The Relationship Between Corporate Governance and Company Performance

New Factors, Models and Approaches to Causality

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Dedication

To my...

Contents

List of Figures

Acknowledgements

Thanks to...

Abstract

This project...

Chapter 1

Introduction

This chapter forms the introduction to the current study, laying out its motivations and aims. We begin with a background of the domain, followed by the business motivation for this study. We follow this with a summary of the academic contribution, the research goals and scope and end with an outline of the document structure as a whole.

1.1 Background

This study is primarily concerned with the relationship between corporate governance and company performance, particularly with how the former can be optimised to positively influence the latter. Corporate governance is a widely discussed, debated and researched topic that is as relevant today as it has ever been. The governance of a company dictates it's policies and motivations, ensuring that all stakeholders [1] have input to how the company is run and share a vision of where it is going. Governance policy also acts to mitigate financial and ethical pitfalls, by setting clear standards. Thus it is fair to say that corporate governance has a wide ranging influence within and also outside the company.

[1] A stakeholder is someone who has a stake, or a personal interest, in the company. Employees, the local community and the media are all stakeholders.

We frequently see instances of corporate governance failure, which can lead to disastrous consequences financially and reputationally. Reputation is often of high importance in both the public and private sectors, which can lead to a promotion of more ethical and fair behaviour in order to protect it. Instances where companies fail in this regard often make eye-catching headlines, for example McLaughlin (2017), McVeigh (2015) and Kirkpatrick (2009). In a hyperconnected world where news spreads quickly, the importance of a functioning governance structure is more important than ever.

The interests of different parties can conflict in any business, between entities such as the shareholders [2] or directors. There is much debate on how best to align these interests, with suggested initiatives like structuring executive compensation to be at least partly dependant on firm performance. Shareholder interests can also conflict with the interests of the wider public as a whole, or the stakeholders. This is especially true for companies that heavy rely on natural resources as a driver for business. In this case, sustainability not just of the company but of finite natural resources that the public depend on must be closely governed and managed. This is often the responsibility not just of those within the company, but those outside it too.

It is reasonable to argue that corporate governance influences all aspects of the company, not least its economic success. Moldovan and Mutu (2015) studied this relationship, collecting data on corporate governance and using it to predict corporate success as measured in various ways. They were able to learn models that did this successfully, resulting in a number of rules dictating governance of high performing companies. The current study uses this as a starting point, and looks to address some limitations within in a number of areas, outlined in section 1.4. Modern work around causation is also studied, with a view to applying it in this domain. This would act to strengthen previ-

[2] A shareholder is often an investor who has equity in the company. They often have no personal interest in the company, solely financial.

ously derived relationships, and presents an opportunity to study the deeper causal influencers of corporate economic success.

1.2 Business Motivation

Moldovan and Mutu (2015) state the conclusions they reached in their research, and point to the business significance of each. For example, they found that for US based companies the number of women on the board of directors was positively connected to company performance. They also found that in Western Europe, companies should employ larger audit teams that in turn lowers the risk of bankruptcy. In Eastern Europe, their main finding is that an independent chairman best influences economic success.

The business benefit of the above is obvious. By deriving a number of relationships between economic success and corporate governance, the authors first prove that a relationship does in fact exist in the first place. That is, high corporate governance performance is strongly linked with success. Secondly they are able to put forward recommendations for governance best practice and show what elements are most influential, with geographic context. A key element of management is identifying levers with which to effect outcomes in a positive way, which leads into the motivation for this research.

We look to first verify some of the above findings, but also look to find new influencers of economic success by expanding the research to include other predictors outside of governance features. This would in effect expand the array of tools available to corporations for effecting economic change. We also aim to strengthen these findings by seeking causal influencers, which would add a hierarchical element to the range of levers for change and direct efforts to spaces that are most likely to yield real success.

1.3 Academic Contribution

A key element of this study is the exploration of causal research and the application of these techniques in this domain. There is continual active research in this area, with interested parties offering new techniques and thought processes for making steps towards proving causation in a variety of domains. To our knowledge, causation research has not be applied in the area of corporate governance and its effect on outcomes, and thus would represent a novel endeavour that stands to contribute to the field in a meaningful way.

For example, the rules proposed by Moldovan and Mutu (2015) are backed by strong correlations drawn from highly accurate statistical model. They make no steps towards estimating a cause and effect element to those relationships, or any other type of deeper analysis. We propose that a significant academic contribution would be had by exploring how causality is reached and applying it here, to see if more can be said of the aforementioned rules.

As mentioned above, this study plans to expand the work of Moldovan and Mutu (2015) to include other types of company actions and activity. This would help gain a more wholistic view of how economic success can be promoted across all company functions.

1.4 Research Goals and Scope

There are a number of key goals that this study aims to achieve. They are presented below, along with a discussion of how success will be measured at each stage.

1. **Reproduce the findings of Moldovan and Mutu (2015).**
   As mentioned, Moldovan and Mutu (2015) made findings that point to interesting relationships between corporate governance and company performance. It would be useful to use similar data to reproduce some of these findings using the same techniques as the authors.

2. **Improve on these findings**
   Next, the aim is to improve on these results using three methods. The first involves considering other predictors of corporate success beyond governance, such as a company's social responsibility performance or their environmental impact. The second involves using alternative measures of corporate success itself, that may better reflect how successful a company is. These may take the form of more informative financial ratios etc. The third method involves using alternative statistical techniques with a view to improving model performance using the standard measures of model accuracy. There are a plethora of techniques and algorithms not considered in the original study that may prove useful. The way in which data is preprocessed may also be altered as part of this step. For example, the authors discretised corporate success and perform classification on the resulting data. It may be advantageous to perform regression analysis here to gain greater granularity.

3. **Apply modern work on causality.**
   A number of conclusions on the influence of corporate governance on company performance have been reached, using established statistical analysis and subsequently discovered correlation. In order to strengthen these findings and and gain deeper insight into the underlying mechanisms of the domain, modern work in causality will be applied. This will involve significant research into the ways in which this can be achieved, including data requirements and required pre-processing. The aim here is to gain a much deeper understanding of the casual influencers of corporate economic success, to drive best practice and contribute to knowledge base in this area.

1.4.1 Out of Scope

A distinction is not made in this study between public and private companies, although regulations dictating how public companies must govern are often more stringent and strictly enforced than private companies. Regulations in-

clude preventative measures for avoiding bankruptcy etc. Privately held firms often how more freedom and flexibility here. This can be especially true when dealing with audits and so on.

Further, regulatory differences from country to country are not considered. Some countries may introduce certain taxation and laws that influence the decisions made by local companies, like a carbon emissions tax that may make companies take their environmental footprint more seriously.

1.5 Document Outline

This report is laid out as follows. Chapter 2 contains a brief literature review of this topic including how corporate success can be measured, other predictive corporate features that may be included, a review of other similar studies and concludes with a summary of research in the area of causation. Chapter 3 contains details of this studies methodology, including a summary of the data used and its pre-processing, algorithms used and methodology around applying casual techniques. Chapter 4 contains the results of this study. Included in chapter 5 is a discussion of these results, with some concluding remarks and opportunities for future research outlined in chapter 6.

Chapter 2

Literature Review

2.1 Introduction

This literature review first presents some of the ways that corporate success can be quantified. We look at how it is defined by Moldovan and Mutu (2015), as well as by others whose approaches may benefit this study. Also included here is a discussion of various fronts on which companies act, such as their corporate social responsibility commitments, with a view to including these aspects in this analysis as independent explanatory features. This is followed by an analysis of existing literature on the relationship between corporate governance and company performance, again including the work of Moldovan and Mutu (2015) as well as other relevant studies. This review finishes with an exploration of literature regarding causation and the statistical techniques used to infer causation. There is also discussion on the issues that arise in attempting to do so, and how they can be addressed.

2.2 Company Performance - Measures and Influencers

2.2.1 Introduction

Among the key aspects of this study is the quantifying of corporate success, in a way that accurately represents good and bad corporate performance. There are many aspects to this. One of the easiest ways to measure corporate economic success is to use financial ratios, many of which have been developed that attempted to assign numerical performance ratings to companies taking into account varying amounts of accounting indictors. Eidleman (1995) outlines the patterns that ratios tend to follow. He states that these ratios are mostly created by academic researchers, who constantly derive new ways of combining individual metrics together to facilitate meaningful comparison between companies. First, researchers find a sample of companies that meet some predetermined criterion of failure, as well as another sample of comparable firms (size, industry etc) that differ only in financial health. A number of ratios are developed and tested against this dataset so analyse which return values that are consistently and significantly different for each group. Those which do so are kept, the rest are discarded. Weights are assigned to each ratio to reach an aggregate equation. New firms are scored, and real-world performance recorded to measure how useful the new ratios are in practice.

This study primarily considers corporate governance features as predictors of corporate economic success. This follows the lead of Moldovan and Mutu (2015) who do the same. Having said this, an aim of this study is to expand the range of predictors considered, and to this end we discuss alternative sources of company data that can be incorporated into the model. Perhaps the inclusion of more varied and diverse independent covariates, such as the companies social responsibility commitments and impact on the environment can enhance understanding in this domain. These areas are discussed in this chapter.

2.2.2 Financial Ratios

Some financial ratios or more useful than others, since they vary significantly in complexity and in what particular aspects of a company they consider. This section includes a discussion of some of the most commonly used ratios, with comments on how best they can be used and in what context they are most powerful.

One of the indicators of corporate performance used by Moldovan and Mutu (2015) is Tobin's Q score. This measure was devised by Tobin (1969) who postulated that the combined market value of a given company should be equal to their replacement costs. When a companies replacement cost is equal to its market value, it is said to be in an ideal state. Any deviation either way, a ratio above or below 1, warrants investment or the selling of assets respectively. Moldovan and Mutu (2015) argue that the Q score allows the estimation of intangible assets, and is thus a worthy inclusion as a dependant measure of corporate success. Intangible assets drive market value up, rising the Q score.

The use of this measure is well established elsewhere in the literature also, for example by Chung and Pruitt (1994), Bhagat and Bolton (2008) and Bolton *et al.* (2011). Chung and Pruitt (1994) state that Tobin's Q plays an important part in financial interactions, and is employed to explain diverse corporate phenomena during the decision making process. Bolton *et al.* (2011) used Tobin's Q to propose a model for dynamic investment and risk management and found that investment is best driven by the Q score as well as to the marginal value of liquidity.

The formal definition of Tobin's Q is presented by Chung and Pruitt (1994), along side a much more simplified and conservative approximation of the authors making. This less complex definition is given below as;

$$(Approximate) \quad q = \frac{MVE + PS + DEBT}{TA} \tag{2.2.1}$$

In the equation above, MVE represents the product of a companies share price and count of common outstanding stock shares. PS represents the liquidating value of the companies preferred stock. $DEBT$ represents the companies short-term liabilities minus its assets, also short-term. Finally, TA represents the book value of the total assets of the company. In layman terms, assets that cannot be easily quantified can not always be entered in a companies books, but do always contribute to the share price of that company. Thus, a firm with lots of this type of asset will have a high Q score.

There is debate as to the practically of the Q score. Intuitively, the Q score places a very high importance on one specific aspect of a business. For example, before WhatApp was acquired by Facebook it had very little concrete physical assets. Rather, it had a platform with approximately 400million users, and a very high Q score. After purchase, the Q score would have dropped significantly since the amount Facebook paid would become the concrete asset recorded in their books. This is not to say that the Q score is a bad success indicator, but rather it may not fully represent the real value of a company at a given time.

Chung and Pruitt (1994) state in their research that the Q score is often neglected in real-world situations. One of the reasons they give for this is the complexity of the necessary calculations, and a potential unfamiliarity with its operational intricacies. Another reason is the unavailability of relevant data, particularly of sufficiently high accuracy and temporal availability. To counteract this, they worked to create and test an accurate approximation of Tobin's Q that utilises only basic financial information, show in equation 2.2.1. They conclude that their approximation is close enough to the more formal definition to be used where more exhaustive calculations are not possible.

Another measure of corporate success used by Moldovan and Mutu (2015) is the Altman Z score, which is often used as a probabilistic measure of whether a company will go into bankruptcy within the next two years. It can also be used more generally as a financial distress measure and to predict corporate

defaults. The authors point out that there is much advocacy in the literature for using this measure, and this study was unable to find any that strongly reject its usefulness. The Altman Z score is given as;

$$\begin{aligned} Z\ Score &= 1.2\left(\frac{Working\ Capital}{Total\ Assets}\right) + \\ & \quad 1.4\left(\frac{Retained\ Earnings}{Total\ Assets}\right) + \\ & \quad 3.3\left(\frac{Earnings\ before\ Interest\ and\ Tax}{Total\ Assets}\right) + \\ & \quad 0.6\left(\frac{Market\ Value\ of\ Equity}{Total\ Liabilities}\right) + \\ & \quad 1.0\left(\frac{Sales}{Total\ Assets}\right) \end{aligned} \tag{2.2.2}$$

Among those that support this scores use is Eidleman (1995), who discusses its use in practice. He begins by highlighting Altman's own tests using the Z score which involved predicting 72% of bankruptcies two years prior to the event, although the sample size or companies involved are not mentioned. Eidleman argues that the Z score is tried and tested, and;

> It has been demonstrated to be quite reliable in a variety of contexts and countries.
>
> — Eidleman (1995)

Eidleman also outlines circumstances that warrant corrections and alterations to equation 2.2.2, in order to generalise it beyond its originally intended means. He argues that before being able to use the Z score, one must ensure the company in question is comparable to those involved in Altman's original study. Altman considered manufacturing and small firms in his original analysis, thus

corrections must be made before scoring companies in different industries. Eidelman points to two specific circumstances here.

The first considers privately held companies, whose stocks are no publicly traded meaning term four of equation 2.2.2 cannot be calculated. To correct for this, the Z score can be re-estimated using book values of equity. In other words, details from balance sheets published by private firms voluntarily can be used rather than details gleamed from the stock market. Certainly a work-around here is to consider solely publicly traded companies. A consequence of this is that such an analysis would only include companies that are bound by the the corporate governance code in their jurisdiction, which would need to be taken into account in studies such as this one.

Eidleman's second consideration is for non-manufacturing firms. The fifth term of equation 2.2.2, according to Eidleman, varies significantly by industry. He argues that merchandise firms for example, are significantly less capital intense and thus are much more likely to enjoy higher asset turnover and consequently Z-Scores. Z scores then would be likely to under-predict bankruptcy in these cases. In order to correct for this, a recommendation comes from Altman to eliminate the fifth term and adjust the weights. The adjusted equation

2.2.3 is shown below;

$$\begin{aligned} Z\ Score &= 6.56\left(\frac{Working\ Capital}{Total\ Assets}\right) + \\ &\quad 3.26\left(\frac{Retained\ Earnings}{Total\ Assets}\right) + \\ &\quad 6.72\left(\frac{Earnings\ before\ Interest\ and\ Tax}{Total\ Assets}\right) + \\ &\quad 1.05\left(\frac{Market\ Value\ of\ Equity}{Total\ Liabilities}\right) \end{aligned} \tag{2.2.3}$$

Overall, the Altman Z score seems a highly appropriate indicator of corporate financial strength and thus success, and one that should be considered in this study. Consideration will need to be had for the type of industry included in this analysis, that will inform the exact calculation of the Z score itself.

2.2.3 Environmental Considerations

As mentioned previously, there is likely much room for improvement in quantifying corporate success beyond financial ratios. One potentially useful alternative is the link between environmental and economic performance, studied by Schaltegger and Synnestvedt (2002). The authors present two conflicting viewpoints in this space. The first states that improved environmental performance predominantly causes an increase in operating costs, which in turn negatively effects the profitability of the company. The second viewpoint states the opposite; improving a firms environmental performance in fact induces cost savings, which drives increases in profitability. These viewpoints are visualised in figure 2.1.

ES_0 represents the current level of economic success (this is described as a

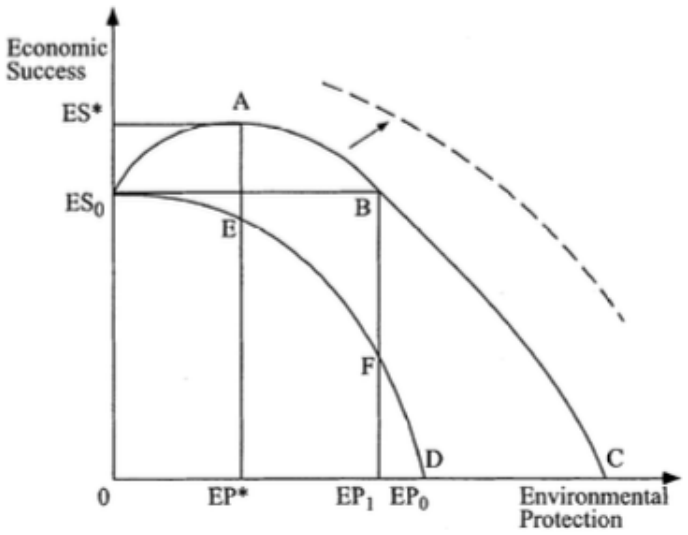

Figure 2.1: Potential correlations between corporate environmental protection and economic success.

certain shareholder value), which decreases as spending in environmental protection increases (through points E and F, to D where non profit can be made). This is the pessimistic view, or the expectation that spending in this space reduces profit making ability to eventual zero. The more optimistic view is represented by the path from ES_0 through points A and B to point C (again where no profit is possible). This represents the ideology that some economic gain can be achieved, at least to some degree before tailing off, by being environmentally conscious.

The authors draw two conclusions from figure 2.1. First, they argue that environmental performance can vary at a given level of economic success. Secondly, the reverse; that economic success can vary for a given level of environmental protection. These are key points, since it indicates that the former may not be a good predictor for the latter, and that an uplift in economic success is not guaranteed with increased environmental efforts. The authors conclude that the correlation between economic and environmental performance depends on not just company externalities but internal variables which are influenced by

management. It is firm management, who moderate this relationship, that must be optimised in order to gain economically. The authors put this forward as an explanatory variable not considered in the literature to this point.

It is natural then to ask how this can be realised in analysis. Schaltegger and Synnestvedt (2002) suggest two cases from which data may be derived. The first relates to the firms ability to utilise to the full the economic benefits of environmental protection measures. This may materialise in R&D spending, or other marketing positioning that communicates their efforts and establishes them as industry leaders. The second relates to how this reputation is achieved in practice, by realising the optimal environmental performance for maximum economic success. This can take the form of identifying the most optimal way to reach clean production for example.

Wahba (2008) also perform research in this area, studying whether the market values corporate environmental responsibility, specifically in an Egyptian context. Similarly to Schaltegger and Synnestvedt (2002), the authors acknowledge divided and inconclusive literature on this topic, stating an aim to present empirical evidence on how engagement with environmental responsibility can influence corporate market value. For their analysis they looked at a sample of 156 firms across 19 industries, using firm market value as the dependant variable (interestingly, quantified by Tobin's Q score mentioned previously). Important to note is the authors use of ISO 14000/14001 certification as a proxy for environmental performance. This is recognised by the authors as non-ideal, however this may still have some utility in future research to address the difficulty in quantifying performance in this area.

Wahba (2008) state that the overall finding of this research is that the market does in fact reward firms for their environmental efforts, by positively influencing that firms Tobin's Q score, but do point to similar issues raised by Schaltegger and Synnestvedt (2002). Namely, that a companies decision to reduce their impact on the environment comes with significant cost and that if this is not managed correctly, the economic benefits evaporate.

There is clear support in the literature for the presence of a relationship between corporate economic success and environmental performance. Schaltegger and Synnestvedt (2002) suggest it is the firm management of environmental considerations that influences success, and put this forward as an explanatory variable not yet considered in literature. This theory is supported by Wahba (2008), who find a strong relationship in this space but with a caveat that management plays a significant role in realising benefits. It remains to be seen exactly how this can be realised in data analysis.

2.2.4 Corporate Social Responsibility

Corporate social responsibility, or CSR, is defined by the European Commission as "the responsibility of enterprises for their impacts on society". This is similar to being conscious of environmental impact, but can be generalised to include compliance with established ethical standards and national and international norms. Central to CSR is the creation of shared value between themselves and their stakeholders and the larger society as well as mitigating their possible adverse impacts with those groups. It is natural to consider elements of CSR then, when discussing firm success metrics.

Orlitzky *et al.* (2003) begin their research in this space by stating

> Most theorising on the relationship between corporate social / environmental performance (CSP) and corporate financial performance (CFP) assumes that the current evidence is too fractured or too variable to draw any generalisable conclusions.
>
> — Orlitzky *et al.* (2003)

Their research aims to show this claim is unfounded, and provide a more rigorous methodology for drawing such conclusions. They argue that many authors have attempted to find causal relationships between CSP and CSR, but have failed in part due to a failure to see vital differences between theory

and operational applications. They also state that an aim of their research is to aggregate knowledge in the area, and highlight important findings they believe to be overlooked. Meta-analysis have been proven to proved value where a number of disparate and conflicting results mean the field is inconclusive.

They present a number of hypotheses. They first states that CSP and CFP are positively related, regardless of industry and the context of the given study relating the two. They base this on a number of studies, stating that CSP is a vital form of "good management theory" that boasts competitive advantage by addressing stakeholder concerns quickly and fairly. Secondly, they hypothesise on the temporal nature of this relationship. They state that there is a bidirectional causality between CSR and CFP. That is, there is a circular casual relationship that governs performance in each area. This is supported by the idea that prior success in CFP facilitates positive engagement in CSP, due to increased responsibility and freedom at the managerial level.

The third hypothesis put forward by Orlitzky *et al.* (2003) involves the underlying logic behind the correlation between CSP and CFP. The first is that CSP boasts managerial competencies and organisational efficiency, by enabling shared knowledge of the firm's market as well as social and political environments. Secondly they suggest that CSP is a driving factor behind the firm's reputation, and thus elicits significant goodwill from stakeholders. The fourth and final hypothesis put forward involves the methodology used by previous studies to draw conclusions from. The authors here suggest that the variance in results seen across studies can be explained by sampling or measurement error, for example.

In order to support these claims, Orlitzky *et al.* (2003) perform a meta-analysis involving 52 studies across both CSP and CFP, resulting in a total sample size of 33,878 observations on which they perform their analysis. This analysis involves a statistical aggregation technique to be applied, which calculated the cumulative correlations across studies, correcting for variable elements of those studies to reach one "true score correlation (ρ)". Using this technique, the au-

thors were able to explain 24% of the cross-study variance in relation to the observed r value, which they suggest is significant. That is, by controlling for sampling and measurement errors across multiple studies, they could reduce the variation in results by 25%. They suggest that this, strengthened with other analysis, supports their first hypothesis.

2.3 Corporate Governance and Company Performance

2.3.1 Introduction

In this chapter, we explore research directly in the same domain as the current study. That is, other works that look at the relationship between corporate governance and company performance. This includes the work of Moldovan and Mutu (2015), whose research forms the basis for the current study. An analysis is made of their methodology and conclusions, as well as a deeper analysis of what areas can be improved upon.

2.3.2 Existing research

Moldovan and Mutu (2015) made an attempt to find relationships between how a company governs, and its economic success using data mining. They derived a dataset from the Bloomberg financial system, containing 50 independent corporate governance features on areas such as board room structure and the companies yearly tax and interest liabilities. They considered three stock indexes; S&P 500 (a collection of 500 american companies), STOXX Europe 600 and STOXX Eastern Europe 300. They complimented this with two dependant, target variables measuring corporate success. They are Tobin's Q and the Altman Z Score, the details both of which are included in section 2.2. Using the aforementioned governance variables, they learned statistical models to predict *good* and *bad* company performance.

Interestingly, Moldovan and Mutu (2015) decided to discretise Tobin's Q into two classes, one for a *good* score and the other for a *bad* score split by the median score. They carry out similar preprocessing on the Altman Z score, creating three classes and allocating observations to each based on performance before using a classification algorithm for learning purposes. While the authors cite this methodology in previous literature, it may prove interesting to allow these variables to remain as real-valued, and perform regression analysis. We believe this alternative methodology may yield positive results.

The formulation of the Altman Z score use by Moldovan and Mutu (2015) is also an area for potential concern. As discussed in section 2.2.2, Altman presents an alternative formulation for non-manufacturing companies that prevents under estimation of bankruptcy likelihood. It remains to be seen what kind of companies are included in this analysis, although should a significant number fall outside of the manufacturing industry then perhaps the alternative formulation should be used.

Using a number of different algorithms, Moldovan and Mutu (2015) were able to highly accurately predict corporate outcomes using governance features. Interestingly, results for the American and European datasets were very similar across algorithms which good performance in each case. Results from the Eastern European dataset were less promises, attributed to missing data on the governance side. Promisingly, no algorithm was shown to be significantly better than any other across datasets.

As mentioned previously, the authors here were able to present some simple rules based on their models for corporate governance best practice. For example, they conclude that there is a positive correlation between women on the board of directors in American companies, thresholding on 20% presence for the benefits to activate. An independent lead director in the same dataset was shown to incur a higher risk of bankruptcy as measured by the Altman Z score. In Europe, the authors came to a similar conclusion, stating that the presence of an independent lead director or former CEO on the board of

directors resulted in poorer Tobin Q scores. Interestingly and contrary to the case in America, the presence of women on the board was negatively linked to performance. Finally, in Eastern Europe Moldovan and Mutu (2015) found that a smaller director age range was positively related with performance. Altman Z scores improve significantly with an independent chairman, or female CEO.

2.4 Inferring Causation

2.4.1 Introduction

It is stated ad nauseum in scientific and popular literature that "Correlation does not imply causation" or similar. In statistical analysis, it is tempting to infer causal relationships between features where only correlation has been proven and indeed a significant amount of literature seems to do exactly this. For example, the study of Moldovan and Mutu (2015) on which the current study is based, makes string claims as to the relationships between corporate governance and company success. In reality, the authors perform insufficient analysis to support such claims, instead finding correlations worthy of further investigation.

Interestingly, there is a significant body of research that argues that it is impossible to prove causation. It is said that if all variables that could possibly be causal are considered, causation can be reliably inferred. Of course in practice this is almost never the case, and so issues around <> require advanced techniques to address and potentially overcome.

One of the major issues with applying causal research in this domain is the study design. Many studies, particularly in the medical field, are able to take advantage of robust experimental design standards that facilitate a deep and accurate exploration of results. They are able to control for unobserved covariates using randomised trials, and generally have a large degree of control over

the statistical parameters of the study. The goal here is often to maintain a treatment and control group, and estimate that treatments effect on outcomes.

Outside of such a highly controlled environment, causal inference becomes more difficult where we begin to deal with observational studies. The work of Moldovan and Mutu (2015) is such a study, where they authors derived historical data that was generated outside of their control and tried to uncover relationships within. Esarey (2015) identifies an interesting problem with this type of work. Often, the act of choosing to be treated has a significant effect on outcomes. He gives the example of education; those who choose to complete higher education may be those who stand to gain from it the most, and so it is difficult to estimate educations effect on income. Similarly in the study of Moldovan and Mutu (2015), it is difficult to assess the benefit of various elements of corporate governance on firm performance due to the self-selecting nature of those who perform well in the former. There is an implicit temporal element to this discussion, and indeed Pearl and Verma (1995) state that often temporal precedence is normally assumed to be essential to defining a causal relationship. They argue that this alone cannot distinguish causation however, and point to research stating that unless one knows all potentially causal covariates it is impossible to make this step at all.

This is a highly complex space, and one that certainly calls for advanced techniques that can mitigate the issues outlined above. The remainder of this section is dedicated to some of these techniques, with discussion of their technicalities and practical applications.

2.4.2 Matching

One approach to bridging the gap between experimental and non-experimental studies is matching, outlined by Stuart (2010) who considers studies that use observational data that can be divided into treated and non-treated cases. Matching is then used to study the effects of this treatment on some outcome, in a very similar way to standard experimental trials in the medical field for

example. He describes first how one of the biggest benefits of randomised experimental studies is that the treated and un-treated groups are guaranteed to be randomly different from one another, on both observed and unobserved covariates (or features that may influence the outcome). That is, such experiments are able to control for factors that have not been explicitly designed for in the experiment. Statistical matching aims to imitate this for observational studies, by balancing the distribution of potentially useful features in the treated and control groups. This is achieved by identifying observations that differ only in treated status, facilitating the analysis of the causal effect of that treatment. In effect this ignores un-observed features, and aims to reduce bias in the distribution of observed features as much as possible. The concept of *strong ignorability* is heavy relied upon here, which is to say that it is assumed that all feature that may influence the outcome are being considered.

Stuart (2010) identifies matching as a potentially useful mechanism in supervised learning, where the outcome is known and the goal is to estimate its effect. Thus, matching is considered in this study where the treatment can be quantified as fluctuations in various explanatory corporate governance variables (among others) which in turn influence the a firms outcome.

Stuart (2010) sets out four key stages in the matching process. They are;

1. Defining the measure of *closeness*.
2. Choosing an appropriate matching method.
3. Quality assessment of matched samples, returning to step 1 depending on results.
4. Treatment analysis, given the results of Step 3.

A measure of closeness quantifiably determines whether an observation is a good match for another. This is a crucial aspect to matching, and can be subdivided into two parts. The first involves pruning the dataset features for those to include, taking into consideration *strong ignorability*. Stuart (2010)

points out that poor results are expected from using small sets of features, particularly those that pertain solely to a narrow view of that observation (for example, demographic details of individuals). He states that there is little disadvantage in including features that are not actually associated with outcome, albeit a slight increase in variance is expected. Conversely, neglecting a feature that is associated with outcome is very costly, and so it is recommended to include as many features as is practical as a precaution. It is also recommended to do so without relying on observed outcomes, and instead make decisions based on domain knowledge.

The second aspect to closeness is the measure of distance itself, or the similarity between two observations in the data. There are many ways to do this, that vary in the exactness of the match required. Stuart (2010) argues that exact matching is ideal, but very often unattainable especially with high dimensional data. Requiring a very high degree of exactness leads to observations remaining unmatched which then fall out of consideration, a phenomenon that in turn can lead to more bias than if the matching measure required less exactness. A way to address this is to categorise continuous features, a practice used in calculating the Mahalanobis distance for example which works well with low dimensionality, but poorly with highly non-uniformly distributed features.

The next stage in the matching process is the choose of matching method, which uses the closeness distance to create the matches themselves. The motivation behind using one method over another lies in the number of observations that remain after matching has taken place, and the relative weights that different individuals receive. One such method is nearest neighbour matching (NNM), which is stated as the most common, most understandable and easiest to implement methods available by Stuart (2010). In essence, this method couples a treated and un-treated observation, minimising the distance between the two. Controls can be put in place to dictate the exactness of each match, potentially discarding treated cases if a suitable match is not found. This helps to prevent bad matches, but leads to difficulties in interpreting results. What results from NNM is a data set of similar dimension to the amount of treated

cases, which arguably reduces the power of the data. Stuart (2010) states in response to this that model precision is effected most by the smaller group size in any dataset, and so balancing observations down to this smaller group size should not in fact dramatically reduce it power.

The third stage of the matching process is a quality assessment of the matched samples, which is the most important step according to Stuart (2010). The aim here is to rate how balanced the matches set is, where balance refers to the similarity of feature distributions, and the independence of features and treatment status. Poor results here calls for alternative distance measures and matching methods, and so iteration is often required to find the optimal methodology. Stuart (2010) proposes numerical diagnostics to achieve this step. This involves the inspection of the difference in means of each feature, divided by the standard deviation which gives the *standard bias*. This is performed for each feature, as well as their two-way interactions and squares. The author discards other common tests here such as hypothesis tests, due to contextual issues and how balance is interpreted by those tests.

The fourth and final step of the matching process as outlined by Stuart (2010) is outcome analysis. It should be noted that matching is not actually a tool used for inferring causation, but rather presents a new dataset that is treated as if sourced through randomised methods.

King *et al.* (2014) also characterise the trade-off between matched sample sizes and the balance between classes into the matched subset, identified above by Stuart (2010). While Stuart (2010) argued that any negative effects of sample reduction were offset by the increased balance between groups, King *et al.* (2014) argues the opposite. They claim that practitioners often do see sample reduction as an issue, citing manual tweaking that research cary out in an effort to optimise sample size as well as balance, or their tendency to settle for suboptimal solutions. King *et al.* (2014) argue that optimising only one of these parameters is not a viable solution nor a necessary one, but that current solutions available for optimising both require significant manual intervention

which is time consuming and usually suboptimal. In response to this, they propose a new approach that they claim address a number of issues.

The so called *matching frontier* is a methodology that the authors claim fully characterises the trade-off between dataset imbalance and matched sample size, allowing researchers to visually inspect where the optimal solution lies for a given dataset. Each location along the frontier is denoted by the resultant matched sample. Moving along this frontier (i.e. varying sample size), the frontier returns a data subset such that no other subset of the same size has more optimal class balance characteristics. That is, the returned matched dataset is optimally balanced for its size. The implications of this for researchers are obvious. Using this method, one has much finer control over the matching process than is apparent in the work of Stuart (2010). The latter provides a framework that involves significant manual iteration, which is shown to be suboptimal and unnecessary by King *et al.* (2014).

2.4.3 Minimal-Model Semantics

Pearl and Verma (1995) present a highly influential theory of causation, and guidelines on how to make the step from strong correlation towards inferring casual relationships. This is certainly one of the more influential studies in this space, and approaches the problem of causation slightly differently to matching laid out in section 2.4.2. The authors here propose what they refer to as *a minimal-model semantics of causation*, which they claim debunk the myth that casual influences cannot be distinguished from illegitimate covariation. They argue this is possible through inductive reasoning.

They begin by stating generalities of proving causation, and of causal systems. Firstly, they state that intelligent systems that aim to learn about their environment and act on that knowledge cannot rely solely on preprogrammed causal knowledge (derived from human knowledge and experience). Rather, it must be able to transform observable phenomenon into cause and effect relationships. They argue further that when causal relationships are stated in

ordinary conversation, they reflect probabilities of event occurring rather than absolutes. Thus, probability theory should be sufficient to identify such relationships. it is clear that the authors place a large degree of faith in ordinary people, going as far as to say of peoples ability to perceive causal relationships *"..we must find a computational model that emulates this perception"*. It remains to be seen whether this is the most fruitful avenue of exploration.

Key to the model proposed by Pearl and Verma (1995) is the notion of a directed acyclic graph (DAG). The authors theorise that fundamentally, all processes in nature are controlled by casual mechanisms that govern how observable and unobservable variables interact. In general, they state that;

> A casual model of a set of variables U is a directed acyclic graph (DAG), in which each node corresponds to a distinct element of U.
>
> — Pearl and Verma (1995)

Variables are representable as nodes, with edges representing casual influences between those variables. Using this model, it becomes clear how the influence of parent variables on child variables can be found. One of the issues that has been raised in this chapter previously is that of the influence of unobservable factors, which are impossible to eliminate in practice. The authors here model these as probabilistic disturbances to the DAG, that perturbs the relationships within. This is certainly a novel approach, and presents a theoretical framework for dealing with inevitable externalities.

Pearl and Verma (1995) on go to discuss the question of model structure and choice. Logically, since the model U is not bounded by any predetermined constraint (i.e. inputted casual knowledge or otherwise) there in an infinite amount of models that could be fitted to a given distribution. Each would create different causal relationships with a different set of probabilistic disturbances. The authors call on inductive reasoning here, arguing that any model can be removed if there is a more simple alternative that is as consistent with the data. Models not removed are referred to as *minimal models*, and are used to reach the authors definition of inferred causation.

> A variable X is said to have a casual influence on a variable Y if a strictly directed path from X to Y exists in every minimal model consistent with the data.
>
> — Pearl and Verma (1995)

Much more to review in this paper including:

1. Stability - Computational Practicality
2. Latent Structures
3. Non-temporal causation
4. Attached algorithm to make this happen

Chapter 3

Methodology

3.1 Introduction

3.2 Data Acquisition

3.3 Data Pre-Processing

3.4 Validating Previous Results

3.5 Causation

Chapter 4

Results

4.1 Introduction

The results ...

Chapter 5

Discussion

5.1 Introduction

In this chapter we examine ...

Chapter 6

Conclusions and Future Research

6.1 Introduction

Program code

Insert snippets of important code here
Point to github where code can be found

`https://github.com/ReidConor/dissertation`

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List of Notation

Entries are listed in the order of appearance. The "Ref" is the number of the section, definition, etc., in which the notation is explained.

Symbol	Description	Ref
$PREFST$	The liquidating value of a firm's preferred stock	