REPORT TO THE AER

ESTIMATION OF THE EQUITY BETA (CONCEPTUAL AND ECONOMETRIC ISSUES) FOR A GAS REGULATORY PROCESS IN 2012

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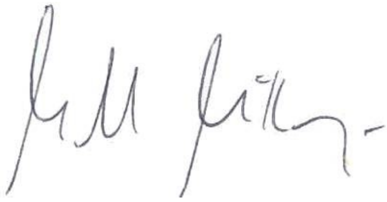
REPORT DATED APRIL 3, 2012.

Expert Witness Compliance Declaration

We have read the Guidelines for Expert Witnesses in proceedings in the Federal Court of Australia and this report has been prepared in accordance with those guidelines. As required by the guidelines we have made all the inquiries that we believe are desirable and appropriate and that no matters of significance that we regard as relevant have, to our knowledge, been withheld from the Court.

Signed



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Preamble

We have been asked to provide a written report that addresses the following questions, in the context of previous analysis on equity beta included in the AER's WACC review and subsequent regulatory decisions:

1. **Are there conceptual or theoretical grounds to expect that the benchmark firm has an equity beta below 1.0?** (See paragraphs 47–49 of the SFG report).
    a. Relative to the average firm in the market, will the benchmark firm have lower or higher *business risk*? Relative to the average firm in the market, will the benchmark firm (which is defined as having 60 per cent gearing) have lower or higher *financial risk*? What will the net result of these two effects be? Are there other conceptual or theoretical grounds for forming an expectation on the equity beta for the benchmark firm? Are your views on these matters the same or different depending on if the benchmark firm is defined as:
        i. generally, a regulated energy network / pipeline (i.e. electricity and gas, transmission and distribution)
        ii. specifically, a regulated gas transmission pipeline
    b. Explain the relationship between equity betas, financial leverage and financial risk. What is the nature or shape of the relationship (e.g. linear or some other form) between financial leverage and financial risk likely to be for:
        i. generally, a regulated energy network / pipeline (i.e. electricity and gas, transmission and distribution)
        ii. specifically, a regulated gas transmission pipeline (if different from (i))
        iii. an unregulated firm in a competitive market

    (see AER WACC review, final decision, pages 249-254)

2. **Do regressions with a low R^2 systematically understate equity beta?** (See paragraphs 80–87 of the SFG report). In particular:
    a. What are the relevant conceptual and econometric issues?
    b. Examine in detail the Monte Carlo simulation presented by SFG (paragraph 86), including the underlying data and statistical code. What conclusion should be drawn from this simulation?
    c. Are the AER/Henry equity beta estimates likely to be downwards biased, given the observed R^2 for these regressions; if so, to what magnitude?

3. **Are all equity betas below 1.0 downwards biased?** (See paragraphs 90–93 of the SFG report). In particular:

a. What are the relevant conceptual and econometric issues? What regard should be had to the industry of the equity beta in forming a view on the likelihood of bias? Is the use of industry portfolio betas an appropriate method to address any bias in the estimation of individual firm equity betas?

b. Examine in detail the Monte Carlo simulation presented by SFG (paragraph 92), including the underlying data and statistical code. What conclusion should be drawn from this simulation?

Are the AER/Henry equity beta estimates likely to be downwards biased, given the method of equity beta estimation; if so, to what magnitude?

In answering these questions, we have engaged with the relevant academic literature and other research as well as the key documents provided, including:

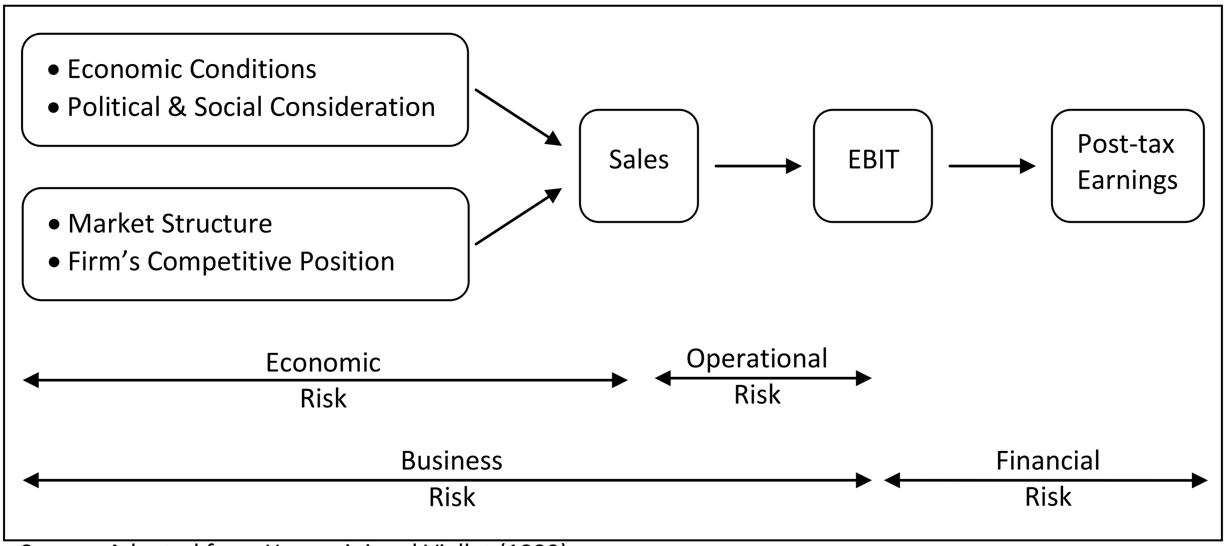
- Material authored or commissioned by the AER:
    - AER, *Final decision, Electricity transmission and distribution network service providers, Review of weighted average cost of capital (WACC) parameters*, 1 May 2009, pp. 239–344.
      Available at <http://www.aer.gov.au/content/index.phtml/itemId/722190>
    - Olan Henry, *Estimating beta*, 23 April 2009.
      Available at <http://www.aer.gov.au/content/index.phtml?itemId=728166>
    - AER, *Final Decision, Envestra Ltd, Access arrangement proposal for the SA gas network, 1 July 2011 – 30 June 2016*, June 2011, pp. 46–49, 176–184.
      Available at <http://www.aer.gov.au/content/index.phtml/itemId/747092>
- Material authored or commissioned by APTPPL:
    - APTPPL, *Access arrangement submission, Effective 12 April 2012 – 30 June 2017*, October 2011, pp. 54–56.
      Available at <http://www.aer.gov.au/content/index.phtml/itemId/750330>
    - APTPPL Attachment 6.2 – SFG, *Equity beta, Report prepared for APT Petroleum Pipelines Ltd*, 11 October 2011.Available at <http://www.aer.gov.au/content/index.phtml/itemId/750330>
    - Statistical analysis (base data and SAS code) underlying the analysis in paragraphs 86 and 92 of the SFG report.

1. Are there conceptual or theoretical grounds to expect that the benchmark firm has an equity beta below 1.0?

1.1 The Theoretical Determinants of Systematic Risk

Equity beta is a measure of a firm's systematic risk and it is useful to conceptualise the systematic risk of a firm as having three main components – economic, operational and financial risk. Figure 1 shows the relationship between each of these different aspects of systematic risk and their relationship to the firm.

Figure 1
Dimensions of Systematic Risk



Source: Adapted from Hawawini and Viallet (1999)

Economic (or intrinsic) risk is determined by factors such as barriers to entry, the firm's position within the industry including elements of monopoly and monopsony power, the firm's competitive strategy and so on. These factors all determine how the business cycle impacts on the firm. The sales of some firms will be highly sensitive to the business cycle – growing through the expansionary phase and contracting through the recessionary phase. However for other firms, their sales will hardly vary at all through the business cycle. The implication is that for firm's whose earnings are more sensitive to the business cycle, they will exhibit a beta of more than one and vice versa. To avoid any confusion on this point, it is important to note the distinction between the earnings variability of the company and the cyclicality of the company earnings. They are not the same thing as the variability of earnings is a form of company risk that can be diversified away, while the latter captures the variability of the company's sales compared to the aggregate earnings of the economy and is a direct determinant of beta.

The operational risk of the company refers to the firm's operating leverage, ie. the firm's proportion of fixed to variable costs. Recall that variable costs directly scale in proportion to sales, while fixed costs do not. Thus, as the firm's sales vary during the business cycle, their variable costs will also vary. Their fixed costs however, do not vary and must continue to be met. The higher are the firm's fixed costs therefore, the higher will be the variability of the firm's earnings before interest and tax (EBIT) for a given change in sales.[1] Thus, operating leverage intensifies the effect of the business cycle on a company's earnings and this higher risk translates into a relatively higher beta. Note that in many references, the economic and the operational risk of the firm are frequently referred to as the business risk of the firm.

The financial risk of a company relates to the indebtedness or leverage of the firm. The interest charge on debt is another form of fixed cost and just as the fixed costs of operations cause EBIT to vary with changes in sales, so too do these fixed financing costs cause profit after tax to vary with changes in EBIT.[2]

Each of these three different components - economic, operational and financial risk - come together to form the systematic risk for the firm. To gain an insight into the systematic risk of the benchmark firm[3] relative to the average firm in the market, we need to consider each of these factors in turn. It is worth noting that although the benchmark firm is a gas transmission pipeline, our discussion has direct implications for all regulated energy networks in general (electricity and gas, distribution and transmission).

Firstly, with respect to the economic risk, it is fairly uncontroversial to suggest that the benchmark firm will have lower risk relative to the average firm in the market. In a previous decision, the AER has stated that in its view, regulated businesses will:

> "...face lower systematic risk than the market, primarily due to the stable cash flows of these businesses. The lower equity beta is the result of a regulatory regime that provides protection to regulated businesses that are not available to those in the competitive environment, including:
>
> - tariff variation mechanism allows for the annual adjustment for inflation, lowering exposure to inflation risk
> - roll forward of the capital asset base occurs in a manner that lowers exposure to cost overruns for capital expenditure
> - cost pass through mechanism allows for certain costs to be passed on to consumers during the access arrangement period, lowering exposure to costs not forecast at the commencement of the access arrangement period
> - the access arrangement provides for acceleration of the review submission date on occurrence of a trigger event

[1] Note - EBIT equal sales less variable and fixed expenses.

[2] Note - post-tax earnings are EBIT less fixed interest and variable tax expenses

[3] A benchmark firm is defined in the terms of reference as an efficient network service provider that: does not undertake business activities other than regulated gas transmission pipeline services (sometimes called a 'pure play' firm), operates within Australia, and has no parent ownership or other form of support. While the discussion is framed in context of this benchmark firm, it has direct implications for all regulated energy networks.

- a service provider may submit an access arrangement variation proposal for the AER's approval."[4]

SFG (2011, p. 14) regards this view as "generally accepted". While these statements specifically refer to the overall systematic risk of the company, it is clear that in terms of the taxonomy provided in Figure 1, they are referring to economic risk, which is one of the components of business risk. As such, it would seem to be reasonable to assume that the benchmark firm will have lower economic risk relative to the average firm in the market.

The second component of business risk is operational risk. The transmission and distribution of energy requires a large infrastructure that manifests itself in the company's financials as a high proportion of fixed costs relative to variable costs in comparison to the average firm in the market. Thus, the benchmark firm will most likely have an operating leverage that will be higher than the average firm whose fixed to variable cost ratio will be lower.

Since interest charges on debt are simply another form of fixed cost, these financing costs may be considered in much the same manner as the previously discussed fixed costs. The financial leverage of the benchmark firm will be higher relative to the average firm in the market. Indeed, the assumption of a 60:40 gearing ratio for the benchmark firm is an explicit recognition of the higher debt ratios of energy transmission and distribution companies. It is worth noting that while the assumption of 60% debt financing for a regulated network distribution or transmission business is (approximately) twice that of the average firm, it is unclear what impact this extra debt will have on the benchmark firm's financial risk (we return to consider this point more fully in the following section).

Prior to any discussion of the relative merits of each of these factors and the conceptual beta for the benchmark firm, it is first necessary to consider the theoretical relationship between equity beta, financial leverage and financial risk.

1.2 The relationship between equity betas, financial leverage and financial risk.

The relationship between equity betas and asset betas is based on the principle that the return on a firm's portfolio of issued securities must equal the return on the firm's assets, since it is the assets that generate the return for the security holders. As a consequence the beta of the assets and the beta of the portfolio of securities must also be equal. Furthermore, since the beta of a portfolio is just a value weighted average of the betas of each security in the portfolio, we can write:

$$\beta_A = \beta_P = \sum_{i=1}^{n} w_i \beta_i$$

[4] AER (2011) Final Decision - Public, N.T. Gas: Access arrangement proposal for the Amadeus gas pipeline, p. 69, July.

where β_A is the beta of the firm's assets, β_P is the beta of the firm's portfolio, β_i is the beta of the individual securities that the firm has issued, w_i is the value weight of the security, and n is the number of types of securities that the firm has issued. If we assume that the firm only has shares and one class of debt then we can write:

$$\beta_A = \beta_D \frac{D}{V} + \beta_E \frac{E}{V}$$

where β_D is the beta of the firm's debt, β_E is the beta of the firm's equity, D is the market value of debt, E is the market value of the equity. Since the market value of the firm is equal to the value of the firm's debt and equity, ie. $V = D + E$, we can restate the previous equation as:

$$\beta_A = \beta_D \frac{D}{D+E} + \beta_E \frac{E}{D+E}$$

Solving for β_E :

$$\beta_E = \beta_A \frac{D+E}{E} - \beta_D \frac{D}{E}$$

$$= \beta_A \left(\frac{D}{E} + 1\right) - \beta_D \frac{D}{E}$$

$$= \beta_A + \frac{D}{E}(\beta_A - \beta_D)$$

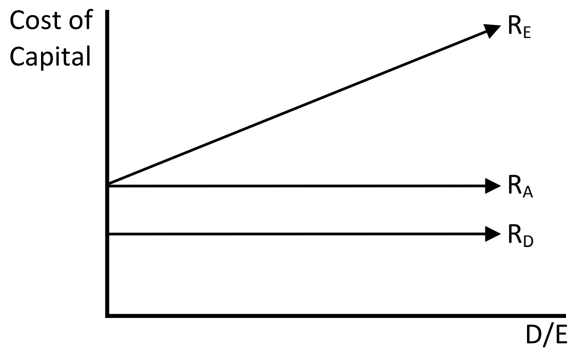
Assuming the beta of debt is zero, the formula used by SFG and the AER is derived:

$$\beta_E = \beta_A \left(1 + \frac{D}{E}\right)$$

This equation clearly shows that as the financial leverage of the firm increases, so must the equity beta. This is the relationship which SFG (2009) is highlighting in the discussion on pages 9 – 12 and in the Appendix.

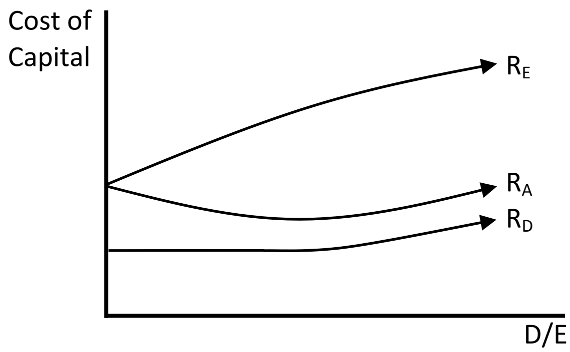
The confusion on this issue between SFG and the AER would appear to lie in the distinction between financial leverage and financial risk. In the Modigliani and Miller (M&M hereafter) framework, which is the basis for the SFG example, financial risk is formally defined as the risk in the cash flows to the *shareholders* caused by changes in the firm's leverage. Figure 1 provides a visual interpretation of this relationship and shows that with zero debt, the cost of capital (R_A) is the return on equity (R_E). As the leverage of the firm increases, the proportion of the firm which is equity financed falls, but the expected return of the shareholders increases leaving the overall WACC unchanged. Since the expected return on the firm's assets (WACC) is $R_A = R_D \frac{D}{V} + R_E \frac{E}{V}$, it logically follows that the beta of the firm's assets is a weighted average of the firm's securities. Hence, the higher R_E will be reflected in a higher equity beta.

Figure 2
The Cost of Equity and Cost of Capital



The previous analysis assumes that there are no taxes and the cost of debt is a constant. Where we modify the analysis to include these two factors, then the analysis changes in that the tax deductibility of interest payments on debt and direct and indirect bankruptcy costs must be taken into account (Figure 3). The tax shield of debt means that the cost of capital falls as more debt is issued by the firm. As the leverage of the firm increases, however, at some point the cost of debt rises as the increased risk of bankruptcy is factored in. This has implications for equity holders as the more debt the firm has, the more business risk is transferred from stockholders to bondholders. Thus, the more debt the firm has, the less sensitive R_E is to further borrowing giving the relation between leverage and R_E a nonlinear shape.

Figure 3
The Cost of Equity and Cost of Capital



The argument made by the AER (2009, p. 253) was that:

> "... a regulated utility can pass through much higher borrowing costs through higher prices and not expect its profitability to diminish. In contrast, if a business in a competitive market was faced with much higher borrowing costs it would likely have to wear some of those higher cost (as attempting to pass those costs through via higher prices may lead to lower

> profitability caused by a loss of market share or consumers substituting away from the product or service)."

These comments, and hence the source of disagreement between the AER and SFG on this issue, may be put in context using Figure 3. To the extent that the firm is able to pass on the borrowing costs, the likelihood of bankruptcy as the leverage of the firm increases is low and so the R_D and R_E curves are more like their linear counterparts as shown in Figure 2 (although the R_A curve would continue to slope down due to the tax shield of debt). If the firm was able to pass on all of these costs such that the bankruptcy costs were zero, then the firm would be 100% debt financed. Thus, the fact that these firms have some equity finance suggests there is a limit to the ability of the firm to pass on higher borrowing costs.

The cost of ordinary shares, and hence the equity beta, always increases with leverage in this framework. As noted, this analysis is conducted within the M&M framework. It is worth noting that many academics do not accept the M&M framework and a 'neo-traditional' position has emerged that challenges the M&M propositions on which the preceding analysis was built. While a detailed exposition of this alternative position is beyond this report, suffice it to say that the basic point of distinction is that they argue that M&M overstate the extent of the increase in the return to equity for moderate levels of debt, but understate the extent of the increases for high levels of debt. Regardless, this alternative view does still find in favour of an increasing equity beta as financial leverage increases.

Both M&M and the neo-traditionalist view find that the equity beta of the firm increases as the leverage of the firm, and hence its financial risk, increases. While the nature of this relationship could be linear or nonlinear, given the existence of bankruptcy costs and the tax shield of debt, our view is that the latter is more likely the case. The type of nonlinearity, however, is unclear given the differing theories governing the nature of the nonlinearity.[5] This is true whether the firm is a regulated energy network, a regulated gas pipeline or an unregulated firm in a competitive market.

1.3 The Assumption of Zero Beta

Recall that the analysis of the previous section assumed the debt beta to be zero. While this is a common assumption among academics and practitioners, it is nonetheless incorrect.[6] It is true that the volatility of the equity market is far greater than the debt market, but this does not mean the covariance is zero as this would imply the expected return on debt equals the risk free rate assuming no default. Thus, while it is likely that the debt beta is low, it is unlikely that it is zero. For example, Brealey and Myers (2003, p. 229) report that

[5] Aretz (2011) shows that a firm's default risk and its expected equity return are non-monotonically related in an equilibrium Black and Scholes (1973) economy.

[6] McLaney et al (2004, p. 128) report that 25% of market practitioners assume a non-zero debt beta when estimating the cost of capital.

debt betas are typically in the range of 0.1 to 0.3. They estimate the beta of a bond portfolio equal to 0.17 for the decade ending December 2000.

The possibility of a non-zero debt beta can make quite a difference to the analysis of de-leveraging and re-leveraging beta. For example, SFG (2011, p. 11) take a firm with an equity beta of one and show that with 30% leverage, it's de-levered beta is estimated to be 0.7. They then take the case of a gas distribution or transmission business with an assumed asset beta of 1 and show that its de-levered beta is equal to 0.4 assuming 60% debt finance. With respect to these differences, the SFG report notes:

> Setting the equity beta for a gas distribution or transmission business to 1.0 is consistent with the business activities of such businesses having only 57% of the systematic risk of the average business (0.4/0.7). (SFG, 2011, p. 11)
>
> The regulatory estimate of 0.8 implies that the business operations of a gas distribution or transmission firm have *less than half the risk* of those of the average firm. … There is no *a priori* reason to believe that the business operations of a gas distribution or transmission firm have *less than half* the risk of those of the average firm (SFG, 2011, p. 15, emphasis in original)

If we do not assume the beta of debt is zero and instead assume a conservative mid-point estimate of debt beta equal to 0.2, the outcome would be different. The de-levered equity beta will be 0.76 for the average firm and 0.52 for the gas distribution or transmission business. The point is that the process of un-levering and re-levering a firm's beta will give different results depending on what you assume about the magnitude of the debt beta.

A further problem with the de-levering re-levering process is that it gets more complicated when we introduce tax. With taxes, the cash flow to security holders no longer depends on just the return on assets, but also on how the firm is financed.

While this discussion certainly has implications for the estimates of beta, it is unclear exactly what conclusions we should draw. The end result of any analysis will rely on a host of factors: which theory of capital structure you is assume, whether you assume the firm targets particular levels of debt in absolute terms, or in terms of a leverage ratio, how frequently you assume the firm rebalances to the target debt level and what adjustments you assume for the effects of imputation. In short, there are so many twists and turns that the de-leveraging and re-levering exercise can take you to a range of different destinations depending on what you assume.

In the light of the foregoing discussion the sort of comparisons proposed by SFG must be treated with extreme caution. We note, however, that there is unlikely to be material error in the de-levering, re-levering process followed by the AER. This is because we understand that the AER's de-levering, re-levering was from an average leverage level of 62% to the benchmark leverage of 60%. The change in leverage is small and consequently the method de-levering and re-levering has little effect. For example, consider the data used by SFG above, and add the condition that the starting level of leverage is 62% and ending level of leverage is 60%. In the case where the debt beta is assumed to be zero the equity beta after de-levering and re-levering is 0.95. In the case where the debt beta is assumed to be 0.2 the equity beta after de-levering and re-levering is 0.96.

1.4 Another Perspective on the relationship between equity betas, financial leverage and financial risk.

Section 1.2 considers the relationship between equity betas, financial leverage and financial risk in the context of M&M framework. An alternative perspective on this relationship may be obtained by drawing on the accounting beta literature. To this end, we begin by recapping the standard formula that is commonly used to estimate the market beta of stock *i*:

$$\beta_i^M = \frac{Cov(R_{it}, R_{mt})}{\sigma^2(R_{mt})}$$

where R_{it} is the return to stock *i* for the estimation period *t-1* to t, R_{mt} is the return to the market portfolio for the same estimation period and $\sigma^2(.)$ is the variance operator and $Cov(.)$ is the covariance operator. To the extent that earnings information captured by accounting data drive share prices, the following equality between the market and the accounting beta may be derived:

$$\beta_i^M \equiv \frac{Cov(R_{it}, R_{mt})}{\sigma^2(R_{mt})} = \frac{Cov(Z_{it}, Z_{mt})}{\sigma^2(Z_{mt})} \equiv \beta_i^A$$

where Z_{it} is the earnings per share relative to price of firm i and Z_{mt} is the equivalent aggregate value for the market (see Beaver, Kettler and Scholes, 1970). This equality suggests that while market beta is not determined by accounting data, it is assumed that these accounting data reflect (imperfectly) the underlying economic factors that are the real drivers of stock prices (and so beta).[7] Further, Mensah (1992) and Ohlson (1979) and Garman and Ohlson (1980) and Beaver, Kettler and Scholes (1970) suggest a linear relationship exists between accounting and market beta, in which case any conclusions about the accounting beta can be applied equally to the market beta.

If we assume that the returns to the company's stock, R_{it}, are related to accounting earnings information, then through a process of substitution and simplification the accounting beta of a firm can be estimated as:

$$\beta_i^A = (DOL)(DFL)\beta_i^0$$

[7] Note that strictly speaking this commonly cited equality is only true under the assumption that the debt beta of the firm is zero. While it is small, the debt beta of the firm is nonetheless positive and as such, while the average accounting beta of the firm is unity, the equivalent equity beta must be less than unity.

where DOL is the Degree of Operating Leverage, DFL is the degree of financial leverage and β_i^0 is the firm's intrinsic risk after the operational and financial risk have been accounted for (see Appendix 1 for full details of this process). Note that a number of authors have since modified this model to include other forms of risk (see *inter alia* Mensah, 1992, Griffin and Dugan, 2003, and Schlueter and Sievers, 2011). For example, Griffin and Dugan (2003) derive a version of this model that explicitly accounts for economic leverage, ie. $\beta_i = (DOL)(DFL)(DEL)\beta_i^0$.

The basic message of this formula is clear. Both DOL and DFL serve to magnify the intrinsic risk of equity as measured by the accounting beta (note that although this equation implies a nonlinear multiplicative effect of financial structure on systematic risk, a log-linear transformation is employed in empirical estimation). This conclusion also applies to the equity market beta given the aforementioned linear relationship between the accounting and market betas.

1.5 The Trade-off between Economic, Operational and Financial Risk

The discussion in Section 1.1 highlighted how a firm's systematic risk is composed of economic, operational and financial risk. Each of these three factors has a positive *theoretical* influence on systematic risk and Sections 1.2 and 1.4 provide specific detail on the theory of how financial leverage, and so financial risk, is linked to a firm's beta. The previous discussion, however, has not considered either the relative influence nor the importance of each of these factors in determining the overall systematic risk of the firm and it is to this issue that we now turn our attention.

We begin by focusing on the operational and financial components of the firm's systematic risk. Van Horne (1977, p. 784) states:

> "Operating and financial leverage can be combined in a number of different ways to obtain a desirable amount of risk in the common stock. High operating leverage can be offset with low financial leverage and vice versa."

This is unlikely to be true for the benchmark firm as regulated energy companies will have high operating *and* financial leverage (a point made by SFG, 2011, para 49). As an interesting aside, Mandelker and Rhee (1984) find that firms with high betas engage in trade-offs more actively than do firms with low betas. In the context of these findings, the fact that gas distribution or transmission firms have only a limited ability to trade off operating and financial leverage, suggests that the benchmark firm may have a beta which is below average.

The inability of the benchmark firm to trade off operating and financial leverage suggests that the level of systematic risk for the firm comes down to a question of the extent to which the higher leverage *per se* offsets the lower business risk of the firm.

For insights on this issue, we can look to the empirical literature for guidance. Most importantly, the evidence provided in Chung (1989), Mensah (1992), Griffin and Dugan (2003) and Schlueter and Sievers (2011) suggests that intrinsic risk is the main driver of a firm's beta rather than either its operating or financial leverage. While these results apply to the market in general, in the context of energy, they are particularly relevant. The insignificance of operating leverage is possibly a reflection of the legislation that requires tariff structures to be cost reflective. In the gas context, rule 94(4) of the NGR states:

> NGR r. 94(4): A tariff, and if it consists of 2 or more charging parameters, each charging parameter for a tariff class:
>
> > (a) must take account the long run marginal cost for the reference service or, in the case of a charging parameter, for the element of the service to which the charging parameter relates…

Hence, a regulated energy network with a large proportion of fixed costs should recover a large proportion of its costs through a fixed charge on users. In practice, the fixed charges prevalent in both electricity and gas (daily charges for network connection, irrespective of gas/electricity use; and capacity charges irrespective of gas use) achieve exactly this. Hence, the firm has a revenue base to meet their fixed costs and so, this feature of their pricing structure insulates them from operational risk.

In terms of financial leverage, Schlueter and Sievers (2011) argue that since changing interest rates affect all firms in a similar fashion, ceteris paribus, financial leverage is not an important part of systematic risk. For energy firms, this is particularly relevant given that most firms have a similar capital structure incorporating a high level of similarly rated debt.

Thus, although a theoretical trade off exists between (operational and financial) leverage and economic risk, in practical terms, the empirical evidence suggests that it is the intrinsic risk of the firm which is the primary, if not sole, driver of its systematic risk.

Recall that intrinsic risk refers to the volatility of the demand for the firm's product due to changes in the macroeconomic conditions. The measurement of intrinsic risk factors is obviously important and Penman (2004, 2010) argues that sales growth risk is the main driver of business risk, affecting both the growth in and the return on net operating assets and, ultimately, the returns on equity (corroborating empirical evidence may be found in Lakonishok, Shleifer and Vishny, 1994, Davis, 1994, Mohanram, 2005, and Cooper, Gulen and Schill, 2008). Note that Schlueter and Sievers (2011) decompose growth risk into factors capturing firm profitability and efficiency, but find in favor of the basic growth measure.

Growth risk in this context refers to the risk that firm sales will differ from the market wide trends. That is to say, the covariance of firm sales with market-wide sales trends (which proxy for market output), is a key determinant of intrinsic risk and so equity beta. For regulated utilities, their price is set by the government authority in the course of the review cycle (see AER, 2009, pp 249 – 250 for details of the relevant price control mechanisms). In terms of quantity, the relevant elasticity is likely to be low given the lack of substitutes, competitors, high barriers to entry, constant consumer tastes and preferences and so on. For example, Bernstein and Griffin (2006) find that the price elasticity of demand for energy is small and that this relationship is also stable, changing little over the 20 years of their study. They suggest that these findings imply, "that there are few options available to the consumer in response to changes in the price of energy, and that price does not respond much to changes in demand" (Bernstein and Griffin, 2006, p. 8). The AER (2009, p. 249) noted this point with respect to the electricity industry and arguably the same applies in the context of the gas industry.

With relatively constant price and quantity, the covariance of firm sales with market-wide sales is likely to be low, resulting in a similarly low economic risk and hence systematic risk estimate.

Taken together, the previous conceptual discussion clearly provides evidence to suggest that the theoretical beta of the benchmark firm is very low. While it is difficult to provide a point estimate of beta, based on these considerations, it is hard to think of an industry that is more insulated from the business cycle due to inelastic demand and a fixed component to their pricing structure. In this case, one would expect the beta to be among the lowest possible and this conclusion would apply equally irrespective as to whether the benchmark firm is a regulated energy network or a regulated gas transmission pipeline.

Empirical support for this proposition may be found by looking at the industry beta tables of Damodoran (see Appendix 2). The equity betas for water, gas and electricity are the lowest in the table, while their debt to equity ratios are among the highest. Although this evidence is based on US companies, there is no reason to believe that a similar pattern would not exist in Australia.

2. Do regressions with a low R^2 systematically understate equity beta?

SFG (2011, para 75 - 87) argues that there is a relationship between the coefficient of determination (ie. the R^2) of a regression and the Ordinary Least Squares (OLS) estimate of the slope coefficient. Simulation evidence is provided that purports to demonstrate this relationship.

On closer examination, we find that this relationship exists by construction and is not unusual. It should not be interpreted as evidence of a systematic relationship. More specifically, the R^2 is obtained from the ratio of the explained sum of squared to the total sum of squares (ie. ESS/TSS). The R^2 and achieves its maximum value of 1 where ESS = TSS. Correspondingly, 1 - $R^2 = RSS / TSS$ (where RSS is the residual sum of squares) and the R^2 achieves its minimum value of zero where RSS = TSS. By construction therefore:

$$R^2 = \frac{ESS}{TSS} = \frac{\hat{\beta}S_{xy}}{S_y}$$

That is, R^2 will be low if the estimate of beta ($\hat{\beta}$) is close to zero (and/or S_{xy} is close to zero meaning that the ESS is small relative to the TSS). Appendix 3 provides a full theoretical derivation of this result including an explanation of the terms.

We may use this basic result to explain many of the outcomes in the simulation results provided by SFG (2011) and we consider this point more fully in the following section

2.1 The SFG Simulation Study

SFG (2011, p. 19) claims that, "Estimates are statistically unreliable when the R^2 is low". This claim is spurious. The R^2 is informative about the proportion of variation in the dependent variable that is explained by the model. It is well known that the statistical reliability of OLS estimates is independent of R^2. OLS estimates will tend to be biased and inefficient when one or more of the four assumptions outlined in Appendix 3 under section A3.3 are violated. The R^2 is uninformative about whether these assumptions are satisfied. Moreover, there is no guarantee that the estimates are statistically reliable when the R^2 is close to unity. Common problems such as serial correlation, heteroscedasticity or endogenous regressors would not be revealed by a high R^2. In the extreme where both x_i and y_i display persistence, OLS regressions are typically uninformative (referred to as spurious regressions) yet yield very high R^2 values. Typically tests are used to determine the degree of persistence in x_i and y_i and indeed u_i to avoid the spurious regression outcome.

As noted by SFG (2011, p. 19), Henry (2008) does not report, consider or give any weight to R^2 statistics because they are uninformative about the statistical reliability of the estimates. Henry (2009) does report these metrics, but it is hard to understand why as the R^2 for market model type regressions are always very low. For example, Bartholdy and Peare (2005) highlight that regressions to estimate beta are typically only associated with R^2 values of 0.03 (ie. 3%) and for a Fama-French 3 factor type model, it only increases to 0.05 (ie. 5%). Thus, Henry's failure to report the R^2 is fairly standard practice in this context as it is generally accepted that the R^2 is of little value.[8]

The AER quotation highlighted by SFG (2011, p. 19) stating that:

[8] We may relate this discussion to Gray et al (2009, pp. 222–223) and comment that we agree it would be inappropriate to filter beta estimates based on the R^2 of the regression. Our arguments however, are based on the uninformativeness of the R^2 and not concerns with omitting low beta stocks. We do find SFG's (2011) questions as to the validity of low beta estimates based on the R^2 somewhat conflicting with the stance of Gray et al (2009) who argued that such estimates are important to prevent bias from the exclusion of low beta stocks.

> "a low-R-squared indicates that more of the variation in the variables is noise that is unrelated to the effect that is being measured, making it more difficult to obtain statistically reliable estimates"

is undoubtedly poorly phrased. Where the R^2 is low, the RSS will tend to be high. The standard errors for the estimates of α and β depend on the least squares estimate for the residual variance, $\hat{\sigma}^2 = RSS/(n-1)$. As the RSS increases the confidence intervals about the estimates increase. The estimates are therefore less statistically reliable in the sense that there is a degree of uncertainty about the estimates, not that they are incorrectly calculated. The higher the R^2, the lower the RSS, and hence the more precise, rather than reliable, are the estimates in that the confidence intervals about the estimates are narrow.

On page 20 of the SFG report, the claim is made that, "Mis-estimation is material when the R^2 is low". This statement is incorrect. As long as the assumptions underlying the OLS approach are satisfied then there is no mis-estimation. The counter-factual that mis-estimation is immaterial when the R^2 is high is equally invalid. A high (low) R^2 simply tells us that the model explains a large (small) proportion of the variation in the dependent variable. The reliability or otherwise of the estimated β depends solely on whether the model is correctly specified. If the model is correctly specified, that is, if the residuals are consistent with the assumptions underlying the classical linear regression model, then $\hat{\beta}$ is the best linear unbiased estimator of β, irrespective of R^2.

2.1.1 The Monte-Carlo experiment outlined on P21 of the SFG report

SFG (2011, p. 20) state that they, "generate stock and market return data in a setting where the true equity beta is 1.0 (the signal) and where there is random variation in the data (the noise) that is commensurate with what is observed in practice".

We agree that the signal in the experiments is 1.0 corresponding to a true beta of unity. We disagree however, that the variation in the data is commensurate with what is observed in practice. Moreover, we are surprised at the assumptions implied about the covariation between the market and stock return. The experiment is constructed to satisfy:

$$R^2 = 1 - \frac{\sigma_e^2}{\sigma_e^2 + \sigma_m^2} = 0.2$$

This implies that $\sigma_e^2 = 4\sigma_m^2$ by construction and can hardly be described as "commensurate with what is observed in practice".

The experiment is constructed under the assumption that R^2 is equal 0.2. This implies that the correlation between the market and stock return is $\sqrt{0.2} = 0.447$. It is not clear to us that this assumption is "commensurate with what is observed in practice". What is clear to us is that an equity with a return that is 4 times as volatile as the market return, but a correlation of 0.447 with the market to ensure a beta of unity is not "commensurate with what is observed in practice".

2.1.2 The simulated data

SFG (2011) provides simulation results designed to illustrate the relationship between R^2 and beta. An examination of the code provided reveals that the study is as described, however, we do have a number of issues with how the simulation is performed.

One issue is that the simulated data for r_i are claimed to be normally distributed with mean zero and variance σ_e^2 on page 21 on the SFG (2011) report. We do not believe that this claim is valid. The market return is drawn with replacement from the empirical distribution of r_m. We note that this distribution is reported to have mean 0.56 and 0.13 for monthly and weekly returns respectively. The distribution of r_i can only have zero mean as claimed if the E(ε)=-0.56 for the monthly returns and -0.13 for the weekly returns, in which case we violate the first assumption underlying the OLS estimator. We suggest that that this is either an artefact of a typographical error or an omission from the text describing the construction of the data.

A more critical issue is the possibility that the r_i data is heteroscedastic, or deviates substantially from normality given the stock return is constructed using market returns bootstrapped from their empirical distribution. It is well known that the empirical distribution of returns, including market returns, deviates from normality and is strongly conditionally heteroscedastic. In this case, we know that the OLS estimate of beta might be biased, but this can only occur because the residuals from the OLS regressions deviate from the assumptions underlying the classical linear regression model. The R^2 is uninformative about any violations of these assumptions. In the case of heteroscedasticity, for example, the R^2 is entirely uninformative and may be high or low. Appropriate tests for heteroscedasticity followed by appropriate estimation can be employed to overcome this deviation from the underlying assumptions.

Based on this discussion, we regard the results in Table 2 of SFG (2011) as entirely uninformative. Specifically, we do agree that the point estimate for the average beta when R^2 is between 3-7% is 0.50 for monthly data based on the table. What we don't agree with, however, is that this result is in any way informative . There are a number of outstanding issues that prevent us from drawing such a conclusion: firstly, we do not know what the source of the deviation from their true values actually is. Secondly, we do not know whether this is a significant deviation as we do not have a measure of uncertainty for the deviation. Finally, we do not know how frequently these cases occur within the experiment. That is to say, what is the relative frequency of the outcomes (or alternatively what proportion of the outcomes lie in each class interval). In summary, there is sufficient doubt about the applicability of these simulations to the case in hand to warrant them being disregarded.

3. Are all equity betas below one downwards biased?

We have been instructed to assume that the equity beta is estimated within the standard Sharpe-Lintner CAPM framework. The most commonly used method is an OLS regression of the market returns against the individual stock returns, where the point estimate of the slope coefficient is the risk parameter.[9] As discussed in Appendix 3, when the assumptions of classical linear regression model are satisfied, then OLS provides the best linear unbiased estimator (BLUE) for α and β. Thus, given an information set, the point estimate of β in a correctly specified CAPM type regression is unbiased irrespective as to the industry of the firm or whether the estimate is above or below one. This is the case for the AER/Henry equity beta estimates.

If we update the information set, a different estimate may result, if for no other reason than the distribution of returns is non-Gaussian and time dependent. For example, if a rolling window of a fixed width is used to estimate beta then old data being replaced by new and the estimate of beta will necessarily be different. If we were able to repeatedly resample the data, the estimate of beta would converge (eventually) on the true beta. Repeat sampling, however, is a luxury not ever afforded to the social scientist, in which case we can never know the true beta.

This helps us to place the arguments of the SFG (2011) report in context. Their thought experiment focuses on the impact of the precision of the estimates and assumes that we know something about the distributional properties of the true beta.[10] This assumption is incorrect as, *a priori*, the true beta is not a known value and therefore an experiment predicated on an assumption about the true beta should be disregarded. Thus, the whole experiment is without foundation (see Section 3.2 for further discussion on the SFG experiment).

Blume (1975) investigates the empirical phenomena whereby the beta estimated for a portfolio in one period tended to be followed by a beta estimate in the next period that was closer to the market beta of unity. Blume (1975) argues that this pattern will appear in both portfolio and individual stock betas and two explanations have been advanced to explain this phenomena. In addition to the statistical explanation (as summarised in SFG, 2011), Blume (1975) also offers an economic justification - the logic is that as a firm with a low beta grows its operations, it is unlikely to find projects of a similar low risk. Thus, it will invest in relatively higher risk projects that increase the firm beta (the reverse is true for high risk

[9] Other techniques are possible, such as the LAD method used in Henry (2008), although their use is uncommon.

[10] If the imprecision of the point estimate is of concern, we should focus on the interval estimate provided by OLS.

firms). Where this is the case, then the change in beta reflects a genuine change in the risk profile of the firm.

Blume (1975, p. 791) considers both the statistical and the economic explanations for the observed pattern in beta and finds that where an adjustment is made for the statistical bias the regression tendency of beta persists supporting the economic interpretation. More recently, Michelfelder and Theodossiou (2010) argue against a Blume style adjustment to public utility betas based on the observation that their betas do not converge to one. Rather they find that long term public utility betas trend downward and the traditional approach may overstate the true cost of capital.[11]

3.1 The use of portfolio betas versus individual stock betas

Rather than focusing on individual stocks, academics and industry often consider industry based stock portfolios when estimating beta. The use of portfolios will reduce *measurement error* – in fact, we can say that if we assume unbiasedness and a sufficiently large sample, the process of averaging may theoretically reduce any measurement error to (near) zero. The use of portfolios, however, will not reduce *estimation bias* as no such bias exists (as highlighted in the discussion of the previous section).

The use of such a portfolio based approach may prove to be useful where some of the observed differences in asset betas are attributable to measurement error. It does however, suffer a number of drawbacks. Firstly, some information is lost in the aggregation of stocks to portfolios. Secondly, a more serious problem exists in the form of the aforementioned issues that surround the process of de- and re-leveraging betas (see Section 1.3). While differences in individual firms' capital structures may be taken into account by re-levering the industry un-levered beta using a particular firm's gearing, the appropriate method to adjust for leverage is an open question. We are of the opinion that such problems more than likely outweigh any benefits from the use of portfolios. Finally, in the context of regulated utilities, it is probable that there would be an insufficient number of firms to give industry estimates that were much more reliable than could be generated from individual firms.

3.2 The SFG simulation study

SFG (2011) provides simulation results designed to illustrate the 'bias' in beta estimates based on an assumed knowledge of the true beta. An examination of the code provided reveals that the study is as described. One problem with this study is that the estimated output for the high and low beta portfolios is highly sensitive to both the assumptions employed and the variable chosen for sorting betas into deciles (SFG form deciles based on

[11] As at the time of writing, we have only been able to secure a copy of the abstract of this paper. As such, we cannot comment on the veracity of this papers findings.

the simulated beta estimates, however, a sort based on the actual beta estimates is arguably more appropriate).

For example, Table 1 presents the SFG (2011) simulation results employing different assumptions. Panel A of Table 1 presents the results of 1,000,000 simulations run using the original parameters reported in the SFG report and the results are consistent with those reported. Panel B examines what happens to these simulation results where the standard deviation of the true beta for all stocks is assumed to be 0.3 instead of 0.5 with all other parameters as per the original results. A value of 0.3 was chosen as it is the actual standard deviation of betas reported in Datastream for all Australian stocks. Panel C reports the results of the simulation study where the standard deviation of the estimation errors are assumed to be 0.4 (we note that SFG does not appear to justify its choice of 0.8 and our arbitrary choice of half of that value is equally as plausible) with all other parameters as per the original results. Panel D reports the results of the simulation study where the standard deviation of the true beta for all stocks is assumed to be 0.3 and the standard deviation of the estimation errors are assumed to be 0.4 with all other parameters as per the original results. Panel E reproduces the simulation results of the original SFG report where the actual betas are used as the sort variable with all other parameters as per the original results. Finally, Panel F reports the simulation results where the standard deviation of the true beta for all stocks is assumed to be 0.3 and the actual betas are used as the sort variable, with all other parameters as per the original results. A detailed discussion of the results of each of these different simulations is unnecessary. They simply serve to highlight the point that the results of the simulation are sensitive to the assumptions employed.

A second problem with the experiment is that it assumes that the beta is normally distributed with a mean value of one. Given the probability mass of the assumed distribution is centered around one, by construction, the simulation must show that any beta below one is estimated with a negative bias and vice versa for any estimate above one. If the simulation were to be repeated assuming an alternative distributional assumption which did not have its mass centered around the measure of central tendency, this result would not apply.[12]

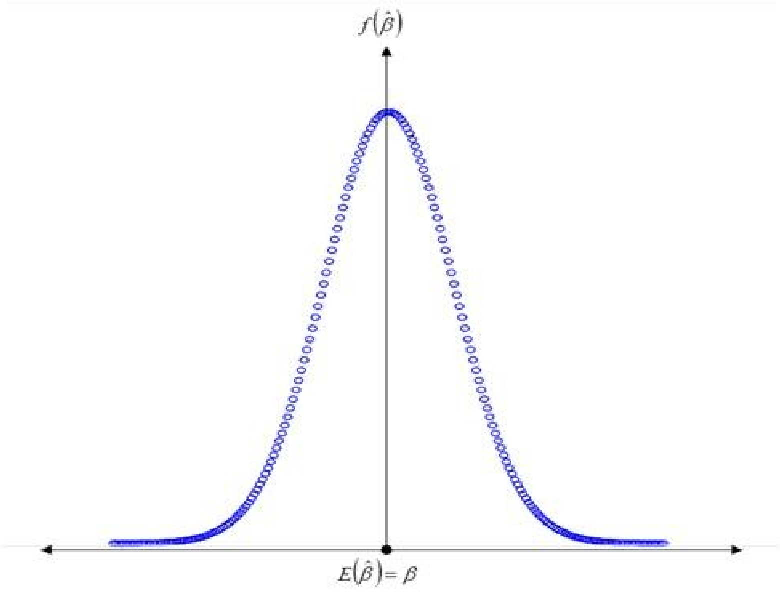
Most importantly, the SFG simulation is inconsistent with the sampling theory on which the estimates of beta are based. There are three issues: first, we never actually know the true value of beta. Second, if we are estimating the beta for a given stock with a true beta of 0.8, the betas of other stocks are irrelevant. Third, the estimate of beta is normally distributed around the true value of beta. That is, the estimator is continuous but the population

[12] It is possible to argue that we don't even know whether the beta of the average firm is equal to one let alone the distribution of the values around that measure of central tendency. A good example of this is provided by Damodoran who reports that more than 90% of all stocks on the Brazilian market have a beta of less than one. In this case only a small number of firms will have a true beta value equal to one even though it is true to say that the weighted average beta is equal to one. (Damodoran, 1999, "Estimating Risk Parameters" available at http://archive.nyu.edu/handle/2451/26906).

parameter is fixed at a point. There is no bias in the case described by SFG, rather there are three true values and three corresponding estimators. Figure 4 illustrates the point where the true beta could be one of the three true values 0.8, 1.0 and 1.2 and the dispersion of the estimates around this measure of central tendency are captured by the value of the variance of the beta estimate. It might well be the case that for any true beta value, 0.8, 1.0 or 1.2 is a perfectly plausible estimate of beta. We may infer nothing from the SFG experiment other than that the probability that beta = 1.0 is equal to one-third. However, this has no relevance for the outcome of the estimate of beta as in the real world we do not know the probability of the population parameter taking on a given value. If we did live in a world in which there were 3 stocks with true betas of 0.8, 1.0 and 1.2, each of these true betas represents a parameter for a particular distinct population. We use data drawn from population *i* to estimate the parameters of this population. We do not need or use data sampled from population *j* or *k*.[13]

Figure 4

The OLS Estimator is Continuous Around the Relevant True Value



In conclusion, as we can never know know the cross-sectional distribution of the true beta, this discussion by SFG amounts to little more than an interesting thought experiment. *A priori*, the true beta is not a known value and therefore any experiment predicated on an assumption about the true beta should be disregarded.

[13] This discussion also relates to issues raised in the AER WACC Review (AER, 2009, pp 300-201).

4. Conclusion

This report was asked to prepare a response to three questions. The first question was whether there are conceptual or theoretical grounds to expect that the benchmark firm has an equity beta below 1.0? A close examination of the components of systematic risk clearly suggests the answer to this question is in the affirmative. In fact, one would expect the beta to be among the lowest possible and this conclusion would apply equally irrespective as to whether the benchmark firm is a regulated energy network or a regulated gas transmission pipeline.

The second question asked whether regressions with a low R^2 systematically understate equity beta? While necessarily technical, the answer to this question is undoubtedly no. Put simply the R^2 depends on the estimate of beta by construction and is in no way informative as to the statistical reliability of the beta estimate.

The final question asked if all equity betas below one are downwards biased? The answer to this question is that the point estimate of beta in a correctly specified CAPM type regression is unbiased irrespective as to whether the estimate is above or below one. Further, as we can never know the cross-sectional distribution of the true beta, the simulation results and associated discussion by SFG amounts to little more than an interesting thought experiment.

Table 1: Sensitivity analysis of SFG (2011) simulation results illustrating the bias in beta estimates

Decile	1	2	3	4	5	6	7	8	9	10
Panel A – Assumed SFG Parameters										
(1) Mean Actual Beta	0.53	0.72	0.82	0.90	0.97	1.03	1.10	1.18	1.28	1.46
(2) Mean Beta Estimate	-0.66	0.02	0.36	0.64	0.88	1.12	1.37	1.64	1.99	2.66
Probability of (1) > (2)	1	5	14	27	42	58	73	86	95	99
Panel B – Beta StDev = 0.3 Sort by Estimated Beta										
(1) Mean Actual Beta	0.81	0.88	0.92	0.95	0.98	1.01	1.04	1.07	1.10	1.18
(2) Mean Beta Estimate	-0.50	0.10	0.42	0.66	0.89	1.10	1.32	1.57	1.89	2.50
Probability of (1) > (2)	0	0	3	15	37	62	84	96	99	99
Panel C – Est Error 0.4 Sort by Estimated Beta										
(1) Mean Actual Beta	0.31	0.59	0.73	0.84	0.94	1.04	1.14	1.26	1.40	1.68
(2) Mean Beta Estimate	-0.12	0.32	0.56	0.75	0.91	1.07	1.24	1.43	1.66	2.12
Probability of (1) > (2)	8	20	29	37	45	53	61	70	79	91
Panel D – Est Error 0.4 StDev = 0.3 Sort by Estimated Beta										
(1) Mean Actual Beta	0.68	0.81	0.87	0.93	0.97	1.02	1.06	1.12	1.18	1.31
(2) Mean Beta Estimate	0.12	0.47	0.66	0.80	0.93	1.06	1.19	1.33	1.52	1.87
Probability of (1) > (2)	1	8	18	30	43	56	69	81	91	98
Panel E – Gray Results Sort by True beta										
(1) Mean Actual Beta	0.66	0.85	0.90	0.94	0.98	1.01	1.05	1.09	1.14	1.33
(2) Mean Beta Estimate	-0.20	0.47	0.65	0.80	0.93	1.06	1.19	1.33	1.52	2.20
Probability of (1) > (2)	4	18	28	37	45	54	63	71	81	95
Panel F – Beta StDev = 0.3 Sort by True Beta										
(1) Mean Actual Beta	0.88	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.11
(2) Mean Beta Estimate	0.05	0.68	0.79	0.88	0.96	1.03	1.11	1.20	1.31	1.94
Probability of (1) > (2)	2	16	26	36	45	54	64	73	83	97

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Appendix 1

Following Mandelker and Rhee (1984), to understand the link between the market equity beta estimate and the accounting beta, consider the standard market beta formula:

$$\beta_i^M = \frac{Cov(R_{it}, R_{mt})}{\sigma^2(R_{mt})} \quad (1)$$

where R_{it} is the return to stock *i* for the estimation period *t-1* to *t*, R_{mt} is the return to the market portfolio for the same estimation period and $\sigma^2(.)$ is the variance operator and $Cov(.)$ is the covariance operator.

If we take an accounting perspective on the determinants of the value of the firm, we can define $R_{it} = (\prod_{it}/E_{it-1}) - 1$, where $\prod_{it}$ denotes earnings after tax and interest at time t and E_{it-1} denotes the market value of common equity at t-1. Substitution of this definition of returns into (1) yields:

$$\beta_i = Cov[(\prod_{it}/E_{it-1}) - 1, R_{mt}]/\sigma^2(R_{mt})$$

Since a constant term does not alter the covariance estimate, this may be simplified to:

$$= Cov[(\prod_{it}/E_{it-1}), R_{mt}]/\sigma^2(R_{mt}) \quad (2)$$

The properties of the covariance under linear transformation means that we can multiply the first term in the covariance equation by $\prod_{it-1}/\prod_{it-1}$ and subtracting a constant from it gives:

$$\beta_i = (\prod_{it-1}/E_{it-1})Cov[(\prod_{it}/\prod_{it-1}) - 1, R_{mt}]/\sigma^2(R_{mt}) \quad (3)$$

The Degree of Financial Leverage (DFL) is the percentage change in $\prod$ that results from a percentage change in X, where X denotes EBIT, ie.:

$$DFL = \left[\left(\frac{\Pi_{it}}{\Pi_{it-1}}\right) - 1\right] / \left[\left(\frac{X_{it}}{X_{it-1}}\right) - 1\right] \quad (4)$$

Solving for $(\prod_{it}/\prod_{it-1}) - 1$ produces:

$$\left(\frac{\Pi_{it}}{\Pi_{it-1}}\right) - 1 = DFL\left[\left(\frac{X_{it}}{X_{it-1}}\right) - 1\right] \quad (5)$$

The Degree of Operating Leverage (DOL) is measured by the percentage change in X that is associated with a given percentage change in the units produced and sold, where Q is the number of units. In this case:

$$DOL = \left[\left(\frac{X_{it}}{X_{it-1}}\right) - 1\right] / \left[\left(\frac{Q_{it}}{Q_{it-1}}\right) - 1\right] \quad (6)$$

Solving for $(X_{it}/X_{it-1}) - 1$ produces:

$$\left[\left(\frac{X_{it}}{X_{it-1}}\right)-1\right]=DOL\left[\left(\frac{Q_{it}}{Q_{it-1}}\right)-1\right] \qquad (7)$$

Successive substitution of (7) into (5) and (5) into (3) produces:

$$\beta_i=(DOL)(DFL)\ Cov[(\prod_{it-1}/Q_{it-1})(\mathrm{Q}_{it}/E_{it-1}),R_{mt}]/\sigma^2(R_{mt}) \qquad (8)$$

Where S denotes sales in dollars, $S = pQ$, where p is the price per unit. Multiplying the first argument of the covariance in (8) by p/p the final equation is derived:

$$\beta_i=(DOL)(DFL)\beta_i^0 \qquad (8)$$

where $\beta_i^0=Cov[(\prod_{it-1}/S_{it-1})(\mathrm{S}_{it}/E_{it-1}),R_{mt}]/\sigma^2(R_{mt})$. Since $(\prod_{it-1}/S_{it-1})$represents the net profit margin at *t-1* and $(\mathrm{S}_{it}/E_{it-1})$ measures the turnover of the firm's common equity for the period from *t-1* to *t*, the covariance of the produce of these two terms with the returns on the market portfolio represents the Intrinsic Business Risk (IBR)of the common stock as measured by β_i^0. As such, we may simply state the derived relationship as:

$$\beta_i=(DOL)(DFL)(IBR) \qquad (8)$$

Appendix 2

Damodoran Industry Beta Estimates

Industry Name	*Number of Firms*	*Average Beta*	*Market D/E Ratio*	*Tax Rate*	*Unlevered Beta*	*Cash/Firm Value*	*Unlevered Beta corrected for cash*
Water Utility	11	0.66	81.42%	35.22%	0.43	0.38%	0.43
Natural Gas Utility	22	0.66	67.38%	30.16%	0.45	1.52%	0.46
Electric Utility (East)	21	0.70	66.16%	33.14%	0.48	2.09%	0.49
Thrift	148	0.71	29.33%	12.43%	0.57	24.35%	0.75
Retail/Wholesale Food	30	0.75	41.34%	31.21%	0.58	8.32%	0.64
Electric Utility (West)	14	0.75	84.54%	31.30%	0.47	2.57%	0.49
Electric Util. (Central)	21	0.75	86.16%	31.82%	0.47	1.71%	0.48
Bank	426	0.77	156.11%	15.97%	0.33	11.41%	0.38
Environmental	82	0.81	43.70%	11.71%	0.58	2.88%	0.60
Educational Services	34	0.83	12.33%	25.17%	0.76	16.55%	0.92
Med Supp Invasive	83	0.85	16.08%	11.86%	0.74	7.20%	0.80
Tobacco	11	0.85	18.71%	31.03%	0.76	3.13%	0.78
Telecom. Utility	25	0.88	96.15%	29.42%	0.52	3.22%	0.54
Beverage	34	0.88	26.52%	19.14%	0.73	5.09%	0.77
Insurance (Prop/Cas.)	49	0.91	23.60%	19.36%	0.76	24.15%	1.01
Medical Services	122	0.91	49.45%	19.93%	0.65	16.30%	0.78
Food Processing	112	0.91	29.53%	20.00%	0.74	4.02%	0.77
Reinsurance	13	0.93	23.54%	7.22%	0.76	27.84%	1.05
Bank (Midwest)	45	0.93	59.52%	17.77%	0.63	14.13%	0.73
Industrial Services	137	0.93	32.71%	19.03%	0.74	8.78%	0.81
Utility (Foreign)	4	0.96	155.03%	26.07%	0.45	6.59%	0.48
Oil/Gas Distribution	13	0.96	58.30%	13.70%	0.64	1.17%	0.65
Telecom. Services	74	0.98	34.09%	14.22%	0.76	8.04%	0.82

Pipeline MLPs	27	0.98	40.97%	6.37%	0.71	0.83%	0.72
Telecom. Equipment	99	1.02	12.96%	13.16%	0.91	28.77%	1.28
E-Commerce	57	1.03	6.40%	12.33%	0.97	10.22%	1.08
Biotechnology	158	1.03	13.48%	2.49%	0.91	21.45%	1.16
Med Supp Non-Invasive	146	1.03	13.02%	12.73%	0.92	13.31%	1.07
Computer Software	184	1.04	7.49%	12.27%	0.98	17.16%	1.18
Retail Building Supply	8	1.04	14.06%	31.39%	0.95	1.63%	0.97
IT Services	60	1.06	6.09%	19.15%	1.01	11.70%	1.14
Electronics	139	1.07	22.33%	10.36%	0.89	17.78%	1.08
Household Products	26	1.07	18.99%	25.12%	0.94	2.03%	0.95
Information Services	27	1.07	30.21%	18.93%	0.86	3.47%	0.89
Internet	186	1.09	2.71%	6.87%	1.06	14.08%	1.24
Foreign Electronics	9	1.09	42.09%	35.12%	0.86	30.82%	1.24
Aerospace/Defence	64	1.10	25.66%	20.72%	0.91	11.84%	1.03
Drug	279	1.12	15.46%	5.36%	0.98	9.18%	1.08
Pharmacy Services	19	1.12	20.48%	24.67%	0.97	2.98%	1.00
Property Management	31	1.13	140.63%	18.59%	0.53	9.96%	0.59
Funeral Services	6	1.14	56.60%	30.84%	0.82	4.49%	0.85
Diversified Co.	107	1.14	102.24%	15.55%	0.61	14.29%	0.71
Precious Metals	84	1.15	8.20%	7.51%	1.07	6.64%	1.14
Packaging & Container	26	1.16	51.82%	24.23%	0.83	5.90%	0.88
Healthcare Information	25	1.17	6.35%	22.19%	1.12	6.95%	1.20
Petroleum (Integrated)	20	1.18	19.19%	27.41%	1.04	7.30%	1.12
Securities Brokerage	28	1.20	430.56%	26.22%	0.29	32.79%	0.43
Machinery	100	1.20	19.12%	22.15%	1.04	8.54%	1.14
Air Transport	36	1.21	24.32%	20.54%	1.02	7.61%	1.10
Engineering & Const	25	1.22	11.99%	26.26%	1.12	19.03%	1.39

Entertainment Tech	40	1.23	9.76%	11.59%	1.14	23.34%	1.48
Human Resources	23	1.24	10.31%	25.35%	1.15	18.00%	1.40
Trucking	36	1.24	27.77%	25.48%	1.03	4.60%	1.08
Publishing	24	1.25	63.28%	18.55%	0.82	7.71%	0.89
Shoe	19	1.25	2.18%	24.31%	1.23	10.72%	1.38
Restaurant	63	1.27	12.77%	21.57%	1.15	3.41%	1.19
Wireless Networking	57	1.27	27.06%	12.12%	1.03	8.43%	1.12
Precision Instrument	77	1.28	15.94%	13.94%	1.12	15.55%	1.33
Chemical (Specialty)	70	1.28	21.15%	17.58%	1.09	5.29%	1.15
Retail Store	37	1.29	25.58%	25.02%	1.08	5.70%	1.14
Computers/Peripherals	87	1.30	10.23%	11.77%	1.19	10.67%	1.33
Apparel	57	1.30	18.38%	16.08%	1.13	7.89%	1.22
Toiletries/Cosmetics	15	1.30	20.64%	20.30%	1.12	6.56%	1.20
Financial Svcs. (Div.)	225	1.31	251.49%	19.18%	0.43	14.47%	0.50
Natural Gas (Div.)	29	1.33	37.07%	21.98%	1.03	3.41%	1.06
Metals & Mining (Div.)	73	1.33	14.10%	11.04%	1.18	7.60%	1.28
Electrical Equipment	68	1.33	12.66%	17.02%	1.20	11.32%	1.35
Petroleum (Producing)	176	1.34	24.88%	11.14%	1.10	3.00%	1.13
Power	93	1.35	148.82%	8.66%	0.57	11.45%	0.65
Paper/Forest Products	32	1.36	59.86%	10.61%	0.89	8.05%	0.96
Chemical (Basic)	16	1.36	27.35%	20.90%	1.12	9.66%	1.24
Retail Automotive	20	1.37	38.11%	34.43%	1.09	2.45%	1.12
Cable TV	21	1.37	68.06%	27.35%	0.92	6.13%	0.98
Office Equip/Supplies	24	1.38	63.03%	21.05%	0.92	11.77%	1.04
Maritime	52	1.40	170.38%	5.55%	0.53	7.62%	0.58
Retail (Softlines)	47	1.44	5.61%	24.64%	1.38	12.40%	1.57
Railroad	12	1.44	25.15%	23.74%	1.21	2.62%	1.24

Recreation	56	1.45	48.69%	17.37%	1.03	6.60%	1.11
Homebuilding	23	1.45	100.28%	5.12%	0.74	27.00%	1.02
R.E.I.T.	5	1.47	34.71%	1.04%	1.09	4.71%	1.15
Semiconductor	141	1.50	8.35%	11.01%	1.40	17.26%	1.69
Building Materials	45	1.50	94.33%	11.17%	0.82	7.75%	0.89
Chemical (Diversified)	31	1.51	22.37%	21.73%	1.29	7.42%	1.39
Coal	20	1.53	28.90%	12.75%	1.22	7.66%	1.32
Oilfield Svcs/Equip.	93	1.55	22.92%	17.39%	1.30	5.99%	1.39
Insurance (Life)	30	1.58	64.14%	28.04%	1.08	29.47%	1.54
Automotive	12	1.59	134.57%	24.07%	0.79	17.77%	0.96
Metal Fabricating	24	1.59	15.49%	26.55%	1.43	12.22%	1.63
Entertainment	77	1.63	40.99%	15.38%	1.21	7.86%	1.31
Steel	32	1.68	46.40%	21.03%	1.23	12.09%	1.40
Auto Parts	51	1.70	27.65%	18.99%	1.39	12.46%	1.59
Hotel/Gaming	51	1.74	52.07%	14.53%	1.20	6.33%	1.28
Newspaper	13	1.76	46.35%	25.13%	1.31	7.73%	1.42
Retail (Hardlines)	75	1.77	24.33%	23.04%	1.49	9.78%	1.65
Semiconductor Equip	12	1.79	15.20%	15.17%	1.59	34.39%	2.42
Heavy Truck & Equip	21	1.80	43.66%	20.62%	1.34	9.47%	1.48
Furn/Home Furnishings	35	1.81	24.39%	20.43%	1.52	8.22%	1.65
Advertising	31	2.02	43.26%	10.73%	1.46	16.60%	1.75
Public/Private Equity	11	2.18	59.87%	3.79%	1.38	15.01%	1.62

Source: http://pages.stern.nyu.edu/~adamodar/

Appendix 3

OLS Estimation and the Coefficient of Determination

A3.1 OLS Estimation

Consider the population regression function:

$$y_i = \alpha + \beta x_i + u_i \quad (1)$$

The purpose of estimation is to provide values for the unknown parameters in the population regression function. In effect, OLS provides us with the best guess possible for α and β. When the assumptions underlying the classical linear regression model are satisfied, then OLS is the Best Linear Unbiased Estimator (BLUE) for α and β in the sense that the uncertainty about these estimates is minimized.

A3.1.1 Notation

Define the total sum of squares (TSS) as $S_y = \sum(y_i - E(y_i))^2$ and also define $S_x = \sum(x_i - E(x_i))^2$ and $S_{xy} = \sum(x_i - E(x_i))(y_i - E(y_i))$.

A3.1.2 The OLS Estimator

Using the notation outlined in A3.1.1, the least squares estimator for β, ie. $\hat{\beta}$, is equal to $\frac{S_{xy}}{S_x}$. Using this slope estimate, the intercept may be estimated as $\hat{\alpha} = E(y_i) - \hat{\beta}E(x_i)$ and the sample residuals may be recovered as $\hat{u}_i = y_i - \hat{\alpha} - \hat{\beta}x_i$.

A3.1.3 Inference about the OLS Estimator

In the event that the sample residuals are shown to be consistent with the assumptions underlying the classical linear regression model (ie. they are zero mean normally distributed homoscedastic random variables that are free from correlation with themselves, or any other random variable), then OLS is BLUE and statistical inference is valid.

***A3.2 The Coefficient of Determination* (R²)**

The coefficient of determination for the regression measures the proportion of the TSS that is explained by the model. Thus, the R^2 must lie in the interval between zero (where the model explains none of the variation in *y*) and unity. We may break the total variation of interest into two components - the variation explained by the model (the explained sum of squares or ESS) and the variation captured by the residual (commonly referred to as the residual sum of squares or RSS).

A3.2.1 The Residual Sum of Squares

The RSS may be written as $RSS = \Sigma\left(y_i - \hat{\alpha} - \hat{\beta}x_i\right)^2$. This expression can be expanded and rearranged to yield $RSS = \Sigma(y_i - E(y))^2 + \hat{\beta}^2\Sigma(x_i - E(x))^2 - 2\hat{\beta}\Sigma(y_i - E(y))(x_i - E(x))$. Using the notation outlined in A3.1.1, the RSS may be written as $RSS = S_y + \hat{\beta}^2 S_x - 2\hat{\beta}S_{xy}$.

A3.2.2 The RSS and $\hat{\beta}$.

Recall from A3.1.2 that $\hat{\beta} = S_{xy} / S_x$. This may be used to rewrite the residual sum of squares as $RSS = S_y - \hat{\beta}S_{xy}$. That is, the RSS depends on the OLS estimate of the slope in equation (1).

A3.2.3. Defining the R^2

The TSS (S_y) is equal to the explained sum of squares (ESS) given as $\hat{\beta}S_{xy}$ plus the residual sum of squares. The proportion of variation in *y* explained by the model is referred to as the coefficient of determination, or R^2.

A3.2.4 R^2 depends on $\hat{\beta}$ by construction

The R^2 is obtained from the ratio ESS/TSS and achieves its maximum value of 1 where ESS=TSS. Correspondingly, 1-R^2=*RSS/TSS* and the R^2 achieves its minimum value of zero where RSS=TSS. By construction therefore

$$R^2 = \frac{ESS}{TSS} = \frac{\hat{\beta}S_{xy}}{S_y} \qquad (2)$$

That is, R^2 will be low if $\hat{\beta}$ is close to zero and/or S_{xy} is close to zero meaning that the ESS is small relative to the TSS. We may use this basic result to explain the outcomes in the simulation results provided by SFG (2011), which purports to show a systematic relationship between R^2 and beta. As we can see from Equation (2), this relationship exists by construction and is not indicative or any systematic relationship.

A3.3 The properties of OLS

OLS estimates are unbiased and have minimum variance when compared to all other linear estimators when four assumptions are satisfied

1. $E(u_i) = 0$
2. $Var(u_i) = \sigma^2$
3. u_i and u_j are uncorrelated

4. the x_i are fixed

It is important to note that the lack of bias and BLUE properties of OLS are satisfied even when the u_i are not normally distributed. The assumption of normality simply allows the construction of confidence intervals and test statistics to allow inference about the population parameters of interest using the OLS estimates. In short, if there is a bias in $\hat{\beta}$ it must be because at least one of the four assumptions outlined above is being violated.