The Effects of Firm Size and Network Span on Return on Capital in Swedish Electricity Distribution

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Förord

I Konkurrensverkets uppdrag ligger bland annat att främja forskning på konkurrens- och upphandlingsområdet.

Konkurrensverket har gett Docent Jon Thor Sturluson, vid Reykjaviks universitet, i uppdrag att utreda och analysera underlag för att bedöma kalkylräntan vid infrastrukturinvesteringar på elmarknaden.

Till projektet har knutits en referensgrupp. Den har bestått av Jan Bergstrand (Handelshögskolan i Stockholm), Göran EK (Energimarknadsinspektionen), Bo Andersson och Mattias Wellander (Post- och telestyrelsen). Från Konkurrensverket har Arvid Fredenberg, Thomas Sundqvist och Joakim Wallenklint deltagit.

Det är författaren som svarar för slutsatser och bedömningar i rapporten.

Stockholm, september 2011

Dan Sjöblom
Generaldirektör

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Sammanfattning

Vilken typ av prisreglering som än används kommer det alltid att finnas ett behov av en bra referens för vad en acceptabel avkastning på kapital bör vara. Att fastställa kapitalkostnaden är emellertid svårt och ofta kontroversiellt. Det finns ingen samsyn vad gäller val av metod, även om vissa traditioner och metoder är vanligare än andra, till exempel capital asset pricing model (CAPM).

På grund av problem med att mäta risk används ofta samlade beräkningar av kapitalkostnaden för en hel rad företag i en bransch. Nuvarande praxis kritiseras ofta för att vara för övergripande och därför olämplig för enskilda företag, vilket inte är förvånande.

Inom ramen för reglering av eldistribution har frågan väckts huruvida ett gemensamt jämförelsetal för avkastningsgrad är lämpligt. Särskilt om nätens storlek eller deras geografiska placering bör tas med i beräkningen. Att driva ett nät på landsbygden kan till exempel innebära en större ekonomisk risk än att driva ett nät i ett tättbebyggt område.

Målet med denna studie är att undersöka om det är möjligt att utveckla ett disaggregerat mått på systematisk risk och viktad genomsnittlig kapitalkostnad (WACC) för eldistributionsföretag i Sverige. Systematisk risk eller beta beräknas ekonometriskt baserat på finansiella data och redovisningsdata om 176 svenska nätföretag som tillhandahålls av Energimarknadsinspektionen. Vad gäller nätens olikhet beaktas särskilt följande faktorer: relationen mellan beta och *verksamhetens skala*, i termer av distribuerad energi; *nätets storlek*, i termer av distributionsnätets fysiska längd; och nätets *gleshet*, som definieras som förhållandet mellan de andra två variablerna. Denna sista faktor avses objektivt mäta den tekniska skillnaden mellan nät på landsbygden och i städer. CAPM används för att förena beta och kostnad för eget kapital.

Under det att fokus ligger på sökning efter heterogena beta, kan vi inte separera metoden för beräkning av beta från andra parameterval vid bedömning av WACC. Betaberäkningen är till exempel knuten till val av marknadsportfölj, som i sin tur, tillsammans med den riskfria räntan avgör riskpremien på eget kapital. Således presenteras den resulterande viktade kapitalkostnaden också.

Huvudresultatet är att det inte finns något stöd för hypotesen att nätets storlek eller verksamhetens skala påverkar systematisk risk. Nätens gleshet visar sig emellertid vara en signifikant faktor. Resultaten tyder på att ett glesare nät innebär större systematisk risk än ett tätt nät. Beta för eget kapital beräknas i området från 0,52 för företag med täta nät och 0,94 för företag med glesa nät. Median beta för eget kapital är 0,65. Liknande heterogena mönster finns inte i en modell för skuldkostnad.

På grundval av CAPM bör glesa nät kräva en högre avkastning på eget kapital. Effekten är statistiskt signifikant och effektens amplitud icke-trivial. Om företag till exempel delas in i tre lika stora grupper enligt gleshet beräknas lämplig WACC vara 6,8% för glesa nät och 5,7% för täta nät medan medianen är 6,0%.

Direkt tillämpning av dessa resultat kräver ändå noggrant övervägande av praktiska detaljer för att balansera överväganden av rättvisa och transparens.

Summary

No matter what type of price regulation is used there will always be a need for a good reference for what an acceptable return on capital should be. Determining the cost of capital is difficult, however, and often controversial. There is no consensus over the choice of methodology even though certain traditions and methods are more prevailing than others, such as the capital asset pricing model (CAPM).

Due to problems with measuring risk, aggregate estimates of cost of capital are often used for a whole range of firms within an industry. Not surprisingly, current practice is often criticized for being too aggregate and thereby inappropriate for individual firms.

Within the context of electricity distribution regulation, the question has been raised whether a common rate of return benchmark is appropriate. Particularly, if the size of networks or their geographic location should be taken into account. Operating a network in a rural area might, for instance, entail more financial risk than operating a network in a densely populated area.

The objective of this study is to investigate whether it is possible to develop a disaggregated measure of systematic risk and weighted average cost of capital (WACC) for electricity distribution firms in Sweden. Systematic risk, or betas, is estimated econometrically based on economic and accounting data provided by the Energy Markets Inspectorate on 176 Swedish network firms. As for the heterogeneity of networks the following factors are considered specifically: The relationship between beta and the *scale of operations*, in terms of energy distributed; *size of the network*, in terms of the physical length of the distribution network; and *sparseness* of the network, which is defined as the ratio of the other two variables. This last factor is intended to measure objectively the technical difference between rural and urban networks. CAPM is used to link betas and cost of equity.

While the focus is on the search for heterogeneous betas, we cannot separate the method of estimating betas from other parameter choices in evaluating the WACC. The beta estimate is, for instance, linked to the choice of market portfolio, which in turn, together with the risk free rate, determines the equity risk premium. Hence, the resulting weighted cost of capital is presented as well.

The main results are that there is no support for the hypothesis that the size of the network or scale of operations affects systematic risk. The sparseness of networks, however, turns out to be a significant factor. The results suggest that a sparser network involves more systematic risk than a dense network. Equity beta is estimated in the range from 0.52 for firms with dense networks and 0.94 for firms with sparse network. The median equity beta is 0.65. Similar heterogeneous patters are not found in a model of cost of debt.

On the basis of CAPM, sparse networks should demand a higher rate of return on equity. The effect is statistically significant and the amplitude of the effect is nontrivial. For example, if firms are separated into three equally sized groups according to sparseness, the appropriate WACC is estimated to be 6.8% in the case of sparse networks and 5.7% for dense networks while the median is 6.0%

Direct application of these results still requires careful consideration of practical details in order to balance off fairness and transparency considerations.

1 Introduction

Electricity distribution networks are monopolies for all practical purposes. While duplication of distribution networks and parallel transmission is technically possible it would be extremely inefficient, due to the large amount of fixed and sunk costs, to introduce competition in this market. As monopolies they are typically regulated and subject governmental supervisions when it comes to quality control and price setting. Distribution companies can be private or public entities. In most cases, similar regulation applies irrespectively.

A whole range of price regulation schemes is feasible. The two classical extreme cases are *cost of service regulation* and *price cap regulation*. Cost of service regulation dictates that the distribution company should be allowed to cover its verifiable costs and earn a reasonable rate of return on its invested capital. As a result, the firm is automatically compensated if costs change. Uncertainty about future costs is borne by consumers. In price cap regulation, a maximum price or revenue is determined beforehand and the uncertainty of costs lays with the firm while consumers' expenditures are predictable. The first scheme has a major flaw in that firms lack incentives to reduce costs and thereby lower prices. In a capital-intensive industry, such as electricity distribution, this can manifest itself in the form of overinvestment – the so-called Averch Johnson effect (Averch & Johnson, 1962). The second one is also inadequate, mainly because it is difficult to commit to a fixed price level for a long time in advance. A large profit or deficit, resulting from unforeseen events, is certain to trigger calls for a price adjustment, by consumers or the firm respectively.

Taking both these problems into account, most practical regulation schemes can be classified somewhere in the space between these two extremes. In practice price-caps, for instance, usually involve predetermined adjustment dates, which soften the high-powered incentives in the pure alternative. The initial design of the incentive scheme, and during regular revisions, acceptable return to capital needs to be considered. The bottom line is that no matter what type of regulation is used there will always be a need for a good reference for what an acceptable return on capital should be.[1]

Determining the appropriate rate of return on invested capital is difficult and often controversial. There is no consensus over the choice of methodology even though certain traditions and methods are more prevailing than others, such as the *capital asset pricing model* (see section 2.1). Also, due to problems with measuring risk, aggregate estimates of an appropriate rate of return are often used for a whole range of firms in a similar industry. Current practice of estimating appropriate rate of return is therefore often criticized for being too aggregate and thereby inappropriate for individual firms (Kaplan & Peterson, 1998). This concern is

[1] See (Liston, 1993) for a more detailed treatment of the these regulation schemes.

particularly relevant in the case of regulation of electricity distribution firms, who usually are assumed to have a similar risk profile and thereby the same appropriate rate of return. It is well known that the common aggregate approach can give imprecise estimates of the rate of return on equity (Fama & French, 1997). As a result it should be a matter of careful consideration when risk measures (betas) are applied uniformly to a group of firms.

The main objective of this study is to investigate whether it is possible to develop a disaggregated measure of systematic risk and weighted average cost of capital (WACC) for electricity distribution firms in Sweden. Systematic risk, or betas, is estimated econometrically based on economic and accounting data provided by the Energy Markets Inspectorate on 176 Swedish network firms.[2] As for the heterogeneity of networks the following will be considered specifically: The relationship between beta and the *scale of operations*, in terms of energy distributed; *size of the network*, in terms of the physical length of the distribution system; and *sparseness* of the network, which is defined as the ratio of the other two variables. The Capital Asset Pricing Model (CAPM), despite its flaws, is used to link betas and cost of equity and then eventually to weighted average cost of capital.

While the focus is on the search for heterogeneous betas, we cannot separate the method of estimating betas from other parameter choices in evaluating the WACC. The beta estimate is, for instance, linked to the choice of market portfolio, which in turn, together with the risk free rate, determines the equity risk premium. Hence, the resulting cost of capital is presented as well. For this secondary objective we rely on other sources and previous analysis on the subject.

The traditional method of estimating beta is by regression analysis, where returns on individual stocks are compared with the returns in an aggregated market portfolio, i.e. a national or an international stock price index-fund. None of the Swedish electricity distribution companies are listed companies except in rare cases as divisions within larger entities. As a result the key firm-level data used is accounting data rather than market data, which calls for special attention, see section 2.5. A related technical issue is that the available data is only available on an annual basis, while betas are usually estimated using weekly or monthly data. By using panel data techniques we can still draw conclusions from the analysis. Not for individual firms but rather certain key characteristics of firms.

The main results of this analysis are that there is no support for the hypothesis that the size of the network or scale of operations affects systematic risk. The sparseness of networks (size of the network itself relative to the amount of energy distributed) however turns out to be a significant factor. The results suggest that a sparser network involves more systematic risk than a dense network and therefore on the

[2] http://www.ei.se/For-Energiforetag/El/Inrapportering-for-elnatsforetag/Inrapporterade-data/

bases of CAPM should demand a higher rate of return on equity. The effect is statistically significant the amplitude of the effect is nontrivial. Direct application of these results in practice still needs careful consideration.

The remainder of this report is structured as follows. Chapter 2 provides various methodological backgrounds. Estimation of betas based on accounting data is provided in chapter 3. In chapter 4, the effects of significant heterogeneity on beta and WACC are considered and their implications for policy discussed. An appendix with additional data mentioned in the report is also provided.

2 Methodology

Price setting by regulated firms and industries is usually constrained in some way. This can either be explicitly by clear *ex ante* price caps or in a more subtle *ex post* fashion, allowing the firm some scope of price flexibility while the regulator reserves the right to challenge prices that are considered excessive. Formal regulation regimes can also be classified into cost based and price based systems, as mentioned above. In the first case the reference price is supposed to cover actual incurred costs in addition to a fair return to capital while in the second case the price or income frame is set in advance, based on expected costs including rent to capital.

It is not a part of this study to go into details about regulation as such. It is still worth emphasizing that the main difference between these different forms of regulation is how they treat unforeseen changes in costs. In a cost-based system a firm can channel any verifiable changes to the cost base into prices while in a price-based system it cannot, at least not in the short run. In practice there is rarely such a thing as a pure price or cost based regulation, as unforeseen events will always need to be accounted for, if not explicitly by predefined rules, then by the use of discretion.

At any rate, the regulator needs to determine the allowed rate of return. Whether it is an ex ante target, that is subject to change if costs change, or an exact ex-post percentage of the capital stock which is added to the incurred costs to define the revenue base.

2.1 Current practice - WACC

Here, as in most similar studies, we focus on *weighted average cost of capital* (WACC) as a methodology for measuring capital cost. This entails that when the allowed return on capital is determined we look at all sources of capital. As the name suggests WACC is the weighted average the cost of the two principal sources of capital – debt and equity.

Figure 1 depicts the main steps in estimating WACC. At the top level the WACC is adjusted for taxes. Sometimes it is appropriate to define the cost of capital in pre-tax terms and this step can be skipped. For the purpose of determining an appropriate rate of return for regulated utilities the post-tax approach is preferable though. At the second level the relative market values of debt and equity are used as weights to calculate the weighted average cost of capital.

Determining the market value of debt is relatively easy and usually corresponds to the outstanding principal on loan obligations. Market value of equity is the market capitalization of the firm (stock price times number of issued stocks). For unlisted

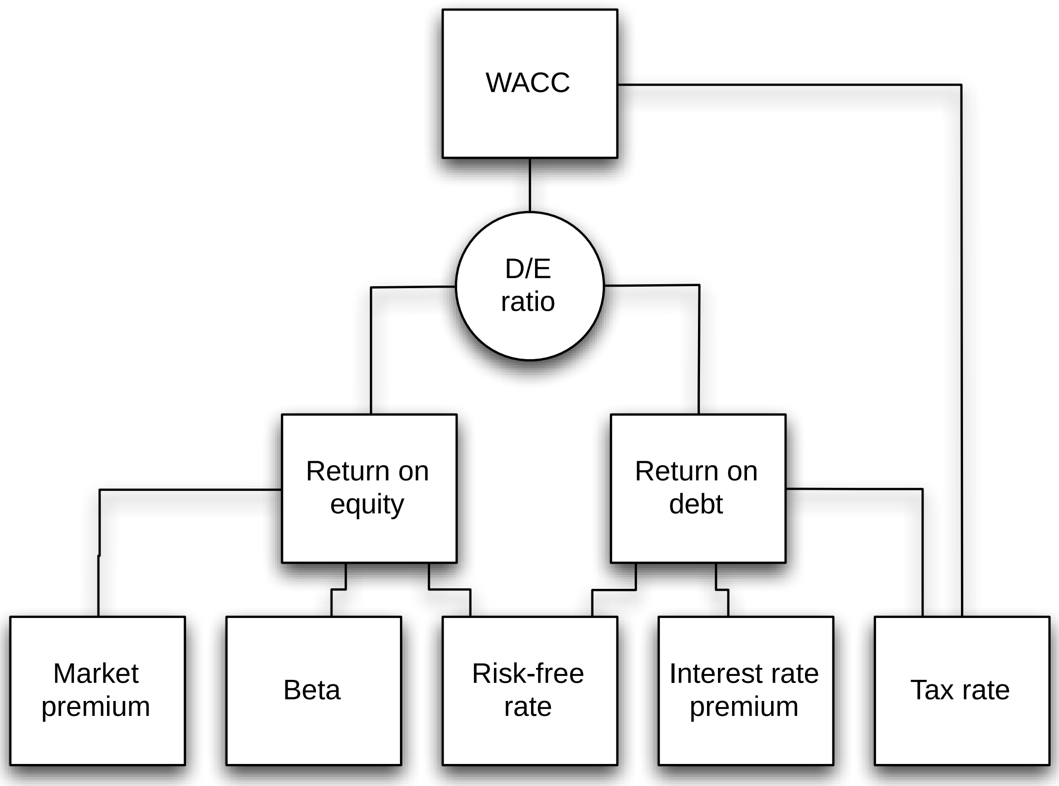

Figure 1. Schematic representation of the WACC framework

firms we have to rely on accounting data or specific valuation of the firms' value net of debt. When determining the appropriate cost of capital for the future it is more befitting to use a firm's target debt to equity (D/E) ratio rather then the actual one, given that the target is reasonable and sustainable.

At the third level we have estimates of return on debt and equity in turn. In a firm, with stable external and internal conditions, the current cost of long-term debt will usually be similar to past cost of long-term debt, in relative terms at least. Changes in market conditions and in a firm's current situation may affect borrowing cost positively or negatively. If the firm has issued bonds, which are traded on a secondary market, the implicit interest determined by its price – or the yield – can be a good reference for the cost of future borrowing. An alternative method is to consider benchmark interest rates, i.e. government bonds, with an appropriate interest rate premium. When cost of debt, r_d, is evaluated it is important to take into account the tax shield provided by deductible interest payments. In the equation below the tax shield is represented by a fixed marginal tax rate τ. The post-tax cost of debt is therefore $r_d(1-\tau)$.

Estimating the appropriate cost of equity, r_e, is much more difficult however. Popular methods include the Capital Asset Pricing Model and the Arbitrage pricing theory (Ross, 1973). Here we will focus on the first method for various reasons discussed further in section 2.3.

Before we turn to the specifics of equity returns we can summarize the definition of WACC by the following formula:

$$WACC = \frac{D}{D+E} r_d (1 - \tau) + \frac{E}{D+E} r_e. \quad (1)$$

Here, *D* and *E* represent the market value of debt and equity respectively and the relative size of each in turn is used as weights when the weighted average is calculated. Note also how the tax rate, τ, only affects the cost of debt and not that of equity since dividend payments are not tax deductible.

2.2 Capital asset pricing model

What is the true appropriate rate of return to equity that investors should require, or be allowed to receive in the case of regulated firms? At first glance, this may seem to be a truly impossible question to answer in general terms. After all, investors' preferences for various investment projects, subjective opportunity cost of invested funds and valuation of risk may vary considerably. As often, the truth lies is in the eye of the beholder.

While each investor has to determine for himself what he believes to be a reasonable return to an investment, with respect to the risk it entails, there is bound to be a certain structure in which investors think about this in general. While individual opinion may diverge there is reason to believe that investors as a whole, facing countless investment opportunities, in stocks, bonds and other assets, tend to price the risk associated with each asset in a systematic manner.

The predominant theory on what this systematic relationship looks like is due to Sharpe (1964) and Lintner (1965) and is called the *Capital asset pricing model* (CAPM).[3] The salient feature of the model is that a distinction is made between two types of risk.

Systematic risk, which is also named *nondiversifiable risk*, is the type of risk that is shared by most stocks. The risk of investing in stocks can be greatly reduced by selecting a portfolio of stocks rather than a single stock. Increasing the number of different stocks in a portfolio reduces the minimum risk level attainable, but only up to a point. Systematic risk is the residual risk that cannot be eliminated through diversifications.

Firm-specific or *diversifiable risk* is the type of risk that is unrelated to the industry or the market as a whole. In a competitive market for assets, where stocks are sold to the highest bidder, the latter kind of risk is less important, or even irrelevant for the

[3] See Brealey et al. (2006), chapter 8, for an excelent exposition at an introductory level and Graham and Harvey (2001) for a survey of its use in practice.

pricing of stocks, since it can be practically eliminated by the construction of a well-diversified portfolio of stocks. [4]

It is convenient to compare the individual stock to a so-called market portfolio, a well-diversified collection of stocks representing the overall asset holdings of the market. A stock's contribution to systematic risk, or the sensitivity of the individual stock to the market portfolio, is measured with the parameter beta, β.

To be more exact, consider a particular stock denoted by the index i. According to the CAPM model, the risk premium or the required rate of return, r_i, in excess of the required return on a risk-free asset, r_f, should be proportional to the market risk premium – the return on the market portfolio, r_m, minus the risk-free rate. The ratio between the two risk premiums is the named beta parameter. It describes the marginal contribution of stock i to the systematic risk of a well-diversified market portfolio when it's weight in the portfolio is increased. In technical terms, it is the covariance between the individual assets excess returns and excess market returns, σ_{im}, divided by the variance of market returns, σ_m^2. Algebraically:

$$r_i - r_f = \beta_i \left(r_m - r_f\right), \tag{2}$$

where

$$\beta_i = \frac{\sigma_{im}}{\sigma_m^2}.$$

This relationship provides a direct and systematic link between risk and return. The theory, on which this result is based, rests on a few important assumptions. First of all the model assumes that all investors prefer returns and dislike risk. Secondly, investors can borrow or lend at the risk-free rate as much as they like. Thirdly, if everyone has the same information, assumptions 1 and 2 imply that there is a single optimal market portfolio which can be used, together with the riskless asset, to build a new portfolio which satisfies an investor's particular risk preference. This means that the only relevant risk in the case of individual assets is its marginal effect on the overall risk of the portfolio or the beta.

Applying (2) to (1) gives us than an updated version of the WACC formula, where the CAPM model has been incorporated:

$$WACC = \frac{D}{D+E} r_d (1-\tau) + \frac{E}{D+E}\left[r_f + \beta_i \left(r_m - r_f\right)\right]. \tag{3}$$

By applying the CAPM model we have managed to simplify the complicated part of the WACC equation, and transformed a rather broad question of what the expected return to equity should be, taking risk into account, to a simple formula with a single key parameter, the value of systematic risk, or beta.

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[4] Note that a high return requirement implies a low price and vice versa. All other things equal, investors with a well diversified portfolio of stocks should be willing to buy stocks at a lower price since they can disregard the firm-specific risk and are content with a premium for systematic risk only.

2.3 Alternative models

Since we apply the CAPM in the remainder of this report much of the following analysis has to with estimation of beta and its effect on returns. Before going into specifics it is worth mentioning alternative approaches and give reasons to why they are not applied here.

A key contestant to the throne of the workhorse model is the Arbitrage pricing theory (APT) (Ross, 1973). In many respects the APT is developed along similar lines as CAPM. But instead of adding different stocks to a portfolio until diversifiable risk has been eliminated the APT model is build on the assumption that the relationship between the returns on different stocks can be multi-dimensional. The model adds factors until the firm-specific risk of a given stock is uncorrelated with the firm-specific risk of all other stocks. A factor is simply a variable that affects returns. The CAPM can be interpreted as a single factor model where the only factor is: Returns on the market portfolio. In practice APT is therefore an extension on the CAPM where we allow for various additional factors to explain returns.[5] While the benefit of APT over CAPM is that it is more complete it is much easier to interpret the parameter estimates of CAPM.

In many cases it is difficult to produce significant estimates for the parameters of such models, and in that case it may be necessary to restrict the attention to as few factors as possible. This is partly the reason for why CAPM is used here. Rather short time-series available for this study call for parsimonious use of parameters. The other main reason for choosing CAPM is its wide application in earlier studies on the subject. We will still consider alternative factors affecting returns, namely scale and sparseness, but using a two-step method, where we first estimate a single beta with the limited data available and then search for patterns in the estimated betas.

The CAPM and APT models are both what is called *risk-based models* and are primarily based on theory. Another class of models can be collectively referred to as *empirical models*. While such models can provide more accurate estimates and more detailed explanations for variability in returns, they can be difficult to interpret and prone to data mining problems.[6]

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[5] Factors that are often used are for instance market capitalization (as a proxy for size) and book-to-market ratio (to distinguish so-called growth stocks and value stocks. Together with the the returns on the market portfolio these two make up the famous Fama-French three-factor model (Fama & French, 1992). Another example of factor that can affect cost of capital is transparency. A recent study indicates that firms with transparent earnings have lower required returns (Barth, Konchitchki & Landsman, 2010).

[6] Data mining occurs when a large set of explanatory variables are tested and only the most significant explanatory factors are used. This method is subject to the risk of accepting false positives, seamingly significant variables which have no fundamental effect to returns.

When good data is not available a common practice is to consider average beta estimates for entire industries. A good example of a large, and regularly updated, compilation of industry betas is the one published by Aswath Damodaran at the Stern School of Business, NYU, shown here in the appendix.[7] From this table we can, for instance, read that the average unlevered beta[8] for electric utilities is between .47 and .49 depending on the region. This is based on a sample of 61 firms.

Using benchmark betas based on industry averages is a rather crude method however. It is particularly problematic when the firms in question operate in more then one line of business. Several identifiable characteristics can also be used to adjust industry betas to a particular firm or divisions. The Boston Consulting Group (BCG) and Fuqua Industries methods are examples of such heuristic approaches that can be applied in such instances (Bufka, Kemper & Schiereck, 2004).

We will rest the subject of industry betas for now but return to the discussion of industry benchmarks for electricity distribution in particular in the conclusions.

2.4 Firms size and systematic risk

The relationship between firm size, both in absolute terms and relative to other firms, and returns has been studied extensively in the literature. Supposedly, smaller firms (small caps) have excess returns relative to large firms (large caps). Possible explanations for the size effect include: misestimation of risks (Reinganum, 1982; Roll, 1981) misestimation of returns (Blume & Stambaugh, 1983; Roll, 1983) and transaction costs (Stoll & Whaley, 1983).

A further explanation could be that a larger proportion of marginal firms, in the sense that they are more vulnerable to changes in the overall economy, falls into the category of small firms rather then large firms. A firm can be marginal for different reasons. A new entrant, not already established as a major player, can be considered marginal. The same can apply to firms in decline who have lost out in the competition with other firms. One strain of literature emphasizes such underlying causes of riskiness rather than the size of the firms per se, which may just as well be the cause of bad outcomes rather than a good predictor of future bad outcomes. In a study specifically intended to separate the effects of being small or being marginal on future returns Chan and Chen (1991) conclude that small firms tend to be firms that have not been doing well and are less efficiently run and have higher financial leverage. The three most important factors are: production efficiency, financial leverage and accessibility to external financing.

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[7] http://people.stern.nyu.edu/adamodar/New_Home_Page/datafile/Betas.html

[8] Unlevered beta is the estimate equity beta corrected for the additional risk associated with leveraging. It gives the beta, as if the firm had no debt and was 100% equity financed. Based on traditional corporate finance theory a straight forward relationship between levered and unlevered beta can be derived, referred to as the Hamada equation.

Despite this critique, the size effect is often visible in empirical studies. Fama and French (1992) expanded earlier studies on the relationship between actual returns and beta to include several other variables that interact with risk and returns. These include size, leverage, price to earnings and book to market ratios. They find that that the relationship between returns and beta is not particularly strong when the mentioned dependent variables are added, but find robust support for a negative relationship between returns and size, where size is measured by market capitalization.[9]

Notably this result is based on a large sample of firms from varying industries and not a large number of firms within the same industries. The reason for the observed effects could therefore be attributed to particular industry characteristics as well as structural reasons within the firm. It should also be noted that the size effect appears to have decreased or even disappeared in recent data, consistent with the original study (Brealey et al., 2006, p. 196).

Several studies have looked at the relationship between product market characteristics and firm risk, with reference to the CAPM model. Early contributions include Booth (1981), Gomes and Islam (1989), Hite (1977) and Lee et al. (1990). Looking at individual markets puts market structure into focus as size of firms is generally positively linked to concentration. Empirical results on the whole, despite some discrepancies between individual studies, suggest at least a weak negative relationship between systematic risk, measured by beta, on the one hand and firm size or concentration on the other (Alexander & Thistle, 1999).

Theoretical studies suggest that the size effect is present in monopolistic and oligopolistic markets (Chen, Roll & Ross, 1986; Wong, 1996). In a model developed by Binder (1992) the negative relationship holds even for competitive markets, which suggests that the size effect not only depends on market structure but also efficiency issues. Alexander and Thistle (1999) attempt to synthesize these different factors and look at market power, entry effects and efficiency effects in a unified model. The result is that the negative relationship holds under a wide range of market forms.

The effect of size on firm performance is not particular to the field of finance and economics. Research in entrepreneurship suggests that there are pros and cons that come with size. One aspect of business, not much discussed in this report, is the ability of firms to cooperate with other firms, for instance through joint ventures. A firm's size can affect a firm's attractiveness as a partner and its benefits from cooperation and therefore determine whether such a relationship is likely or not. A firm's size can also affect what kind of joint ventures are mutually beneficial. As a result, the effects of size on risk can be ambiguous (Aldrich & Auster, 2009).

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[9] They also find the Book-to-market equity ratio to be imporatant determinant of returns. In the current analysis we are unable to take this factor into consideration as we do not have firm specific market data available.

2.5 Accounting beta

The standard practice of estimating betas is to use market returns for individual firms and dependent variables. This is obviously impossible to do when firms are not listed. An alternative is to use accounting data. Several scholars have studied the relationship between market and accounting data specifically including Mendelker and Rhee (1984), Chun and Ramasamy (1989), and Toms, Salama and Nguyen (2005).

At least in theory, there is a strong link between the two, but both the level and distribution can be slightly unpredictable. One approach is to decompose the traditional (market) measure of beta into: intrinsic systematic risk, degree of financial leverage and degree of operating leverage. In a way this efforts can be seen as generalizations of the Hamada equation. Empirical analysis suggests that both types of leverage amplify intrinsic business risk (Mandelker & Rhee, 1984; Mensah, 1992).

We need not enter into further details regarding accounting betas at this point. The existing literature does not provide sufficiently sound basis for establishing a correction formula to translate accounting betas into market beta equivalents. Hence a different approach is selected in order to reconcile the current results with previous estimates of beta for electricity distribution.

3 Empirical findings

In this section we turn to the estimation of systematic risk or betas for Swedish electricity distribution firms, the crucial determinant of the cost of equity capital in CAPM. The focus is not on finding better average estimates but on testing whether there is evidence of heterogeneity along the lines described in the preceding chapter. For completeness we will also consider possible heterogeneity in the cost of debt.

3.1 Data

Our main data source is an extensive database of financial accounting and technical data collected and published by the Energy Markets Inspectorate (EMI). The data consists of four sets of tables for the periods 1998-2001, 2002-2003, 2003-2007 and 2004-2008. The tables give annual values for a large number of variables for a varying number of distribution firms. A similar set of tables exists for transmission firms, but due to the small number of cross sections and low frequency of the data it is impossible to get reliable results for transmission. The study of transmission firms is therefore omitted in this report.

The data tables were compiled into a single database ranging from 1998 to 2008, eleven years in total. The total number of firms (cross sections), that span the whole period, is 176. This consolidation of the data was complicated, for two reasons.

Firstly, the tables from different time periods were not fully compatible. Classification of the data was different in later periods and measurements are not fully compatible in all instances. The most recent tables were, for instance, more detailed than the earlier ones. The level of aggregation therefore depends, in part, on the structure of the data in early periods.

Secondly, several mergers occurred during the period under study, adding severely to the compilation problems. Mergers are treated in the following way. Any firms that merge sometime in the period 1998-2008 are considered to be the same firm going backwards. Where appropriate, observations for such firms are added up. In some (few cases) we use average values. This is far from fool proof as changes in accounting methods, reevaluations and adjustments in capital structure, due to mergers, can create unintended irregularities. Several missing observations are due to incomplete or inconsistent reporting before or after a merger.

The following variables from the dataset are used in the regression analysis. This selection is based on a number of factors. Relevance to existing theory and data availability are the most important.

- DEBT: The book value of debt (both short-term and long-term) as reported in the firms' balance sheets. Interest-bearing debt as a separate variable is only available from 2004 and is used to calculate INTRR below).
- EQUITY: The sum of the book value of equity capital and non-taxed reserves. In some instances the data shows unexplained large changes in equity. This can be due to changes in accounting methods, mergers and other reasons. Cases with large unexplained changes are omitted in the following analysis.
- REVENUE: The total income from operations. Used here as an alternative measure of the scale of operations.
- EBIT: Earnings before interest and tax payments are a well-known accounting definition, commonly used in finance as well. It describes the net income from operations (revenues – operating expenses).
- PROFIT: Net income before taxes is used as a primary measure of profit.
- RETURNS: Accounting based return on equity is defined as profit divided by the book value of equity in the beginning of the period.
- INTRR: The effective interest rate based on reported interest payments, divided by the average of interest-bearing debt at the start and end of each year.
- ENERGY: The aggregate megawatt hours of energy distributed through the network in each year, excluding losses. This is the primary measure of output or the scale of operations. Not surprisingly, it is highly correlated with REVENUE.
- NETSIZE: The aggregate length of wires and cables (all voltages) in kilometers, as a primary measure of the size of the network or its geographic span. Alternative measures for span were also considered but did not alter any of the results qualitatively.

In all cases, where possible, we consider accounting values before taxes. This is due to the fact that reported taxes are highly irregular in the dataset. One apparent reason are consolidated accounting rules. Other factors may play a part as well.

In addition we use reference values for Swedish securities markets, as reported by Thomson Reuters Datastream. Returns on the OMXS30 index are used to approximate market portfolio returns.[10] One-month yield on Swedish treasury bills is used as a proxy for the risk-free interest rate. When comparing the firms' cost of debt to a benchmark the yield on 10 year government bonds is used.

The data has a panel structure, with 11 time periods and 176 cross sections. Due to time differentiation only 10 time periods are used for estimation. Some firms are not included in the final analysis due to large unexplained jumps in the data.

It is unusual to use annual data when estimating betas. While there is certainly no consensus on the subject of frequency, the industry standard is to use a five-year period of monthly data. The problem is less severe given the fact that we do not put emphasis on beta for individual firms. Instead we look for certain patterns or tendencies in beta relative to selected key factors.

It is also not in line with standard practice to apply accounting data. This is not unknown however, as described in section 2.5. Accounting betas and market betas are not directly comparable. Accounting betas are systematically lower than market betas, primarily because accounting returns only focus on the profits of the current period while market returns are based on expectations about all future periods as well. It is possible to make certain adjustments to approximate market beta from accounting beta, but such adjustments are bound to be rather crude. For our purposes it suffices to assume that there is considerable correlation between accounting and market returns. General conclusions about the heterogeneity of accounting betas and accounting returns should then also apply to the standard case of market betas and market returns, at least qualitatively.

3.2 Sample selection

The data shows considerable variation and a high number of seemingly erratic observations. Different reasons can be found in individual cases. Two examples are: negative equity and negative interest expenses despite low equity ratio, which result in profits being larger than EBIT. The strategy chosen here is to eliminate from the estimation any observations that give particularly suspicious outcomes in key indicators and produce extremely fat-tailed estimation errors. In each case when observations are omitted, the whole firm is removed from the sample. This both keeps the remaining dataset balanced and limits selection bias within each cross section.[11]

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[10] Dividend yields were not explicitly calculated and actual returns may be biased downwards as a result. A more detailed study of Swedish stocks should take divindents explicitly into accounts as dividends are relatively high in Sweden. It is unliklely however that this will change the relationship between energy firm returns and stock returns in gerneral as measured by beta.

[11] Of course, this precedure can create selection bias on the whole.

Further 10 firms are omitted from the dataset due to missing data. These include firms with non-standard accounting periods and intermittent reporting. A list of excluded firms is found in the appendix.

3.3 Estimation of beta

Consider Figure 2 depicting returns on the OMX30 (OMX returns) portfolio and average returns for the electricity distribution firms (DC returns). It is noticeable that returns in electricity distribution were quite stable with a downward trend from 1999 to 2008 with an average of 12.5 percent. 1998 stands out a little bit with 26 percent returns on equity. These are unweighted averages and the outcome varies for different firms.

The OMX returns show a somewhat similar pattern, qualitatively, but with a higher amplitude. The period under study has been particularly dramatic for stock returns, with two worldwide bubbles bursting with dramatic loss in asset value, first in the wake of 2000 and then again starting late 2007. These dramatic events together with only 10 observations are a cause of concern. The risk that the data observed is not typical for the relationship under study increases with lower frequency of data and is probably only partly offset by the large cross section.

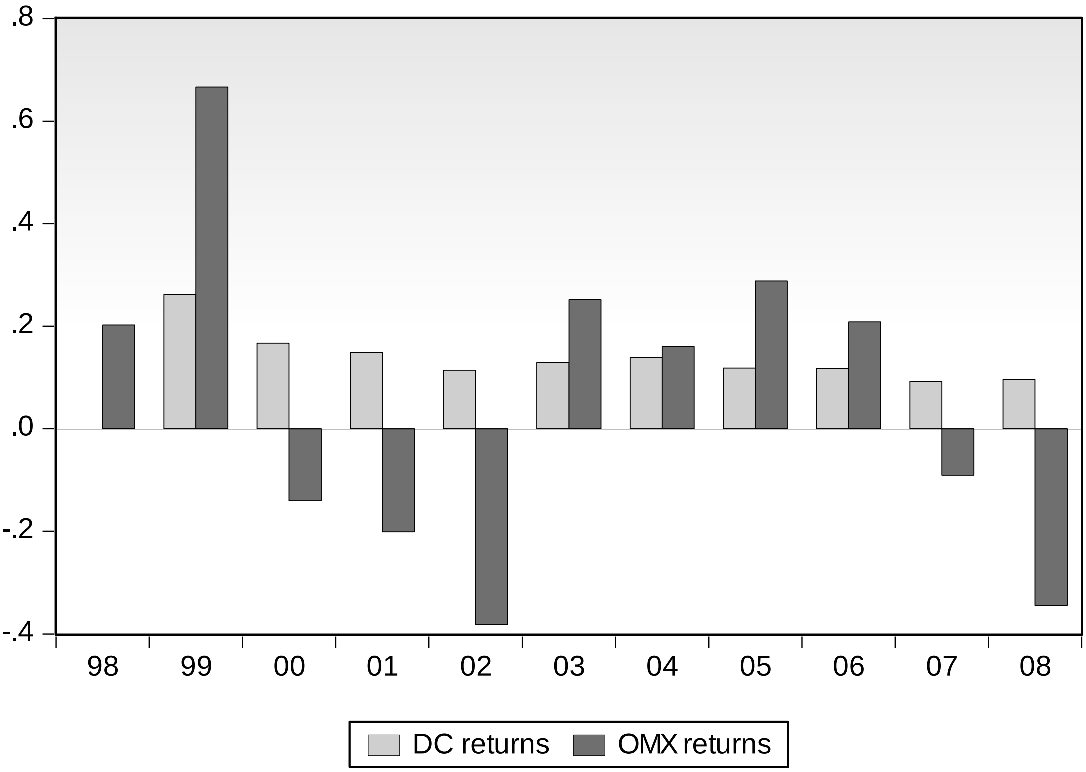

Figure 2: Returns on own capital vs. average returns on the Stockholm OMX stock exchange

Table 1: A panel beta regression, random effects model

Dependent Variable: ER
Method: Panel EGLS (Cross-section random effects)
Periods included: 10
Cross-sections included: 158
Swamy and Arora estimator of component variances
Cross-section SUR (PCSE) standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.069112	0.016487	4.191954	0.0000
Excess market returns	0.037602	0.017619	2.134125	0.0330
R-squared	0.020085			
Adjusted R-squared	0.019459			

3.3.1 Estimating firm-level beta

The first regression model we estimate is a relatively simple one where we try to explain excess returns in electricity distribution (returns above the risk-free rate) with excess returns on the stock market or the market risk premium. We assume that cross-sectional effects are random and allow for contemporaneous correlation in error terms between cross sections (SUR).

This is essentially an attempt to estimate beta assuming that all distribution firms are similar apart from an unobserved random factor. Most importantly, that they have the same beta. As shown in Table 1 estimated beta, or the coefficient for excess market returns, is very small or about 0.04. It is significant however at the 5% level. The equation as a whole is not very significant however. This is not terribly surprising as all firms are more or less assumed to have a similar relationship with the market. In other words, possible heterogeneity in systematic risk is ignored.

The small value of beta compared to traditional values used for the energy sector of about 0.5[12] is not particularly worrying. On the one hand, electricity distribution is often considered to be less risky than the electricity sector as a whole so that that a smaller beta can be expected. On the other hand and more importantly, this is an accounting beta that is not directly compatible with market beta and is expected to be significantly lower.

What we are primarily interested in studying is how betas can depend on key characteristics of firms. For this purpose we use a two-step procedure, where in the first step we estimate a simple fixed-effects model of betas and then, in the second step, estimate a model where the firm specific beta is the dependent variable and

[12] See that appendix for an example of estimates based on stock market data for for a wide spectrum of industies, including electric power.

different characteristic variables the independent ones. As a first step in this process we estimate similar model to that described in Table 1 but with specific fixed beta coefficient for each firm, see Table 9 in the appendix. This fixed-effects model produces betas that are on average similar to the mixed effects model, but vary considerable between firms. The estimated equation (Table 9) has a much better fit, understandably so given the added parameters. Only a minority of individual beta coefficients is significant however at the 5% level.

3.3.2 Explaining variations in firm-level beta

As a second step we estimate models in which individual betas are functions of key characteristics of the firms: size, span and sparseness.

Size is a tricky issue in this context and we have considered three different measures of size. Firstly we consider equity, which is the closest parallel to Fama's and French's method discussed above. Equity turns out to be less significant as a determinant of beta than other size variables we while producing similar parameter estimates. Therefore we choose to skip it in the exposition. Secondly, we consider the energy distributed on the network per year, ENERGY. This measure of size is stripped of any prices and is as good a measure of output as such measures get. This is not to say that distribution of energy is a completely homogenous good. The cost of distributing energy depends on the time of use and the variation of use over time. Thirdly, we consider total revenue, REVENUE, as a measure of the firms total operations. While this measure is sensitive to prices it is less prone to create a bias when distribution firms have different types of customer base, e.g. residential relative to industrial customers.

Geographic *span* can also affect risk. We consider the size of the network, NETSIZE, measured as the combined length of wires and cables in each network in kilometers. It has been suggested that operating a network in a rural area entails more financial risk than operating a network in a densely populated area. While the size of the network can capture this effect up to a point, it is rather the size of the network in relation to the energy distributed that is the more appropriate measure. We refer to this combined effect of span and size as *Sparseness* and measure it as the ratio between NETSIZE and ENERGY. These two variables represent different aspects of size and combined work as a measure of network sparseness or density. A sparse network is one with relatively long set of wires and cables with respect to the energy that flows through it. This is also, in a way, a method to capture geographical aspects of the comparison between networks, as rural networks tend to have large networks relative to the energy they distribute.

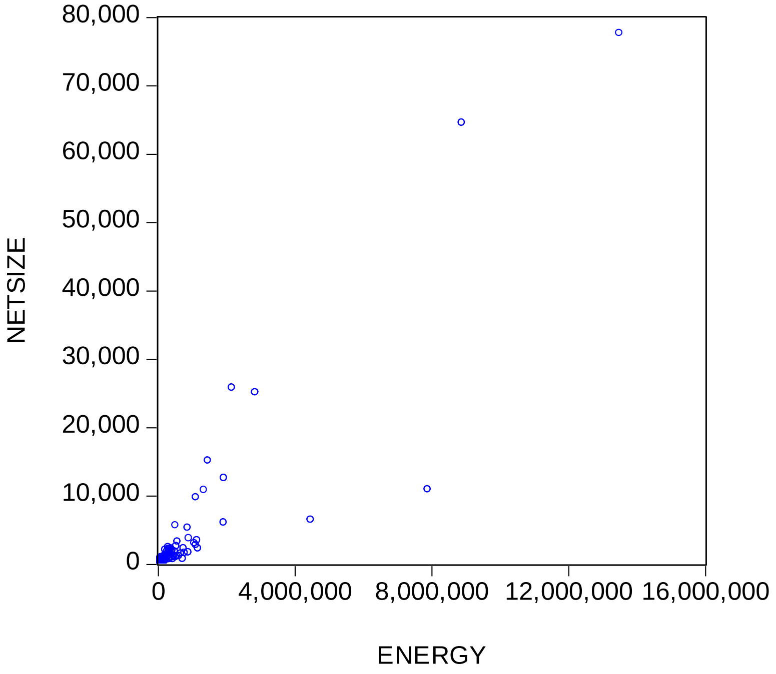

Figure 3: Energy distributed and size of network (all networks in sample)

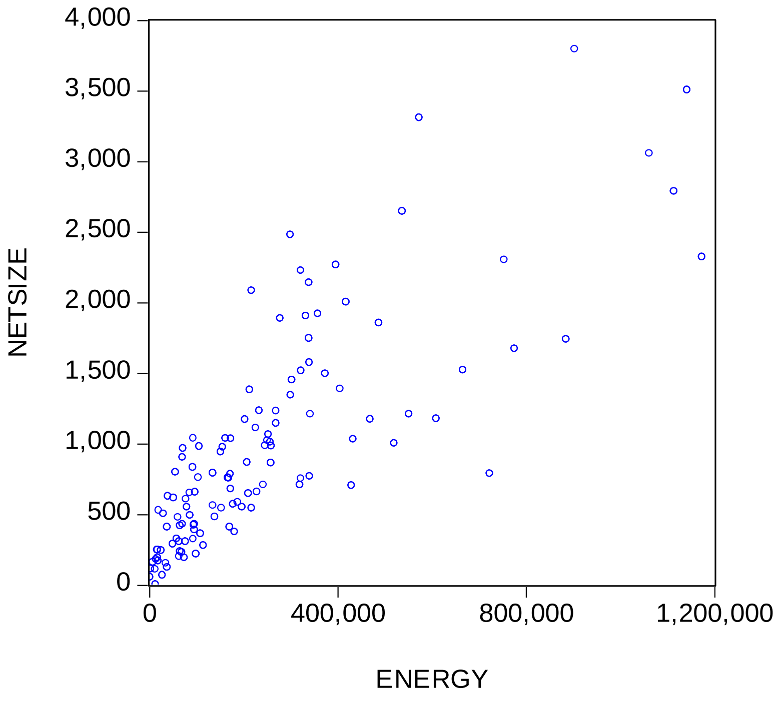

Figure 4: Energy distributed and size of network (Netsize < 5000 km)

Two scatterplots depict the relationship between these two variables, the first for the whole range of values (Figure 3). As a large majority of networks are much smaller then the largest ones we also provide a second figure for networks of span less than 5000 km only (Figure 4). Figures 3 and 4 show that ENERGY and NETSIZE are highly correlated but still have a considerable variation.

The relationship between beta and the measures of size, span and sparseness are shown in Figures 5 to 7. There does not appear to be a clear relationship between size and beta, as measure by energy and neither is span an apparent determinant of beta. Similar pattern appears when we use revenue as a measure for size. Sparseness (see Figure 7), on the other hand seems to be positively related to beta. Even though it is far from dominating the spread in beta, there is a detectable positive relationship in the data.

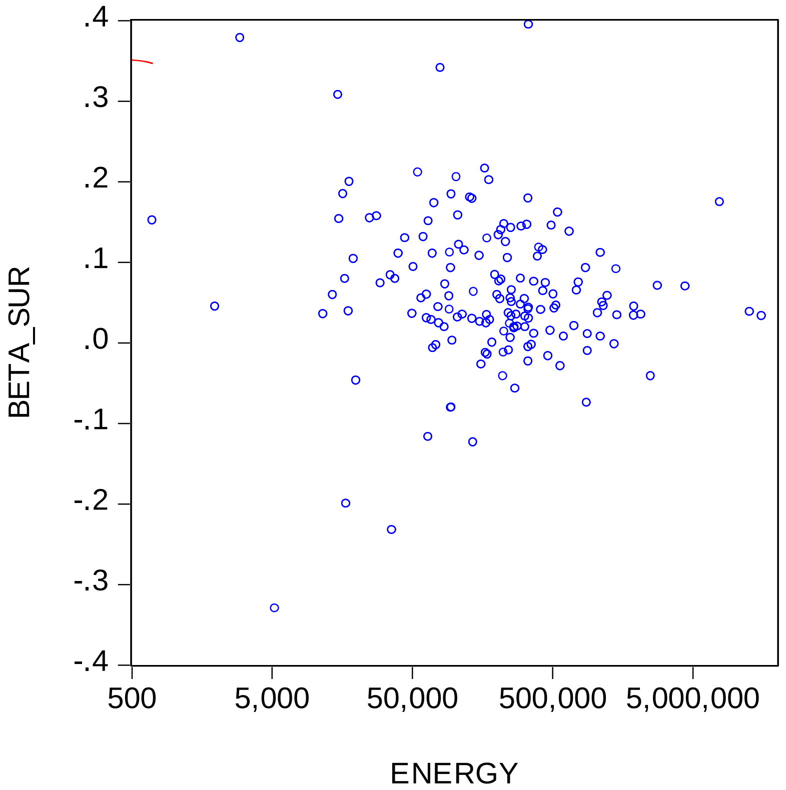

Figure 5: The relationship between individual betas and energy (logarithmic scale)

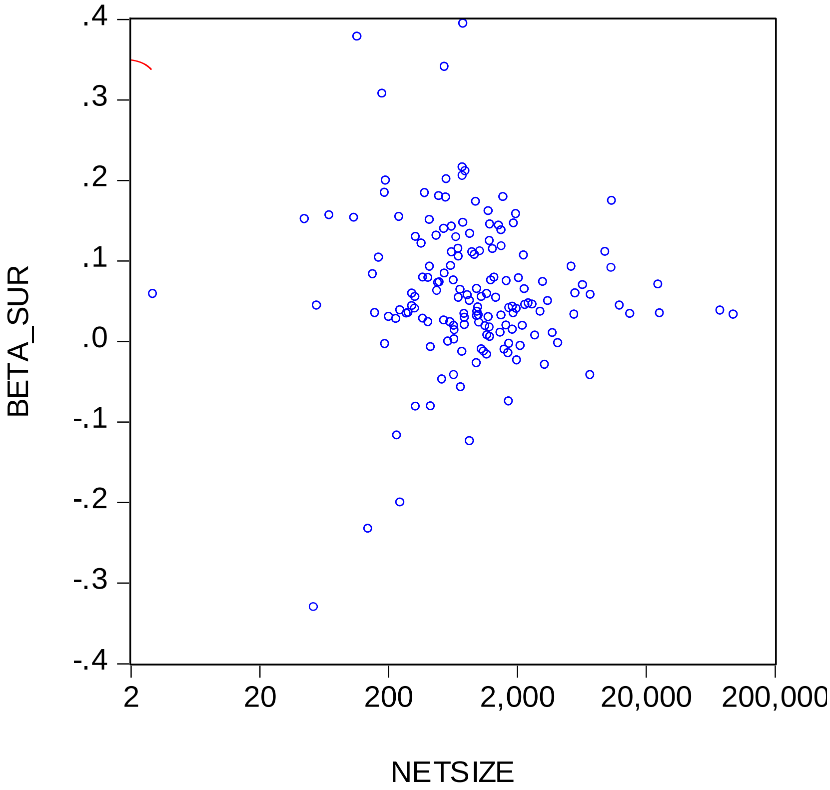

Figure 6: The relationship between individual betas and size of network (logarithmic scale)

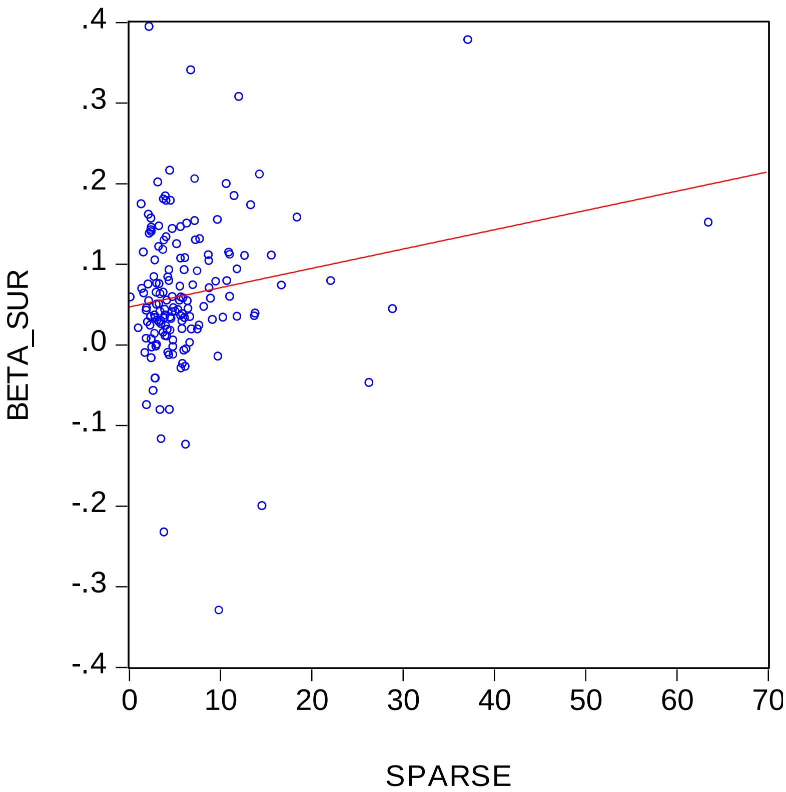

Figure 7: The relationship between individual betas an sparseness (with a linear regression line)

Table 2: The effects of size, span and sparseness on beta

Model:	B1	B2	B3	B4	B5	B6	B7
Dep. Var:	BETA	BETA	BETA	BETA	BETA	BETA	BETA
Constant	0.040335	0.038631	0.039100	0.038523	0.040823	0.041919	0.040905
	(0.0060)**	(0.0065)**	(0.0063)**	(0.0064)**	(0.0064)**	(0.0063)**	(0.0064)**
SPARSE[1]	0.003738				0.003711	0.003776	0.003718
	(0.0014)**				(0.0014)**	(0.0014)**	(0.0014)**
ENERGY[2]		-0.001563			-0.000841		
		(0.0035)			(0.0034)		
NETSIZE[2]			-0.483739			-0.533009	
			(0.6031)			(0.5913)	
REVENUE[2]				-0.006543			-0.004576
				(0.0154)			(0.0152)
Observations:	158	158	158	158	158	158	158
R-squared:	0.0449	0.0013	0.0041	0.0012	0.0452	0.0498	0.0454
F-statistic:	7.3277	0.2028	0.6434	0.1796	3.6721	4.0658	3.6881

[1] Deviation from mean.
[2] Divided by 10^6.
* The parameter is significantly different from zero at the 5% level of significance.
** The parameter is significantly different from zero at the 1% level of significance.

These visual observations give a clear indication of what can be expected from formal linear regression analysis, reported in Table 2. Seven different specifications are estimated. First we have four models where each of the above mentioned variables are used as exogenous variables with respect to beta. Revenue is also considered as an alternative measure of size. Models B5 to B7 show alternative specifications where two simultaneous explanatory variables are considered, sparseness and each of the other ones in turn.

The only parameter, apart from the constant, which is significant is the SPARSE coefficient (at the 5% level of significance). It is also robust to changes in the specification with a value of about 0.0024. None of the other parameters are close to being significant.

Several examples of the predicted beta, given different values for network size and energy distributed are shown in Table 3, to give some idea about the size of the sparseness effect. The calculations are based on model B1. These examples show that beta can grow relatively large for large networks with relatively small energy throughput. The extremely high values in the bottom left corner are not representative since none of the firms in the dataset have such large networks and small throughput.

Table 3: The effects of network size and energy distributed on beta due to the sparseness effect (based on model Beta 1)

Network size km of wires and cables	Energy distributed, mWh: 5,000	50,000	500,000	1,000,000	5,000,000
1,000	0.79	0.12	0.05	0.04	0.04
5,000	3.78	0.41	0.08	0.06	0.04
10,000	7.52	0.79	0.12	0.08	0.05
50,000	37.42	3.78	0.41	0.23	0.08
100,000	74.80	7.52	0.79	0.41	0.12

Table 3 shows us how the predicted beta based on model B1 turns out for the actual firms in the sample. The estimated beta ranges from 0.048 to 0.20 depending on the sparseness of the networks. The distribution is rather fat tailed on the higher end. There are only few firms that have a high beta value while the vast majority is at around the mean of 0.063. The standard deviation is 0.016. This means that in most relevant cases the predicted difference in beta is rather small.

Thus far we have only considered accounting beta and the logical next step is to consider reasonable adjustments that will allow us to interpret these results in the context of market beta. The literature on accounting betas, discussed in section 2.5 provides only limited guidance. One thing is certain though, that the market equivalent of accounting beta is considerably larger. Another indication from this literature is that any scaling of these results is likely to be proportional. At least that is the case in the decomposition of systematic risk into: intrinsic risk, financial

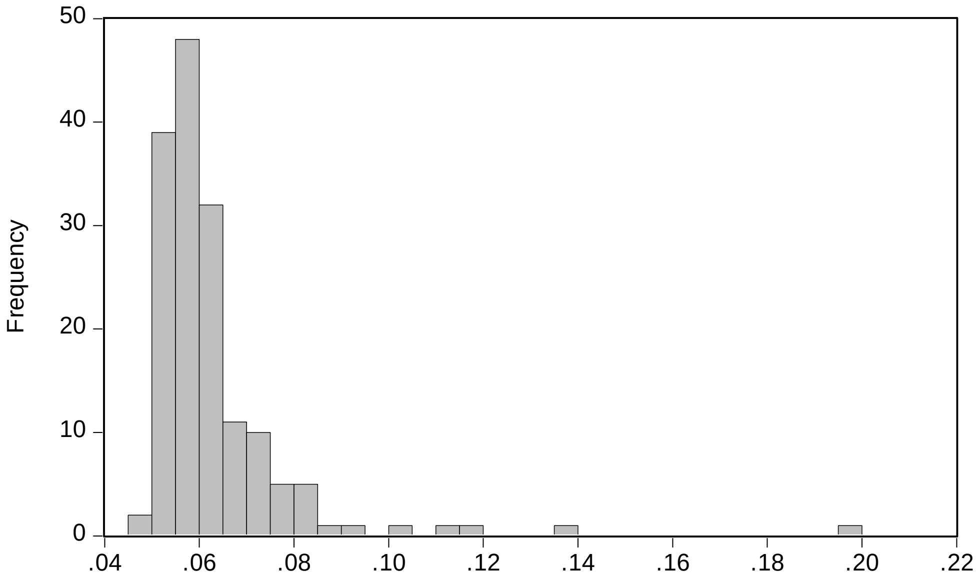

Figure 8: Predicted beta (based on model B1)

leverage and operating leverage.

In the concluding chapter an attempt will be made to quantify these effects based on earlier average estimates of beta for the relevant industry, both for beta as such and for WACC. But before we do that we will take a look at cost of debt in more detail.

3.4 Estimation of cost of debt

It is also possible that firm size, geographic span and sparseness affects firms' cost of debt. Since the dataset includes both the income statements and balance sheets of all electricity distribution firms in Sweden it is possible to test whether any of these factors matter.

As a measure of cost of debt we choose the ratio of interest payments for each year and the average of interest-bearing debt at the beginning and end of each year. It is customary to focus on interest bearing debt only in a context like this, instead of total debt, which may for instance include old loan agreements that are not based on market rates.

There are a few caveats that need to be mentioned. The underlying theory requires that the measure of cost of capital is forward looking while the data is based on actual or historic borrowing. Apart from a series of mergers, this industry is relatively stable and we can expect a relatively good approximation for the period in question. If we would like to make forecasts about the near future, one possible method is to calculate the implied premium over prevailing long-term government bonds.

The accounting data is not perfectly accurate either. Some observations are missing and others are unreliable. Hence, a few observations are omitted here, as we did in the previous analysis. The general guideline applied here is to omit observations with negative interest rates or rates above 25%. The analysis is also constrained to the period from 2004 to 2008 since consistent earlier data is not available.

First observe that there is a time trend in the interest rate. Table 4 describes a simple panel regression where the estimated average interest rate is 5.07% and negative time trend of the magnitude 0.005% (or half a basis point) is significant.

In comparison the average yield on Swedish ten-year government bonds was 3.88% in the same period, with similar trend over time. This implies that electric network firms in Sweden were charged a 1.19% premium on the average yield of long-term government bonds on average.

Table 4: Mean cost of debt and its time trend

Dependent Variable: INTERR
Method: Panel Least Squares
Periods included: 5
Cross-sections included: 143
Total panel (unbalanced) observations: 626

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.050676	0.001091	46.46055	0.0000
Time trend	-0.004777	0.000804	-5.939713	0.0000

R-squared	0.559594	Mean dependent var	0.050676
Adjusted R-squared	0.428934	S.D. dependent var	0.036113
F-statistic	4.282825	Durbin-Watson stat	1.424956

Just as in the previous section we are interested in testing whether the size of the network, its geographic span or the size of its wire network and the sparseness of the network can explain differences between firms. We do this with a series of linear regressions shown in Table 5.

The same analysis was repeated using interest payments against total debt to define interest rates. While this alternative measure is cruder and less appropriate when applying the CAPM model it is available for the whole period from 1998. Incidentally this did not change the results qualitatively. None of the heterogeneity factors are significant in this case either. Hence, we do not find any indication of systematic heterogeneity in cost of debt.

Table 5: The effects of size, span and sparseness on cost of debt

Model:	Rd 1	Rd 2	Rd 3	Rd 4	Rd 5	Rd 6	Rd 07
Dep. Var:	INTRR	INTRR	INTRR	INTRR	INTRR	INTRR	INTRR
C	0.054849	0.053841	0.054703	0.054222	0.053890	0.054702	0.054253
	(0.0029)**	(0.0030)**	(0.0030)**	(0.0030)**	(0.0030)**	(0.0030)**	(0.0030)**
SPARSE[1]	-0.000389				-0.000359	-0.000389	-0.000376
	(0.0004)				(0.0005)	(0.0005)	(0.0005)
ENERGY[2]		0.001730			0.001645		
		(0.0016)			(0.0016)		
NETSIZE[2]			0.050193			0.050455	
			(0.2716)			(0.2718)	
REVENUE[2]				0.005201			0.004944
				(0.0073)			(0.0073)
Observations:	138	138	138	138	138	138	138
R-squared:	0.0055	0.0083	0.0003	0.0038	0.0129	0.0057	0.0089
F-statistic:	0.7485	1.1326	0.0342	0.5135	0.8829	0.3888	0.6039

[1] Deviation from mean.
[2] Divided by 10^6
* The parameter is significantly different from zero at the 5% level of significance.

** The parameter is significantly different from zero at the 1% level of significance.

4 Conclusions

In the preceding chapters we have demonstrated how a significant relationship can be traced between the sparseness of electricity distribution networks in Sweden and systematic risk, as measured by beta. Other alternative measures of size and span did not turn out to be significant. Similar heterogeneous patters were not found in a model of cost of debt.

Statistical significance is not a sufficient condition for adaptation of a seemingly robust pattern in systematic risk in regulatory practice however. Several other conditions should be considered as well. First of all, the indicated pattern needs to be *nontrivial*. Only if it has a noticeable impact on WACC should it be applied, given the general uncertainty and limited accuracy of the methodology. Secondly, it has to be implementable in a *fair and transparent* manner, or else the cost of additional political and legal disputes may outweigh the benefits of the exercise. And thirdly, there should be a *clear benefit* in introducing a variation in WACC used in the regulation of the industry.

One method to implement the pattern would be to separate the firms into groups according to sparseness and use the estimated results to calculate a representative beta for each group. We can, for example, divide the firms into three equally large groups, or tertiles, by the order of sparseness and then proceed to calculate beta and WACC for each group. The upper half of Table 6 shows selected descriptive statistics for each group in turn, the lowest third, middle third and the highest third. To avoid unwanted influence of extreme values the median is a more appropriate measure of central tendency than the mean. The median also has the nice property that the median of the middle group is also the median of the whole. The table also points out the range of sparseness within each group and thereby the boundaries between them. Firms with a sparseness level lower than 3.56 km/MWh belong to the lowest third and firms with sparseness greater than 6.11 km/MWh belong to the highest third.

The lower half of Table 6 shows estimates of beta and WACC for each tertile and the whole. First, an accounting beta is calculated using model B1 and the respective median sparseness. The level of these betas is much lower than typically for market betas in this industry. Therefore, we need to adjust the accounting betas. In this case we do that for each group in turn and by the same factor. As discussed in section 2.5 we might prefer to use previous estimates of the relationships between accounting and financial beta. Unfortunately, such estimates are rather inaccurate and cannot be applied directly. The methodology suggests, however, that proportional scaling is appropriate. Here we assume that the median firm level (asset) beta for the industry is 0.4, or similar to what Johnsen (2006) and others have suggested. When accounting for the impact of leveraging on equity beta we assume that ratio of debt to total assets is 50%, which implies a debt-to-equity ratio of 1 and a prevailing marginal corporate tax rate 26,3%. This target capital structure

Table 6: Descriptive statistics of Sparseness and implied beta and WACC, for three quantiles (tertiles)

Tertiles	Lowest third	Middle third	Highest third	All firms
Mean	2.550571	4.804423	12.24453	6.542999
Median	2.504978	4.662028	9.57888	4.662028
Min.	0.220935	3.589909	6.137987	0.220935
Max	3.554147	6.100008	63.55116	63.55116
Std. Dev.	0.705651	0.754265	9.033323	6.688091
Obs.	59	58	59	176
Accounting beta	0.0323	0.0403	0.0587	0.0403
Firm beta	0.32	0.40	0.58	0.40
Equity beta	0.52	0.65	0.94	0.65
Implied WACC	5.7%	6.0%	6.8%	6.0%

is within a typical range used in cost of capital studies (IceCapital, 2006; e.g., Öhrlings PWC, 2004). The outcome then is a considerable range of equity beta, from 0.52 for firms with dense networks and 0.94 for firms with sparse network. The median equity beta is 0.65.

To complete the calculations of weighted average cost of capital (WACC) as defined in equation (3) on page 14 we need a few additional assumptions. If we assume that the risk-free interest rate is 4%, which is consistent with earlier studies and the yield on 10-year Swedish government bonds; that the market risk premium is 5%, also a common assumption in the literature; and that firms pay an interest rate premium of 1.19% over the risk free rate, we end up with an estimate of WACC in range of 5.7% to 6.8%. The interest rate premium is slightly higher than usual where1% is the most frequent assumption. Our analysis of firm level data in section 3.4 suggested this slightly higher level.

All these assumptions, summarized in Table 7, can be put in question. The debate about the appropriate overall level of WACC will be continued elsewhere however. Here, we merely illustrate how the present results of heterogeneity in systematic risk could be implemented on top of standard practice in choosing WACC.

Table 7: Parameter assumptions used in the WACC and CAPM model

Parameter		Value
Debt to asset ratio	D/A	0.5
Risk free rate	rf	4%
Market premium	mp	5%
Marginal tax rate	tax	26,3%
Interest rate premium	dp	1.19%

The above results suggest that the measured heterogeneity is nontrivial and should therefore be considered for adoption. It is slightly more difficult to tell whether this can be done in a sufficiently fair and transparent manner. The suggested method of dividing firms into three groups according to the sparseness of their networks is rather straightforward and transparent. It is not foolproof however. A discrete threshold between the groups, for instance, may create unintended incentives for wasteful investment in power lines and fairness might become an issue, at least from the perspective of firms close the threshold.

An alternative implementation would be to define a continuous function, mapping measured sparseness to beta. Perhaps with a floor and a ceiling. Such a system might be considered fairer and clearly less prone to wasteful investment. The added complexity of the outcome, where practically all firms would have a unique WACC, is an obvious downside however.

The benefit of choosing the most appropriate WACC for the regulated firm is unquestionable. An inappropriate allowance for rate of return is always wasteful. There is bound be a rate-of-return element to any regulation scheme, either directly or indirectly through periodic adjustments. A too high WACC will therefore always incite overinvestment and a too low WACC can lead to underinvestment and quality degradation. An inappropriate WACC also means a transfer, from consumers to firms if set too high and vise versa if set too low, and an inefficient use of electricity.

On the whole, it seems feasible to implement this heterogeneity in practice. A careful consideration of practical details is still necessary to balance off fairness and transparency considerations.

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Appendix

Table 8: Distribution firms not used in the analysis (in whole or in part)due to missing data or extreme values

Obsno.	*RELnummer*	*Name*
Observations skipped because of missing data		
24	REL00029	Ekfors Kraft AB
42	REL00068	Hamra Besparingsskog
54	REL00083	Jukkasjärvi Sockens Belysningsförening upa
112	REL00168	Skyllbergs Bruks AB
118	REL00177	Sturefors Eldistribution AB
140	REL00231	Viggafors Elektriska Andelsförening UPA
164	REL00582	Fortum Distribution Ryssa AB
166	REL00584	Umeå Energi Elnät AB
167	REL00585	Götene Elförening ek för
168	REL00590	LKAB Nät AB
169	REL00591	Kreab Energi AB
170	REL00592	Kreab Öst AB
Observations skipped because of extreme values		
3	REL00003	Almnäs Bruk AB
4	REL00004	Alvesta Elnät AB
7	REL00008	Bergs Tingslags Elektriska AB
12	REL00015	Bodens Energi Nät AB
50	REL00077	Härnösand Elnät AB
55	REL00085	Jämtkraft Elnät AB
61	REL00091	Affärsverken Karlskrona AB
69	REL00103	Landskrona kommun Teknik- & stadsbyggnadsförvaltn
78	REL00115	LJW Nät HB
80	REL00119	Lunds Energi AB
92	REL00139	Näckåns Elnät AB
119	REL00178	Sundsvall Elnät AB
125	REL00186	Telge Nät AB
126	REL00187	Tibro Energi AB
129	REL00191	Trollhättan Energi Elnät AB
134	REL00201	Vallebygdens Energi ek för
135	REL00202	Elverket Vallentuna AB
138	REL00205	Varbergsortens Elkraft
141	REL00232	Vimmerby Energi AB
143	REL00235	Värnamo Elnät AB
144	REL00239	Västerviks Kraft Elnät AB
146	REL00243	Växjö Energi Elnät AB
147	REL00244	Ystad Energi AB
148	REL00245	Åkab Nät & Skog AB
149	REL00246	Ålem Energi AB
150	REL00249	Årsunda Kraft & Belysningsförening upa
151	REL00250	Öresundskraft Ängelholm AB
154	REL00257	Övik Energi Nät AB
161	REL00571	E.ON Elnät Stockholm AB

Table 9: Fixed effects estimation of CAPM betas

Dependent Variable: ER
Method: Panel Least Squares
Periods included: 10
Cross-sections included: 158
Total panel (unbalanced) observations: 1568
Cross-section SUR (PCSE) standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.069346	0.006388	10.85652	0.0000
Beta 2	0.040794	0.013705	2.976477	0.0030
Beta 4	0.112567	0.115336	0.975993	0.3293
Beta 5	0.057522	0.122931	0.467922	0.6399
Beta 6	0.079645	0.110517	0.720660	0.4713
Beta 7	0.112457	0.075352	1.492426	0.1358
Beta 8	0.029486	0.022451	1.313361	0.1893
Beta 9	0.053478	0.015615	3.424741	0.0006
Beta 10	0.086456	0.048648	1.777182	0.0758
Beta 11	0.337732	0.209928	1.608796	0.1079
Beta 12	-0.022057	0.030817	-0.715749	0.4743
Beta 13	0.080057	0.061911	1.293095	0.1962
Beta 14	0.047900	0.070394	0.680452	0.4963
Beta 15	0.011585	0.046601	0.248589	0.8037
Beta 16	0.127272	0.089619	1.420150	0.1558
Beta 17	0.054501	0.151434	0.359901	0.7190
Beta 18	-0.084100	0.276365	-0.304308	0.7609
Beta 19	0.147503	0.060740	2.428420	0.0153
Beta 20	-0.005017	0.322045	-0.015578	0.9876
Beta 21	-0.019691	0.049515	-0.397673	0.6909
Beta 22	0.073012	0.075880	0.962202	0.3361
Beta 23	0.011942	0.042950	0.278044	0.7810
Beta 25	0.054730	0.137536	0.397935	0.6907
Beta 26	0.100857	0.117829	0.855964	0.3922
Beta 27	-0.077278	0.046411	-1.665073	0.0961
Beta 28	0.117757	0.264578	0.445076	0.6563
Beta 29	0.044325	0.228568	0.193925	0.8463
Beta 30	-0.007539	0.022724	-0.331752	0.7401
Beta 31	0.017510	0.024331	0.719673	0.4719
Beta 32	-0.035412	0.029337	-1.207080	0.2276
Beta 33	-0.111154	0.065964	-1.685063	0.0922
Beta 34	0.004044	0.029157	0.138684	0.8897
Beta 35	0.028889	0.035189	0.820968	0.4118
Beta 36	0.080637	0.069786	1.155490	0.2481
Beta 37	-0.018370	0.046165	-0.397920	0.6908
Beta 38	0.058303	0.036862	1.581665	0.1140
Beta 39	0.062894	0.034653	1.814968	0.0698
Beta 40	0.006935	0.032889	0.210857	0.8330
Beta 41	0.042443	0.019270	2.202583	0.0278
Beta 43	0.024796	0.015005	1.652517	0.0987
Beta 44	0.204043	0.057483	3.549633	0.0004
Beta 45	0.032072	0.042168	0.760583	0.4470
Beta 46	0.064632	0.025277	2.556979	0.0107

Table 7 (Continued)

Beta 47	-0.000642	0.029925	-0.021456	0.9829
Beta 48	0.063618	0.021507	2.957939	0.0032
Beta 49	0.020550	0.045634	0.450322	0.6526
Beta 50	0.013656	0.059119	0.230994	0.8174
Beta 51	-0.014342	0.073808	-0.194319	0.8460
Beta 52	0.028232	0.028555	0.988691	0.3230
Beta 53	-0.056068	0.253797	-0.220918	0.8252
Beta 55	0.061897	0.041187	1.502829	0.1331
Beta 56	0.007627	0.022373	0.340882	0.7332
Beta 57	-0.026201	0.055638	-0.470919	0.6378
Beta 58	0.046595	0.043302	1.076060	0.2821
Beta 59	0.029062	0.044817	0.648455	0.5168
Beta 60	0.109419	0.067652	1.617386	0.1060
Beta 62	0.000977	0.049906	0.019585	0.9844
Beta 63	-0.004026	0.024823	-0.162190	0.8712
Beta 64	-0.166342	0.127619	-1.303433	0.1927
Beta 65	-0.013349	0.054532	-0.244794	0.8067
Beta 66	-0.016355	0.021208	-0.771181	0.4407
Beta 67	0.431885	0.320458	1.347712	0.1780
Beta 68	0.034527	0.020468	1.686905	0.0919
Beta 70	0.050729	0.019840	2.556862	0.0107
Beta 71	0.018044	0.027262	0.661881	0.5082
Beta 72	-0.020403	0.051611	-0.395325	0.6927
Beta 73	-0.030920	0.077177	-0.400640	0.6888
Beta 74	0.143156	0.073071	1.959122	0.0503
Beta 75	0.044258	0.025670	1.724126	0.0849
Beta 76	0.077906	0.064434	1.209074	0.2269
Beta 77	0.043132	0.117193	0.368044	0.7129
Beta 79	0.015029	0.017953	0.837121	0.4027
Beta 80	-0.015539	0.032403	-0.479560	0.6316
Beta 81	-0.024728	0.058040	-0.426053	0.6701
Beta 82	0.035045	0.024009	1.459647	0.1446
Beta 83	0.031807	0.060313	0.527369	0.5980
Beta 84	0.116994	0.032900	3.556029	0.0004
Beta 85	0.054428	0.041314	1.317422	0.1879
Beta 86	0.043611	0.036090	1.208387	0.2271
Beta 87	0.062673	0.022493	2.786283	0.0054
Beta 88	0.102916	0.062756	1.639946	0.1013
Beta 89	0.018137	0.049643	0.365341	0.7149
Beta 90	-0.013804	0.060665	-0.227548	0.8200
Beta 91	-0.117332	0.042251	-2.777040	0.0056
Beta 93	0.045081	0.036222	1.244564	0.2135
Beta 94	0.025982	0.014156	1.835393	0.0667
Beta 95	0.088851	0.147152	0.603806	0.5461
Beta 96	-0.092640	0.113064	-0.819354	0.4127
Beta 97	0.055748	0.016849	3.308736	0.0010
Beta 98	-0.005346	0.076368	-0.070005	0.9442
Beta 99	0.000691	0.068513	0.010091	0.9920
Beta 100	-0.021722	0.101882	-0.213211	0.8312
Beta 101	0.099355	0.049279	2.016196	0.0440
Beta 102	0.053845	0.043232	1.245475	0.2132

Table 7 (Continued)

Beta 103	-0.068188	0.072015	-0.946851	0.3439
Beta 104	0.029264	0.024370	1.200851	0.2300
Beta 105	0.038880	0.040587	0.957938	0.3383
Beta 106	0.031510	0.038506	0.818298	0.4133
Beta 107	0.078163	0.024834	3.147430	0.0017
Beta 108	0.100735	0.028309	3.558348	0.0004
Beta 109	0.005573	0.075999	0.073329	0.9416
Beta 110	0.033589	0.035633	0.942635	0.3460
Beta 111	0.048264	0.028751	1.678700	0.0935
Beta 113	0.100624	0.075034	1.341032	0.1802
Beta 114	0.061771	0.053047	1.164450	0.2445
Beta 115	-0.168400	0.099516	-1.692198	0.0909
Beta 116	-0.021681	0.017936	-1.208826	0.2270
Beta 117	0.045301	0.036334	1.246798	0.2127
Beta 119	0.084289	0.070919	1.188532	0.2348
Beta 120	0.046612	0.034987	1.332286	0.1830
Beta 121	-0.009844	0.078461	-0.125470	0.9002
Beta 122	0.133790	0.072908	1.835037	0.0667
Beta 123	0.044551	0.031704	1.405225	0.1602
Beta 124	0.046149	0.029412	1.569073	0.1169
Beta 125	-0.146994	0.175943	-0.835460	0.4036
Beta 126	0.072372	0.054363	1.331272	0.1833
Beta 127	0.082470	0.045611	1.808112	0.0708
Beta 128	0.154164	0.109334	1.410020	0.1588
Beta 129	0.079608	0.059155	1.345752	0.1786
Beta 130	0.025623	0.020859	1.228353	0.2195
Beta 131	-0.001328	0.070197	-0.018911	0.9849
Beta 132	0.033208	0.041302	0.804030	0.4215
Beta 133	0.013412	0.022772	0.588966	0.5560
Beta 134	0.210559	0.160543	1.311544	0.1899
Beta 135	0.028171	0.054293	0.518870	0.6039
Beta 136	0.115575	0.030702	3.764479	0.0002
Beta 137	0.029703	0.015698	1.892108	0.0587
Beta 138	0.005180	0.074251	0.069764	0.9444
Beta 139	0.014651	0.040142	0.364988	0.7152
Beta 141	-0.086649	0.068894	-1.257716	0.2087
Beta 142	0.025009	0.021708	1.152045	0.2495
Beta 143	-0.066050	0.090728	-0.727996	0.4668
Beta 144	0.088134	0.067257	1.310400	0.1903
Beta 145	0.048684	0.046201	1.053742	0.2922
Beta 146	0.127614	0.080975	1.575970	0.1153
Beta 147	-0.016349	0.035637	-0.458760	0.6465
Beta 149	0.131920	0.025223	5.230214	0.0000
Beta 150	0.148481	0.148203	1.001878	0.3166
Beta 151	0.011154	0.016968	0.657345	0.5111
Beta 152	0.050207	0.043632	1.150683	0.2501
Beta 153	0.034476	0.021733	1.586326	0.1129
Beta 154	-0.022799	0.120385	-0.189380	0.8498
Beta 155	0.011320	0.020532	0.551346	0.5815
Beta 156	-0.144582	0.123233	-1.173245	0.2409
Beta 157	0.203207	0.180246	1.127389	0.2598

Table 7 (Continued)

Beta 158	0.108920	0.039932	2.727631	0.0065
Beta 159	0.045538	0.021430	2.125030	0.0338
Beta 160	0.036717	0.045165	0.812940	0.4164
Beta 161	-0.045243	0.026821	-1.686849	0.0919
Beta 162	0.050324	0.062508	0.805086	0.4209
Beta 163	0.021282	0.036436	0.584100	0.5593
Beta 165	0.032374	0.056775	0.570219	0.5686
Beta 171	0.039465	0.017765	2.221535	0.0265
Beta 172	-0.017329	0.029137	-0.594750	0.5521
Beta 173	0.168645	0.083141	2.028420	0.0427
Beta 174	0.065445	0.047983	1.363926	0.1728
Beta 175	-0.050968	0.099602	-0.511716	0.6089
Beta 176	0.045073	0.022441	2.008540	0.0448

R-squared	0.538948	Mean dependent var	0.069758
Adjusted R-squared	0.423409	S.D. dependent var	0.111127

Table 10: Betas by industry (source: Aswath Damodaran, NYU)

Industry Name	*Number of Firms*	*Average Beta*	*Market D/E Ratio*	*Tax Rate*	*Unlevered Beta*	*Cash/Firm Value*	*Unlevered Beta corrected for cash*
Advertising	36	1.6	72.76%	13.01%	0.98	11.92%	1.12
Aerospace/Defense	67	1.19	22.94%	20.05%	1	7.90%	1.09
Air Transport	44	1.06	70.74%	17.63%	0.67	11.84%	0.76
Apparel	56	1.3	23.61%	16.54%	1.09	6.95%	1.17
Auto & Truck	22	1.72	154.47%	13.25%	0.74	11.75%	0.83
Auto Parts	54	1.75	51.24%	12.09%	1.21	12.38%	1.38
Bank	481	0.75	198.22%	17.50%	0.28	10.36%	0.32
Bank (Canadian)	7	0.86	16.44%	14.94%	0.76	7.37%	0.82
Bank (Midwest)	39	0.96	110.54%	20.65%	0.51	9.63%	0.57
Beverage	41	1.04	16.92%	12.12%	0.9	3.20%	0.93
Biotechnology	121	1.1	14.78%	4.46%	0.96	14.59%	1.12
Building Materials	53	1.45	83.80%	14.56%	0.84	5.48%	0.89
Cable TV	24	1.69	85.22%	21.86%	1.02	4.02%	1.06
Canadian Energy	10	1.18	30.86%	26.99%	0.96	2.32%	0.98
Chemical (Basic)	17	1.27	20.37%	21.59%	1.1	6.74%	1.18
Chemical (Diversified)	31	1.37	19.85%	20.84%	1.19	4.73%	1.25
Chemical (Specialty)	97	1.29	29.01%	12.86%	1.03	4.17%	1.08
Coal	21	1.67	23.68%	13.15%	1.39	4.31%	1.45
Computer Software/Svcs	333	1.02	5.61%	10.12%	0.97	10.34%	1.08
Computers/Peripherals	129	1.29	10.93%	8.65%	1.17	12.20%	1.33
Diversified Co.	121	1.2	138.78%	18.93%	0.57	11.12%	0.64
Drug	337	1.11	12.58%	5.62%	0.99	7.79%	1.07
E-Commerce	56	1.18	8.74%	13.50%	1.09	11.63%	1.24
Educational Services	38	0.75	7.21%	24.06%	0.71	8.58%	0.78
Electric Util. (Central)	23	0.79	102.89%	32.27%	0.47	2.31%	0.48
Electric Utility (East)	24	0.73	75.74%	33.77%	0.49	1.70%	0.5
Electric Utility (West)	14	0.75	89.99%	32.45%	0.47	4.25%	0.49
Electrical Equipment	87	1.41	16.91%	14.07%	1.23	7.16%	1.33
Electronics	183	1.16	26.37%	10.63%	0.94	14.90%	1.1
Entertainment	95	1.81	56.83%	11.78%	1.21	6.56%	1.29
Entertainment Tech	35	1.32	11.72%	6.28%	1.19	22.36%	1.53
Environmental	91	0.97	49.42%	14.27%	0.68	2.49%	0.7
Financial Svcs. (Div.)	296	1.39	305.02%	16.53%	0.39	15.76%	0.47
Food Processing	121	0.86	29.31%	17.29%	0.69	3.79%	0.72
Foreign Electronics	9	1.13	29.12%	10.71%	0.9	22.65%	1.16
Funeral Services	5	1.19	56.52%	24.34%	0.83	3.51%	0.86
Furn/Home Furnishings	35	1.52	38.54%	17.48%	1.16	6.12%	1.23
Healthcare Information	33	0.97	13.57%	17.80%	0.87	6.85%	0.94
Heavy Construction	14	1.42	7.58%	33.76%	1.35	16.86%	1.63

Table 10 (continued)

Industry Name	*Number of Firms*	*Average Beta*	*Market D/E Ratio*	*Tax Rate*	*Unlevered Beta*	*Cash/Firm Value*	*Unlevered Beta corrected for cash*
Homebuilding	28	1.45	102.34%	1.42%	0.72	26.11%	0.98
Hotel/Gaming	74	1.74	85.90%	12.93%	1	6.19%	1.06
Household Products	23	1.15	22.36%	24.87%	0.98	2.23%	1
Human Resources	30	1.38	13.17%	23.63%	1.25	14.81%	1.47
Industrial Services	168	1.07	33.96%	17.89%	0.84	8.10%	0.91
Information Services	29	1.28	23.68%	19.37%	1.08	3.91%	1.12
Insurance (Life)	31	1.38	36.81%	22.47%	1.07	38.96%	1.75
Insurance (Prop/Cas.)	85	0.92	24.03%	15.68%	0.76	23.51%	1
Internet	239	1.04	2.28%	5.94%	1.02	9.53%	1.13
Investment Co.	19	0.76	59.26%	0.00%	0.48	72.09%	1.71
Investment Co.(Foreign)	16	1.39	9.38%	2.10%	1.27	6.84%	1.36
Machinery	130	1.32	46.80%	20.41%	0.96	6.70%	1.03
Manuf. Housing/RV	15	1.21	3.98%	14.80%	1.17	13.51%	1.35
Maritime	53	1.38	159.57%	9.70%	0.57	6.93%	0.61
Medical Services	162	0.97	43.09%	18.84%	0.72	10.96%	0.81
Medical Supplies	264	1.04	11.36%	11.24%	0.95	6.57%	1.02
Metal Fabricating	36	1.54	18.80%	18.10%	1.33	11.77%	1.51
Metals & Mining (Div.)	79	1.23	14.78%	7.41%	1.08	2.81%	1.11
Natural Gas (Div.)	32	1.29	47.84%	25.01%	0.95	2.44%	0.97
Natural Gas Utility	24	0.68	80.53%	24.87%	0.42	2.69%	0.43
Newspaper	15	1.94	55.65%	27.26%	1.38	3.68%	1.44
Office Equip/Supplies	25	1.19	56.84%	22.62%	0.83	6.73%	0.89
Oil/Gas Distribution	19	0.89	61.46%	7.15%	0.56	1.83%	0.58
Oilfield Svcs/Equip.	113	1.45	25.97%	22.05%	1.21	4.77%	1.27
Packaging & Container	31	1.2	61.31%	18.18%	0.8	4.26%	0.83
Paper/Forest Products	39	1.63	86.48%	7.70%	0.91	5.49%	0.96
Petroleum (Integrated)	24	1.24	14.44%	33.00%	1.13	6.13%	1.21
Petroleum (Producing)	198	1.16	27.01%	11.27%	0.94	3.10%	0.97
Pharmacy Services	21	0.88	20.07%	24.36%	0.76	3.23%	0.79
Power	77	1.23	103.58%	7.00%	0.63	9.56%	0.69
Precious Metals	78	1.18	8.49%	8.41%	1.1	2.94%	1.13
Precision Instrument	98	1.24	15.02%	10.50%	1.09	12.53%	1.24
Property Management	20	1.63	191.86%	9.03%	0.59	5.94%	0.63
Public/Private Equity	9	2.4	169.66%	0.80%	0.89	12.16%	1.02
Publishing	30	1.43	70.33%	15.54%	0.9	4.27%	0.94
R.E.I.T.	143	1.6	67.45%	0.72%	0.96	5.72%	1.01
Railroad	15	1.29	32.95%	27.39%	1.04	2.31%	1.07
Recreation	65	1.43	49.77%	16.86%	1.01	5.05%	1.06
Reinsurance	8	1.07	17.69%	4.17%	0.91	28.41%	1.28

Table 10 (continued)

Industry Name	*Number of Firms*	*Average Beta*	*Market D/E Ratio*	*Tax Rate*	*Unlevered Beta*	*Cash/Firm Value*	*Unlevered Beta corrected for cash*
Restaurant	68	1.34	22.48%	19.86%	1.14	2.52%	1.17
Retail (Special Lines)	157	1.43	16.08%	18.49%	1.27	8.52%	1.38
Retail Automotive	15	1.46	44.57%	32.68%	1.13	2.65%	1.16
Retail Building Supply	7	0.95	19.12%	27.05%	0.83	1.34%	0.85
Retail Store	43	1.35	26.98%	18.42%	1.1	4.55%	1.16
Retail/Wholesale Food	32	0.73	26.17%	30.39%	0.62	3.01%	0.63
Securities Brokerage	30	1.18	281.05%	20.49%	0.36	34.11%	0.55
Semiconductor	125	1.56	8.06%	10.85%	1.45	12.95%	1.67
Semiconductor Equip	14	1.93	7.28%	16.66%	1.82	14.50%	2.13
Shoe	19	1.34	3.55%	22.11%	1.3	11.41%	1.47
Steel (General)	20	1.61	30.81%	22.29%	1.3	7.65%	1.4
Steel (Integrated)	15	1.85	39.30%	22.94%	1.42	7.93%	1.55
Telecom. Equipment	115	1.15	10.90%	13.79%	1.05	21.02%	1.33
Telecom. Services	140	1.1	47.03%	12.80%	0.78	5.75%	0.83
Thrift	227	0.73	21.74%	11.90%	0.61	14.51%	0.72
Tobacco	12	0.78	22.93%	26.03%	0.67	5.57%	0.71
Toiletries/Cosmetics	19	1.23	26.33%	26.27%	1.03	6.89%	1.1
Trucking	33	1.3	85.30%	30.87%	0.82	4.84%	0.86
Utility (Foreign)	5	1.07	101.26%	12.11%	0.57	4.80%	0.59
Water Utility	15	0.82	87.95%	31.16%	0.51	0.77%	0.51
Wireless Networking	60	1.5	19.83%	9.92%	1.28	5.01%	1.34
Total Market	7036	1.17	49.99%	14.07%	0.82	9.49%	0.9

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