.89	1.17
Means																
2771 Delivery Svcs.	32	2406	0.70	0.39	0.52	0.36	0.33	1.08	0.97	1.28	1.03	0.92	1.13	1.02	0.82	1.19
2773 Marine Trans.	56	552	1.19	1.31	0.49	0.64	0.66	1.33	1.07	1.52	1.18	0.86	1.44	1.19	0.93	1.36
2775 Railroads	9	7133	0.83	0.46	0.79	0.51	0.41	0.99	0.80	1.15	0.96	0.81	1.08	0.99	0.80	1.13
2777 Trans. Svcs.	24	656	1.00	1.39	0.48	0.55	0.57	1.22	1.16	1.27	1.17	1.08	1.23	1.14	0.99	1.21
2779 Trucking	71	779	0.77	0.72	0.47	0.43	0.44	0.95	0.77	1.14	0.91	0.72	1.09	0.95	0.76	1.10
2775 Railroads	9	7133	0.83	0.46	0.79	0.51	0.41	0.99	0.80	1.15	0.96	0.81	1.08	0.99	0.80	1.13
Ex. Rail	183	978	0.92	0.93	0.49	0.50	0.50	1.12	0.95	1.30	1.05	0.84	1.22	1.06	0.85	1.21
2770 Ind. Trans.	192	1266	0.91	0.91	0.50	0.50	0.50	1.12	0.94	1.29	1.04	0.84	1.21	1.06	0.85	1.21
Medians																
2771 Delivery Svcs.	32	355	0.53	0.27	0.48	0.24	0.28	1.04	0.81	1.17	1.01	0.90	1.15	1.02	0.81	1.22
2773 Marine Trans.	56	362	1.15	1.08	0.49	0.74	0.71	1.32	0.96	1.46	1.17	0.81	1.43	1.16	0.90	1.34
2775 Railroads	9	2344	0.72	0.51	0.94	0.45	0.46	0.96	0.88	1.08	1.06	0.93	1.15	1.09	0.89	1.17
2777 Trans. Svcs.	24	486	0.81	0.92	0.54	0.54	0.65	1.02	0.98	1.13	1.15	1.05	1.23	1.12	0.97	1.18
2779 Trucking	71	291	0.69	0.42	0.43	0.42	0.41	0.95	0.81	1.08	0.90	0.69	1.10	0.90	0.73	1.08
2775 Railroads	9	2344	0.72	0.51	0.94	0.45	0.46	0.96	0.88	1.08	0.96	0.88	1.08	1.06	0.93	1.15
Ex. rail	183	355	0.77	0.57	0.48	0.50	0.51	1.09	0.86	1.24	1.05	0.82	1.20	1.09	0.85	1.24
2770 Ind. Trans.	192	379	0.77	0.56	0.50	0.50	0.50	1.08	0.87	1.20	1.05	0.83	1.19	1.09	0.86	1.22

5. Conclusion

The detailed rationale behind our conclusion is presented in the executive summary. In short, the returns information is consistent with an equity beta of 1.00 for QR Network, if 60% leverage is assumed.

Our conclusion is are based upon three specific sub-samples – nine Australian-listed energy networks, 29 Australian-listed Industrial Transportation firms and 9 US-listed Railroads – but they are informed by information from much larger samples of 2400 Australian-listed firms and 192 US-listed Industrial Transportation firms. They are also based upon three estimation techniques, two of which account for firm characteristics aside from industry, namely market capitalisation, book-to-market ratio and debt-to-equity ratio.

Neither sample of data is perfect for the task at hand, nor is any one estimation technique, so the issue becomes how much weight to place on each sample and technique. With respect to techniques, we repeat that if, within the sample, firm characteristics had no role to play in estimating systematic risk, then the coefficients on these variables would be zero. So it seems that if the returns information itself was considered reliable for the purposes of beta estimation, at least some reasonable weight should be placed upon this relevant information. With respect to samples, there is an obvious limitation associated with each sample in terms of product, customers and market. Again, the issue is simply how much weight should be placed on each sample.

What we observe is that we arrive at a re-levered equity beta of approximately 1.00 if reasonable weight is placed upon estimation techniques which account for firm characteristics and on samples other than Australian-listed energy networks.

6. References

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