1996

The Importance Of Beliefs In Monetary And Financial Settings

Toni R. Gravelle

Follow this and additional works at: https://ir.lib.uwo.ca/digitizedtheses

Recommended Citation
https://ir.lib.uwo.ca/digitizedtheses/2675

This Dissertation is brought to you for free and open access by the Digitized Special Collections at Scholarship@Western. It has been accepted for inclusion in Digitized Theses by an authorized administrator of Scholarship@Western. For more information, please contact tadam@uwo.ca, wlswadmin@uwo.ca.
The author of this thesis has granted The University of Western Ontario a non-exclusive license to reproduce and distribute copies of this thesis to users of Western Libraries. Copyright remains with the author.

Electronic theses and dissertations available in The University of Western Ontario’s institutional repository (Scholarship@Western) are solely for the purpose of private study and research. They may not be copied or reproduced, except as permitted by copyright laws, without written authority of the copyright owner. Any commercial use or publication is strictly prohibited.

The original copyright license attesting to these terms and signed by the author of this thesis may be found in the original print version of the thesis, held by Western Libraries.

The thesis approval page signed by the examining committee may also be found in the original print version of the thesis held in Western Libraries.

Please contact Western Libraries for further information:
E-mail: libadmin@uwo.ca
Telephone: (519) 661-2111 Ext. 84796
Web site: http://www.lib.uwo.ca/
The Importance of Beliefs in Monetary and Financial Settings

by

Toni Gravelle

Department of Economics

Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Faculty of Graduate Studies
University of Western Ontario
London, Ontario
Canada
May 1996

© Toni Gravelle, 1996
The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.
ABSTRACT

This thesis investigates the effects of beliefs in both a monetary and a financial setting. Specifically, the thesis studies the potential effects that price level fluctuations have on societal beliefs, the general medium of exchange, and economic welfare. In a finance setting, this thesis also studies how fluctuations in beliefs can explain the observed “hot issues” market phenomena in the initial public offering (IPO) equity market. The “hot issues” market phenomena refers to recurring periods in which the volume of IPOs and the magnitude of their first day returns are observed to be systematically larger than average.

Chapter 2 is a study that exposes the deficiency inherent in monetary models that ignore the medium of exchange function of money. The chapter starts out by reviewing some of the ideas put forward by early economic and social theorists, such as Carl Menger and Georg Simmel, on the origins and continued existence of money as a medium of exchange. These early theorists not only found societal beliefs about money’s ability to act as a medium of exchange critical in explaining, at a fundamental level, why money (commodity or fiat money) emerges as a medium of exchange but also found that price level stability is a necessary factor in the maintenance of these beliefs and in turn the maintenance of money’s ability to act as a medium of exchange. Chapter 2 reviews the recently developed search models that formalize the idea that beliefs in an object’s ability to act as a medium of exchange are a critical prerequisite for an object to circulate as a medium of exchange. However, in reviewing these search theoretic models of money, the study finds that this approach to modelling money would be an ideal framework in which to formalize the idea that price level fluctuations have a detrimental effect on beliefs and, in the end, on economic welfare. This study also shows that finding money to have important economic effects contradicts the usual predictions found in what is regarded as the mainstream of monetary theory.

Chapter 3 of this thesis presents an overview of the defining empirical characteristics of the IPO market as well as a review of some of the explanations put
forward regarding the empirical anomalies associated with the pricing and the volume of IPOs. In reviewing the literature concerned with the IPO process, this chapter also shows that the “hot issues” market phenomena needs further study.

Chapter 4 empirically investigates various implications of the “windows of opportunity” explanation of the “hot issues” market phenomena. This informal explanation relies on a form of investor speculation. Specifically, it assumes that investors undergo periods (or regimes) in which they hold overoptimistic beliefs about the expected returns of firms in certain sectors or industries. Subsequently, the stocks in these sectors become overvalued. Companies take advantage of the overvaluation of stocks in their related sector and decide to go public during these periods of investor overenthusiasm. Thus, this explanation suggests that the observed cyclical fluctuations in IPO data may be better viewed as fluctuations arising from unobservable stochastic regime changes in investor sentiment.

In order to be able to test for the presence of recurring stochastic regime changes in the IPO data, a Markov switching technique for modelling time series processes subject to discrete state-dependent regime changes is used. Modelling the IPO data as being driven by a Markov switching process also allows for the revelation of certain patterns in the data that go beyond simple well documented facts.

In the fifth chapter the firm’s decision to go public is modelled using an optimal stopping model found in statistical decision theory. This model formalizes the “windows of opportunity” hypothesis of the “hot issues” market phenomena. This model predicts that IPOs will be clustered during certain periods. By allowing some degree of firm heterogeneity, as measured by the firms’ public information content, this model also predicts that older, larger “information rich” firms are more likely to go public than “information poor” firms.
Dedication

To my parents, Reg and Noella, whom I love and am very proud of.
And to Michelle whom I love lots.
ACKNOWLEDGEMENTS

First and foremost I would especially like to thank Prof. John Knight for the excellent supervisory guidance given during the later part of my thesis research. Without his help in structuring and reading various aspects of my thesis I would not have completed it in any expeditious time. Prof. Knight's approachability and his relaxed manners made it easy for me to talk to him about topics other than school which helped to keep our academic relationship fresh and sustainable. I also owe an eternal debt to Prof. David Laidler. He was of considerable importance in aiding me to craft the *What is Old is New Again* chapter of the thesis. Aside from providing comments on a plethora of drafts, he also provided me with employment as a research assistance, which, at the time, was my sole source of badly needed income. Though I always felt the research assistance that I provided was not as complete or as thorough, due perhaps to my lack of expertise in the historical aspects of monetary thought, Prof. Laidler was always kind enough to compliment the work I did for him. For this reason and for his ability to always find the time to chat and give guidance, Prof. Laidler receives my greatest respect. (Part of Chapter 2 was undertaken while working as his research assistant on a project funded by the Lynde and Harry Bradley Foundation of Milwaukee Wisconsin.) Prof. Joel Fried, by always asking the hardest questions about my initial public offerings research, elevated the final product of my graduate student career. my doctorate education, to a level required for my continuation in academic research. Prof. Fried also deserves thanks for both organizing my thesis prospectus and supporting my research topic. He too, therefore, deserves my upmost gratitude. As a whole, these three members of my supervisory committee have played a central role in the development of this thesis.

I would also like to thank Prof. Victor Aguirregabiria for his enthusiastic guidance in helping me complete the fifth chapter of my thesis. Without his fervour, I would not have been as interested or as driven in developing a theoretical model of the IPO problem. He also deserves my deepest gratitude for his unsolicited kindness and friendship displayed by his interest and aid in my career advancement. I owe a debt of
gratitude to Prof. Audra Bowlus who was always there (on short notice) to read and comment on various parts of my thesis. I would like to thank Prof. Ian Wooton who, without his fairness as a graduate director, I would certainly not have completed my dissertation. Prof. Robin Carter also deserves some thanks for his support of my research interest and for his love of departmental hockey which inspired me. Prof. Ig Horstmann also gave me some academic inspiration as he is, in my view, an "economist's economist."

Jane McAndrew deserves a special mention for putting my academic needs before the Reference Centre's labour needs. I would also like to thank her for being the source of an excellent professional, working relationship that allowed me to develop some of my non-academic life skills. Also, for being a kind and wonderful person to work for. While working for the department I have also gotten to know a wonderful bunch of people; these include Darlene, Debra, Karin, Melissa, Paula, Sue. and Yvonne.

I should also mention some of my friends in the graduate program for which I would like to express my gratitude for their help and support. These people are Murali Agastia, Brian Rivard, Philip Gunby, Scott Hendry, Martin Gervais and Winnie Lam.

Finally, this thesis would not have been possible without the love and support of Michelle, the love of my life. Thank you Michelle for putting up with being a thesis widow even before we were married. Without your continual "kicks in the butt" I would never have been able to complete this seemingly unending process.

The IPO initial returns and volume data set used in Chapter 4 originate from the Ibbotson, Sindelar and Ritter (1994) paper. The data set was updated by the authors and supplied to this author by Jay Ritter. The closed-end funds data used in Chapter 4 was kindly provided by Charles Lee. This data was originally presented in Lee, Schleifer, and Thaler (1991).

Any errors remaining are of course my own.
# TABLE OF CONTENTS

CERTIFICATE OF EXAMINATION ................................................................. ii
ABSTRACT ........................................................................................... iii
ACKNOWLEDGEMENTS ..................................................................... vi
TABLE OF CONTENTS ........................................................................ viii

CHAPTER 1 — INTRODUCTION ................................................................. 1
   Beliefs in a Monetary Setting ....................................................... 1
   Beliefs in a Finance Setting ......................................................... 2

CHAPTER 2 — WHAT IS OLD IS NEW AGAIN ........................................... 7
   2.1 Introduction ........................................................................... 7
   2.2 Historical Perspective .......................................................... 9
   2.3 The STNCE Approach and its Similarity to the Ideas of the Earlier Monetary
       Theorists .............................................................................. 17
   2.4 New Monetary Economics Versus the STNCE Models of Money ........ 30
   2.5 Conclusion ........................................................................... 33

CHAPTER 3 — INITIAL PUBLIC OFFERINGS: AN OVERVIEW ............... 34
   3.1 Introduction ........................................................................... 34
   3.2 Terminology and Institutional Characteristics .......................... 36
   3.3 The Empirical Characteristics of the IPO Market and the Positive Initial
       Returns Puzzle ....................................................................... 38
       3.3.1 Empirical Characteristics of the IPO Market .................. 39
       3.3.2 Competing Theories Explaining the Observed Positive Initial
           Returns ................................................................................ 42
           Winner's Curse .................................................................... 43
           Signalling Models .................................................................. 43
           Strategic Multi-Period Signalling Models ............................ 44
           Other Explanations ................................................................ 46
   3.4 Long-run Underperformance and “Hot Issues” Markets ............... 47
   3.5 The Noise Trader Model .......................................................... 51
   3.6 Conclusion ........................................................................... 54

CHAPTER 4 — AN EMPIRICAL ANALYSIS OF THE IPO CYCLICAL PUZZLE: A
   DYNAMIC REGIME SWITCHING APPROACH ..................................... 56
   4.1 Introduction ........................................................................... 56
   4.2 Sample Description and Data Sources ..................................... 61
   4.3 The Statistical Model and Estimation Method ........................... 63
   4.4 Sensitivity Analysis ............................................................... 66
       4.4.1 Testing for the Presence of Regime Switching ............... 66
       4.4.2 Results for IPO Initial Returns ................................... 68
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4.3 Results for IPO Volume</td>
<td>78</td>
</tr>
<tr>
<td>4.4.4 Remaining ARCH Effects for the IPO Initial Returns and Volume</td>
<td>84</td>
</tr>
<tr>
<td>4.4.5 Summary</td>
<td>85</td>
</tr>
<tr>
<td>4.5 Empirical Results for the Switching Models of IPO Initial Returns and Volume</td>
<td>86</td>
</tr>
<tr>
<td>4.5.1 IPO Initial Returns Switching Model</td>
<td>86</td>
</tr>
<tr>
<td>4.5.2 IPO Volume Switching Model</td>
<td>90</td>
</tr>
<tr>
<td>4.6 Some Economics</td>
<td>92</td>
</tr>
<tr>
<td>4.6.1 Added Regressor Switching Specification</td>
<td>94</td>
</tr>
<tr>
<td>4.6.2 Linear Probability Specification</td>
<td>97</td>
</tr>
<tr>
<td>4.7 Vector Markov-Switching Model</td>
<td>101</td>
</tr>
<tr>
<td>4.7.1 The Stochastic Nature of the Closed-End Fund Process</td>
<td>103</td>
</tr>
<tr>
<td>4.7.2 The Closed-end Funds-IPO Vector Stochastic Process</td>
<td>108</td>
</tr>
<tr>
<td>4.7.3 Nature of the Correlation Between IPO Volume and Closed-End Funds</td>
<td>110</td>
</tr>
<tr>
<td>4.7.4 Estimation Results of the Vector Markov-Switching Process of the CEFs and IPO Volume Data</td>
<td>112</td>
</tr>
<tr>
<td>4.8 Summary and Conclusion</td>
<td>117</td>
</tr>
<tr>
<td>Appendix 4.1</td>
<td>119</td>
</tr>
<tr>
<td>Appendix 4.2</td>
<td>122</td>
</tr>
</tbody>
</table>

CHAPTER 5 — AN OPTIMAL STOPPING MODEL OF A FIRM'S DECISION TO GO PUBLIC

5.1 Introduction                                                        | 126  |
5.2 An Overview of the Information Environment Surrounding an IPO and IPO Pricing Theory | 129  |
| 5.2.1 Information's Role in the IPO Process: An Overview              | 129  |
| 5.2.2 Formal Summary                                                  | 134  |
5.3 The Environment of the Model                                        | 137  |
| 5.3.1 The Firm                                                        | 138  |
| 5.3.2 Investors                                                       | 139  |
| 5.3.3 The Underwriter's Calculation of the Offering Proceeds          | 143  |
| 5.3.4 The Offer Distribution                                          | 145  |
5.4 Decision-Making Process of the Firm                                 | 147  |
| 5.4.1 The Optimal Stopping Model                                      | 148  |
| 5.4.2 Numerical Solution to Optimal Stopping Model                    | 151  |
5.5 Sensitivity Analysis                                                | 155  |
5.6 Heterogeneous Firm Types                                            | 160  |
| 5.6.1 Heterogenous Probability of Receiving an Offer                  | 161  |
| 5.6.2 Heterogenous Divergence of Beliefs                              | 164  |
| 5.6.3 Heterogeneous Participation Costs                               | 166  |
5.7 Concluding Remarks                                                 | 167  |
Appendix 5.1                                                            | 173  |
Chapter 1

Introduction

This thesis investigates the effects of beliefs in both a monetary and a financial setting. The importance of beliefs in monetary matters is investigated in the essay presented in Chapter 2, which discusses the potential and yet un-modelled effects that price level fluctuations have on societal beliefs, the general medium of exchange, and economic welfare. The importance of beliefs in corporate finance is the subject matter studied in Chapters 3, 4, and 5. Here, beliefs are shown to be an important factor affecting a firm's decision to raise outside capital for the first time by way of an initial public equity offering. Specifically this part of the thesis studies how fluctuations in investor beliefs can explain the observed "hot issues" market phenomena in the initial public offerings (IPO) equities market. The "hot issues" market phenomena refers to recurring periods in which the volume of IPOs and the magnitude of their first day returns are observed to be systematically larger than average. Chapter 6 of the thesis recapitulates the subject matter, reviews the main findings, and draws some concluding remarks.

Beliefs in a Monetary Setting

Chapter 2 of this thesis, entitled "What is Old is New Again," exposes the deficiency inherent in monetary models that ignore the medium of exchange function of money. The chapter starts out by reviewing some of the ideas put forward by early economic and social theorist, such as Carl Menger and Georg Simmel, on the origins and continued existence of money as a medium of exchange. These early theorists not only found societal beliefs about money's ability to act as a medium of exchange critical in
explaining, at a fundamental level, why money (commodity or fiat money) emerges as a medium of exchange, but also found that price level stability is a necessary factor in the maintenance of these beliefs and, in turn, the maintenance of money's ability to act as a medium of exchange. Chapter 2 then reviews the recently developed search models of money that formalize the idea that beliefs in an object's ability to act as a medium of exchange are a critical prerequisite for an object to circulate as a medium of exchange. These models parameterise the societal beliefs or trust envisioned by earlier theorists like Menger and Simmel. However, in reviewing these search theoretic models of money, the study finds that this approach to modelling money would be an ideal framework in which to formalize the idea that price level fluctuations have a detrimental effect on beliefs and in the end on economic welfare. This study also shows that finding money to have important economic effects contradicts the usual predictions found in what is regarded as the mainstream of monetary theory. Specifically, it is argued that by focusing on the role money plays—a medium of exchange, rather than its role as a store of value, money is likely to play a more important role in the economic well-being of society.

Chapter 2 also stresses that by formalizing the endogenous existence of fiat money, the search theoretic models of money can show that, under "laissez-faire", fiat money does not vanish (when dominated in its rate of return) so long as it is believed to be the most liquid item of exchange. This reverses the finding associated with models of money that focus solely on money's store of value role, which suggests that there should be "laissez-faire" in matters of monetary institution because intervention (legal restrictions) on the part of the government is welfare-reducing.

Beliefs in a Finance Setting

For the entrepreneurial firm, a public listing of its shares on a stock market is considered a major event. Interestingly, the decision to go public is also one of the least studied questions in financial economics. The absence of active research in this area of finance is remarkable in light of the fact that approximately one third of the capital requirements raised by way of common equity issue in the United States are raised
through initial public offerings (IPOs). The fact that an IPO is usually the largest equity
issue a firm will ever make also makes the absence of research in this area remarkable.
An IPO not only provides a new source of capital for the firm, it also affects the nature of
the firm’s governance and managerial structure. The capital raised in an IPO can either
go toward funding growth enhancing investment needs or rewarding the initial owners of
the firm for their startup efforts. An understanding of what affects the likelihood or the
timing of going public is important in attempting to ease access to equity financing which
may in turn stimulate entrepreneurial activity.

Though there has not been much research investigating the motives behind a
firm’s decision to go public, there have been numerous studies documenting the empirical
anomalies associated with the pricing and volume of IPOs. These anomalies can be
summarized as (i) “first-day of trading” stock returns that are on average significantly
positive,1 the so-called “underpricing” phenomenon,2 (ii) long-run investment
underperformance of IPO stock prices relative to non-issuing firms or market indices, and
(iii) the even more unusual phenomena of observed cyclical patterns in the volume of
new issues and the magnitudes of initial returns. The recurring periods of abnormally
high initial returns and abnormally high IPO volume are commonly referred to in the
securities industry as “hot issues” markets.

An informal explanation of the “hot issues” market phenomena is the so-called
“window of opportunity” hypothesis. This informal explanation relies on a form of

1The returns from the offering price to the close of the first-day of trading have been
shown to be in the range of 10 to 15 percent over a period of 33 years for U.S. IPOs. This means
that the price increase for an IPO share will, on average, increase by about 15 percent during the
first day it trades on the market.

2The first of these anomalies has garnered the attention of the vast majority of the
empirical studies concerned with the IPO pricing process. These studies, under the assumption
that IPO shares are “efficiently” priced in the aftermarket, find that the positive initial returns arise
because of the adverse selection problem engendered by the asymmetric information between the
investors and the owners of the firm going public. They are primarily concerned with the price at
which firms go public rather than modelling what affects the probability of firms going public. In
these models there is no modelling of the timing of the firm’s decision to go public and thus there
is no explanation of the observed cycles in the volume of IPOs. Also, the environment in which
the agent interacts is a static one.
investor speculation or stock mis-pricing. Specifically, it assumes that investors undergo periods (or regimes) of overenthusiasm for firms in certain sectors or industries. Subsequently, the stocks in these sectors become overvalued, as suggested by the “noise trader” model by De Long, Schleifer, Summers, and Waldmann (1990a) (DSSW). In this “noise trader” asset pricing model investors are assumed to be less than fully rational. Their beliefs, which may not necessarily be based on fundamentals, affect their demands for risky assets. Consequently, the price of the assets may become overvalued relative to its “efficient” market price. Companies take advantage of the overvaluation of stocks in their related sector and decide to go public during this period of investor overenthusiasm. Therefore, this explanation implies that the cyclical fluctuations in IPO returns and the volume of firms going public may be better viewed as fluctuations arising from unobservable stochastic regime changes in investor beliefs. This “windows of opportunity” hypothesis of the firm’s decision to go public is consistent with the long-run underperformance evidence (Loughran and Ritter (1995). It is also consistent with the clustering of IPOs near sectoral stock market peaks (Lerner (1994)), and supports the evidence that the probability of an IPO is significantly positively related to the median market-to-book ratios of firms in the same industry (Pagano, Panetta, and Zingales (1995)).

Chapter 3 of this thesis presents an overview of the defining empirical characteristics of the IPO market as well as reviews some of the explanations put forward regarding the empirical anomalies associated with the pricing and the volume of IPOs. In reviewing the literature concerned with the IPO process, this chapter also shows that academic research on IPOs has been concentrated on the investigation of the underpricing phenomena while the “hot issues” market phenomena has garnered little attention from academic researchers. Chapter 3 also presents a synopsis of the “noise trader” model and its relevant implications for the IPO process.

Chapter 4 of this thesis, entitled “An Empirical Analysis of the IPO Cyclical Puzzle: A Dynamic Regime Switching Approach,” emerges from the observation that little empirical work has been undertaken on the “hot issues” market phenomena. It
provides a detailed statistical description of the stochastic nature of the IPO initial returns and volume series. Since the "windows of opportunity" explanation suggests that the cyclical fluctuations in IPO returns and the volume of firms going public may be better viewed as fluctuations arising from unobservable stochastic regime changes in investor sentiment, I test for the presence of recurring stochastic regime changes in the IPO data. Hamilton's (1989) Markov-switching technique is used since it allows one to model time series processes subject to discrete state-dependent regime changes. Having found the IPO processes to be regime switching in nature, this chapter also investigates which economic factors may be important in the firm's decision to go public. Finally, the study tests the "noise trader" model's implication that shifts in investor beliefs, which underpin regime shifts in the IPO processes (according to the "windows of opportunity" hypothesis), also underpin shifts in the returns of other assets. To test the nature of the correlation of the regimes governing two separate securities (IPOs and closed-end funds) Hamilton's approach is extended to a vector setup.

In the fifth chapter, the firm's decision to go public is modelled using an optimal stopping model found in statistical decision theory. This model formalizes the "windows of opportunity" hypothesis of the "hot issues" market phenomena. Starting from the premise that offering proceeds (that the firm receives by going public) depend on the price investors are willing to pay for the IPO shares, and that this price in turn depends on the state of stochastic investor beliefs, this model finds that the probability that a firm goes public will fluctuate in a manner reflecting the fluctuations in investor beliefs. Therefore, this model predicts that IPOs will be clustered during certain periods (thus consistent with the observed "hot issues" markets) and that these IPO clusters will coincide with market peaks (which is consistent with the evidence presented by Lerner (1994) and Pagano, Panetta, and Zingales (1995)). By allowing some degree of firm heterogeneity, as measured by the firms' public information content, this model also predicts that older, larger "information rich" firms are more likely to go public than smaller, younger "information poor" firms (which is consistent with the empirical evidence presented by Pagano, Panetta, and Zingales (1995)). This model also shows that
“information rich” firms are more responsive to swings in investor beliefs.
Chapter 2

What is Old is New Again

2.1 Introduction

It has now been more than a hundred years since Carl Menger wrote, in his "On the Origin of Money" (1892), this frequently quoted statement: "... that every economic unit in a nation should be ready to exchange his good for little metal disks apparently useless as such, or for documents representing the latter, is a procedure so opposed to the ordinary course of things, ... [it is] downright 'mysterious'.” The mystery that Menger alludes to is why useless objects (little metal disks in his time) circulate as media of exchange. Menger, in addressing the question how does a certain object become money, concludes that the use of money emerges (in an evolutionary fashion) over time and is a consequence of individuals' self-interest guided by the "invisible hand.” As well, he finds that the use of money requires individuals to believe other agents will accept it in turn.

Formal modelling of this matter has until recently been elusive. However, the advent of search theory in macroeconomics has led to the development of a new class of models which analyse the existence of money as a generally acceptable medium of exchange in a dynamic optimization framework. Specifically, works by Kiyotaki and Wright (1989, 1991, 1993), in which they develop a class of search-based models called Search-Theoretic Non-Cooperative Equilibrium (STNCE) models, have been the driving force behind a renewed interest in explaining the use of money as a medium of exchange. A sample of other contributors who follow Kiyotaki and Wright's approach include: Matsuyama, Kiyotaki and Matsui (1993), Kehoe, Kiyotaki and Wright (1993).

*A slightly different version of this chapter is forthcoming in the journal The Manchester School.*

One purpose of this study is to show that these STNCE models are only new in their analytical structure. In terms of ideas put forth, these models are in fact formalizing only some of the ideas attributed to early economic and social theorists such as Carl Menger and Georg Simmel. In examining in detail how well the STNCE methodology addresses Menger's and Simmel's insights on how money comes into and continues to exist, I find that the formalization of their ideas is incomplete. What remains to be addressed is the broader issue explored by earlier theorists, of how instability in the social institution, embodied by money, may have detrimental effects on individual and social welfare.

The STNCE approach stands out in the field of monetary theory since it reverses a recent trend of modelling money as a store of value, while ignoring its services as medium of exchange and unit of account. The practice of modelling money simply as a store of value evolved as a byproduct of a search for 'sound' theoretical microfoundations for empirical generalizations associated with the "Monetarist" analysis of the 1960s and 1970s. These 'sound' theoretical foundations were sought in general equilibrium Walrasian modelling techniques, and that branch of monetary theory classified as "new monetary economics"\(^1\) was one of the principal outcomes of the search in question. Unfortunately, this theoretical approach leaves no role for money to serve as a medium of exchange since, in the environment it postulates, markets behave 'as if' there are no costly frictions. Upon analysis, one finds that the coexistence in equilibrium of fiat money and divisible interest-bearing assets to be theoretically tenuous in these Walrasian models of money. Not surprisingly, one also finds that price inflation does not engender much in the way of social welfare costs.

In reality, fiat money indeed exist, even when dominated in rate of return by

\(^1\)Hall (1982) seems to be the originator of this term taken up by Cowen and Kroszner (1987). Examples of work typical of new monetary economics, which are predominantly based on Overlapping Generations models, include Bryant and Wallace (1984), Sargent and Wallace (1982), and Hall (1982).
other assets. One explanation, which emanates from new monetary economics, is that fiat
money is held because of State imposed legal restrictions. This study seeks to emphasize
the STNCE methodology's ability to derive equilibria in which valued fiat money,
dominated in rate of return, exists concurrently with alternative stores of value, and is
held in the absence of State decrees. Also, this study will illustrate the advantages of the
STNCE approach over the Walrasian framework in modelling the institutional aspects of
money.

In section 2.2 of this study, a historical perspective on the literature dealing with
the genesis of money and its medium of exchange function is presented. It highlights the
ideas put forward by Carl Menger and Georg Simmel. Section 2.3 provides a brief
outline of the STNCE approach and compares the insights derived from STNCE models
to those of these earlier theorists. This section also suggests some possible avenues of
further study dealing with other issues raised by these pioneers of the evolutionary theory
of money. Section 2.4 evaluates the importance of STNCE models for monetary theory.
Finally, some concluding remarks are offered in the last section.2

2.2 Historical Perspective

Carl Menger was a pioneer in the development of the Austrian school's
evolutionary approach to the genesis of money. The Austrian evolutionary theory of
money argues that money emerges out of barter as a consequence of the self-interested
interactions of individuals who make up an economic society. This "invisible hand"
explanation of money's genesis rests on an assumption of "confidence" or "trust" on the
part of individuals in monetary institutions, which in turn fosters the beliefs that
determine money's value. Though ideas on how money first appears turn up in the
literature before the development of the Austrian evolutionary theory (see footnote #4

---

2Since this study was completed, Selgin (1994) has appeared. Selgin's study is principally
concerned with the implication of the evolutionary approach for the creation of new fiat monies,
and, therefore, touches upon certain issues raised here. However, it does not discuss in any detail,
the many points of contact between the older "Austrian Literature" and the modern STNCE
approach to these issues.
below for an example), it was Menger who developed a concise explanation of how the medium's value is related to confidence in the monetary institutions.³

Menger, in his "On the Origin of Money" (1892), explains "... how it has come to pass that certain commodities ... should be promoted amongst the mass of all other commodities and accepted as the generally acknowledged media of exchange" (1892, p.241, italics my own). He proposes that the emergence of money requires an economic environment with the following three characteristics. First, the acceptance of money by any one agent must be based on his or her belief that other agents will accept it as well. Specifically, Menger argues that part of money's general acceptance in "mediate exchange" is due to its high degree of saleability. This high degree of saleability in turn, attracts more economic agents to exchange their less saleable commodities for this more saleable good (eventually to become money).

"... when any one has brought goods not highly saleable to market, the idea uppermost in his mind is to exchange them, not only for such as he happens to be in need of, but, if this cannot be effected directly, for other goods also, which, while he did not want them himself, were never the less more saleable than his own."(1892, p.248)⁴

Menger indicates that the degree of saleability is, in part, affected by the "want" of this commodity by other agents, as well as by such intrinsic properties as "transportability" and "fitness for presentation". In turn this "want" is affected by the degree of saleability of the object. That is, as more agents accept a commodity for the purpose of further trade the more saleable the commodity becomes. As this commodity becomes more saleable, agents become more willing to accept these goods until finally "... the relatively most

³Other pioneering work on the evolutionary approach to the development of money is also attributed to Ludwig von Mises. See Ellis (1934) for a survey of monetary theories established in the German economic literature.

⁴The value of saleable goods at market is certainly not new as this quote from Adam Smith's famous tome would indicate: "... [people] ... have endeavoured ... [to hold] ... a certain quantity of some one commodity or other, such as he imagined few people would be likely to refuse in exchange."(1776, p.18).
saleable commodities have become 'money'. . . " (1892, p.250). Menger summarizes his first point by claiming that as time passes, the most saleable goods " . . . [will] in every market become the wares which it is not only in the interest of every one to accept in exchange for his own less saleable goods, but which are also those he actually does readily accept." (1892, p.248, italics my own)

Second, Menger describes money coming into being " . . . as the spontaneous outcome, the unpremeditated resultant, of particular, individual efforts of the members of a society . . . " (1892, p.250). Moreover, he states:

"No accident, nor the consequence of state compulsion, nor voluntary convention of traders effected [the use money]. It was the just apprehending of their individual self-interest which brought it to pass . . . " (1892, p.254)

He assumes explicitly that "Money has not been generated by law" (1892, p.255). Rather, it is the unorganized efforts of individuals, each taking actions in hope of increasing their economic well being.

Third, Menger suggests that " . . . each individual would learn, from his own economic interests, to good heed that he bartered his less saleable goods for those special commodities which displayed . . . a wide range of saleableness both in time and place" (1982, p.248, italics my own). He explains that as time goes on, agents become "increasingly conversant" with the economic advantages of exchanging their less saleable items for the most saleable objects. Eventually, those objects become "generally acceptable media of exchange". At first, the habit of exchanging less saleable for more saleable goods is localized within a small part of the community. This behaviour becomes wide spread as agents learn of the potential economic gains by observing the success of agents already in the habit of carrying out this type of exchange:

" . . . it is clear that nothing may have been so favourable to the genesis of a medium of exchange as the acceptance, on the part of most discerning and capable economic subjects, for their economic gain, and over a considerable period of time, of eminently saleable goods in preference to all others. In this way practice and habit have certainly contributed not a little to cause goods, which were most
saleable at any time, to be accepted not only by many, but finally by all..." (1892, p.249)

Thus, Menger's third point emphasizes that the establishment of a generally acceptable medium of exchange, money, is achieved over many generations and requires that agents be able to learn of the advantages of indirect trade and money.

Menger gives a somewhat broader, more sociological version of his explanation of money's origin in his book *Problems of Economics and Sociology* (1882). There, he emphasizes money's role as a social institution as well as the evolutionary and "invisible hand" aspects of its genesis. Menger asserts that money, as with the legal constructs of society, is not the result of self-conscious collective efforts on the part of individuals. Rather, the institution called money is the outgrowth of customs or habits based on trust which at first, is between traders who are acquaintances, but eventually evolves to be a trust between traders and a third party, society itself.

Menger's characterization of money's origin as being comparable to the origin of social institutions such as law, was taken up by Georg Simmel in his book *Philosophy of Money* (1907). Simmel is described as a turn of the century "social philosopher and pioneer of modern sociology" who "laid bare [the nineteenth century view of money's] origins and foresaw its consequences."[6]

Simmel believed that as well as being the spontaneous result of social evolution, money incorporates or embodies the mutual trust that exists within society. The holder of money can trust that somebody else in the community will, in exchange for the money he now holds, return to him a service equivalent to that he had previously rendered to society in exchange for money. Money is valued because of the community's ability to

_________________________

[5] The works of Simmel have already been reviewed by Frankel (1977) and by Laidler and Rowe (1980), both of which argue in favour of the importance of Simmel's insights to modern monetary theory. It should be understood that this brief review of Simmel's ideas on money's origin and its medium of exchange characteristics owes a debt to both of these works. As is pointed out by Laidler and Rowe, one should also note that "...Simmel seem[s] to have drawn heavily on the work of Carl Menger, but later Austrians... in their turn drew on him." (1980, p.97)

incorporate a society's mutual trust in the form of money. Like Menger, Simmel believes that "society" acts as a "third party" whose role is to perform the services of an intermediary and thus to relieve individual agents engaged in the trading process of the need to waste effort and resources building up a reputation as a trustworthy trader. Specifically, trades in which money changes hands, no longer simply involve two agents because when money is used, "the value of exchange given by one party . . . [must be] a claim upon definite values . . . whose realization depends upon the economic community as a whole . . ." (1907, p.77).

For Simmel, the benefits of the social institution, money, are akin to the gains that arise from converting a personal trust to a general trust throughout society. Such general trust eliminates the uncertainty that can arise from the unforeseeability of the action of other individuals, thus allowing agents to pursue their own economic advantages with less trepidation and more single-mindedness than would otherwise be possible. Simmel's broader characterization of money's role as being comparable to that of a social institution, is in effect, an extension of Menger's first point, that agents value and hold money partly because they believe (and trust) that money will be accepted by other agents in the future. The idea that money is accepted in trade as a medium of exchange because agents believe it will be accepted by others in return, is simply a consequence (or, using economic terminology, a special case) of money's nature as a social institution. In fact, Simmel goes so far as to imply that trust is what generates these beliefs. Laidler and Rowe (1980) summarize his views on this issue:

'[money's] value in turn is underpinned not so much by physical properties of money as by an implicit guarantee given by the community as to the acceptability of money . . ." (1980, p.99)

The implication of Simmel's argument, is that money's services are inherently public in nature. Underlying this conclusion however, is a requirement for continued trust in money, and for Simmel, trust in money must be underpinned by trust in monetary order. He believes that short-term uncertainty about the purchasing power of money will have long-run effects, because the adjustments engendered by short-run uncertainty can
permanently affect that order.

"For the transitional period, the instability and difficulties of which are admitted, would . . . become a permanent condition, and the state of adjustment that is attainable in principle for any quantity of money would never be reached . . ." (1907. p.164, italics my own)

Also, as Frankel succinctly summarizes, Simmel believes that,

". . . the maintenance of a free monetary order implies that contracts freely made in money do, as such, carry society's guarantee that the measuring-rod of money in terms of which they are made will not be deliberately tampered with by anyone, not even the government itself." (1977, p.40, italics in original text)

Therefore Simmel draws the conclusion that uncertainty in the purchasing power of money would undermine this society's trust in money. To be precise, Simmel fears price level fluctuations because their occurrence will reduce agents' trust in monetary order, the mutual trust required to insure the continued acceptance of money, and hence undermine the institution called money.

Laidler and Rowe (1980) argue that the "Austrian" line of thought summarised above has important implications for modern monetary theory, which can be brought out by contrasting Simmel's characterization of money to the current mainstream point of view. The latter has it that money acts as a store of value and is held as any other durable good by utility maximizing agents. Laidler and Rowe indicate that, if money is assumed to be a store of value, the consequences of variations in its purchasing power are purely private, but when money's medium of exchange function is emphasized, such variation would undermine the process of monetary exchange. This in turn would hamper the efficiency of market mechanisms reducing the possibility of (or increasing the costs of) trading, and thus "reduce the number of mutually beneficial and desired exchange that actually took place . . ." (1980. p.102). They conclude that modern economic theory underestimates the effects of monetary instability when it is compared to the concerns put forward by the "Austrians".

As previously mentioned, the Austrian views on money's origin and nature were
not uncontested. Rather than promoting the view that money was a social institution that evolved over many generations out of the uncoordinated self-serving behaviour of individuals, Georg F. Knapp contended that money was created and regulated by the State.

In his State Theory of Money (1924), Knapp "formulates a universally valid theory of the nature and origin of the economic instrument money." However, it is worth noting that Knapp's views have been criticized by such authors as Frankel (1977), Rist (1940), and to a lesser extent Ellis (1934), as being too absolute when defining money. For example, Knapp does not give any indication that money may arise in societies without any government. Also, on a related bases, Knapp misapprehends how the state—if understood as not being separate from society—can create money. I will briefly highlight some of these criticisms further on but first, I furnish a brief summery of Knapp's ideas.

Knapp asserts that "Money is a creation of law because it appears in the course of history under the most diverse forms. A theory of money must therefore at the same time be a theory of history of law."(1924, p.1) Also Knapp contends, as is succinctly phrased by Rist, that

"The question of the value of money is secondary; what is important is its validity. . .that is to say the powers to discharge debt given it by the State, that to which in virtue of the law, money gives a right."(1940 p.354)

For Knapp, the intrinsic form (paper, gold etc.) of the unit of value (francs, dollars etc.) is not important. In fact, he argues that the medium of exchange is purely "nominal". Francs and dollars for example are simply abstract units.

The nominal characteristics of money are easily illustrated, by Knapp, when noting that the State is able to change the means of payment of debts while keeping the size of the different debts the same. Knapp explains that debt can be expressed only in the monetary unit.

---

7Ellis (1934), p.20
"Each alteration of the means of payment implies that the unit of value, at least at the moment of transition, should be regarded as nominal. Once a money has been established, it can only be changed by an admission of the nominal character of the monetary unit; this character consists in the possibility of the State changing the means of payment, while the relative magnitude of different debts remains unchanged." (1924 p.19)

Ellis, who is kinder in his criticism than Frankel and Rist, nicely summarize Knapp's views by framing them in these three concise propositions:

"1. Money comes into being when the state selects a certain unit of value, describes its physical bearer carefully, gives it a name, and proclaims its validity in terms of the historically preceding unit.

"2. Proclaimed validity is secured in trade by the state's accepting all its money at face value; legal tender in private trade is a complementary measure, not a universal one. The state causes a money to be standard by forcing it out in payments to private persons.

"3. For all money, proclaimed validity is independent of substance value." (p.21, italics my own)

Criticisms of Knapp's work are briefly summarized in what follows. For Charles Rist, Knapp develops an unnecessary explanation of the State's ability to change the monetary unit. He argues that "The [monetary] unit cannot merely be a name; it is only a unit in relation to sums expressed in multiples of that unit . . . . But to be a unit of value, the franc must represent a certain value for these who demand it." (1940, p.360) Rist concludes that Knapp's theory has nothing to do with economics. Specifically,

". . . Knapp's theory is not an economic theory of money. It is a juridical construction designed, like all such constructions, to provide an explanation of a number of legal decisions" (1940 pp.360-61, italics in his text)

Frankel's criticism implies that Knapp's theory would allow for political abuse, through inflation. Frankel argues that the state cannot, by the declaration of a new monetary unit, just create new credit as payment of obligations; what is required is some
form of real production from society. By continually creating credit the government only serves to increase the uncertainty in the monetary system, eventually leading to a debasement of the currency.

Frankel also explains that if the state has the last word in all monetary matters then the economy would not in fact be operating under a free monetary order. This line of reasoning follows Menger's thoughts on the inadequacy of the juridical perspective of money. Menger believed that the use of money as being dependent on force, was absurd.

Ellis finds that Knapp, to a certain degree, correctly understands how the government's acceptance of fiat or near fiat money as legal tender and at state pay offices, would account for the acceptance of this type of money in the general populace. But he too argues that Knapp's definition of money "denies that money is valued as people understand the term . . ." In the end Knapp's use of "unwieldy terminology" his "errors in the amphitropic arguments, of historic definitions", the danger that Knapp's work is susceptible to "inflationistic interpretation", his "ignorance of important facts", and his "exaggeration of ideas" leads Ellis to conclude that Knapp's work is unsatisfactory for the purpose of gathering insights on the nature and origins of money.

Frankel suggest that Knapp makes the analytic mistake of viewing government and money as being institutions separate from society. Frankel, by taking into consideration Simmel's and Menger's ideas on money being a social construct, explains that money should no more be regarded as separate from society than economic activity should. For Frankel, it is not the State — if it is assumed to be acting outside of society — that can change the monetary order but it is "changes . . . in society as a whole — in its beliefs, goals and institutions . . ." that are important to the existence of money. As I shall indicate in section 2.4, this same criticism can be applied to the modern legal restrictions explanation of the existence of fiat money.

2.3 The STNCE Approach and its Similarity to the Ideas of the Earlier Monetary Theorists

As Ostroy and Starr (1990) show, a shared feature of all STNCE models of money
is that agents meet randomly and sequentially in pairwise fashion to carry out bilateral trades. The trading process itself is characterised by a *quid pro quo* requirement at the time of exchange, meaning that equal market value must be given and received. Agents are typically restricted to holding one type of object (good or money) and no more than one real unit of that object. This *inventory restriction* then implies one-for-one trades, trivially satisfies the *quid pro quo* requirement. Because many of the STNCE models are variants of it, the Kiyotaki and Wright "A Search-Theoretic Approach to Monetary Economics" (1993) model will be used as a basis for the following summary of the STNCE features. In that model, and others that follow its lead, a number of infinitely-lived agents each specialize in the production of indivisible consumption goods which cannot be consumed by the agents themselves. The agents are assumed to have heterogeneous preferences over these goods. Specifically, each agent is thought of as having a most preferred (or a set of most preferred) good (goods). The amount of utility derived by an agent can be pictured as reaching a maximum — if for example goods had colour as their only preference characteristic — when the agent consumes a good of his or her ideal colour. Utility would decrease as the agent consumed goods further away from this ideal colour. There are two variants of "most preferred good" preferences. *Discrete preferences*: here there is a limited number of goods, three for example, and agents derive positive utility only from one of these goods. In this discrete case, goods are differentiated by intrinsic or physical properties such as storage cost or ease of transport, as well as by the fact that they yield different utility to different individuals. *Symmetric preferences*: here there exists a continuum of (intrinsic) symmetric goods for which each agent derives, with probability $x$, some positive utility from consumption of a good selected at random.

The *symmetric* preference relation is more tractable in demonstrating a role for fiat money. Since the goods are undifferentiated by transport or storage costs, there is no "natural" candidate to play the role of commodity money. A parameter $x$ is used to

---

*Natural, when speaking of its physical or real properties, such as storage costs. In other words, the commodities can be thought of as having the same ease of transport but may be painted*
characterise the double coincidence of wants problem stated in Jevons (1875).
Specifically, in the STNCE approach, agents are assumed to want only goods for which they derive positive utility from consumption, with the parameter $x$ being the probability that an agent would derive positive utility from the good held by his trading partner.
Thus, the typical agent, upon meeting a trading partner with a good, will wish to acquire this good with probability $x$. Therefore $x^2$ represents the probability that two traders will consummate a barter exchange; the probability of a double coincidence of wants being satisfied. Obviously, smaller values of $x$ make barter more difficult because the probability of a double coincidence of wants, $x^2$, is smaller. For $x=1$, barter becomes trivial in the sense that any good is accepted in trade.

The trading process, in the STNCE class of models, has agents searching for exchange partners in a trading area and facing transaction costs should they actually trade. They choose trading strategies, decision rules determining whether or not, on any encounter, they should trade. These decision rules are determined in such a manner as to maximize their expected discounted utility from consumption net of any transaction costs, given the strategies of others.

Because authors using this search theoretic approach typically wish to show that valued fiat currency can exist in equilibrium, they assume that, at the outset, a fraction $M$ of the agents are endowed with fiat money while the rest are initially endowed with a real commodity. If they do trade, agents holding money are required to spend all their holdings in exchange for one unit of a real commodity. Therefore there are two types of traders, each defined by what they bring to the market area, either one unit of real balances (money traders) or one unit of the real commodity (commodity traders).

The critical question is to determine whether traders holding a commodity will accept fiat money in exchange for it. The notion that agents will accept money in trade because they expect that others will do the same, is formalized in STNCE models by determining a commodity trader's strategy when meeting a money trader. Let $II$ denote

---

with a different colour yielding various levels of utility to various individuals.
the probability that a randomly selected commodity trader accepts money, so that, when a money trader meets a goods trader, the money trader knows that commodity traders in general accept money with probability \(\Pi\). Now let \(\pi\) denote a commodity trader's optimal strategy when he meets a money trader, that commodity trader's probability of accepting money. For example, if the expected utility of holding money (becoming a money trader) is always greater than remaining a goods trader, then \(\pi\) will be equal to one. However in general, \(\pi\) is dependent on \(\Pi\), the societal beliefs, if you will, of other agents. This means that if \(\Pi\) is low enough, it may never be optimal for the goods trader to accept money, thus making \(\pi=0\).

A pure money equilibrium can exist in such a framework, however, and is described as follows. When the beliefs are such that \(\Pi > x\), money will be accepted in the exchange, by any encountered trading partner holding goods, with higher probability than goods. Since money is accepted more often, the expected gain to becoming a money trader is greater than that remaining a goods trader. The commodity trader's best response when meeting a money trader is therefore to always accept money (\(\pi=1\)). Since \(\pi=1\) for all goods traders, money becomes universally accepted. This in turn implies that \(\Pi=1\) in this, the pure monetary equilibrium. Note that in equilibrium, beliefs about the general acceptability of money are self-fulfilling.

There are in general, three steady-state equilibria in a STNCE model of the type we have described. These can be described as: a pure monetary equilibrium where \(\Pi=1\), a nonmonetary equilibrium where \(\Pi=0\) (money is never accepted in exchange), and a mixed monetary equilibrium in which \(\Pi=x\) and \(\pi\epsilon[0,1]\) (money is accepted in some exchanges).

The foregoing analysis characterises equilibria, but says nothing about how they are reached. Until Robert Jones' "The Origin and Development of Media of Exchange" (1976), modern work on the medium of exchange role of money did not explicitly address Menger's question: how can an object become a generally accepted medium of exchange? The modern work illustrated how money (as a medium of exchange) could overcome the difficulty of achieving an efficient allocation within a decentralized exchange economy.
In other words, it explained why a general medium of exchange was necessary, or what was the economic gain from the use of a general medium of exchange. Only incidentally did it shed light on aspects of money's genesis. Jones' model, on the other hand, captures the Austrian "invisible hand" view of the origin of money by demonstrating that agents, through their self-interested cost minimizing (welfare maximizing) behaviour, choose, as Menger puts it, without "...state compulsion, nor voluntary convention of traders" (1892, p.254), to use a commodity money in an indirect exchange process, rather than barter.

Specifically, Jones' framework has exchanges of commodities taking place bilaterally and sequentially. He assumes that agents choose between a direct trading strategy and an indirect (2 stage) trading strategy. The conclusion drawn by Jones is that indirect exchange may be optimal in some equilibria, since it may minimize exchange costs. Should indirect exchange be favoured, agents will choose the commodity that is most frequently bought and sold as the intermediary commodity, which in turn becomes a commodity money. Jones' model also formalizes the learning process described by Menger. Jones presents an adaptive formula that has the agents' estimate of the fraction of individuals in the market wishing to purchase the various goods, an estimate that is revised in accordance with the actual state of the market. Over time, a locally stable equilibrium pattern of exchange emerges, with the particular level of monetization of trade to which the economy converges, depending on the initial pattern of trade. Jones finds that the relative "commonness" of goods — a market characteristic rather than an intrinsic characteristic — plays a role in determining which good evolves into commodity money.

Jones' approach does not directly address Menger's point about the genesis of money being dependent on the agents' beliefs about the acceptability of money. STNCE models add to the insight provided by Jones by making it clear that, as well as arising from the uncoordinated market behaviour of economic agents, money is a creation of

---

*Oh (1989) and Iwai (1988), with the use of more sophisticated trading strategies, develop updated versions of Jones (1976) model.
social acceptability.\textsuperscript{10} It is an essential insight of the STNCE approach that money must be believed to be a general medium of exchange before it can actually fulfil that role. This point emerges clearly in Kiyotaki and Wright's seminal earlier paper "On Money as a Medium of Exchange" (1989). There they demonstrate that even if an object has physical properties, such as storability, making it a natural candidate for the role of commodity money, these properties may be overridden as the deciding factor in the choice of a commodity money strictly because a necessary condition for it to play this role, namely that agents believe that the object will be accepted by others, is missing. Therefore, the model set out in Kiyotaki and Wright (1989) is a logical starting point for a comparison of issues addressed by the early theorist and the findings derived from search-based models of money.

The Kiyotaki and Wright (1989) model involves three indivisible goods and three types of agents, with each agent deriving utility from only one of these goods. They assume the preference relation described as discrete. The three commodities in their model have different storage costs (or different physical properties). Depending on the commodity's intrinsic or physical properties and the extrinsic beliefs of the agents, Kiyotaki and Wright derive equilibria in which one (or even two) of the commodities become the medium (or media) of exchange. In one equilibrium, the low-storage-cost object serves as commodity money. However, Kiyotaki and Wright demonstrate that another equilibrium exists in which the highest-cost object (the least natural candidate for money) circulates as commodity money provided that other agents believe that it will be the most readily accepted. In this equilibrium, the dependence of the medium of exchange selection on the population's beliefs is all important, and its existence shows that this model (as do all STNCE models) captures the idea stressed by Menger (his first point) that the emergence and continued existence of a generally acceptable medium of

\textsuperscript{10}It can be argued that in modelling the individual's belief about the state of the market (ie. the proportion of individuals wishing to buy each good) that Jones also formalizes Menger's point about the agents beliefs. However, I put forward the interpretation that the agents' beliefs, in Jones model, are estimates of the relative abundance of each good rather than beliefs about the societal acceptability of each good. I admit, the difference in interpretation is a subtle one.
exchange depends on societal beliefs or customs.

Beliefs about money's degree of acceptability becomes even more important in modelling the existence of valued *fiat* currency. As we saw in discussing Kiyotaki and Wright (1993), the individuals' self-fulfilling beliefs (II above) are critical in determining whether fiat currency will be accepted in trade. Simmel's idea that money derives its value not from its physical properties, but from a guarantee given by the society itself as to its acceptability in future trades, is thus highlighted in this model. Specifically, it is possible to interpret the parameter II, the measure of money's general acceptability, as measuring the trust that other individuals have in money. For example, when II = 1, an individual who is contemplating accepting money in trade, believes that there exists an absolute guarantee that some future trading partner will in turn accept it. It is also worth stressing that because all STNCE models describe the maximizing behaviour of agents, Menger's second insight, that money emerges out of the decentralized, sequential and *optimal* decision-making process, is indeed formalized by them.

There remains one point of Menger's which the STNCE approach has yet to address. As was noted above, these models are typically used to characterise steady state equilibria. However, they ignore the learning and evolutionary aspects of the origin of money expounded by the Austrian school, Menger's third point. Since all beliefs are self-fulfilling in the steady state equilibria, there is no learning involved in the maintenance of the monetary institution, as there would be during its evolution. There is no mechanism which explains how expectations of money acceptability (II) are developed or generated within society. It may be possible to address this issue by modelling some explicit dynamic activity within the STNCE framework in which agents are able to learn the advantages of using an intermediated object possessing high saleability properties. Presumably, beliefs would have to be updated (perhaps in a Bayesian manner) as more agents learned to use the more saleable objects to achieve their final allocation. Saleability of an object at any moment would then have to be dependent on these changing beliefs as well as the varying level of use of the object as a medium of
exchange. What seems to be called for is an integration of the insights yielded by Jones' model into the STNCE framework.

Private information about a commodity's qualities can often impede trade if agents have limited means of enforcing contracts. Brunner and Meltzer (1963, 1971) and Alchian (1977) suggest that money's medium of exchange role in overcoming the asymmetric information frictions may be of greater importance than its role in reducing friction due to pure barter. For example, when information gathering about a good's qualities is costly, agents will wish to minimize their transaction costs by choosing a sequence of exchanges that reduce the cost of trading and information gathering. If money, because of its universal recognizability, has a zero (or near zero) marginal cost of acquiring information, then the use of money in intermediate exchange would significantly reduce transaction costs.

The relation between Brunner and Meltzer's (1963) informational content of money concept and Simmel's notion of societal "trust" being embodied in money can be illustrated by the following comparison. For Brunner and Meltzer (1963), money's high degree of information content (its recognizability throughout society), requires agents to undertake little or no costly information gathering activities. For Simmel, money's high degree of trustworthiness (all individuals trust that it will be accepted by others), requires agents to spend little or no time investigating exchange opportunities (searching for barter

---

11 Kehoe, Kiyotaki and Wright (1993) derive dynamic equilibria using a search-based model similar to Kiyotaki and Wright (1989). However, the model does not formalize the mechanics involved in learning (the updating of beliefs in particular), which is described by the forerunners.

12 As we have seen, Jones' model closely parallels Menger's description of the learning process. The integration of learning beliefs is partially accomplished in Wright's (1995) paper in which he endogenises the distribution of commodity producer types and allows for evolutionary dynamics to affect the distribution of types over time. Though the methodology used does allow for the study of learning, Wright does not model Menger's point that the agent's trading strategies will evolve over time to take advantage of the gains brought about with the use of a medium of exchange.

13 This explanation of money's use in overcoming the asymmetric information problem is derived from Brunner and Meltzer (1971).
opportunities). Therefore money, in both interpretations, has societal underpinnings in its ability to reduce transactions costs associated with the market exchange process.

Williamson and Wright (1994) present a search model of money in which money plays an important role in mitigating frictions associated with asymmetric information such as moral hazard and adverse selection described by Brunner and Meltzer (1963, 1971) and Alchian (1977). In their STNCE model, fiat money acts as a catalyst for exchange that in turn increases welfare. Specifically, Williamson and Wright abstract from the double coincidence of wants problem by assuming that the parameter $x$ (described in above) is equal to one. However they introduce the possibility of producing two different types of commodities, one of them yielding positive utility (the "good" or high quality commodity) with positive production costs, while the other yields no utility and has negligible production costs. They then assume that the individuals involved in the trading process may be unable to recognize the quality of the other's wares such that each possesses some degree of private information. If these private information frictions are severe enough — meaning the probability of recognizing the quality of the goods is small — then the nonmonetary equilibria (equilibria where money has not been introduced) will be degenerate. That is to say, that agents are so weary of trading for goods of unrecognizable quality that no trade takes place.\textsuperscript{14} However, due to its universal recognition throughout society, the introduction of money generates the existence of active trading equilibria by reducing the private information disincentives of consummating trades.

Welfare, in this circumstance, is at its lowest in the degenerate nonmonetary economy.\textsuperscript{15} Fiat money increases welfare by freeing the producers of good commodities

\textsuperscript{14}Without the possibility of exchange, there is no incentive for the agents to produce the costly positive utility "good" commodity. Therefore the degenerate equilibrium is one in which in the aggregate, output is zero and no trades occur (the autarky case). Since no good commodities are produced in this case, the degenerate equilibrium is akin to the standard "lemons problem" where no sales of the good quality good takes place in equilibrium (see Akerlof (1970)).

\textsuperscript{15}Note that Williamson and Wright show that the introduction of fiat money in active (as opposed to degenerate) nonmonetary equilibria will also improve welfare by allowing for an increase in the number of trades that take place.
to sell their wares to money holders rather than simply to other commodity holders. This forces some discipline on the producers of "bad" commodities since they must first sell their product for fiat money in order to buy a good commodity. This added layer of exchange can be thought of as a "cash-in-advance" constraint. The incentive to produce good commodities is then increased since producers prefer to avoid this constraint. Therefore welfare increases with a higher number of good commodities being produced and traded.

Simmel's description of trust in the institution of money is addressed in the Williamson and Wright (1994) work in which the introduction of money, with its negligible informational costs, leads to an increase in mutually beneficial trading. Specifically, if one concedes that Simmel's notion of "trust" bears a close relationship to "the informational content of money" concept expounded by t'.e likes of Brunner and Meltzer (1963) and Alchian (1977), then Williamson and Wright, by focusing on money's universal (social) recognition, have captured Simmel's notion that money reduces the uncertainty of trade due to the unforeseen actions of others.

A criticism of many search-based models of money is that prices are not explicitly determined within these models. Specifically, Kiyotaky and Wright (1989) show how, in a random matching environment with specialization in production, certain commodities can endogenously become media of exchange while Kiyotaky and Wright (1993) use a simplified commodity side to show that equilibria with valued fiat money are robust to perturbations such as rate of return dominance and transaction costs. However STNCE models of money in general (all but three to my knowledge) do not provide a framework for the determination of prices. This is because goods and money are always subject to one-for-one trades implying that prices are always 1 when an exchange takes place. Hendry (1993), Trejos and Wright (1995) and Shi (1995) relax this one-for-one restriction and provide an explicit bargaining mechanism that determines prices endogenously.

---

16The constraint introduces a pattern of indirect exchange that increases the expected time until a trader receives the high quality good. This makes them more inclined to produce the higher cost high quality good since the constraint imposes an indirect cost to producing the bad, low-cost good.
The Trejos and Wright (1993) paper is essentially a summary review of two similar STNCE models of money, Shi's (1995) model and their "Search, Bargaining, Money, and Prices" (1995) model. In Trejos and Wright (1993) money, as in previous STNCE models, is perfectly storable and transferable. However, the commodities are now assumed to be perfectly divisible. A commodity holder will provide an amount q in exchange for one unit of money. This amount q is determined through bargaining. Because one unit of money is always given up for q units of the commodity, the price p is implicitly defined as \( p = \frac{1}{q} \). Trejos and Wright (1993) find that for monetary equilibria, where prices are endogenously determined, output tends to be too low relative to nonmonetary frictionless (\( x = 1 \)) economies. This is primarily due to the fact that, in accepting money, commodity holders are forced to spend it some time in the future to purchase their preferred good. Since the future is discounted, they are willing to provide less now than they would if they received their consumption directly.

What turns out to be important is that a proportion \( M \in (0, 1) \) of the population is endowed with one unit of money. Any variation (increase) in the money supply M, is therefore a fluctuation in the cross-sectional distribution of money holders. In a sense M measures the liquidity in the system since M is a measure of the fraction of the population looking to buy a commodity with money. Because of this, variations in M are non-neutral in this model. By increasing the liquidity (money supply), Trejos and Wright show that real output, nominal output and welfare will first increasing and then decreasing in M. Going into more detail, when liquidity is low and, in particular, when few agents are money holders, an increase in the money supply will increase the probability of transacting and in turn the number of goods (q's) exchanged as the proportion of money holders grows. Welfare is increased as more output is exchanged (and consumed) in equilibrium. However, as liquidity continues to increase, the relative bargaining power of the money holders decreases. This decrease in the bargaining power implies that money

---

17 The major difference between the two papers is that in Trejos and Wright (1995), barter between commodity holders is explicitly ruled out while in Shi (1995), direct barter is allowed in addition to monetary exchange.
holders receive less of the commodity (q is smaller and \( p \) is larger) in the exchange. Trejos and Wright (1993) in turn show that, in general, the price level is monotonically increasing in \( M \) (or \( q \) is monotonically decreasing in \( M \)). Therefore, in this model, the type of money growth that increases nominal balances in the system without affecting the ratio of money holders and commodity holders, does not affect welfare. The non-neutrality of money result is due to the fact that money is introduced in the system in a non-neutral way by varying the cross-sectional distribution of money holders. If the fraction of money holders is kept constant as the money supply is increased, the price level simply increases in proportion without any effect on real variables. In summary, the inflationary effects of money supply growth on prices in these models are not the typical inflationary effects considered in mainstream monetary economic theory where money growth occurs through time and is uniform across agents. If it were the case, money would be neutral in these search theoretic models of money.

Hendry (1993) extends the typical STNCE model by also relaxing the inventory restrictions. However as opposed to the Trejos and Wright (1993) setup, Hendry allows the agents to hold up to \( M \) discrete nominal units of money where \( M \in \{1, 2, 3, \ldots \} \) and restricts the commodity to be indivisible. He also allows the agents to hold both a commodity and nominal money balances simultaneously. With endogenously determined prices, Hendry is able to analyse some aspects of the issue of neutrality within a search-based model of money. Specifically, he finds that when the money inventory restrictions are severe (ie when an agent is allowed to hold 0 or 1 unit of nominal money), money is non-neutral since any increase in the aggregate money supply will have a less than proportional effect on the aggregate price level in equilibrium. This result has similar characteristics to the liquidity effects of money supply increases derived in Trejos and Wright (1993).\(^8\) However, money is shown to be asymptotically neutral as the

---

\(^8\)The money is non-neutral in the sense that real balances increase as the money supply increased. The results is similar to Trejos and Wright (1993) findings since the increase in money supply has consequences for the equilibrium distribution of money/commodity holders in the steady state equilibrium.
inventory restrictions are decreased.19

As yet, the STNCE literature has failed to formalize possible interactions between price volatility (or inflation) and societal beliefs. Assuming, as Simmel asserts, that increased price level fluctuations or inflation causes a decrease in the willingness of maximizing individuals to accept money in an exchange, the societal acceptability (or measure of trust) of money (Π above) would be negatively affected. It seems plausible that the asymptotic neutrality of money finding in Hendry’s (1993) work and the welfare results derived in the Trejos and Wright (1993) paper would be significantly altered.

Fluctuations in the value of money may also reduce the welfare increasing benefits of its use in the private information STNCE model of money proposed by Williamson and Wright (1994). One can imagine that inflation may cause money’s value in exchange for the unrecognizable goods to fluctuate (or to become uncertain) thus offsetting some of the benefits money yields as a universally recognizable object in a model with private information. Therefore an extension of the Williamson and Wright model where prices are endogenously determined may be well suited to investigate Simmel’s claim that inflation has detrimental effects for the societal trust engendered in money and thus have important welfare effects.

In a similar vein, the degree to which agents specialise in production may also be affected by fluctuation in purchasing power. Specifically, Kiyotaki and Wright (1993) formalize the idea (which dates back to at least Adam Smith (1776)) that money encourages specialization in production by introducing a tradeoff between the acceptability of commodities (x) and production. They assume that increased specialization increases output per unit time for the producer, but at a cost of reducing the acceptability of their wares (x decreases). Kiyotaki and Wright (1993) find that specialization and welfare, is greatest in the pure monetary equilibria. Clearly if the value of money as a medium of exchange is reduced because inflation (uncertainty)

19When the restriction imposed on the divisibility of money holdings is relaxed, money supply increases have little impact in the equilibrium distributions of the agents and a large affect on the equilibrium price. As money becomes infinitely divisible, distributional effects disappear, prices increase in proportion with the money supply and real money balances remain constant.
decreases the willingness of agents to accept it (II), this would cause agents to diversify their output, reducing welfare.

As a final note, Menger's idea that once a universal medium of exchange has been established in society, the State can enhance this money's ability to act as a medium of exchange by standardizing the form it takes and by accepting it in trade may be addressed in a STNCE framework. The State, being a large trading entity in the economy, would affect, by its behaviour, the beliefs of other agents about money's acceptability. It would therefore seem possible to formulate a STNCE model in which the population acceptability of money (II) depends on the number of transactions that the State carried out with money.

2.4 New Monetary Economics Versus the STNCE Models of Money

The last two decades have seen monetary theorists seeking microfoundations for the analysis of various issues in macroeconomics. Those who have applied general equilibrium analysis and Walrasian market theory to monetary topics have found that money plays no unique role in an environment in which market prices are set costlessly and in which there are no trading frictions. The only function for money in such an environment is as a store of value. That is why Overlapping Generations\textsuperscript{39} models have been frequently used (in modelling money) by contributors of what has been dubbed "the new monetary economics."

When divisible assets with greater rates-of-return than money are introduced into an Overlapping Generations framework, the continued existence, in equilibrium, of valued fiat money, which can be thought of as "non-interest-bearing, intrinsically

\textsuperscript{39}This microfoundations Walrasian market theory analysis also brought the development of Cash in Advance (CIA) models in which money is valued because of an exogenously imposed medium of exchange function for money. Fiat money is required in these models for the purchase of consumption goods.
valueless store of value."\(^{21}\) cannot be supported.\(^{22}\) A result that arises directly from modelling only money's store of value function. This is succinctly put by Laidler in his work *Taking Money Seriously* (1990).

"To treat money [as a store of value] of course immediately rules out of court the traditional analysis of the welfare costs of inflation. Indeed it goes much further, because any expected rate of return on money below that yielded by productive assets . . . will lead to its not being held at all. If money bears explicit interest at market rates, it becomes indistinguishable from other assets. but if it does not, and consists of some intrinsically valueless item, then expected inflation at any rate in excess of minus the real rate of interest immediately leads to money's disappearance from the economy, which nevertheless continues to function in its absence!" (1990, p.104)

However, as an empirical fact, fiat currency does circulate and its rate-of-return is dominated by default-free securities (or risk-free interest-bearing assets). Neil Wallace, in his "A Suggestion for Oversimplifying the Theory of Money" (1988), suggests that fiat currency circulates because of "unnatural" State created barriers limiting "substitution between privately issued inside money, . . . and outside or government issued money . . ." (1988, p.26). He argues that without legal restrictions, we have either

". . . a world in which currency as we know it — non-interest-bearing currency — continues to be valued and all real returns are driven down to approximately that on such currency, or . . . a world in which currency as we know it disappears and the currency we use is different stuff, perhaps claims denominated in terms of some commodity like ounces of gold . . ." (1988, p.29)

This line of argument also suggests that there should be "laissez-faire" in matters of

\(^{21}\)Laidler (1990), p.104

\(^{22}\)Because of their frictionless Walrasian constructs, the existence (in equilibrium) of fiat money in CIA models is equally tenuous without legal restrictions. Specifically, these are restrictions in the pattern of trade as well as restrictions on the agents ability to issue their own currency or, to be more exact, to issue liabilities that could be traded for goods. Therefore many of these comments apply to CIA models as well.
monetary institutions because intervention (legal restrictions) on the part of the government is welfare-reducing. Specifically, agents who are left to their own devices will provide well-backed stores of value as a medium of exchange. No government intervention is required. In fact, State intervention in the form of forced usage of fiat money is argued to be welfare reducing.\textsuperscript{23}

In their "A Contribution to the Pure Theory of Money" (1991) paper, Kiyotaki and Wright illustrate the robustness of valued fiat currency equilibria by showing that even when rate of return dominated by other assets, fiat currency may still circulate in equilibrium. Thus under laissez-faire, fiat money does not vanish so long as it is believed to be the most liquid (or the most saleable) item of exchange. That fiat money should exist in such circumstances is due to the non-Walrasian market frictions in the STNCE world, and the public services yielded by money in coordinating market exchanges. Matters which are absent from Walrasian Overlapping Generations models. The STNCE literature shows that money does not need to be designated as legal tender or have a rate of return equal to other assets in the economy in order to exist. All that is required is that society believes that money will be the generally accepted medium of exchange.

This suggests that the same criticisms put forward by Frankel (1977) about Knapp's \textit{State Theory of Money}, may be applied to the legal restrictions explanation of fiat money's existence. Specifically, by viewing the State (and its imposed legal restrictions) as acting upon society from the outside, the new monetary economics fails to capture some of the important welfare effects of monetary instability caused by say, purchasing power uncertainty.

Now it must be said that in a world in which economic activity takes place over time and in which the future is uncertain, stores of value capable of insuring against unforeseen events are important, and money (even fiat money), along with other assets, can provide such insurance. Just as the Overlapping Generations models do not capture the richness of what occurs at a point in time in the friction laden markets where current

\textsuperscript{23}See Wallace (1988) or Sargent and Wallace (1982) for examples of such arguments.
goods and services are traded, the STNCE approach does not capture the richness of what happens over time. The STNCE framework, in its current state of development, is one in which goods do not appear in a stochastic manner, and which there are no real uncertainties about future consumption needs, and in which, therefore, there is no need to save. Thus, it should be understood that the medium of exchange and the store of value function (as well as the unit of account function) are complementary in the explanation of the existence money.

2.5 Conclusion

It is evident that the STNCE class of models represent an important advance in monetary theory. However, the implications of this class of models gain added importance when compared with older "Austrian" ideas on the origin of money. Their ability to formalize the ideas put forward by Menger, specifically that for money to exist as a medium of exchange it must be believed to be a medium of exchange, is striking. Their tractability also makes them useful when it comes to addressing such questions of current interest as the existence of the rate of return dominated money. Furthermore, their emphasis on money's medium of exchange function and their ability to show that fiat or commodity money exists simply because of belief held by agents, makes them a natural tool for further analysis of "Austrian" ideas about the evolution of money, and about the importance of price stability as a factor affecting its acceptability.
Chapter 3

Initial Public Offerings: An Overview

3.1 Introduction

Going public is one of the most important decisions a corporation will ever make. An initial public offering (IPO) not only provides a new source of funds for the corporation to put into growth enhancing projects, it also affects the nature of the corporation's governance and managerial structure. The IPO frequently comprises the largest equity issue a corporation will undertake. As well as raising funds for investment needs, an IPO is also an important channel through which initial owners, be it entrepreneurs or venture capitalists, get rewarded for their startup effort. It is therefore critical to understand what are the key factors affecting the corporation's decision to go public. An understanding of what affects the likelihood of going public is important in attempting to ease access to equity financing which may in turn stimulate entrepreneurial activities and economic growth.

What are the incentives to going public? Publicly traded stock has greater liquidity which allows the company to raise capital on more favourable terms than a privately held firm. It allows the initial owners to diversify their portfolio and allows for the possibility of equity financing beyond the initial entrepreneur’s limited wealth. Zingales (1985) shows that the IPO can also aid the owners of a company to maximize the proceeds from an eventual divestiture. The costs of going public consist of the one-time registration and underwriting costs, the annual disclosure costs, and the agency problems generated by separation between ownership and control.

Important factors affecting the decision process of a firm contemplating going public are the price at which the company goes public and the date it goes public. The
pricing of initial public offerings (IPOs) is difficult for two reasons. First, no observable past prices of the issue exist, and second, many issuing firms have a short operating history. The timing of the public offering is related to the pricing problem. Specifically, getting an offering price that allows the firm to fulfill its capital requirements may be easier in certain periods than in others. A firm's growth rate also tends to fluctuate over time, thus causing its capital requirements for growth projects to fluctuate. Similarly, leverage costs and/or costs due to a high concentration of credit sources (see Pagano, Panetta and Zingales (1995)) may also fluctuate, thus forcing the firm to seek outside financing.

This chapter seeks to offer an overview of the defining empirical characteristics of the Initial Public Offering (IPO) market as well as review some explanations put forward regarding the empirical anomalies associated with the pricing and the volume of IPOs. These anomalies can be summarized as (i) initial returns that are on average positive, the so-called “underpricing” phenomenon, (ii) long-run underperformance of IPO stock prices relative to non-issuing firms or market indices, and (iii) the even more unusual phenomena of observed cyclical patterns in the volume of new issues and the magnitudes of initial returns. The recurring periods in which the volume of IPOs and the degree of “underpricing” appear to be systematically larger than average are commonly referred to in the securities industry as “hot issues” market.

These three anomalies guide the structure of this overview.\(^1\) Section 3.2 provides a brief summary of the finance terminology used throughout this and the following chapters of the thesis concerned with initial public offerings. This section also offers a brief overview of some of the institutional structure behind the process of taking a company public. Section 3.3 reviews the empirical characteristics of the pricing of IPOs and provides a general overview of the existing theories explaining the pervasive positive initial returns observed for IPOs. This section also provides an overview of some of the

\(^1\)A detailed review of the empirical characteristics of the three IPO anomalies and a summary of the explanations put forward for these anomalies is presented in Ibbotson, Sindelar and Ritter (1994). Parts of this overview chapter rely on the information presented in this study.
major empirical characteristics of the IPO market. Section 3.4 provides an overview of
the documented evidence of long-run investment underperformance and “hot issues”
market. The evidence of long-run underperformance is consistent with the “windows of
opportunity” explanation of the cyclical fluctuations in IPO volume and returns which is
also outlined in this section. Section 3.5 summarises the “noise trader” model put
forward by De Long, Schleifer, Summers, and Waldmann (1990a) that underpins the
“windows of opportunity” hypothesis. Some concluding remarks are provided in Section
3.6.

3.2 Terminology and Institutional Characteristics

This section briefly defines some terminology prevalent in IPO studies and
summarise some of the regulatory aspects of issuing stock. In what follows, the term
firm, company and corporation will be used interchangeably. Though it is implicitly
assumed that the controlling ownership decides whether to go public or not, the firm will
often be referred to as making the decision. The firm is also the issuer of stock in the
initial public offering. An initial return is defined as the price change measured from the
offering price to the first traded (market) price observed divided by the offering price. As
the first traded price is not always available, the closing price at the end of the first day of
trading or, in certain circumstance, the closing price at the end of the week is often used
by researchers. The offer or offering price is the price at which investors may subscribe
to the new share issue. Underpricing occurs when the first traded price is higher than the
offering price. The term aftermarket is used to refer to the sequence of prices observed in
the secondary market once the issue starts trading. The secondary market is the term used
for the market in traded stocks (eg. the New York Stock Exchange). Seasoning refers to
the process by which a new issue gains a price history in the secondary market. Leaving
money on the table is the securities practitioner’s jargon to describe a situation in which a
stock issuer is not getting the highest price possible at the offering. Subscribing to a new
share issue means that investors must place orders with underwriters specifying the
number of shares they are willing to purchase at the offering price. A fully subscribed issue is one for which all the new shares have been allocated to investors. It is common for a new share issue to be oversubscribed. Here, investors do not receive all the shares demanded and rationing occurs.

New issues are made on either a firm commitment or best efforts basis. On a firm commitment basis, the underwriter acts as the principal and purchases the whole issue from the firm. He then seeks to resell the issue at a higher (offer) price to outside investors. In this case the underwriter bears the risk that the issue may not be fully subscribed due to setting the price too high. In a best efforts underwriting, the investment banker undertakes to sell the issue on an agency basis and gets a fee for the number of shares sold. Here the risk of not selling all the shares, and thus not raising the required capital at the offering, is borne by the issuing company. Ritter (1987) documents higher initial returns for the best efforts contracts. He shows that the results range from 36.1 percent initial returns for best efforts versus 19.6 percent for firm commitment offerings. It should be noted that the long-run stock price underperformance studies described later in this chapter utilised only firm commitment data to ascertain their findings. This implies that the anomalies associated with IPOs are robust to the type of offering contract.

To issue equity in the United States a firm has to file a prospectus with the Securities Exchange Commission (SEC) that complies with both the provisions of the Securities Act as well as state laws which regulate offerings of securities in that state. The prospectus is a document that discloses information regarding the issue offering price, the number of shares to be issued, and the use of the proceeds from the IPO. It also contains various financial statements and historic information about the firm's operation. The task of compiling the information required, and the filing of the requisite documents, is specialised and one usually beyond the capability of the officers of the firm. Further, even if the firm could accomplish the registration process itself, there is the additional step of marketing the shares. For these reasons an underwriter is employed. The

\[2\text{American securities regulation is relevant here since the data utilised in the empirical study in the following chapter is carried out with American data.}\]
underwriter not only facilitates the registration procedure, it also has the ability to market the securities directly to the investment community.

The *underwriter spread* or *underwriter fee* is the difference between the offer price and the price per share received by the company. This spread varies depending on size and risk of the issuing firm. For larger issues the percentage per share commission earned by the underwriter is in the 4 percent to 5 percent range, while for smaller issuers (firms that possess a higher risk that the issue will fail) it is between 7 percent and 9 percent.¹ American values are assumed to be similar.⁴ Empirical evidence indicates that this spread does not vary much over time and thus does not seem to be affected by "hot issues" market. However, the number of smaller (riskier) issues taken on by "prestigious" underwriters does vary over time.⁵ Specifically, there is an increase in the number of "low-quality issue" relative to the number of large issues brought forward by prestigious underwriters in "hot issue" markets (see Wolfe, Cooperman and Ferris (1994)). It is also common knowledge in the securities industry that the underwriters' profits increase as the volume of new issues increases.

### 3.3 The Empirical Characteristics of the IPO Market and the Positive Initial Returns Puzzle

The best known anomaly associated with the process of going public is that of large *initial returns* accruing to investors of common stock IPOs. Empirical academic studies of initial returns date back to Ibbotson (1975). Positive initial returns seem robust to the length of the initial return period and whether or not returns are market adjusted

---

¹These numbers are taken from the Canadian Securities textbook and represent the average Canadian values of the commissions earned on new issues.

⁴On average 14 percent of the funds raised, according to Ritter (1987), pay for registration and underwriting costs in the U.S.

⁵See Carter and Manaster (1990) on this issue.
(see Miller and Reilly (1987), and Barry and Jennings (1993) for example). Numerous studies, using data from the 1970s and 1980s, have confirmed the positive initial returns of new issues. Jog and Riding (1987) show that Canadian IPOs are on average underpriced by 9.3 percent while Ibbotson, Sindelar and Ritter (1994) indicate that American IPOs experience underpricing costs that average 15.3 percent. In fact, Loughran, Ritter and Rydqvist (1994) show that the positive initial returns exist in every nation with a stock market, although the magnitude of these positive initial returns varies from country to country. In what follows a brief description of the observed characteristics of the IPO market and a review of some the empirical and theoretical work concerned with the anomalous positive initial returns is presented.

3.3.1 Empirical Characteristics of the IPO Market

Most of the empirical findings collected to date can be succinctly summarized in Figures 1 and 2. Figures 1 and 2 present the monthly average initial returns and monthly number of firms going public in the United States over the period 1960 to 1993 inclusive.\(^6\) The extent of the positive initial returns is evident in the Figure 2.

During this period more than 11,000 companies have gone public in the U.S. This figure, which greatly exceeds the number of publicly traded companies that have withdrawn from the market because of bankruptcy, mergers or takeovers during this period, gives an indication of the dynamic nature of the U.S. economy. This supports the conventional wisdom that the U.S. has the most advanced capital market in the world. In addition to revealing the positive initial returns, Figures 1 and 2 confirm the existence of cycles in both the number of firms going public and the initial returns. As previously mentioned, the periods of above average IPO returns and volume are known as “hot issues” market periods.

\(^6\)The data for the figures comprise an updated data set used in Ibbotson, Sindelar and Ritter (1994) which was provided by Jay Ritter to this author.
The "hot issues" market phenomena was first documented in the academic literature by Ibbotson and Jaffe (1975). In this study, both the initial returns data and the volume data display significant serial correlation. Specifically, the first-order autocorrelation of the returns series is 0.65 while the autocorrelation measure for volume is 0.90. Therefore, the cycles in the IPO returns and volume allow one to "predict" next months' average initial returns and volume with a high degree of accuracy. As an example of what is meant by "predict," consider the autocorrelation measure of 0.90 for the volume data. This measure of predictability (or persistence) in the volume process implies that high-volume months are almost always followed by high-volume months. This predictability in the IPO initial returns data is not consistent with the efficient market hypothesis and is why the cyclical patterns are considered an anomaly. Markets are said
to be efficient if past price patterns of an asset are not able to "predict" the future price movement of the asset. Any departure from previous prices should be random. Statistically speaking, the serial correlation between successive price changes should be zero. Therefore, an asset that displays significant serial correlation in returns represents an anomaly since asset returns are assumed to behave according to the efficient market hypothesis.

Ibbotson, Sindelar and Ritter (1994) show that "smaller offerings" experience larger initial returns, on average, than larger offerings.\(^7\) This study reveals that, for a sample of 2,439 IPOs (between 1975-1984), firms with sales between $1,000,000 and $5,000,000 experienced initial returns of 14.3 percent, while firms with sales of $25,000,000 or higher experienced initial returns of 5.3 percent. This evidence is in concurrence with Pagano, Panetta and Zingales (1995) findings for Italy. They find that larger, older firms are more likely to go public than smaller, younger firms. They attribute this to the fact that larger firms are more able to absorb the offering costs, and that the asymmetric information costs borne by the older/larger firms are less severe.

Other stock issue characteristics have been documented which help to explain the different degrees of positive initial returns. As mentioned earlier, the type of underwriter contract also plays a role in the size of the initial returns. However, best efforts contracts are generally associated with smaller firms thus making it difficult to ascertain the importance of the underwriter contract for initial returns, without controlling for firm size in the offering. The "prestige" of the lead underwriter has been documented to have an inverse relationship with an IPO’s initial return. Logue (1973) found initial returns to be 52.1 percent for IPOs with less prestigious underwriters versus 20.8 percent for more prestigious underwriters. Similar results were found by Tinic (1988) (with a larger data set) of 14.27 percent versus 4.89 percent. Ritter (1984) documents that smaller firms are often represented by less prestigious underwriters. Therefore, variations in initial returns with prestige of the underwriter may be caused by the size of the firm rather than simply

\(^7\)Smaller offerings are defined by the amount of funds raised and/or by the offer price.
the prestige alone. In fact, age and size of a firm seem to be a good proxy for the availability of information regarding the firm's profitability and/or its survivorship (see Carter and Dark (1993) and Ritter (1991)). This result is not surprising since older firms are often larger firms. Muscarella and Vetsuypens (1987) find a significant negative relationship between initial returns and the age of the firm. Finally, the industry or sectoral characteristics may play a role in the degree that initial returns are positive. Ritter (1984), in analysing the very large degree of underpricing in 1980-81 (48.8 percent), found there was a predominance of oil and gas industry related new issues during that period. This suggests that firms in some sectors may experience different degrees of underpricing compared with other sectors.

3.3.2 Competing Theories Explaining the Observed Positive Initial Returns

Given that the aftermarket is efficient, with prices reflecting some measure of the fundamental value of the firm, why do issuers consent to leaving “money on the table?” While hardly a cause for complaint from investors, such underpricing might hurt emerging firms trying to raise capital. This enduring anomaly has therefore attracted numerous competing explanations over the years. Many of these explanations are not necessarily mutually exclusive. Since there are a large number of competing theories explaining why initial returns are positive, only a subset will be reviewed here. The explanations based on rigorous theoretical analyses of IPO underpricing that are included, though by far not a complete listing of those put forward, comprise what is viewed to be either the most adhered to explanations and/or the most consistent with the empirical evidence of positive initial returns. Prevalent in these explanations is the concept of asymmetric information. The asymmetries in information are either between two groups of investors (informed and uninformed) interested in investing in IPOs, between types of firms (good and bad) and investors, or between the issuer and the underwriting firm. The asymmetric information-based explanations of underpricing are segregated into three types of models, and are explained below. A brief summary of other explanations that do not rely on the presence of asymmetric information is also provided at the end of this
subsection.

**Winner's Curse**

Rock (1986) puts forward an *adverse selection* based hypothesis of underpricing referred to as the “winner’s curse” model. It assumes that when some fixed number of shares are sold at a fixed offering price rationing will often be the result. Investors are assumed to fall into two groups, informed (insiders) and uninformed (outsiders). Informed investors are assumed to know whether the offering price is a true reflection of the firms actual value. If the offering price is above the actual value of the firm and rationing occurs, then uninformed investors are faced with the winner’s curse: these investors get all the shares they demand in firms that are overpriced but are rationed when the issuing firm is underpriced. This creates a bias downwards for the uninformed investors’ returns. Therefore, to keep attracting as many investors as possible to the IPO market, the underwriters lower the average offering price of new issues to compensate the uninformed investors for the possibility of receiving overpriced shares. Rock’s model is extended by Beatty and Ritter (1986) where they show that the expected underpricing is an increasing function of the uncertainty about the market-clearing price of an IPO. Ritter (1984) extends Rock’s model to allow for time varying risk due to the uncertainty of the type of issuing firm. Specifically, Ritter looks at the composition of IPOs and whether fluctuations in the type of IPOs over time are able to account for “hot issues” markets. Ritter finds that the changing risk composition of IPOs is not a significant cause of the 1980-1981 “hot issues” IPO market.

**Signalling Models**

Leland and Pyle (1977) have proposed a model where the fraction of equity retained by initial shareholders (owners) serves as a signal of the firm’s expected future cash flows. Larger expected future cash flows are signalled by the larger fraction retained ownership. This signal is credible because the original owners sustain higher costs due to their less diversified portfolios. Consequently, this model is consistent with the prediction
that IPOs where original owners retain a larger percentage of the total equity after the IPO are less underpriced than IPOs where the original owners retain little ownership. This model is extended by Grinblatt and Hwang (1989). They assume that the information asymmetry between the investors and the original owners is more severe than in Leland and Pyle’s model. In Leland and Pyle, the investors know the variance of the firm’s future returns but do not know the expected value of these returns. Grinblatt and Hwang also assume that the investors lack information on the variance of the returns and thus one signal becomes inadequate in signalling the value of two variables. Grinblatt and Hwang overcome this problem by allowing the firm to use two signals, retained equity and underpricing of the IPO. In a related study, Jensen and Meckling (1976) present a moral hazard model that predicts that as the stake of the controlling shareholder is reduced, the incentive for him to extract private benefits will increase and therefore lower the firm’s value to secondary investors.

Jain and Kini (1994) present evidence that is consistent with these signalling models of underpricing. They show that, after an IPO, firms experience a significant decline in operating performance, but that this decline is smaller for firms where the original owners retain more equity. Pagano, Panetta, and Zingales (1995), with a sample of Italian IPOs, also find that profitability after the offering is significantly inversely related to the share of retained ownership for certain types of IPOs they categorise as carve-outs.

*Strategic Multi-Period Signalling Models*

In the winner’s curse type of model two types of investors were asymmetrically informed as to the true value of a firm going public, while in the Leland and Pyle signalling model it was simply assumed that investors were less informed than the owners about the true value of the firm. For the multi-period signalling models, as was the case for the winner’s curse models, there are two possible types of firms. However investors in the multi-period signalling models are equally uninformed about the type (e.g., good or bad) of the issuing firm at the offering. Three similar models have been put forward that
assume that the issuing firms choose to use a costly signal (a low offer price) in order to enhance the return from, for example, a secondary stock issuance that will take place some time in the future. Specifically, Allen and Faulhaber (1989) develop a model in which high (good) quality firms underprice their IPO to a greater extent than low quality firms so that investors interpret any future dividends received in a more favourable light. Imitating is costly for low quality firms as they are unlikely to experience high future cash flows and hence pay higher future dividends.

Welch (1989) proposes a model where IPO underpricing results in higher proceeds for high quality firms in the future sales of seasoned equity issues. In this model, as in the previous model, high quality firms underprice to obtain a higher price in a future seasoned offering. This underpricing signal is assumed to be sufficiently costly to deter imitation by the low quality firm.

Using a rational expectations framework, Chemmanur (1993) puts forward a model where a good firm's original owners underprice more than a bad firm in order to induce outside investors to gather information about the firm, reducing the informational asymmetry between investors and owners at some future seasoned offering, thus increasing the firm's seasoned offering price. Again, the bad firm finds it costly to imitate these actions.

In summary, these models show that issuing firms of high quality signal that they are of high quality by underpricing their IPOs to obtain a favourable price when they put out a secondary issue at some point in the future. Firms of low quality cannot afford to imitate this underpricing and thus the level of underpricing should predict the likelihood of future seasoned equity offerings by the IPO firms.

The empirical evidence supporting these explanations is very weak. The multiperiod signalling explanations predict that IPOs that underprice more than others should exhibit better long-run investment returns as the true quality of the firm becomes evident over time. However empirical evidence of long-run underperformance presented in Section 3.4 shows that this is not the case (see also Jain and Kini (1994)).
Other Explanations

An informal explanation of the first anomaly, based on an industry wide "folklore," is one in which the underwriters underprice the IPO relative to its actual value in order to ingratiate themselves with their favoured clientele in hope of continuing to be their clients preferred agent in the future. The underwriters take advantage of their superior knowledge of market conditions (relative to the issuer's market knowledge) to underprice the offering (thus lower the firm's receipts from the offering). While there may be some truth to this argument, Muscarella and Vetsuypens (1989) find that when underwriting firms go public they tend to display positive initial returns and these returns are as large as the returns for other types of IPOs; this is contrary to the explanation that the underwriters take advantage of the superior knowledge of the market relative to the issuing firm. This argument does not resolve the puzzle of the observed cycles in volume of IPOs.

Tinic (1988) has developed a hypothesis that underpricing is a form of insurance against legal liability and reputational damage for underwriters. Underwriters are required to exercise "due diligence" in their investigation of a firm before they bring an IPO to the market. Poor performance of a new issue could result in lawsuits by investors who purchase the new issue, on the grounds that insufficient information was disclosed or the underwriter failed to conduct due diligence. As a result, the underwriter has an incentive to underprice IPOs to avoid such problems.

Ruud (1993) also looks into the regulatory aspect of the IPO and finds that underwriters can and do intervene to support IPO prices early in the aftermarket. She finds that the effect of such intervention is to reduce the number of negative initial returns from what would otherwise be observed. This results in censoring of the negative tail of the distribution of initial returns, which in turn produces a positive mean initial return, even when the offering price is set at the true expected market value.  

Ruud notes that underwriters legally can and do take actions to support IPO prices. She cites that the Securities Act's rule 10b-7 makes this legal. To give an idea of how often this occurs, Rudd states that 57 percent of all underwritten NYSE-listed new issues between January 1, 1975 and March 1, 1977 were stabilized under the 10b-7 rules. It should also be noted that the
Welch (1992) introduces a sequential sales model of IPOs in which potential investors in an IPO not only pay attention to their own information about a new issue, but also to the past purchasing pattern of the other investors for this issue. In this environment, investors can potentially disregard their own private information in favour of the information they derive from observing how well the offering has sold to date. Welch shows that even when investors hold perfectly accurate information about the firm's value in aggregate, it may be the case that underpriced offerings fail while overpriced offerings succeed. Welch therefore formalizes an information cascade effect that induces a herding behaviour among the IPO investors.

3.4 Long-run Underperformance and “Hot Issues” Markets

This section reviews some of the empirical literature documenting long-run investment underperformance as well as some of the explanations put forward for the IPO “hot issues” market phenomena. As will soon be apparent, the evidence of long-run underperformance of IPO shares is consistent with the hypotheses put forward for the “hot issues” market phenomena. In fact, explanations put forward for the underperformance puzzle are directly related to, or are very similar to, explanations of the “hot issues” market anomaly. What should also be noted is that because most of the explanations of positive initial returns put forward above assume that the aftermarket prices are “efficient,” they are not able to explain the empirical evidence of long-run underperformance. If the aftermarket prices of IPO shares are set at the true expected market value, then their efficient market performance, measured by their market-adjusted returns, should not vary. However, findings of long-run underperformance for the IPO market-adjusted returns contradicts this. With this evidence, one is led to the conclusion that the early aftermarket price of the IPO is actually overpriced relative to its fundamental value.

______________________________

highest support price is the offering price under these regulations.
Studies by Dark and Carter (1993), Ritter (1991) and Loughran and Ritter (1995) present evidence of long-run investment underperformance. Jain and Kini (1994), with a sample of 682 IPOs between 1976 and 1988, document the long-run operating underperformance of IPO firms. Dark and Carter, and Ritter find evidence that firms that go public during "hot issues" markets experience poorer long-run performance than firms that go public in low volume periods. Dark and Carter show that firms characterised by low levels of available information, for which the firm's age is a proxy, are more likely to underperform in the long-run. Related to this, Ritter (1991) finds that the long-run investment performance is negatively related to the size of issue which is asserted to be a measure of the firm's publicly available information level. Dark and Carter also find that the firm's long-run performance is negatively related to prestige of their underwriter.

To understand what is meant by long-run underperformance, some stylized facts derived from Loughran and Ritter (1995) are presented. They document evidence showing that an initial investment in an IPO at its offering price would on average have to be 30 percent larger than an initial investment in a similar non-issuing or seasoned firm to achieve the same terminal wealth (due to capital gains) after five years. Specifically, the empirical findings can be succinctly summarized by the following example (using their empirical results). What is the required investment in an IPO to achieve the same terminal wealth at the end of five years as a $10 investment in a matched seasoned firm? With an average return for the matched seasoned firms of 66.4 percent after five years, a $10 investment in the seasoned firm would grow to $16.64. Since the average five-year return for an IPO (when buying at the first-day closing price) is merely 15.7 percent, it would take an investment of $14.38 to achieve the same terminal wealth of $16.64. This

---


10Loughran and Ritter (1995) matched the characteristics of the seasoned firm, such as its market capitalisation size, with the characteristics of the firm going public.
implies that an investor buying at the first closing market price would need to invest 43.8 percent more money in the IPO rather than buying shares of the seasoned firm of the same size. Moreover, those fortunate enough to have purchased an IPO at the offering price require only an extra 30 percent more money invested in an IPO to achieve the same terminal wealth [as a $10 investment in a matched seasoned firm]. With a 10 percent average initial return, the price of the IPO moves from $13 to $14.38 immediately after issuing, which then increases to $16.64 after five years given the 15.7 percent average return. However the $13 initial investment at the offering is still 30 percent higher than the $10 investment in the seasoned firms that produces $16.64 in terminal wealth.\footnote{Similar findings are revealed for the 3-year investment time frame.} Loughran and Ritter (1995), Ritter (1991), and Dark and Carter (1993) posit that IPO shares are overpriced early in the aftermarket which in turn allows for the possibility that the offering price is actually at or above the true expected market value.

What is interesting is that there is very little work done, empirical or theoretical, on the “hot issues” market anomaly. As pointed out, much of the research on IPOs is concerned with explaining the underpricing puzzle. However, the above asymmetric information models tend to be static models intent on solving the pricing puzzle. Any dynamics found in the models simply formalizes the idea that the investors learn about the firm’s intrinsic value over time. Furthermore, each theory of underpricing implicitly or explicitly assumes that a deliberate decision is made by the issuer or the underwriter to set the price below the expected market value. Specifically, one can classify theories that assume the existence of asymmetric information among IPO participants, such as Rock (1986), Leland and Pyle (1977), Tinic (1988), and Chemmanur (1993) to name a few, as deliberate underpricing (or strategic underpricing) theories explaining the positive initial returns puzzle. However, the recently documented evidence of anomalous long-run IPO stock underperformance gives credence to explanations that attribute the observed positive initial returns to market overpricing of IPO stocks rather than deliberate underpricing on the part of the firm.
As an example of work on "hot issues" markets, Ritter (1984) looks into the mean return on IPOs during a 6-year period (1977-82) and categorises a 15-month period, starting in January 1980, as a "hot issues" market based on the exceedingly high mean initial return for IPOs of 48.4 percent as compared with a mean return of 16.3 percent for the remainder of the period. Ritter presents some rudimentary time series analysis depicting how hot markets come and go over the years. He concludes that underpricing results from a form of monopsony power held by the underwriters of IPOs. Ritter finds that the offering prices were set "too low" relative to the market valuation of other securities. Ritter argues that this is an indication of monopsony power because the IPOs for this "hot issues" market were concentrated in one region and one industry, and because small underwriting firms exploited the small issuing firms coming to market for the first time. Ritter rejects the hypothesis of a speculative bubble driving the "hot issues" markets since he does not find the indicative "bubble bursting" sharp drop in the aftermarket price of IPOs after the hot market period.

The only other empirical study that specifically looks into the "hot issues" market phenomena is Ibbotson and Jaffe (1975). As previously mentioned, Ibbotson and Jaffe (1975) were the first to document "hot issues" markets in the academic literature. They examine the serial dependency of initial returns and find that "hot issues" markets are serially correlated stationary processes and thus predictable. Though Ibbotson and Jaffe find that initial returns are predictable, they conclude that no relation between the aftermarket performance and the long-run returns exists. This result has, as presented above, been recently reversed. Ibbotson's and Jaffe's, and Ritter's (1984) finding of efficient pricing in the initial aftermarket helped discourage any research that entertains the possibility that the aftermarket valuation of IPO shares was anything but efficient. However, the recent evidence of long-run underperformance is in fact consistent with the hypothesis that IPOs have poor subsequent (market adjusted) returns due to overpricing that occurs early in the aftermarket. To the extent that this is correct, IPOs may not be underpriced after all. Instead, the initial aftermarket share valuation for IPO firms may actually be overpriced, particularly during "hot issues" market periods. Moreover, if
there are periods when investors are especially optimistic about the growth potential of firms going public, thus causing them to be overvalued in the initial aftermarket, then the large cycles in IPO volume may be a response by firms attempting to take advantage of a "window of opportunity."

This "windows of opportunity" hypothesis is the most empirically consistent explanation of the "hot issues" market phenomena. The finding that long-run underperformance is negatively related to new-issue volume is consistent with the hypothesis that firms take advantage of windows of opportunity during which investors are willing to overpay for IPOs. It is also consistent with the evidence presented in Lerner (1994). Lerner tracks all the financing of the biotechnology industry in the United States during January 1978 to September 1992, using information on both private and public sources of capital. Lerner finds that IPO activity is highly related to the price that public investors are willing to pay, with much of the IPO activity substituting for additional venture capital financing. In other words, Lerner finds that biotechnology companies go public near the peak of biotech equity valuations. Similarly, Pagano, Panetta and Zingales (1995) find that the market-to-book value of equity of public companies in the same industry as the private firm has a significant positive effect on the probability that this firm goes public. However, underpinning the "windows of opportunity" hypothesis is the assumption that investors overprice assets in certain periods and that the level of overpricing is stochastic. This is the subject of the next section.

3.5 The Noise Trader Model

There has been a recent increase in theoretical work based on the premise that the asset's price is not necessarily driven by the asset's fundamentals. Of interest here is the "noise trader" model of asset price formation put forward in a series of papers by De Long, Schleifer, Summers and Waldmann (1989, 1990a, 1990b). This model can be described as an alternative to the efficient market paradigm; the model relies on the idea that the efficient market hypothesis is simply the limiting case of finite time arbitrage and
is unlikely to apply in practice. Specifically, this concept assumes that some investor expectations are not fully rational and that these beliefs, which may not necessarily be based on fundamentals, have an effect on their demands for risky assets. Furthermore, market opportunities are such that arbitrage is risky and therefore limited. For example, De Long, Schleifer, Summers and Waldmann (1990a) develop a model where stocks, because of their subjection to investor sentiment, must have equilibrium returns higher than warranted by their fundamentals.\(^\text{12}\) This is due to the fact that arbitrageurs cannot completely counter the shifts in demand prompted by changes in investor sentiment. Specifically, they develop a model in which the price of a risky asset is driven by the uninformed segment of the population with stochastically varying beliefs about the asset's expected value (price) and by the fact that informed investors (arbitrageurs) must take into account the near future resale price of the asset since they are required to liquidate within some finite time frame. They find that the risky asset's price is dependent on the uninformed investor sentiment and thus may not be solely driven by fundamentals.

To further elaborate, De Long et al. (1990a) present an overlapping generations model with two groups of investors: “noise traders” and “sophisticated traders” (or fundamentals-based traders). In each period the noise traders price the asset at its true fundamental value plus an error term. Such incorrect pricing generates additional risk in holding the asset. This risk limits the willingness of the sophisticated traders to go against the noise traders, even if these traders know the true value of the asset. Because of this and the assumed limited life span of the traders, sophisticated traders do not completely drive the asset’s price toward its fundamental value. In addition, the noise traders earn higher average returns than the sophisticated traders due to the risk generated by the noise traders.

An important implication of the “noise trader” model is that as investors become

\(^\text{12}\)Shiller (1990) suggests that investors are driven by fads for certain types of investments. The idea that investors periodically invest in certain types of firms or investment vehicles because it is the current “in thing” is very similar to the noise trader model’s investor sentiment fluctuations. DeBondt and Thaler (1985) suggest that a stock price may temporarily deviate from its fundamental value due to overoptimism (or overpessimism) on the part of investors.
optimistic about the expected returns of the security in certain periods, the price, relative to the fundamental, is driven up. At other times, noise traders may be pessimistic about the returns on these securities thus driving down their prices. These overreactions by investors are more likely to occur for assets with less public information available about their underlying value, as well as for assets that are predominately held by unsophisticated “noise traders.” Another implication derived from this model is that investor sentiment risk is systematic and thus will affect a wide range of securities in which the noise trader is the predominant trader.

The main criticism of the noise trader model is that it does not produce any testable implications. However, Lee, Schleifer and Thaler (1991) empirically test several derived implications of the noise trader model for closed-end funds. Their empirical findings are consistent with the prediction of the noise trader theory of closed-end funds. Specifically, this theory predicts that discounts on closed-end funds will vary together since the discounts reflect the market wide variance in noise trader investor sentiment. It also predicts that new funds will emerge when investors are optimistic about funds, which in turn is when old (seasoned) funds trade at or near a premium. Finally, a third prediction is that fluctuations in the discounts on closed-end funds reflect the investor sentiment factor that is also present in other assets in which noise traders predominate. All these predictions are confirmed in the empirical work of Lee, Schleifer and Thaler (1991).

Another criticism of the noise trader model is that the exogenously fluctuating noise trader sentiment or beliefs do not have any economic interpretation. These exogenous fluctuations are just too “black box” for mainstream economists to swallow. However there is a growing literature that, at the microeconomic level, is able to account for such seemingly exogenous fluctuations in investor sentiment. An excellent example of this type of micro-based model is that put forward by Morris (1995). In his model speculative premia occur because agents hold heterogeneous beliefs about the true value of

---

13 Morris' model adds learning to the overlooked Harris and Kreps (1978) model of speculative pricing due to heterogeneous beliefs.
the risky asset in an information scarce environment such as an initial public equity offering. Morris shows that as investors learn about the true value of the firm, the speculative premia converges to zero over time. Bikhchandani, Hershleifer and Welch (1992) show that an information cascade occurs where it is optimal for individuals, after observing the actions of previous agents, to ignore their own information and mimic the decisions of their predecessors. Informational cascades produce uniform actions by a large number of rational agents who possess disparate and conflicting private information. They are likely to be most evident in a sequential trading environment in which individuals have limited private information. This class of model shows that when individuals base their decisions on private information and observations of their predecessors’ behaviour information cascades develop with virtual certainty. Kurz (1992) develops a model in which assets are mis-priced relative to their fundamental value because of the heterogeneous beliefs of rational economic agents reacting to the same piece of information. Kurz introduces the notion of rational beliefs defined as the “probability beliefs about future economic variables that cannot be contradicted by the data generated by the economy.” Consequently, it is possible that two rational economic agents who receive the same piece of information, will hold totally different views about its likely impact on asset prices. These are a few examples of a growing literature that seeks to formalise seemingly exogenous (irrational) behaviour on the part of the investing agents.\textsuperscript{14}

3.6 Conclusion

A summary of the various IPO characteristics and the explanations of the IPO anomalies reviewed is now in order. Recall that the IPO market has three anomalies

\textsuperscript{14}The following is a summary of other models of interest. Grossman (1988), Bulow and Klemperer (1994), Caplin and Leahy (1994), and Romer (1993) put forward models that contend that the dispersion of asymmetric information between investors, the trading process itself and the frictions involved in aggregating information over time across the investor community, play an important part in the perceived speculative behaviour and mis-pricing of assets in general.
associated with it. First, initial returns that average 10-15%, second, cycles in both the volume of new issues and the magnitude of initial returns, and third, long-run underperformance. Recall that most of the studies concerned with IPOs delved into the first of the anomalies. This is due to the implicit assumption found in all these studies that the early aftermarket price is set at the efficient market value. From there, these studies attempt to explain the observed positive initial returns as occurring because firms are deliberately “underpricing” their offerings relative to the initial aftermarket price. Though these models have had some success in explaining the positive returns, they are unfortunately unable to explain the cyclical properties of the IPO data better known as the “hot issues” market phenomena.

Recent evidence of long-run investment performance, which contradicts early findings of market efficiency, reveals that IPOs may not be underpriced but in fact overpriced, particularly during “hot issues” markets. From this, an explanation of the cyclical characteristics of the IPO data is presented that is consistent with recent empirical findings. This “windows of opportunity” explanation asserts that if there are periods in which stocks are overpriced, as suggested by DeLong et al. (1990a), firms that realize that other firms are overvalued have an incentive to go public. Excluding Chapter 4 of this thesis, little work has been carried out to test empirically this hypothesis.
Chapter 4

An Empirical Analysis of the IPO Cyclical Puzzle: A Dynamic Regime Switching Approach

4.1 Introduction

Why do firms decide to go public? This question is one of the most important but least studied in corporate finance. Finance text books provide few remarks on the motivation (and timing) of the firm's decision to go public. Most describe the regulatory or institutional underpinnings of the public equity offering process. The absence of active research in this area of corporate finance is remarkable considering the fact that, in any year, approximately one third of the capital requirement raised by way of common equity in the US are raised through initial public offerings (IPOs) and that an IPO is usually the largest equity issue that a firm will ever make. The standard convention is that the decision to go public is simply a stage in the growth process of the firm. Although this may be part of the story, this "theory" by itself seems ill equipped to explain the observed pattern of IPOs. First, it ignores the fact that there is a considerable number of large firms that remain private in the US, which arguably has the most advanced capital market in the world. Second, IPOs are an important channel for entrepreneurs and venture capitalists to receive the rewards for their efforts in producing a viable and growing company. Related to this, the increased number of reverse leveraged buy-outs and equity "carve-outs" over the last decade is evidence that growth is not the only motive for a firm's owners to go public.\(^1\) Finally, it also ignores the fact that there is an observed cyclical pattern in the

\(^1\)Zingales (1995) presents a model of a firm going public as a maximizing decisions made by the original owners who seek to eventually divest themselves of the entire firm. These owners use the IPO as a strategic tool to maximize the rents that can be extract from future purchasers of
magnitude of first-day returns and the number of firms going public that is difficult to reconcile with this "theory."

The observed cyclical pattern in the aggregate dynamics of the IPO market, the focus of this chapter, is commonly referred to as the "hot issues" market phenomena in the financial community. This pattern is puzzling for several reasons. Though one would expect some variation through time in the volume of firms going public due to the business cycle (if conventional wisdom holds true), the large amplitude of the observed cycles in IPO volume seems difficult to explain as the result of normal business cycle activity. This seems to be a fair statement when also taking into consideration the observed low correlation between output growth and the monthly volume of firms.\(^2\) The cyclical pattern in the magnitude of initial returns also seems at odds with the "stage of growth" theory of going public. Not only does the conventional explanation of a firm's decision to go public fail to explain the consistently positive initial returns gained by investors who purchase shares in the IPO at the offering, it is even less able to explain the cyclical changes in magnitude of initial returns.\(^3\) This begs the question, what is at the root of the "hot issues" market phenomena?

As detailed in Chapter 3, the majority of the models concerned with the IPO process emphasize the costs of the so-called "underpricing" phenomena that arise due to adverse selection associated with the decision to go public in an environment of asymmetric information.\(^4\) These models of deliberate "underpricing," however, do not

\(^2\)Note that in certain periods, the number of firms going public in the U.S. is more than double the average level while the correlation coefficient between monthly industrial output growth and monthly IPO volume is 0.153.

\(^3\)There is a large body of literature documenting the positive initial returns of IPOs. For a sample of the work documenting positive initial returns that average between 10% to 15% see Chapter 3 of this thesis.

\(^4\)See for example, Rock's (1986) "winner's curse" explanation in which the asymmetric information causes an "adverse selection" problem for which underpricing of the IPO helps to counteract. Other recent theories suggest underpricing signals firm quality (see Allen and Faulhaber (1989), Welch (1989) and Chemmanur (1993)). Recent models have moved away from
directly consider the motivation behind the decision to go public nor are they stochastic in nature. Thus, they ignore any possible time variation in the tradeoffs between the costs and benefits of going public. The goal of this chapter to provide an ex-post characterisation of the statistical properties of the IPO initial returns and volume series that could be useful in directing attention to a class of theoretical models that take into consideration possible fluctuations in the offsetting costs and benefits of going public that may affect the firms’ decision. This is carried out by establishing an accurate statistical model of the dynamic properties of IPO initial returns and volume processes.

An informal explanation that is consistent with the cyclical pattern of IPO markets is the so-called “window of opportunity” hypothesis. This informal explanation relies on a form of investor speculation. Specifically, it assumes that investors undergo periods (or regimes) of overenthusiasm for firms in certain sectors or industries. Subsequently, the stocks in these sectors become overpriced, as suggested by the “noise trader” model presented in De Long, Schleifer, summer, and Waldmann (1990a) paper. Companies take advantage of the overvaluation of stocks in their related sector and decide to go public during this period of investor overenthusiasm. This explanation implies that the cyclical fluctuations in the number of firms going public may be better viewed as fluctuations arising from unobservable stochastic regime changes in investor sentiment. Specifically, one should observe shifts in regime in the IPO volume process as firms take advantage of the shifts in investor sentiment as revealed by the seasoned price of similar firms or by recent IPO initial returns. Similarly, under the assumption that shares are rationed at the offering, one should observe shifts in regimes for IPO initial returns as investor demand for these IPO shares shift. In other words, the “window of opportunity” hypothesis is consistent with IPC time series data that displays evidence of distinct regime changes.

---

focussing solely on the underpricing issues (see Zingales (1995) and Pagano (1993) for example). However, these models also do not consider the dynamics of the IPO market and the “hot issues” market phenomena.

5The informal hypothesis is consistent with the documents long-run investment underperformance for IPOs (Ritter (1991) and Loughran and Ritter (1995)) and the clustering of IPOs near sectoral stock price peaks (Lerner (1994)).
Therefore, a goal of this chapter is to provide a statistical description of the time path of IPO initial returns and volume that allows for stochastic, regime dependent means and variances. Within this framework, it is then possible to test for the presence of regime switching that is consistent with the "windows of opportunity" hypothesis.

Hamilton's (1989) Markov-switching technique for modelling non-stationary time series is applied to ascertain the best statistical description of the IPO initial returns and volume. The Hamilton approach, where parameters are viewed as the outcome of a discrete-state Markov process, seems particularly well suited for the analysis of non-stationary time series. The advantage of utilizing the Markov-switching approach to modelling time series processes is that it allows for a richer set of qualitative descriptions of a series. In summarising the properties of the series, the Markov-switching technique describes, when and how regimes change, as well as the number of switches between regimes. In other words, modelling the IPO data as a Markov-switching process allows the revelation of certain dynamic patterns in the data that go beyond simple, well documented stylised facts such as the observed first-order autocorrelation measures of the series.

Previous papers that have estimated Markov-switching models for financial time series data have faced the problem of testing the null hypothesis of no switching against the alternative hypothesis of switching. This problem is overcome in this work by applying a battery of tests assessing whether or not the evidence of switching is statistically significant.

By identifying which "economic" factors may be important (in a dynamic setting) for a firm's decision to go public this empirical study hopes to give some direction to

---

*There is a growing literature utilizing the Hamilton approach to examine stock market returns and/or their fundamentals such as stock dividends. Cecchetti, Lam and Mark (1990) fit a stochastic switching model to a hundred years of data on dividends paid on US stocks. They find that in typical years the growth in dividends will be slightly above the inflation rate with the process lapsing into a few episodes with negative growth rates. Examples of Hamilton's approach to stock market returns include a paper by Schwert (1989) which allows the market returns to have a discretely switching variance and van Norden and Schaller (1993) who put forward a Markov-switching model in which the mean, the variance or both may differ between regimes. See also Sola and Timmerman (1993) and Hamilton and Susmel (1995).*
future research on the IPO "hot issues" market phenomena. This issue is approached in
two ways. First, regressors are added to the "standard" autoregressive switching
framework to test whether or not IPO initial returns and volume levels are explained with
the use of certain economic variables even after accounting for the switching behaviour.
Second, this study examines whether or not the endogenously dated shifts in regime are
significantly affected by these same economic variables. This second approach is
interested in finding out if the timing of the regimes is explained by observable economic
factors.

This study finds that IPO initial returns and volume can be characterised as drawn
from distinct autoregressive regimes that vary in mean and variance. This work also finds
that after controlling for switching, there is little evidence that IPO volume and initial
returns processes can be explained using "economic" variables. However, results indicate
that the stock market index or the growth rate of the index affects the timing of regime
changes in IPO initial returns and volume.

Because an assumption underpinning the "windows of opportunity" hypothesis is
that stocks become overvalued, testing whether there is empirical support for this
assertion is important. How stocks become mis-priced relative to their fundamental value
is a puzzle for which De Long et al. (1990a) have provided an explanation. A test of the
"noise trader" model put forward by De Long et al. is carried out by extending
Hamilton's approach to a vector setup. The results weakly support the "noise trader"
model's predictions and in turn supports the "windows of opportunity" explanation of the
"hot issues" market phenomena.

The chapter proceeds as follow. In Section 4.2, a brief description of the data is
presented. Section 4.3 introduces and presents the statistical methodology used to
characterize the IPO data. In Section 4.4, sensitivity analysis is conducted to test whether
or not the IPO initial returns and volume can be modelled by a switching process. Tests
are carried out on various specifications of the number of regimes and the general
robustness of the results are explored. Section 4.5 discusses the results for the chosen
switching models while Section 4.6 examines whether IPO initial returns and volume are
related to "economic" factors after accounting for Markov-switching. Also in Section 4.6, a linear probability model is employed to ascertain whether or not the timing of the regime changes can be explained by other economic variables. In Section 4.7, Hamilton's approach is extended to a vector setup in order to test the implication derived from De Long, Schleifer, Summers, and Waldmann "noise trader" model. Section 4.8 provides some concluding remarks.

4.2 Sample Description and Data Sources

The data used in this chapter are monthly observations of initial returns and volume of United States IPOs over the period 1960 through December 1993 (for a total of 408 observations). The monthly average initial returns were calculated by taking the non-weighted average of the initial returns\(^7\) (in percentages) of all offerings for the month. The monthly volume of IPOs simply represents the total number of IPOs for each month.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{IPO_Volume}
\caption{IPO Volume}
\end{figure}

\(^{7}\)Initial returns are measured by taking the difference between the offering price and the end of the first day of trading closing price (then dividing by the offering price and multiplying by 100 to get a percentage).
As well as revealing the extent of positive initial returns, Figures 1 and 2 show the presence of cycles in both the initial returns and the volume of IPOs. The persistence of positive initial returns shows no sign of abating; with the average initial returns for the 1960 to 1990 of 15.2% followed by the early 1990s showing average initial returns of 10.9%. Higher volatility in the 1960-1984 average initial returns data is the result of the exclusion of best-efforts IPOs from the sample after 1984. In other words, the data set is measured differently after the 1984. This break in how IPO returns are sampled implies that these initial returns observations may not necessarily be drawn from the same data generating process after 1984 as it was before 1984.

Periods of above average levels of initial returns are followed by, with an approximate 6 to 12 month lag high-volume periods. These periods of above average IPO initial returns and IPO activity are commonly referred to as “hot issues” markets.

The first-order correlations of the volume and initial returns data are 0.89 and 0.61, respectively. The measured persistence in the volume data suggests that there is a

---

There are two ways initial public offerings can be carried out. In a firm commitment offering, the underwriter bears all the risk of selling the offering to the public. The risk that the underwriter bears is that of not being able to resell all shares of the issue to the public. In a best efforts offering, the underwriter acts as the agent in the offering process. Here the firm bears the risk that the issue may not be fully subscribed due to setting the price too high. No information on what proportion of best efforts offerings comprise the whole of the IPO market after 1984 was ascertained. However Smith (1986) reports that 35 percent of IPOs from 1977 to 1982 are sold with best efforts contracts, although they represent only 13 percent of gross proceeds.
strong likelihood that a high-volume month will be followed by another high-volume month thus it is in this sense that the earlier studies termed the IPO initial returns and volume processes as "predictable".

The data set, originally presented in Ibbotson, Sindelar and Ritter (1994), was updated by the authors and supplied to this author by Jay Ritter. A more detailed description of the sample properties of the data set, as well as an overview of the IPO market anomalies, is provided in Ibbotson, Sindelar and Ritter (1994).

4.3 The Statistical Model and Estimation Method

To extract information from these data, an econometric method developed by Hamilton (1989) is utilized. The Hamilton algorithm is best suited for estimation of empirical models in which there is an unobservable state variable which takes on values from a small set of discrete values. Hamilton’s algorithm is similar to the switching-regression maximum likelihood method introduced by Goldfeld and Quandt (1972) applied to a situation in which the discrete regime variable follows a Markov process. It must be emphasised that unlike traditional methods, the Hamilton approach does not assume that all states are permanent. The estimation procedure produces an estimate of the transition matrix for the Markov process. From the transition probabilities, one can infer the frequency of switches between states. Estimates of the probability that the regime is in either of the states are also obtained. These are called the filter probabilities. These estimates allow one to contrast estimated regime changes in IPO initial returns and volume data to known (or theorised) periods of “hot issues” markets.

The Markov-switching specification that is examined is one in which the serially correlated IPO initial returns and volume data are drawn from distinct data generating processes that differ in means, variances and possibly the autoregressive parameters.

An autoregressive specification of order one is used to describe the monthly IPO initial returns and volume data series, $y_t$. 

\[ y_t - \mu(S_t) = \phi[y_{t-1} - \mu(S_{t-1})] + \sigma(S_t) \epsilon_t \]  \hspace{1cm} (1)

\[ \text{where the mean } \mu \text{ and the standard deviation } \sigma \text{ of the process depend on the regime at time } t, \text{ indexed by } S_t, \text{ a discrete valued variable, and } \{ \epsilon_t \} \text{ is a sequence of i.i.d. N}(0, 1) \text{ random variables. As described above, } y_t, \text{ representing either the IPO initial returns series or the IPO volume series, has an observed cyclical pattern. } S_t \text{ in the statistical model (1), represents the unobservable stochastic process driving the swings in the IPO processes. In some specifications of (1), } \phi \text{ will also be state-dependent with } \phi = \phi(S_t). \]

To make the model (1) tractable, the econometrician must specify a stochastic process for the variable \( S_t \). Hamilton (1989, 1994) models \( S_t \) as the outcome of an unobserved discrete-time, discrete-state Markov process with \( S_t \in \{0, 1, 2, \ldots, k\} \). This is the assumption used here as well. For a two-state specification of the first-order Markov (k=2) process, the transition probability matrix is specified as:

\[ P = \begin{bmatrix} p & 1-p \\ 1-q & q \end{bmatrix} \]

where \( p = \Pr[S_t = 0 \mid S_{t-1} = 0] \) and \( q = \Pr[S_t = 1 \mid S_{t-1} = 1] \).

The state dependent means and variances of \( y_t \) are specified linearly as:

\[ \mu(S_t) = \alpha_0 + \alpha_1 S_t \]

\[ \sigma(S_t) = \omega_0 + \omega_1 S_t \]  \hspace{1cm} (2)

The choice of the number of regimes for \( S_t \) and the specification of the state dependent parameters will be based upon a series of tests calculated in Section 4.4. When the sequence of states from time 1 to \( T \) is known, one can write the joint conditional log-likelihood function of the time series \( y_t \) as:
\[
\log f(y_1, \ldots, y_T | S_1, S_{T-1}, \ldots, S_1, y_1) = -\frac{1}{2} \ln 2\pi - \sum_{t=1}^{T} \left\{ \ln \sigma(S_t) + \frac{[y_t - \mu(S_t) - \Phi(y_{t+1} - \mu(S_{t+1}))]^2}{2\sigma(S_t)^2} \right\}
\]

(3)

with \(\mu(S_t)\) and \(\sigma(S_t)\) given in equation (2). Since one does not observe the state (indicator) variable \(S_t\), but only \(y_t\) from time 1 to \(T\), Hamilton introduces an algorithm that calculates the optimal inference about the current state based on the history of the observed values for \(y_t\). This recursive algorithm gives as by-product the conditional likelihood function for the sequence of \(y_t\)'s:

\[
f(y_T, \ldots, y_2, y_1) = \prod_{t=2}^{T} f(y_t | y_{t-1}, y_{t-2}, \ldots, y_1)
\]

(4)

from which estimates of the parameters \(\alpha, \phi, \omega, p,\) and \(q\) can be calculated by way of a maximum likelihood. In constructing the first observations, the procedure uses the limiting unconditional probabilities for each state to start the algorithm. The unconditional probability for the first state is given by:

\[
\pi_0 = \frac{1-q}{2-p-q}.
\]

As a by-product of the algorithm, one also obtains a sequence of joint conditional probabilities \(p(S_t=i, S_{t-1}=j | y_t, y_{t-1}, \ldots, y_1)\), which are the probabilities that the series is in state \(i, j\) (i.e., \(i = 0, 1\)) at times \(t\) and \(t-1\) respectively, conditional upon the information available at time \(t\). By summing these joint probabilities, one can obtain the so-called filter probabilities, \(p(S_t=i | y_t, y_{t-1}, \ldots, y_1)\), which are the probabilities of being in state 0 or 1 at time \(t\), given the information available at time \(t\). The filter probabilities provide information about the regime in which the series is most likely to be at every point in the sample. Two-sided filter probabilities, described in Hamilton (1994), can also be estimated in which all available information to the end of the sample is used in determining the probability of being in state \(S_t \in \{0, 1\}\). These filter probabilities are
therefore very useful for dating the various switches.

4.4 Sensitivity Analysis

This section tests for the presence of distinct regimes in the IPO initial returns and volume processes. As a first step, a series of tests are carried out to determine whether the series is best characterized by two states rather than one state. Before undertaking the series of tests for the significance of switching, the robustness of the Markov-switching specification assumed for the IPO data is first tested. Under model (1), it is assumed that the autoregressive parameter $\phi$ was the same in both states of the switching model. This restriction is then relaxed as this coefficient is allowed to differ between states. Finally, in checking the robustness of the switching regime specification of the IPO data chosen, tests are carried out for any remaining ARCH effects that may still be present in the residuals of the chosen model.

4.4.1 Testing for the Presence of Regime Switching

As suggested by Hamilton (1994) and Garcia and Perron (1996), a battery of tests are used to determine whether the switching regime specification of the IPO data is statistically significant. Regime-switching models refer to a situation in which the IPO initial returns and volume are drawn from two or more distinct data generating processes (DGPs), with a stochastic (unobservable) Markov-switching process determining the likelihood that each series is drawn from a given DGP.

Past studies which have used the Hamilton approach to modelling asset returns have faced the problem in testing the null hypothesis of a switching regime. The problem is that in the context of Markov-switching models, the usual tests (likelihood ratio, Wald, and lagrange multiplier) do not have the standard asymptotic distribution. This arises because, under the null hypothesis, some parameters are not identified and the scores are identically zero. To illustrate, take the case where the null hypothesis is a linear model (a one state model) and the alternative hypothesis a two-state homoskedastic Markov-
switching model. The null can be expressed as \( \{ \alpha_i = 0 \} \) (with \( \alpha_i \) described in equation (2)). The problem of identifying parameters under the null arises because as \( \{ \alpha_i = 0 \} \), the transition probability parameter \( p \) is unidentified since any value between 0 and 1 will leave the likelihood function unchanged. As for the zero score problem, note that if \( \{ p=1 \} \), the scores with respect to \( p \), \( q \), and \( \alpha_i \) will be identically zero and the asymptotic information matrix will be singular. Hansen (1992) proposes a bounds test to address these problems. Garcia (1995) calculates asymptotic critical values for certain forms of the Markov-switching model based in Hansen's work. However, there are no computed critical values that apply strictly to the linear model considered here as the null hypothesis. For Markov-switching models with more than two states, critical values are currently unknown.

Therefore, this work will rely on a number of tests that try to overcome these problems. Davies' (1987) bound test and Gallant's (1977) test, described in Appendix 4.1, begin with the idea of giving a range of values to the parameters under the alternative hypothesis. This avoids the problem of estimating them, and allows one to construct some statistics based on the value of the objective function obtained with these parameter values. For the Davies test, one obtains an upper bound for the significance level of the likelihood ratio statistic under the null hypothesis, which consists of the model with the lower number of states. Gallant's procedure consists of calculating the estimated values of the dependent variable associated with given values of the unidentified parameters. These fabricated variables (or a few principal components of them) are added to the model with the lower number of states and their significance is judged according to an F-test.

Another approach undertaken is to estimate the model with the larger number of states and run tests for non-nested models as in Davidson and MacKinnon (1981). The so-called J-test uses a t-test on \( \delta \) in the regression:

\[
y_t = (1 - \delta)h_t(\theta) + \delta g_t + u_t \quad (5)
\]
where $h_t(\theta)$ represents the statistical model of $y_t$ with the lower number of states and $\hat{g}_t$ represents the forecast of $y_t$ obtained in estimating the model with the larger number of states.

### 4.4.2 Results for IPO Initial Returns

To assess whether IPO initial returns are best characterised by a two-regime model, a progressive estimation procedure is used with a one-state autoregressive specification building up to a test for the possible presence of three states.

The stochastic one-state model of the IPO initial returns series is chosen via a Box-Jenkins methodology. The identification of the candidate one-state specification for the data is carried out by analysing the sample autocorrelation function (ACF) and the sample partial autocorrelation function (PACF) for the data. These are calculated for up to order 15 and presented in Figures 3 and 4.

![Sample ACF for IPO Initial Returns](image)

**Figure 3**
Sample PACF for Initial Returns

![PACF Chart]

Figure 4

Compared with the bound $2/T^{1/2} = 0.099$ (the solid lines in Figures 3 and 4) the partial autocorrelations seem to cut off after the second lag; that is, they are not (in general) significantly different than zero after lag $k=2$. The tentative choices for the specification of the one-state process are an autoregressive of order 1, AR(1), an AR(2) and an AR(3) specification, with estimates:

**AR1**: $\hat{\gamma}_1 = 5.836 + 0.617 y_{t-1}$ \hspace{1cm} est($\sigma^2$) = 226.773

$(0.953)$ $(0.059)$ <= s.e.

**AR2**: $\hat{\gamma}_1 = 4.993 + 0.527 y_{t-1} + 0.147 y_{t-2}$ est($\sigma^2$) = 226.51

$(0.996)$ $(0.049)$ $(0.049)$ <= s.e.

**AR3**: $\hat{\gamma}_1 = 4.914 + 0.526 y_{t-1} + 0.141 y_{t-2} + 0.011 y_{t-3}$ est($\sigma^2$) = 227.44

$(1.029)$ $(0.049)$ $(0.056)$ $(0.049)$ <= s.e.

Diagnostic analysis of the estimated specifications consist of carrying out tests for which the null hypothesis is that the residuals from each estimated specification are serially uncorrelated. Three checks are carried out on the residuals in search of an appropriate one-state specification. The first diagnostic check consists of examining the ACF of the residuals from each specification. Under the null hypothesis that the true error terms of the autoregressive (AR) processes are white noise, $r_c \sim N(0,1/T)$ (where $r_c$,
are the ACF coefficient of order \( \tau \). Therefore, if the ACF coefficients lie within the interval of \( \pm 2(T)^{-1/2} \), this would suggest white noise residuals.\(^9\) An examination of the results shown in Figure 5 (found in Appendix 4.2), which plots the ACF of the residuals for the estimated specifications, suggest that the residuals of the AR(2) specification come closest to resembling the ACF from a white noise process.

A second diagnostic check on the residuals of the AR processes utilizes the Box-Ljung portmanteau Q-statistic of order \( m \) (where \( m \) is the number of ACF coefficient). Unfortunately, this type of test suffers from a lack of statistical power in finite samples.\(^10\) Therefore, as well as calculating the Box-Ljung Q-statistic, a third diagnostic check performs a Lagrange Multiplier (LM) test for the significance of added regressors in the specified AR models. This LM test cannot discriminate between a misspecification in the autoregressive (AR) or moving average MA \( \text{pe}^\cdot \) of the univariate stochastic process but is useful in uncovering a problem with the maintained specification.\(^11\)

The Box-Ljung Q-statistics and their P-values are reported in Table 1. None of the statistics lead to the rejection of the null hypothesis at the 5% significance level, though the AR(2) and AR(3) specifications have notably higher P-values at order 2 and 7 than the AR(1) specification.

The LM test statistics and their P-values are also reported in Table 1. The additional MA coefficients are more significant in the AR(1) and AR(3), and thus are more likely to lead to the rejection of the specification. The AR(2) specification provides the least evidence of rejection under the LM test with the non-rejection of the null at the 2% level or higher for 7 and 15 extra MA coefficients. The Akaike Information Criterion (AIC) and Finite Prediction Error (FPE) minimum criterion statistics are presented in

---

\(^9\)Note Paquet (1994) indicates that this check is biased in favour of nonsignificance of the smaller order autocorrelations and thus encourages the use of additional test for serial correlation of the residuals.

\(^10\)See Paquet (1994) for more details.

\(^11\)The LM test for extra coefficients is found in Paquet (1994) and has essentially the same properties as a Breusch/Godfrey test for serial correlation. See Breusch (1978), and Godfrey (1978) for details of their test.
Table 2. Again, the AR(2) specification is favoured over the AR(1) and AR(3) one-state specification.

<table>
<thead>
<tr>
<th>Model</th>
<th>Order M</th>
<th>Statistic</th>
<th>p-value</th>
<th>Statistic</th>
<th>p-value</th>
<th>Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>Q-Stat</td>
<td>3.461</td>
<td>0.177</td>
<td>2.872</td>
<td>0.896</td>
<td>2.502</td>
<td>0.999</td>
</tr>
<tr>
<td>AR(2)</td>
<td>Q-Stat</td>
<td>0.191</td>
<td>0.908</td>
<td>1.422</td>
<td>0.985</td>
<td>1.824</td>
<td>0.999</td>
</tr>
<tr>
<td>AR(3)</td>
<td>Q-Stat</td>
<td>0.139</td>
<td>0.936</td>
<td>1.444</td>
<td>0.984</td>
<td>1.787</td>
<td>0.999</td>
</tr>
<tr>
<td>AR(1)</td>
<td>LM</td>
<td>6.263</td>
<td>0.044</td>
<td>19.201</td>
<td>0.008</td>
<td>36.007</td>
<td>0.002</td>
</tr>
<tr>
<td>AR(2)</td>
<td>LM</td>
<td>0.381</td>
<td>0.826</td>
<td>10.818</td>
<td>0.147</td>
<td>28.100</td>
<td>0.021</td>
</tr>
<tr>
<td>AR(3)</td>
<td>LM</td>
<td>4.367</td>
<td>0.113</td>
<td>18.36</td>
<td>0.005</td>
<td>29.270</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Table 2 AIC and FPE Criterion for the one state initial returns specification

<table>
<thead>
<tr>
<th>Criterion</th>
<th>AR1</th>
<th>AR2</th>
<th>AR3</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIC</td>
<td>245.365</td>
<td>243.796</td>
<td>244.115</td>
</tr>
<tr>
<td>FPE</td>
<td>244.740</td>
<td>244.116</td>
<td>246.235</td>
</tr>
</tbody>
</table>

Therefore the result of this Box-Jenkins procedure indicates that the one-state specification for IPO initial returns is best described by an autoregressive specification of order two, an AR(2) process. As mentioned in Section 2, the IPO initial returns data is sampled in a different manner after 1984. A dummy variable, which from 1960 to 1984 inclusive was set equal to zero and one for the rest of the sample, was added to the above one-state specifications. The parameter estimates of the dummy variable in the one-state AR specifications of the IPO initial returns were not found to be significant.

It is also interesting to note that the findings indicate the presence of ARCH effects. Using an Engle (1982) LM test with k=5 lags of squared residuals, the LM statistic for the estimated one-state AR(2) specification for the IPO initial returns is 93.948 with a p-value of 1.545E-09. The k=10 LM statistic was 100.483 with a p-value of 0.000. Therefore an AR(2) model was estimated again as an ARCH model with the
variance of the disturbances assumed to follow an autoregressive process of order 1 2. The conclusions drawn from the tests of significance of switching below, remained unchanged and are not reported. However, the evidence of a non-constant variance for the IPO initial returns process does support the choice of a state-dependent variance specification of the Markov-switching model of the data. In fact, Hamilton and Susmel (1995) and Sola and Timmermann (1994) show that not only do Markov-switching models of stock returns possess the same properties as ARCH models, such as persistence in conditional volatility, but are also a statistically better fit to the data.

Because of the break in the sample after 1984, the two-state specification was estimated with and without a dummy variable added as an independent regressor in equation (1). The switching model with added regressor is specified as:

$$y_t - \mu(S_t) = \phi[y_{t-1} - \mu(S_{t-1})] + \beta_D + \sigma(S_t)\varepsilon_t$$  \hspace{1cm} (6)

where $\beta_D = \beta$ and the dummy variable $D_t$ equals unity after 1984 and zero otherwise.

Parameter estimates of the 2-state specification of the initial returns series are presented in Table 3 below. The likelihood ratio (LR) statistic for a null of no added regressors (1) and alternative specified as (6) (with estimates found in the second column of Table 3) is 10.844 implying rejection of the null at the 1% significance level. A less restricted version of equation (6) is estimated by allowing the dummy variable coefficient to be state-dependent with $\beta = \beta(S_t)$ replacing $\beta_D = \beta$. An LR statistic of 0.600 for the null that $\beta(S_t=0) = \beta(S_t=1)$ indicates that the dummy coefficients can be restricted to be the same across states. In calculating the battery of tests for the significance of switching, the state-dependent mean and variance specification with the added state-independent dummy regressor will be utilised as the specification of the two-state statistical model of IPO initial returns.
Before testing for the significance of switching, I also check on the robustness of restricting the autoregressive effects of the lag dependent variable to be symmetric across states. Specifically, the model specified by equation (6) implicitly restricts the autoregressive coefficient to be identical for all states. To see if this assumption is stringent or not, a Markov model where the autoregressive parameter depends on the state is estimated. Having estimated the state-dependent model, the null of symmetric autoregressive effects is then tested against the alternative state dependent specification. Equation (6), with state dependent autoregressive parameter, is:

$$y_t - \mu(S_t) = \phi(S_t)[y_{t-1} - \mu(S_{t-1})] + \beta D_t + \sigma(S_t) \epsilon_t. \quad (7)$$

The likelihood ratio statistic for the null of a state-independent autoregressive coefficient specification (6), versus state-dependent specification (7) for IPO initial returns is 0.580. This indicates that the null cannot be rejected at the 1% significance
level. Therefore the two-state specification of IPO initial returns process is found to be best specified as in equation (6).

Having estimated the one- and two-state models of the initial returns data, it is now possible to carry out tests to determine whether the evidence of switching is significant. The tests carried out are the Davies' bound test, the J-test, and Gallant's test. The one-state specification is the null for "1 versus 2" battery of tests presented in Table 4 below. More importantly, the "1 versus 2" tests are essentially testing the significance of switching. The results indicate that the two-state specification is favoured at the 1% significance for all three tests. The quick rule for the Davies test leads to a upper bound of less then 1% (7.725E-13%) for the significance level of the LR test statistic. The Gallant test was calculated by adding to the one-state AR(2) model a vector of fitted values of the dependent variable from the two-state model with the nuisance parameters drawn randomly. The Gallant test result shows that the null hypothesis of a one-state AR(2) specification is strongly rejected. The coefficient associated with the J-test, δ, is derived from using the parameter estimates of the maximum log likelihood estimate of the two-state model to calculate the fitted values of the dependent variable to construct the variable \( \hat{g} \) in (5). The estimated coefficient is 1.687 with a p-value of 0.000, in concurrence with the rejection of the null derived from the two other tests. Therefore the evidence implies the rejection of the null hypothesis of no switching.

<table>
<thead>
<tr>
<th>Table 4: Test Results for IPO initial returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 versus 2 states:</td>
</tr>
<tr>
<td>Davies:</td>
</tr>
<tr>
<td>p value bound ∙ 7.725E-13</td>
</tr>
<tr>
<td>J-test:</td>
</tr>
<tr>
<td>( \delta = 1.687 ) (p-value=0.000)</td>
</tr>
<tr>
<td>Gallant:</td>
</tr>
<tr>
<td>p-value &lt; 0.01</td>
</tr>
</tbody>
</table>

Garcia (1995) provides asymptotic critical values for the likelihood ratio test of the null that the IPO initial returns are drawn from a single distribution AR(1) model while the alternative is a two-state AR(1) Markov-switching model with state dependent means but homoskedastic variance. While the null is AR(2) and the alternative
specification considered here is heteroskedastic,\textsuperscript{12} carrying out the same LR test, for which Garcia provides asymptotic critical values, with the homoskedastic version of equation (1) as the alternative, yields an LR statistic of 845.701. Garcia shows that with a autoregressive parameter set to 0.5 (which is close to the actual estimated value for the heteroskedastic two-state model of 0.496) that the 5\% and 1\% critical values for the likelihood ratio statistic are 8.57 and 12.07 respectively. Though this test is not relevant for the chosen specifications considered here, the result does give an indication of the accuracy of the bounds tests utilized in testing for the significance of switching.

In a formal sense, regime switching econometric models refer to situations in which the data are drawn from different data generating processes (DGPs). Since there is a well defined break in the data at the end of 1984, it seems credible to assume that the IPO initial returns are drawn from at least two different processes. Because of measurement bias, the IPO initial returns data after 1984 are likely drawn from a distinct DGP than the 1960-1984 subperiod data. Once more, as is displayed in Figure 2, it seems also likely that the data from 1960 to 1984 are drawn from more than one process. Therefore, a three-state specification for the IPO initial returns is estimated.

The three-state Markov model is estimated with state-dependent means and variances and one autoregressive parameter. The three-state specification of IPO initial returns is identical to equation (1) except the \( S_t = \{0, 1, 2\} \).\textsuperscript{13} A three-state model of IPO initial returns with the dummy variable added (equation (6)) is also estimated. Results indicate that the parameter estimate for the added dummy regressor is not significant with an LR statistic of 1.34. This result is not surprising since the estimated filter probabilities of the three-state specification in Figure 10 (in Appendix 4.2), show that the IPO initial

\textsuperscript{12}An LR test statistic of 90.638 for the null of a homoskedastic variance implies the strong rejection of this null at the 1\% level of significance.

\textsuperscript{13}For a three-state model equation (2) is redefined as:
\[
\begin{align*}
\mu(S_t) &= \alpha, \quad \text{if } S_t = i, \quad \forall i = \{0, 1, 2\} \\
\sigma(S_t) &= \omega, \quad \text{if } S_t = i, \quad \forall i = \{0, 1, 2\}
\end{align*}
\]
returns series is predominately in the middle state for the post-1984 subperiod of the series. Therefore it seems that the middle state captures all the effects derived from the measurement bias in the sample after 1984 thus taking away any role for the dummy variable in contributing to the fit of the model.

As in the two-state switching specification, I also check on the robustness of restricting the autoregressive effects of the lag dependent variable to be symmetric across three states. Specifically, the three-state model specified by (1) implicitly restricts the autoregressive coefficient to be identical for all states. A model of IPO initial returns in which the autoregressive parameter is allowed to be state dependent and thus asymmetric across states is specified as:

\[ y_t - \mu(S_t) = \phi(S_t)[y_{t-1} - \mu(S_{t-1})] + \sigma(S_t) \epsilon_t. \]  \hspace{1cm} (8)

The estimated maximum log-likelihood for the symmetric autoregressive coefficient specification is -1199.88. With a maximum log-likelihood of -1198.25 for the three-state model (8), the LR statistic for the null of identical autoregressive coefficients across states is 3.26 in this case. Comparing this value to the \( \chi^2_{12} \) 1% critical value of 9.2103 implies that the null of identical autoregressive coefficients across states cannot be rejected.

Having estimated the two- and three-state models of the initial returns data, it is now possible to carry out tests to determine whether the IPO initial returns switching regime process is better specified as a two-state process, with an added dummy regressor capturing the effects of measurement bias after 1984, or a three-state process that directly attribute a third regime to the biased subperiod.

The results from Davies’ bound test, the J-test, and Gallant’s test are presented in Table 5. The two-state specification (with added regressor) is essentially the null in the “2 versus 3” tests. There is little evidence supporting the null of a two-state specification at the 2% level of significance. The evidence indicates that the IPO initial returns are drawn from three distinct regimes. This is likely due to the measurement bias present in
the 1985 to 1993 period of the sample where the best efforts offerings' average monthly initial returns are omitted from the sample.

<table>
<thead>
<tr>
<th>Table 5: Test Results for IPO initial returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 versus 3 states:</td>
</tr>
<tr>
<td>Davies.</td>
</tr>
<tr>
<td>J-test.</td>
</tr>
<tr>
<td>Gallant.</td>
</tr>
</tbody>
</table>

With at least two known regimes in how the IPO initial returns data are measured, the conclusion that IPO initial returns are best modelled as a three-state switching process is, as previously mentioned, not surprising. Ordinarily, in a linear regression framework, one would either add a dummy variable to take care of the known break in the sample or one would have to estimate the subperiods separately. However, when using a non-linear switching regime approach, the presence of a known break in the IPO initial returns data simply presents itself as a check of the regime switching model's ability to capture structural breaks. Though the switching model is not able to differentiate between unobserved structural breaks in how the data is measured or unobserved structural breaks in the data generating process itself, the known date of the break in the data does allow one to check the robustness of the switching model for tagging structural breaks (of any kind). Specifically, because of the known break in the data at the end of 1984, a distinct regime should be estimated for the switching model for the period after 1984. As is revealed in Figure 10 (in Appendix 4.2 below), this turns out to be the case.

What is not known with certainty is that the IPO initial returns were generated by only two distinct processes before the end of 1984. It is possible that the actual data generating process for the IPO initial returns is in fact a three-state process with the break in the data forcing the estimated measure of the true third regime to the post-1984 period. By calculating restricted pre-1985 sample versions of the battery of tests presented above one can actually shed light on this assertion. The result of the significance tests for the two-state null versus the three-state alternative are presented in Table 6. All tests cannot reject the null of a two-state switching model for IPO initial returns.
Table 6: Test Results for IPO initial returns
1960-1984 restricted sample

<table>
<thead>
<tr>
<th>2 versus 3 states:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Davies</td>
<td>p-value bound * 0.226</td>
</tr>
<tr>
<td>J-test. ( \delta = \cdot 0.156 ) (p-value=0.092)</td>
<td></td>
</tr>
<tr>
<td>Gallant</td>
<td>p-value &gt; 0.01</td>
</tr>
</tbody>
</table>

The 1 versus 2 state test results, as was the case for the full sample, reject the one-state null.\(^{14}\) These results support the conclusion that before the end of 1984, the IPO initial returns are characterised as being drawn from two distinct data generating processes while the estimated third state simply is capturing the structural break in how the IPO initial returns are measured after 1984.

The conclusion that can be drawn from the battery tests determining the number of regimes for the IPO initial returns data is that there is strong evidence of regime switching in U.S. IPO initial returns. Because of the poor sample qualities, the results indicate that IPO initial returns can be characterised as being drawn from two DGP\( s\) from 1960 to 1984 and a third different DGP from 1985 to 1993.

4.4.3 Results for IPO Volume

We follow same procedure used in identifying the stochastic switching specification of the IPO initial returns to identifying the time series specification of the IPO volume series. It is worth reminding the reader that the data on the number of firms going public does not have the same sampling problems as the initial returns data. Though testing for evidence of regime switching in IPO volume with tests of a one-state null versus a two-state specification should be sufficient in this case, for completeness, results of the battery of tests with a null of the two-state model compared to the three-state are also presented. To start, the correct one-state specification of the IPO volume

\(^{14}\)No dummy variable was added to the specifications since there is no information warranting such additional regressor.
process is determined.

The first step in determining the correct one-state specification requires one to examine the ACF and PACF of the volume series. The estimated PACF and ACF for the volume series are presented in Figures 6 and 7. By comparing the estimated values autocorrelation functions to the bound of $2/T^{1/2} = 0.099$ reveals that the partial autocorrelations are not significantly different from zero after the third lag. The sample autocorrelation function dies out slowly. It does not get below the bound until the 40th lag, thus suggesting the possibility that the volume series is nonstationary.

To test whether or not the IPO volume series is nonstationary, Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) unit root tests are performed. The hypothesis tested
in the unit root test is as follows:

\[ H_0: \ y_t = \alpha + y_{t-1} + u_t \quad \alpha = 0, \ u_t \sim \text{i.i.d. } N(0, \sigma^2) \]
\[ H_1: \ y_t = \alpha + \rho y_{t-1} + u_t. \]

As Hamilton (1994) points out, the test statistic, when the null is assumed to be a random walk with drift, is distributed as:

\[ (\hat{\rho} - 1)/\sigma_{\hat{\rho}} \sim N(0, 1) \]

where \( \hat{\rho} \) is the estimate of \( \rho \) with \( \sigma_{\hat{\rho}} \) the estimated standard error for \( \hat{\rho} \).

The calculated DF test statistic is -4.873 compared to -2.326 critical value, implies that the null is rejected at the 1% level. The ADF test statistic\(^{15}\) with 4 lags of the differenced series is -2.836 which when compared to the critical value of -2.326 again rejects the null of a unit root.

From Figure 2, there is little indication of any drift in the volume series. It may therefore be more appropriate to test for the presence of a unit root without drift. The test statistic when the null is a pure random walk with \( \hat{\rho} = 1 \) and \( \hat{\alpha} = 0 \) has a non-normal distribution calculated in MacKinnon (1991). The critical value of the test statistic at the 1% level is -3.431. Again the DF test statistic of -4.873 implies that the null is rejected. The ADF test statistic of -2.836 on the other hand, does not reject this null. However, because of the low power of the Dickey-Fuller tests, the Phillips-Perron (1988) test for unit roots is also calculated. The Phillips-Perron t-test statistic with 4 lags of the differenced series is -5.494. Comparing this to the critical value of -3.431 for the 1% significance level, implies that the null of a unit root is rejected.

Since there does not seem to be much consistent support for the presence of a unit root in the volume series, the tentative choices, based on the observed ACF and PACF of the series, for the one-state process are an AR(2), an AR(3), and an AR(4) specifications.

\(^{15}\)Campbell and Perron's (1991) suggested data dependent procedure was used to select the value of the lag length chosen.
The estimates are calculated as:

\[
\begin{align*}
\text{AR2} \quad \hat{y}_t &= 2.412 + 0.681 y_{t-1} + 0.234 y_{t-2} \quad \text{est}(\sigma^2)=119.42 \\
& \quad (0.819) \quad (0.048) \quad (0.048) \quad \leq \text{s.e.}
\end{align*}
\]

\[
\begin{align*}
\text{AR3} \quad \hat{y}_t &= 2.156 + 0.657 y_{t-1} + 0.164 y_{t-2} + 0.104 y_{t-3} \quad \text{est}(\sigma^2)=117.092 \\
& \quad (0.820) \quad (0.048) \quad (0.058) \quad (0.049) \quad \leq \text{s.e}
\end{align*}
\]

\[
\begin{align*}
\text{AR4} \quad \hat{y}_t &= 2.122 + 0.655 y_{t-1} + 0.160 y_{t-2} + 0.088 y_{t-3} + 0.024 y_{t-4} \quad \text{est}(\sigma^2)=115.98 \\
& \quad (0.823) \quad (0.049) \quad (0.058) \quad (0.058) \quad (0.049) \quad \leq \text{s.e}
\end{align*}
\]

I then carry out the same set of diagnostics on the IPO volume data that was performed on the IPO initial returns data. The correlogram of the residuals plotted in Figure 8 (in Appendix 4.2), suggest that the AR(3) specification comes closest to resembling the ACF of a white noise process.

The Box-Ljung Q-statistics and the LM statistics for each tentative specification are presented in Table 7. The calculated Q-statistics offer little evidence of the possible rejection, at the 5% significance level, of any of the estimated specifications for the one-state volume series. There is a notable rise in the p-values of the Q-statistics from the AR(2) specification to the AR(3) specification with only a marginal rise in the p-values from the AR(3) to AR(4) specification. The LM test results indicate that the AR(3) specification offers greatest evidence of non-rejection of the null of white noise errors for the residuals. The Akaike Information Criterion (AIC) and Finite Prediction Error (FPE) minimum criterion statistics are presented in Table 8. Again, the AR(3) specification is favoured over the AR(2) and AR(4) one-state specification.
Table 7: Box-Ljung Q-statistic and the LM test of $H_0: \text{ARMA}(p, q)$ versus $H_1: \text{ARMA}(p, q+m)$ (with $q=0$) and their p-values for IPO Volume from 1960-1-1993-12

<table>
<thead>
<tr>
<th>Model</th>
<th>Order M</th>
<th>2</th>
<th>7</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>p-value</td>
<td>Statistic</td>
<td>p-value</td>
</tr>
<tr>
<td>AR(2)</td>
<td>Q-Stat</td>
<td>3.579</td>
<td>0.167</td>
<td>7.504</td>
</tr>
<tr>
<td>AR(3)</td>
<td>Q-Stat</td>
<td>0.022</td>
<td>0.989</td>
<td>3.750</td>
</tr>
<tr>
<td>AR(4)</td>
<td>Q-Stat</td>
<td>0.0019</td>
<td>0.999</td>
<td>3.317</td>
</tr>
<tr>
<td>AR(2)</td>
<td>LM</td>
<td>4.476</td>
<td>0.107</td>
<td>7.974</td>
</tr>
<tr>
<td>AR(3)</td>
<td>LM</td>
<td>0.301</td>
<td>0.860</td>
<td>6.965</td>
</tr>
<tr>
<td>AR(4)</td>
<td>LM</td>
<td>2.660</td>
<td>0.264</td>
<td>6.526</td>
</tr>
</tbody>
</table>

Table 8: AIC and FPE Criterion for the one state Volume Specification

<table>
<thead>
<tr>
<th>Criterion</th>
<th>AR2</th>
<th>AR3</th>
<th>AR4</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIC</td>
<td>124.240</td>
<td>123.696</td>
<td>124.598</td>
</tr>
<tr>
<td>FPE</td>
<td>126.240</td>
<td>123.796</td>
<td>125.598</td>
</tr>
</tbody>
</table>

Therefore the result of this Box-Jenkins procedure indicates that the one-state specification for the IPO volume series is best described by an autoregressive specification of order three, an AR(3) process.

As was found for the IPO initial returns data, there also evidence of ARCH affects in the AR(3) specification. For $k=5$ lags of squared residuals, the LM statistic for the estimated one-state AR(3) specification for the IPO volume is 90.561 with a significance value of 1.541E-09. The $k=10$ LM statistic is 122.287 with a significance value of 0.000. Therefore an AR(3) model was estimated again as an ARCH model with the variance of the disturbances assumed to follow an autoregressive process of order 12. The implication of the tests for significance of switching presented below remained unchanged and are not reported. However as mentioned above, this does support the choice of a state dependent variance specification of the Markov-switching process for the volume series.

Two specifications of the two-state switching model of the IPO volume series are
considered. In the first, the effect of the centred lag-dependent variable on the dependent variable and its mean is assumed to be symmetric (equation (1)) while in the second less restricted version, this effect is allowed to enter asymmetrically across states (equation (8)). The maximum log-likelihood estimate for the state-dependent autoregressive parameter model is -1066.500 while the state-independent log-likelihood estimate is calculated as -1073.174. This yields a likelihood ratio statistic for the null of a restricted coefficient two-state specification of IPO volume of 13.348, rejecting the null at 1% significance level.\textsuperscript{16} Therefore, autoregressive coefficients are significantly different across states.

The three-state version of the symmetric (1) and asymmetric (8) specifications of the IPO volume series are also estimated. The LR statistic for the null of identical autoregressive coefficients across states is 2.480. Comparing this value to the $\chi^2_{(2)}$ 1% critical value of 9.210 implies that the null of identical autoregressive coefficients across states cannot be rejected.

Therefore, for the two-state model of IPO volume, the state dependent autoregressive coefficient specification seems to be the appropriate model for the volume series. On the other hand, the three-state version can be specified with the restriction of identical coefficients across states.

Having estimated the one-, and two-state model of the volume data, it is now possible to carry out tests to determine whether the evidence of switching is significant. The same tests are carried on the two- and three-state specification to check whether there is evidence that the IPO volume data is drawn from three separate data generating processes rather than two.

The results of the tests are presented in Table 9. From the "1 versus 2" grouping of tests, the results indicate that the two-state specification is favoured at the 1%
significance.\textsuperscript{17} The results therefore imply rejection of the null hypothesis of no switching.

In the two- versus three-state comparisons, all but the Davies test cannot reject the null of the 2-state specification at the 1\% significance level. Therefore, the results generally do not support a three-state specification for the IPO volume series.

<table>
<thead>
<tr>
<th>Table 9: Test Results for IPO Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 versus 2 states:</td>
</tr>
<tr>
<td>Davies:</td>
</tr>
<tr>
<td>p-value bound = 1.545E-09</td>
</tr>
<tr>
<td>J-test:</td>
</tr>
<tr>
<td>$\delta = 1.189$ (p-value = 0.000)</td>
</tr>
<tr>
<td>Gallant:</td>
</tr>
<tr>
<td>p-value &lt; 0.01</td>
</tr>
<tr>
<td>2 versus 3 states:</td>
</tr>
<tr>
<td>Davies:</td>
</tr>
<tr>
<td>p-value bound = 5.01E-09</td>
</tr>
<tr>
<td>J-test:</td>
</tr>
<tr>
<td>$\delta = 0.00934$ (p-value = 0.382)</td>
</tr>
<tr>
<td>Gallant:</td>
</tr>
<tr>
<td>p-value &gt; 0.01</td>
</tr>
</tbody>
</table>

The results indicate that there is strong evidence of regime switching in U.S. IPO volume. However there is little evidence indicating that the IPO volume series can be drawn from three rather than two separate distribution over the sample.

4.4.4 Remaining ARCH Effects for the IPO Initial Returns and Volume

A lagrange multiplier (LM) test to assess the presence of any ARCH effects in the residuals of the switching models can be undertaken by first projecting the squared residuals of the Markov-switching specification on the filter probabilities to account for the state-dependent heteroskedasticity, and then, in an "artificial" regression, taking the residuals from this regression and regressing them on the filter probabilities and an autoregressive structure for these squared residuals.\textsuperscript{18} From this, one can compute an LM-test statistic for the significance of the lagged squared residuals. The results of this test procedure are reproduced in Table 10. Except for the 8 lag specifications of the

\textsuperscript{17}Also carried out is a likelihood ratio test of a one-state AR(1) specification null against an AR(1) two-state dependent mean with homoskedastic variance with the known asymptotic critical value given in Garcia (1995). The resulting estimated LR statistic of 836.46 strongly rejects the null with a 1\% critical value of 12.6\textsuperscript{.} This result supports the findings of the battery tests utilized in testing for the significance of switching.

\textsuperscript{18}This test is an LM version of an F-test suggested in Garcia and Ferron (1996)
volume residuals, the tests cannot support the presence of any ARCH effects remaining in the residuals of the Markov-switching models of IPO data.

<table>
<thead>
<tr>
<th>Table 10: Results from Arch tests on two-state Returns and Volume models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns Three-State Markov Model</td>
</tr>
<tr>
<td>AR lags of Residuals</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>8</td>
</tr>
</tbody>
</table>

To assess the presence of any remaining serial correlation effects in the residuals from the selected state-dependent models of IPO initial returns and volume series, Box-Ljung diagnostics are performed on the residuals of the specification of the respective IPO series. The Q-statistics and their p-values are presented in Table 11 below. There is little evidence to reject the null of no serial correlation at the 1% significance level for IPO initial returns model. Similarly, for the IPO volume specification, there is little evidence to reject the null of no serial correlation at the 1% significance level.

<table>
<thead>
<tr>
<th>Table 11: Results from Box-Ljung test for serial correlation in two-state IPO initial returns and volume models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns 3-state Model</td>
</tr>
<tr>
<td>Order</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
</tbody>
</table>

4.4.5 Summary

The evidence of distinct regimes for the IPO volume and initial returns processes supports the hypothesis that in the aggregate, investors and therefore, firms behave differently in certain periods. Since the aggregate number of firms going public per month can be described by two distinct regimes, it seems that the firms' decisions are affected by stochastic fluctuations in the incentive(s) to go public. The results are
consistent with the view that the firms’ benefits (or their costs) to going public undergo

distinct regime changes which in turn causes fluctuations in the number of firms going

public at any given time. Similarly, the regime changes in IPO initial returns are

consistent with discrete changes in investor demand for IPO shares. The findings for both

the IPO initial returns and volume series are therefore consistent the “windows of

opportunity” explanation of “hot issues” markets.

4.5 Empirical Results for the Switching Models of IPO Initial

Returns and Volume

Section 4.4 showed that the IPO returns and volume series were characterised as

undergoing discrete regime changes consistent with the “windows of opportunity”

explanation of the “hot issues” markets. In this section the empirical estimates of the

two-state specification of the IPO volume process and the three-state IPO returns process

are presented in Tables 12a, 12b, and 13. As mentioned in Section 3, the empirical “filter

probabilities” are calculated when using Hamilton’s Markov-switching approach. The

resulting filter probability estimates are discussed below and presented in Figures 9 and

10 (found in the Appendix 4.2).

4.5.1 IPO Initial Returns Switching Model

The discussion about the estimates for the IPO initial returns Markov-switching

model presented in Table 12a and 12b, is made a little easier by labelling the states. State

2, the high mean state, is labelled as “hot”; state 1, the state in which the initial returns

data resides in for most of the 1985 to 1993 period, as “bias”; and state 0, the low mean

state, as “cold”. The parameter \( \mu_0 \) denotes the mean of the cold state, \( \mu_1 \) the bias mean,

while the parameter \( \mu_2 \) denotes the mean of the hot state. Similarly, \( \sigma_0 \), \( \sigma_1 \) and \( \sigma_2 \) denote

\[\text{\textsuperscript{16}}\text{The middle state is labelled “bias” because it occurs predominately during the 1985 to 1993 subperiod which, as mentioned in Section 4.2, was in fact censored data.}\]
the standard deviations for the cold, bias and hot states, respectively.

The filter probabilities for the IPO initial returns are presented in Figure 10 (in Appendix 4.2 of this chapter) where they are plotted as a function of time *. As mentioned, these filter probabilities are the estimated probabilities of being in either of the three states and are useful in dating switches in regime. They indicate that the series is drawn from two different DGPs for most of the sample before 1985 while being drawn from a third DGP from 1985 onwards. The series spends some time in the hot state in 1961, from 1967 to 1969, from 1971 to 1972, briefly around 1977, most of late 1979 to 1981 period, and briefly in 1983. These estimated time periods correspond fairly well with documented “hot issues” periods. Ibbotson and Jaffe (1985) indicate that the period 1959 to 1961 and the period 1968 to 1969 were considered “hot issues” market periods. Ritter (1984) singles out the 15 month period beginning January 1980 as a “hot issues” market period. Loughran and Ritter (1995) indicate that 1992 through to 1993 seem to be another “hot issues” market period in the U.S. These “hot issues” periods are determined informally (usually) sometime after the “hot issues” period occurred. It is important to emphasize that though these dates correspond fairly well with the derived “filter” dates of hot and cold regimes of the model, these documented “hot issues” cycle dates were not utilized in any way to estimate the parameters of the model or to form some inference about the probability of \( S_t = \{0, 1, 2\} \) occurring.

The cold state mean of IPO returns is 1.989, while the mean for the hot state is a much larger 33.639. This implies that if one were to purchase shares at the offering during a hot period, one would gain a return of 33% on average during the first day of trading which is over 16 time greater than the first-day returns gained during cold periods. The mean monthly IPO return for the 1985 to 1993 period is estimated to be 13.071. As is the case for a majority of financial data, the IPO initial returns have a non-constant variance. The standard deviation in the hot regime is approximately 3 times that of the cold regime.20

---

20See Fama (1991) for a review of the literature documenting non-constant variances in stock market data.
Since the IPO initial returns series remains predominately in the middle "bias" state during the later subsample (1985-1993), the estimated parameters associated with the middle state could be viewed as parameter estimates of an AR(1) (one-state) specification for that part of the sample. As presented in Table 12a, the middle state's mean is 13.071, its variance is equal to 6.326 and the autoregressive parameter is 0.295. The restricted sample estimates of a first-order serially correlated (one-state) regression model for the period 1985 to 1993 results in a mean of 12.912, a variance of 7.234 and an autoregressive coefficient of 0.229 thus supporting this view. Though the whole sample set was utilized in Hamilton's Markov-switching estimation procedure, this result shows that this approach is flexible enough to accurately catalogue known regimes within the sample. At first glance, this break in the sample may have seemed to have reduced the viability of the data set in modelling the IPO initial returns process, but in fact it has been useful in checking the switching model's ability to capture changes in regime.
The persistence of each regime, the probability of being in the current regime again in the next period, are given by the estimated transition probabilities down the diagonal of the matrix presented in Table 12b. These results indicate that the cold state is more persistent with a probability of 0.934 than the hot state with a probability of 0.884. This implies that it is more likely that the initial returns will switch out of the hot regime than the cold regime.

Another interesting implication of the Markov framework is that one can calculate from the estimated parameters the (long-run) ergodic expected duration of a typical session in each state. This is of interest to any firm deciding to issue stock for the first
4.5.2 IPO Volume Switching Model

For the IPO volume data, the states are labelled "hot" for state 1 and "cold" for state 0. The filter estimates presented in Figure 9 (in Appendix 4.2 of this chapter) show that the time periods in which the hot state filter probabilities are greater than 0.5 correspond fairly well with the hot "issues" markets and the cold "cold state 0. (as the case for the IPO initial returns) indicates that the number of firms going public per month compared to the cold state is approximately 5 times more variable than the number of firms going public per month as compared to the cold state.

The estimated means for each regime for the IPO volume are 22,629 for the hot state and 44,022 for the cold state. This implies that on average (in the aggregate) the hot state filter probabilities are approximately 0.5 greater (in the aggregate) than the cold state's.

The terms of equity capital. It is noted that the average annual returns on 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime or 8.62 months. Specifically, the long-run ergodic expected duration of the hot regime.

explained in terms of other factors. The regime change in investor demand for IPO stocks in general which in turn would effect the terms at which equity capital can be raised. Firms observing that IPO initial returns are presently in a hot state would be interested in knowing how long, on average, these states will remain in effect. Conditional on being in the hot state the expected duration of

\[ \hat{p}_t = (1 - r) \hat{p}_{t-1} + r \hat{p}_0 \]
long-run than the respective regimes for the IPO initial returns switching model. For example, the (long-run) ergodic expected duration for the hot state for IPO volume is 16.129 months (conditional on being in the hot state). This implies that hot regimes for the IPO volume series are more persistent than that of the hot regimes of the IPO initial returns.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimates</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_0 = \alpha_0$</td>
<td>23.639</td>
<td>4.017</td>
</tr>
<tr>
<td>$\mu_1 = \alpha_0 + \alpha_1$</td>
<td>44.392</td>
<td>4.672</td>
</tr>
<tr>
<td>$\sigma_0 = \omega_0$</td>
<td>3.826</td>
<td>1.434</td>
</tr>
<tr>
<td>$\sigma_1 = \omega_0 + \omega_1$</td>
<td>15.551</td>
<td>5.192</td>
</tr>
<tr>
<td>$p$</td>
<td>0.949</td>
<td>0.0163</td>
</tr>
<tr>
<td>$q$</td>
<td>0.938</td>
<td>0.0209</td>
</tr>
<tr>
<td>$\phi_1(0)$</td>
<td>0.968</td>
<td>0.0176</td>
</tr>
<tr>
<td>$\phi_1(1)$</td>
<td>0.748</td>
<td>0.0537</td>
</tr>
</tbody>
</table>

Expected duration of "hot" state (state 1) = $(1-q)^{-1} = 16.129$ months

Expected duration of "normal" state (state 0) = $(1-p)^{-1} = 19.763$ months

log-likelihood = -1066.500

In summary, the statistical results support the characterization of initial returns of IPOs for the subperiod 1960 to 1984 (when ignoring the middle state representing the censored sample) as essentially switching from one state characterised as low initial returns to another state that can be characterised by high initial returns. The same can be said for the number of firms going public. The frequency of these switches for the IPO series roughly corresponds to the occurrences of the industry delineated “hot issues” markets for IPOs.
4.6 Some Economics

In this section of the study, the relation between the IPO series and “economic” variables is investigated. Specifically, significance tests are carried out in order to determine whether or not these economic variables have any predictive powers, given the IPO data are specified as regime switching processes. Tests of the significance of these economic variables are carried out in two ways. First, the significance of these variables in explaining the level of the IPO processes, while controlling for switching, is investigated by placing these economic variables directly in the switching model as added regressors. Second, the significance of these variables in affecting the timing of the regime changes or, more precisely, in explaining the probability measure of being in a certain state at time t, is tested. This is carried out by using the estimated filter probabilities as the dependent variable in a linear probability model.

What are the economic variables that may have some predictive power? Because most of the theoretical models of the firm’s decision to go public focus on adverse section costs or some other firm-specific benefit to going public rather than the dynamic variation in benefits/costs to going public, the choice of the economic variables is not made evident by the predictive implication derived from a set of competing models. With a dearth of theoretical models explaining the cyclical properties of the IPO data, one is left to use a "mixed bag" of economic variables referred to in informal explanations of either the "hot issues" market phenomena or variables assumed, under some conventional wisdom, to be of some relevance to the firms in deciding to raise capital through a public equity offering.

In the "windows of opportunity" explanation of "hot issues" markets, firms take advantage of favourable terms of raising equity or, more precisely, higher than average offering prices. Lerner (1994) shows that biotechnology firm owners time their initial offering to coincide with market peaks (in the biotechnology index). This turns out to be a rough proxy for the average equity valuation of the firms going public (which in turn affects the offering price the firms are able to receive). It is therefore likely that a stock
market index or the growth rate of a market index\textsuperscript{21} should have a positive relation to the number of firms going public. Since IPO initial returns depend on the early after market demand for IPO shares, the economic variables that may be able to explain returns should be variables that affect investor demand for IPO shares as well as seasoned shares traded on the stock market. On that note, the stock market index may be of use as a proxy for the aggregate demand for equity (ignoring the fundamentals that may have caused this aggregate demand). If this variable is a measure of investor enthusiasm for stocks in general (and IPOs in particular) it should have some positive relation to initial returns, though it may be of relatively less importance than the positive effects it has on the IPO volume.

Conventional wisdom is that an IPO is simply a stage in the firm's growth process. Specifically, one possible benefit that a firm hopes to capture in going public is access to larger pools of equity to fund growth enhancing projects. Therefore it may be reasonable to expect some variation through time in the number of firms going public as the growth prospects of the firms vary due to the gyrations of the business cycle which is measured as the growth rate in U.S. industrial production. Fluctuations in economic activity may also affect the demand for stocks in general, and in turn IPO initial returns, since economic growth often has important consequences for dividend growth rates (this is of course of less consequence for IPOs since returns arise mostly from capital gains). This implies that IPO initial returns are likely positively related to output growth.

With debt financing acting as a substitute to equity financing, another factor that may affect the need for public equity financing and thus the number of IPOs, is interest rates. The variable used here is the Federal Reserve funds rate. As for IPO initial returns, the growth rate of the money stock may also have an important positive effect on the demand for shares since changes in the money stock is theorised to be of consequence for

\textsuperscript{21}It is not strictly correct to consider a stock market index as an "economic" variable. However, with Lerner's (1994) study indicating that IPO volume being dependent on a market index, it would seem prudent to add this to the list of predictive variables.
the portfolio balance between bonds and money holdings.\textsuperscript{22}

4.6.1 Added Regressor Switching Specification

Estimates of the following added regressor regime switching specification will allow for likelihood ratio tests to be carried out on the significance of economic variables for the IPO processes after controlling for switching. The added regressor switching specification is defined as:

\[ y_t - \mu(S_t) = \phi(S_t)[y_{t-1} - \mu(S_{t-1})] + \beta_t X_t + \sigma(S_t) \varepsilon_t \]  

(9)

where \( S_t = \{0, 1, 2 \ldots k\} \), \( \phi_t = \phi(S_t) \), and \( X_t \) is a \( k \) by 1 vector of economic variables with \( \beta_t = \beta \) or \( \beta_t = \beta(S_t) \).

Table 14 presents the empirical estimate of the IPO volume switching model with the log of the S&P500 index (logsp), S&P500 growth rate (spg), the growth rate of US industrial production\textsuperscript{23} (gdp), and the Federal Reserve’s funds rate (intr) as the \( k \) added explanatory variables. Which yields a maximum log-likelihood estimate of -1064.824. None of the added explanatory regressors are individually significant. As well, the market index growth rate and the interest rate both have the opposite sign than posited. The likelihood ratio (LR) statistic with null of no added regressors (equation (8)) is 3.36. Therefore one cannot rejection of the null of no added regressors at the 1% level of confidence. Of interest is the fact that the estimated state-dependent means and variances are relatively unaffected after adding the explanatory economic variable. Therefore the non-rejection of the null does not come as a great surprise.

The estimation of the switching model with added regressors in which the added

\textsuperscript{22}In an earlier draft, both the growth rate of the U.S. monetary aggregate and the interest rate were considered as added explanatory variables in both the IPO initial returns and volume added regressor switching models. However due to concerns of multicollinearity, one of these variables is used in each model.

\textsuperscript{23}The growth rates are calculated by taking the log of the observation at t, subtracting by the log of the observation at t-1, then multiplying by 100.
explanatory variables' effect on IPO volume in an asymmetric way, with $\beta = \beta(s_i)$, is also estimated. The log-likelihood estimated for this specification is -1059.780. Given a $\chi^2_{1,0.01}$ critical value of 20.120 at the 1% level of confidence and a LR statistic of 13.44, the null once again cannot be rejected.

<table>
<thead>
<tr>
<th>Table 14</th>
<th>Added regressor model of IPO initial returns</th>
<th>Added regressor model of IPO volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimates</td>
<td>Standard Errors</td>
</tr>
<tr>
<td>$\mu_0$</td>
<td>15.073</td>
<td>6.889</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>27.584</td>
<td>7.627</td>
</tr>
<tr>
<td>$\mu_2$</td>
<td>47.197</td>
<td>7.845</td>
</tr>
<tr>
<td>$\sigma_0$</td>
<td>7.806</td>
<td>3.948</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>6.333</td>
<td>2.593</td>
</tr>
<tr>
<td>$\sigma_2$</td>
<td>22.774</td>
<td>8.813</td>
</tr>
<tr>
<td>$\phi$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>0.258</td>
<td>0.0818</td>
</tr>
<tr>
<td>intr</td>
<td>-0.01001</td>
<td>0.0944</td>
</tr>
<tr>
<td>m2g</td>
<td>1.792</td>
<td>1.758</td>
</tr>
<tr>
<td>logsp</td>
<td>4.809</td>
<td>2.478</td>
</tr>
<tr>
<td>gdp</td>
<td>0.0159</td>
<td>0.639</td>
</tr>
<tr>
<td>spg</td>
<td>-2.0670</td>
<td>0.752</td>
</tr>
<tr>
<td>log-likelihood = -1194.801</td>
<td>log-likelihood = -1064.824</td>
<td></td>
</tr>
</tbody>
</table>

A similar procedure is carried out for the IPO initial returns data. Table 14 presents the empirical estimate of the IPO initial returns added regressor switching model with the log of the S&P 500 index, S&P 500 growth rate, the growth rate of industrial production, and M2 growth rates (m2g) as the added explanatory variables which yields a maximum log-likelihood estimate of -1194.801. Individually, both the log of the stock market index and the growth rate of the index are significant with the log of the index

$^{24}$For space considerations the results from the $\beta(s_i)$ specification are not presented. None of the 8 added regressors were individually significant.
having the only correct sign. However, given a $\chi^2_{14}$, critical value of 13.323 at the 1% level of confidence and a LR statistic of 10.158, the null of no added regressors cannot be rejected. This is not surprising since the estimates of the state-dependent means and variance as well as the autoregressive coefficient are not very different than those presented in Tables 12a for the univariate switching model of IPO initial returns.

The estimation of the switching model with added regressors in which the added explanatory variables' effect on IPO initial returns in an asymmetric state-dependent way, with $\beta_{i}^{*}-\beta(S_{i})$, is also estimated. The log-likelihood estimated for this specification is -1187.12. Given a $\chi^2_{12}$, critical value of 26.258 at the 1% level of confidence and a LR statistic of 25.52, the null once again cannot be rejected.

In summary the findings indicate that after controlling for switching, there is little evidence that the levels of the IPO series can be explained using added explanatory economic variables. For the most part, no added insight can be gained as to what macroeconomic factors may effect the decision to go public or the level of initial returns within a switching model. The unobservable state variable seems to be the controlling factor effecting the IPO series.\textsuperscript{35} Without some formal theoretical model explaining the cyclical behaviour of the IPO market, it is difficult to isolate possible factors (other than switching in an unobserved state variable) that may have some predictive powers for IPO initial returns and volume. Until formal models are developed, the results presented here indicate that, after controlling for switching, there is little evidence that IPO initial returns or volume can be explained using economic data.

\textsuperscript{35}One possible source of concern for the added regressor specification adopted here is that it ignores the possibility of the explanatory variables having some important but lagged effects on the IPO volume or initial returns. For example it may be the case that the money supply growth rates or the stock market index measures have lagged effects that the model ignores. For this reason added regressor switching models with the explanatory variable entering in a lag distributed manner were also estimated. At low levels of lag length the added regressors remained insignificant. However as the lag length increased, the iterative procedure, with a larger number of parameters to estimate, became ill behaved in the sense that it converged to several local maxima dependent on the starting values given. This makes testing the null of no added regressors problematic because one is less certain of finding a global maximum. In fact the log likelihood was often less than the restricted model and hence no inference can be made about the added regressors model.
4.6.2 Linear Probability Specification

In estimating the means of the switching model one could consider these values to be the observed values of a discrete valued dependent variable in a limited dependent variable model. In a limited dependent variable framework, the estimated "filter probabilities" calculated with Hamilton's algorithm may be viewed as the "empirical probabilities" that are typically estimated in models of limited dependent variables with grouped data. When the empirical probabilities are available, Maddala (1983) shows how the linear probability model for limited dependent variables, after taking care of the implicit heteroskedasticity, is similar to that of the logit model. With the estimated filter probabilities in hand, it seems reasonable to use them as the empirical probabilities in a linear probability model with economic independent variables in gauging the significance of these independent variables for the timing of regime changes. Specifically, in using the minimum chi-squared method described in Maddala to estimate the parameters in a linear probability model, one hopes to get some indication of how the explanatory variables affect the probability of being in each state and implicitly, to gauge whether or not these variables are important to the timing of the regime changes.

In what follows, a linear probability model is estimated with the hot-state filter probabilities for the volume switching model as dependent variable. A linear probability model with the hot-state filter probabilities estimates of the truncated sample two-state IPO initial returns switching model as the dependent variable is also estimated.\textsuperscript{26} The reason that the filter probabilities from the full sample three-state model are not used, is that any strong interaction between the economic variables and the probability of switching in and out of the hot state during the subperiod 1960 to 1984 may be reduced by the lack of variability in the dependent variable in the latter subperiod (it remains at or near 0 for most of the subperiod). As it turns out, the results presented bellow for the truncated two-state hot filter probabilities model are generally the same for the full

\textsuperscript{26}A two-state switching model is used to derive the filter probabilities of the hot state for the truncated sample because, as Table 6 indicate, there is no evidence of the three-state model being significant for that restricted sample.
sample linear probability model of the three-state hot filter probabilities. For space consideration these results or not presented. A logit model with the binary version of the filter probabilities as the “dependent” indicator variable was also estimated for both initial returns and volume series hot states.\footnote{The indicator variable is derived from the filter probabilities by setting $y_t = 1$, if the filter probability at $t$ is less than 0.5 and $y_t = 0$ otherwise.} Again, the results of the estimated logit models are in general accordance with those found for the linear probability models presented below and are thus omitted for space considerations.

The independent variables used in a linear probability model of the hot-state filter probabilities of the IPO volume switching process are the same as those utilised in the added regressor switching model of IPO volume (plus an intercept). These variables should have the same sign as per the explanation in the added regressor subsection. The current and lagged IPO initial returns is also add to the list of explanatory variables. If it is the case, as the “windows of opportunity” explanation asserts, that IPOs experience periods of overpricing, as suggested in the “noise trader” model of De Long et al. (1990a), then it is likely that the higher than average initial returns are simply a signal to the firms of an overoptimistic demand for IPO stocks. Since no share price history for the firm contemplating going public exists, the increased demand for IPOs overall is revealed through the observable after-market prices of recent IPOs (and thus in the initial returns of recent IPOs). If firms tend to go public in their sectoral market peaks, as Lerner (1994) finds, then it is also reasonable that firms take advantage of increased investor demand for IPO shares and go public during peak IPO initial returns. This implies that the sign of the IPO initial returns coefficients should be positive since an increase in initial returns should increase the probability of firms going public and thus increase the probability that the IPO series is in a hot state. Lagged IPO initial returns were used because of the existence of an imposed institutional regulatory delay between the time a firm decides to go public and the actual public offering. The current and 8th lag value of the IPO initial
returns data is used as explanatory variables.²⁸

The results of estimating the linear probability model for the volume hot-state filter probabilities are presented in Table 15. In the initial unrestricted specification, the constant, current initial returns, lagged initial returns and the log level of the S&P500 are all significant with the sign of the current initial returns opposite to that posited. A testing down procedure is used to determine which of the explanatory variables are significant. Table 15 shows the estimated final (restricted) specification settle upon. The likelihood ratio statistic with this restricted specification as the null is also presented. The timing of the switches into the hot regime for the IPO volume is significantly dependent on the log level of the market index and lagged initial returns as well as a constant. The positive significant estimate for the log level of the market index suggests that an increase in the market index increases the probability that the IPO volume process is in a “hot” state. These results support Lerner’s (1994) findings that firms tend to go public near market peaks. Similarly, the sign of the lagged initial returns implies that it serves as an important signal to firms contemplating going public that their share prices at the offering, may be higher than average due to higher than average demand for IPOs.

A similar procedure is carried out for the IPO initial returns series in which the dependent variable is the filter probability estimates of the hot state. The added independent variables are the same as those applied in the added regressor switching model of IPO initial returns. The results are present in Table 15. In the initial unrestricted specification, only the growth rate of the market index has the correct (posited) sign and is significant. The money supply growth rate parameter is also significant but is negative. Again a testing down procedure is undertaken to ascertain the most parsimonious specification. The results of the procedure show that the growth rate of the stock market index and the growth rate of the monetary aggregate are important to

²⁸Ritter (1984) indicates that several studies find that there is on average a 6 to 12 month lag from the period when IPO initial returns are abnormally high to when IPO volume are abnormally high. Ritter suggest that this may in part be due to the institutional aspects of the IPO process. Therefore an 8th lag value of the IPO initial returns is used as an independent regressor in the case.
the timing of the regime changes of the IPO initial returns switching process. The positive sign of the market index growth rate suggests that initial returns are more likely to be above average when the market is increasing. A negative sign for the money supply growth rate is difficult to explain. It is possible that lagged values of the money supply growth rate are significant and positive. A linear probability model, with distributed lags of the explanatory (up to the 8th lag) variables, is also estimated. The final parsimonious model turns out to be the same as presented in Table 15, with a significance value for the LR statistic of 0.647.

| Table 15: Linear Probability Model with filter probability estimates as dependent |
|---------------------------------|---------------------------------|---------------------------------|
|                                | IPO Volume hot state            | IPO initial returns hot state   |
| Parameters                     | Parameter estimates             | T-statistics                    | Parameter estimates | T-statistics |
| constant                       | -1.064                         | -6.608                          | -0.334              | -0.749       |
| output growth                  | 0.0299                         | 1.410                           | -0.00647            | -0.235       |
| Fed Funds rate                 | -0.00668                       | -1.121                          |                     |             |
| M2 growth rate                 |                                |                                 | -0.272              | -3.939       |
| market index growth            | 0.015                          | 1.259                           | 0.119               | 7.059        |
| returns                        | -0.00252                       | -2.529                          |                     |             |
| returns(-8)                    | 0.006550                       | 5.488                           |                     |             |
| log level of market index      | 0.303                          | 9.793                           | -0.157              | -1.630       |
| **Final specification**        |                                |                                 |                     |             |
| constant                       | -1.120                         | -7.110                          | 0.386               | 8.935        |
| market index growth            |                                |                                 | 0.121               | 8.45         |
| money supply growth            |                                |                                 | -0.286              | -4.537       |
| returns(-8)                    | 0.00570                        | 5.028                           |                     |             |
| log level of market index      | 0.303                          | 9.379                           |                     |             |
| LR Statistic and sign.         | 11.151                         | $p = 0.0249$                    | 2.421               | $p = 0.298$ |

In summary, the conclusion that can be drawn from the added regressor switching models of the IPO series is that the added "economic" variables are not significantly
important after controlling for switching. The set of variables that have some predictive power in explaining the probability of IPO initial returns or volume being drawn from a particular state-dependent data generating process is larger. Evidence suggests that for the volume process, the log level of the market index and lagged IPO initial returns are important for the timing of regimes. As for the predictability of the IPO initial returns regimes, the growth rate in the stock market index is important. These results are consistent with the "windows of opportunity" hypothesis and support Lerner's (1994) findings that firms time their public offerings with market peaks.

4.7 Vector Markov-Switching Model

As noted earlier, the "windows of opportunity" explanation of the cyclical patterns in IPO initial returns and volume requires that in certain periods, stocks become overvalued in some sectors or industries. Firms realizing the overvaluation of other firms in the industry, take advantage of the opportunity and go public. How stocks get mispriced relative to their fundamental value is a puzzle for which DeLong, Schleifer, Summers, and Waldmann (1990a) (DSSW) have provided an explanation. DSSW develop a model in which rational investors interact in financial markets with noise traders who are less than fully rational. Though DSSW simply assume that these noise traders are affected by exogenous, stochastic swings in non-fundamentally-based beliefs or "sentiment," there is a growing literature modelling the microeconomic foundation of the asset trading process in relation to incomplete or imperfect aggregation of information and heterogenous rational beliefs about asset fundamentals, that can account for the "perceived" irrationality of the traders modelled by DSSW.\(^{29}\) An important implication of the DSSW noise trader model is that the shifting investor sentiment (beliefs) will not only affect securities like IPO shares but will also affect other securities in which the noise trader investor holds and trades a preponderance of shares. This implies that shifts

\(^{29}\)See Chapter 3 for a partial survey of models explaining speculation and "perceived" irrational beliefs.
in investor sentiment underpinning regime shifts in the volume of IPOs (according to the "windows of opportunity" hypothesis) should also underpin shifts in the returns of other assets. In other words, the unobserved process that drives the changes in investor demand for the IPO stock should influence both the initial returns and in turn the IPO volume as well as the returns of other assets for which the same IPO investors are the principal active traders. The other asset used here is closed-end funds discounts data. Closed-end funds (CEFs) data is chosen because Lee, Schleifer, and Thaler (1991) find that "The evidence suggests that discounts on closed-end funds are indeed a proxy for changes in individual investor sentiment . . ." (p.107).\textsuperscript{30} The reason Lee, Schleifer and Thaler use closed-end fund data to test the derived implications of the DSSW noise trader model is that closed-end funds are unique in that their fundamental value is directly observable since a closed-end fund is simply a (traded) basket of other traded assets. In theory the closed-end fund's share price should exactly equal the value of the basket of shares that makes-up its composition. However, on average, the closed-end funds trade at a discount thus comprising one of the more perplexing puzzles in finance. Lee, Schleifer and Thaler find that the noise trader theory is able to explain this puzzle.

To test whether the shifts in regime between the IPO processes and the closed-end fund process are correlated, I extend Hamilton's analysis to a vector setup. In a vector framework, the nature of the transition matrix between the states will have strong implications for the correlation of the shifts between processes.\textsuperscript{31} Highly correlated regime shifts across assets would support DSSW model's implications that noise traders sentiment will be systematic across risky assets in which noise trader are important. By

\textsuperscript{30}Lee, Schleifer and Thaler (1991) argue that noise traders are most likely to be (uniformed) individual investors rather than institutional investors. They indicate that individual investor comprise of approximately 94% of the shareholders of closed-end funds. Individual investors also hold approximately 75% IPO shares thus comprising the majority of shareholders in that domain as well. If this type of investor does behave in accordance with the investor sentiment hypothesis put forward be DSSW, then the cyclical behaviour of both type of assets should be highly correlated.

\textsuperscript{31}Phillips (1991) applies a similar methodology to a statistical investigation of business cycles transmissions from one country to another.
testing cross-regime correlation, this study is able to formally test the noise trader model's implications and therefore dispelling some of the apprehensions for the usefulness of the noise trader approach to asset pricing.\footnote{Evaluating the implications derived from the DSSW model is of importance in itself, since there is only one other study carried out, with this goal in mind, that of Lee, Schleifer, and Thaler (1991). They review and extend the implications of the DSSW model to the “closed-end fund” puzzle. Their results support the DSSW implications for closed-end funds. However, the empirical approach taken here is significantly different than that taken by Lee, Schleifer, and Thaler whose focus was on closed-end funds rather than IPOs.}

In the previous sections of this chapter, the specifications ((1), and (8) for example) were non-linear difference equations. The only independent variables are the past values of the dependent variable (and added regressors). The cyclical or dynamic interaction between two regime switching series is not modelled. In a vector specification, there will be high and low state-dependent parameters for both the IPO series and the closed-end funds discount series. However, because the series are modelled in tandem, there are four possible combinations of these parameters, implying that the vector combination of the series will be dependent on four states of the world rather than simply two states. Implications about the cyclical transmission mechanics can be drawn from the nature of the four-state (first-order) Markov transition matrix.

4.7.1 The Stochastic Nature of the Closed-End Fund Process

In testing the correlation of the regime shift between the IPO volume process and the CEFs process, one implicitly assumes that the CEFs undergoes regime changes. This implicit assumption is tested in this subsection using the same battery of tests utilized in Section 4.4.

The specifics of the closed-end fund data are as follows. The data used in this study is the monthly measure of the value-weighted index of the discounts on closed-end funds constructed in the Lee, Schleifer, and Thaler (1991) paper entitled, “Investor Sentiment and the Closed-End Fund Puzzle.” The data was kindly supplied by the Charles Lee. The value-weighted discount data consists of a weighted average of the
discounts of approximately 20 funds. The monthly time series spans 246 months, from July 1965 to December 1985 inclusive. This implies that the vector switching model was restricted to this time frame even though a longer data set is available for the IPO volume and returns processes. Because of the sample bias in the returns data mentioned earlier, estimation of the CEFs IPO returns vector model is restricted to the months spanned from 7/65 to 12/84. CEFs data is plotted in Figure 11 below. A more detailed description of how the data is computed is available in Lee, Schleifer and Thaler (1991).

For the one-state model, based on an analysis of the estimated residuals for remaining serial correlation, an AR(3) specification is chosen. Table 16 presents the Box-Ljung Q-statistics and the LM statistics that formed the choice of the one-state model. The AR(2) consistently displays lower p-values than either the AR(3) and AR(4) specification. There is not much difference between the AR(4) and AR(3) specification. For parsimonious models reason, the AR(3) specification is chosen for the one-state model of CEFs discounts.

<table>
<thead>
<tr>
<th>Model</th>
<th>Order M</th>
<th>2</th>
<th>6</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Statistic</td>
<td>p-value</td>
<td>Statistic</td>
</tr>
<tr>
<td>AR(2)</td>
<td>Q-Stat</td>
<td>2.533</td>
<td>0.282</td>
<td>12.534</td>
</tr>
<tr>
<td>AR(3)</td>
<td>Q-Stat</td>
<td>0.00142</td>
<td>0.999</td>
<td>8.253</td>
</tr>
<tr>
<td>AR(4)</td>
<td>Q-Stat</td>
<td>0.0239</td>
<td>0.998</td>
<td>7.625</td>
</tr>
<tr>
<td>AR(2)</td>
<td>LM</td>
<td>2.897</td>
<td>0.236</td>
<td>17.541</td>
</tr>
<tr>
<td>AR(3)</td>
<td>LM</td>
<td>1.246</td>
<td>0.536</td>
<td>10.013</td>
</tr>
<tr>
<td>AR(4)</td>
<td>LM</td>
<td>1.422</td>
<td>0.491</td>
<td>9.199</td>
</tr>
</tbody>
</table>

Two specifications of the two-state switching model are considered. The baseline model is the symmetric autoregressive coefficient across states specification, (1), and the alternative specification where the autoregressive coefficient is allowed to have
asymmetric effects across states as in (8). The derived LR statistic for the null of symmetric coefficients across states is 0.28 implying that the null cannot be rejected at the 1% level. Therefore the two-state model of the CEFs discount process is specified as equation (1), with identical autoregressive coefficients across states. With the one- and two-state specifications of the CEFs discount process now established, the three model selection tests are calculated.

The results of the one- versus two-state tests are presented in Table 17. The results of the bounds tests favour the alternative two-state model over the AR(3) one-state model. The Davies test leads to a upper bound of less then 1% (1.545E-09%) for the significance level of the LR test statistic. The Gallant test was calculated by adding to the one-state AR(3) model a vector of fitted values of the dependent variable from a two-state model with parameters drawn randomly. The Gallant test result imply the strong rejection of null hypothesis of a one-state AR(3) specification. The estimated coefficient associated with the J-test (δ) is 1.00948 which, with a p-value of 0.000, is in concurrence with the rejection of the null derived from the two other tests. Therefore the evidence presented in Table 17 strongly supports the presence of regime switching in the closed-end funds discount process.

<table>
<thead>
<tr>
<th>Table 17: Test Results for CEFs Discount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 versus 2 states:</strong></td>
</tr>
<tr>
<td>Davies:</td>
</tr>
<tr>
<td>p-value bound: 1.545E-09</td>
</tr>
<tr>
<td>J-test:</td>
</tr>
<tr>
<td>δ = 1.00948 (p-value=0.000)</td>
</tr>
<tr>
<td>Gallant:</td>
</tr>
<tr>
<td>p-value &lt; 0.01</td>
</tr>
</tbody>
</table>

Estimation of a three-state model of the closed-end funds discount process failed to converged to a three-state global maximum. The estimation process yielded parameter estimates identical to the two-state parameter estimates for two of the three states with

---

33With a $\chi^2(1)$ LR statistic of 7.04, the null of homoskedastic variance for the two-state model with symmetric coefficients is rejected at the 1% level of significance.
transition matrix probability estimates that imply that the third state is never attained.\textsuperscript{34} Note also that the maximum log-likelihood approximately equal to the two-state switching estimated log-likelihood. Since this result is robust for a distribution of starting values two- versus three-state model selection test are not undertaken.

It should be emphasised that the results indicating that the CEFs discount process is driven by a discrete state Markov-switching process supports the "noise trader" model's implication that investor beliefs are stochastic in nature.

The parameter estimates of the two-state switching model of the CEFs discount series are presented in Table 18. The 'premium' regime is labelled as state 0, the low-mean state, since the discount in the closed-end funds data is measured positively while a premium is measured by a negative value. This is made clear by inspection of Figure 11 which presents the value weighted closed-end funds discount data. The estimated means for each regime of the CEFs discount switching model are 3.851 for the 'premium' state (\( \mu_{0} \)) and 10.623 for the 'discount' state. This implies that there is a 300 percent swing in the average of the value weighted discount on closed-end funds between regimes.

\textsuperscript{34}Simply put, the transition probabilities are such that there is never a transition to the third state. Specifically, the CEFs discount process never switches into the third state from either the first or second state.
### Table 18: Estimation results for 2-state model of CEFs discount

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimates</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_n$</td>
<td>3.851</td>
<td>3.406</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>10.263</td>
<td>3.375</td>
</tr>
<tr>
<td>$\sigma_n$</td>
<td>5.0273</td>
<td>0.731</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>2.912</td>
<td>0.418</td>
</tr>
<tr>
<td>$p$</td>
<td>0.966</td>
<td>0.0209</td>
</tr>
<tr>
<td>$q$</td>
<td>0.974</td>
<td>0.0141</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0.961</td>
<td>0.0179</td>
</tr>
</tbody>
</table>

Expected duration of "premium" state (state 0) = $(1-p)^{-1} = 29.4$ months

Expected duration of "discount" state (state 1) = $(1-q)^{-1} = 38.5$ months

log-likelihood = -310.46

### Figure 11

The estimated transition probabilities of the Markov process ($p$ and $q$) indicate that the regimes are persistent in the long-run. For example, the long-run (ergodic) expected duration of the premium regime is 29.4 months which is less persistent than the 'discount' regime but notably more persistent than the hot state of the IPO volume process which has an average long-run duration of 16.1 months.
The filter probabilities of the premium state are presented in Figure 12 where they are plotted as a function of time $t$ (months). Except for the 1974 to 1977 period, the filter probabilities seem to be in concurrence with the time that the actual value weighted closed-end funds discount is actually in a premium period, as depicted in Figure 11. The reason why the switching model of the CEFs discount attributes a premium period between 1974 and 1977 is likely due to the fact that there was a large, but brief drop in the discount during that period which the algorithm picks up as a move into a premium state.

![Prob. of Premium State](image)

Figure 12

To sum up, there is strong evidence that the closed-end funds process can be characterised as a regime switching process, which on its own is lends support for the "noise trader" model. With this evidence, it is now possible to combine both the closed-end found data and the IPO volume data in a vector switching model in order to test the implications of the DSSW noise trader model of speculative asset pricing which underpins the "windows of opportunity" hypothesis of the "hot issues" IPO markets.

4.7.2 The Closed-end Funds-IPO Vector Stochastic Process

Extending Hamilton's approach to a vector setup means that there will be up to four combinations of the high- and low-means from each series. This implies that there
are four possible states, one for each combination of mean. The four-state first order autoregressive specification of the vector process is:

\[ y_t - \mu(S_t) = \phi [y_{t-1} - \mu(S_{t-1})] \ast \varepsilon_t \quad \varepsilon_t \sim N(0, \Sigma) \quad (10) \]

The four different combinations of these states are represented by a four-state Markov process with \( S_t \in \{1, 2, 3, 4\} \). For this vector specification, \( y_t, y_{t-1}, \varepsilon_t \), and the four state-dependent \( \mu \)'s are two-by-one vectors. Note that a 'w' superscript indicates the element corresponding to the closed-end funds (CEFs) data and the 'v' superscript corresponds to the volume data. \( \Sigma \) is a two-by-two matrix with diagonal elements \( \sigma^w, \sigma^v \) and off diagonal element \( \sigma^{wv} \). \( \phi \) is a two-by-two matrix of the autocorrelation coefficients like those found in a standard VAR statistical specifications. To keep notation terminology to a minimum, it is simpler to continually refer to CEFs and IPO volume pairing of switching processes. However, the same description should be applied to the CEFs and IPO returns pairing. For the most part, substituting the returns process in place of the volume process and substitute and \( r \) superscript for the \( v \) superscript is all that is required to extend the following description to the CEFs-IPO returns pairing.

The four possible states simply delineate the four possible combinations for the means. State 1, represents the state in which the CEFs discount process is in a premium state and the IPO volume process is in a hot state. In state 2, the CEFs process is in the discount state while the volume process is in the hot state. In state 3, the CEFs process is in the premium state while the volume process is in the cold state. Finally, state 4 represents the state in which the CEFs discount is in a 'discount' state and the volume process is in a cold state. The four \( \mu \) vectors can be denoted as:

\[ \mu_1 = \begin{bmatrix} \mu^w_0 \\ \mu^v_1 \end{bmatrix}, \mu_2 = \begin{bmatrix} \mu^w_1 \\ \mu^v_1 \end{bmatrix}, \mu_3 = \begin{bmatrix} \mu^w_0 \\ \mu^v_0 \end{bmatrix}, \mu_4 = \begin{bmatrix} \mu^w_1 \\ \mu^v_0 \end{bmatrix}. \quad (11) \]

where \( \mu_1 > \mu_0 \) for both series. The transition matrix for the Markov process is a four-by-
four matrix of probabilities $P_{ij}$, where $P_{ij} = \Pr(s_t = j | s_{t-1} = i)$ ($i, j \in \{1, 2, 3, 4\}$). These probabilities sum to one over $j$ for each $i$.

Though each individual process is modelled with a state-dependent variance, the vector setup of the Hamilton model assumes that the variance-covariance matrix is not state-dependent. Allowing for a state-dependent covariance matrix would require the algorithm to maximize the likelihood function over an extra 9 variables (when the baseline model already has 23 to maximize over) which would entail an exponential increase in the time to compute the parameter estimates. As well, convergence to a global maximum becomes more problematic as the number of parameters to estimate increases. For these reasons, the variance covariance matrix is assumed to be symmetric across states.

4.7.3 Nature of the Correlation Between IPO Volume and Closed-End Funds

Implications that can be drawn from the estimated transition matrix of the vector process are derived from the fact that the correlations between the cycles for each series will be governed by the structure of the estimated transition matrix. The following examples will illustrate the interdependence of the shape of the transition matrix with the correlation between the respective cycles.

Suppose first that the two series each follow an independent two-state regime-shifting process like those estimated in the previous sections of this chapter (simply the univariate specification of the difference equation (1)). There is no dynamic interdependence in this case. If both processes are truly independent, then the four-by-four transition matrix can be defined as follows:

$$
\begin{pmatrix}
P_{00}^* P_{00} & P_{00}^* (1 - P_{00}^*) & P_{00}^* (1 - P_{00}^*) & (1 - P_{00}^*) (1 - P_{00}^*) \\
(1 - P_{11}^*) P_{00} & P_{11}^* P_{00} & (1 - P_{11}^*) (1 - P_{00}^*) & P_{11}^* (1 - P_{00}^*) \\
P_{00}^* (1 - P_{11}^*) & (1 - P_{00}^*) (1 - P_{11}^*) & P_{00}^* P_{11}^* & w_{00} (1 - P_{11}^*) \\
(1 - P_{11}^*) (1 - P_{11}^*) & P_{11}^* (1 - P_{11}^*) & (1 - P_{11}^*) P_{11}^* & P_{11}^* P_{11}^* \\
\end{pmatrix}
$$

(12)
Here $P^i_j$ corresponds to the probability of process $i$ of staying in state $j$ when in $j$ the previous period, with $i \in \{w, v\}$ and $j \in \{0, 1\}$. These $P^i_j$ transition probabilities correspond to the two-state univariate specification of each process (matrix $\tau$ in section 4.3 above) rather than vector specification in (10).

Another example is when the two processes are perfectly correlated. This can occur when both processes move into and out of their premium/hot or discount/cold regimes at the same time. In this case, a two-by-two matrix could be used since the two middle states ($S = \{2, 3\}$) do not occur and $P^w_{11} = P^v_{11}, P^w_{00} = P^v_{00}$. The four-by-four representation of perfectly correlated vector processes is:

$$
\begin{bmatrix}
P^w_{00} & 0 & 0 & (1 - P^w_{00}) \\
0 & \ddots & \ddots & \ddots \\
0 & \ddots & \ddots & \ddots \\
(1 - P^v_{11}) & 0 & 0 & P^v_{11}
\end{bmatrix}.
$$

The case in which one process leads another can also be demonstrated. For example, the CEFs process could switch into the premium regime a period before the volume process switches into its hot regime. The matrix below illustrates a case where the length of the lead of the CEFs process over the volume process into the high mean state is $1/(1-a)$ and the expected lead of the returns into the low mean state is $1/(1-b)$:

$$
\begin{bmatrix}
P^w_{00} & (1 - P^w_{00}) & 0 & 0 \\
0 & a & 0 & 1 - a \\
1 - b & 0 & b & 0 \\
0 & 0 & (1 - P^v_{11}) & P^v_{11}
\end{bmatrix}.
$$

It appears from these examples that this four-state Markov process permits a great variety of IPO volume/CEFs cycle transmissions to occur. Other possibilities that are more difficult to model exist as well. For example, it could be possible that the two
processes alternate leads into and out of the state 1, the hot/premium state. For these
more complicated cyclical patterns, it would be necessary to look at the filter probabilities
as well as the estimated transition matrix in order determine how the states actually
evolve over time.

4.7.4 Estimation Results of the Vector Markov-Switching Process of the CEFs and
IPO Volume Data

Evidence that supports the noise trader model’s implication that swing in
unobservable investor sentiment will be systematic across assets in which they are
important players, would require that the vector model’s transitions matrix to be perfectly
 correlated, as in (13) or one series would lead the other into and out of states 1 and 4, as
in (14). If the Markov processes driving each series are independent, then the transition
matrix for the four-state process can be represented by equation (12). It is straightforward
to conduct a test of perfect correlation using the likelihood ratio test. It only requires
the estimation of the restricted model (13) as well as the baseline unrestricted (transition
matrix) model. Since there are twelve independent transition probabilities in the baseline
model and four when restricted as in (13), the statistic will be distributed as $\chi^2(10)$. Tests
for the null for specifications of the vector model with the transition matrix as in (12) or
(14) are similarly constructed. All that is required is that model be estimated with
specific transition probabilities set to zero. The test statistics for (12) and (14) are $\chi^2(8)$. An examination of the results of each pairing follows.

A baseline model and four models with restrictions on the transition matrix, as
described above, were estimated. The parameter estimates and the maximum log-
likelihood values of the baseline model and the restricted models that were not rejected
are presented in Table 19a and 19b. The likelihood ratio test statistics are presented in
Table 20. For the CEFs discount and IPO volume pairing, one can reject the hypothesis
that the Markov process driving the switching regimes is described by a situation were the
CEF's discount process leads or lags the volume process. On the other hand, the
hypothesis that the cyclical properties of the two processes are independent cannot be
rejected. Moreover, the hypothesis that the two processes are perfectly correlated cannot be rejected at the 1% significance level. Finding evidence supporting the null of perfectly correlated regimes means that both the CEFs discounts and IPO volume will move into and out of their respective premium/hot regimes simultaneously. Now if the CEFs discount process is in fact a proxy for the level of investor sentiment prevalent in noise traders, as shown in Lee, Schleifer and Thaler (1991), then this in turn supports the "noise trader" model's implication that investor sentiment is systematic across risky assets in which noise traders are the predominate investors.

Table 19a shows that the high- and low-mean values for the IPO volume process are similar across the two cases and are similar to the mean values of the single equation two-state model presented in Section 4.5. However the means for the CEFs discount varies considerably depending on the restrictions. The high- and low-means in the independent model are 9.674 and 2.862 (which are similar to the single equation values), while the perfect correlation model yields values of 7.401 and 7.0156 for the means. For the perfectly correlated case, the expected (ergodic) length of a premium/hot period is 1.9 months which is vastly different than the independent case where premium periods are expected to last 23.8 months which is near the length calculated in the single equation framework. The expected length of the volume hot state is the same for both cases at 15.6 months. The filter probability estimates from the baseline model presented in Figure 14 indicate that the both series will be in the premium/hot regime at the same time but that their length of stay in that regime are not equal. This may be indication of why the test statistic more strongly favour the support of the independent model. Inspection of the \( \rho \) matrix for either model shows that the series have an autocorrelation of 0.942 and 0.957 respectively for the CEFs process and the volume process in the baseline model. These values are similar to the estimate derived in the other two models. Also, these autocorrelation values are not far from their individual two-state measure of autocorrelation measure.
Table 19a
Results of the vector CEFs-Volume estimation

Baseline model

<table>
<thead>
<tr>
<th>CEFs</th>
<th>Volume</th>
<th>Log-likelihood: -953.246</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ₀</td>
<td>4.992</td>
<td>47.135</td>
</tr>
<tr>
<td>μ₁</td>
<td>9.976</td>
<td>25.138</td>
</tr>
<tr>
<td>ρ matrix</td>
<td>0.942</td>
<td>-0.00407</td>
</tr>
<tr>
<td></td>
<td>-0.0058</td>
<td>0.957</td>
</tr>
<tr>
<td>Σ matrix</td>
<td>2.0297</td>
<td>-0.292</td>
</tr>
<tr>
<td></td>
<td>-0.292</td>
<td>6.356</td>
</tr>
</tbody>
</table>

Independent model (12)

<table>
<thead>
<tr>
<th>CEFs</th>
<th>Volume</th>
<th>Log-likelihood: -955.300</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ₀</td>
<td>2.862</td>
<td>25.808</td>
</tr>
<tr>
<td>μ₁</td>
<td>9.674</td>
<td>49.106</td>
</tr>
<tr>
<td>ρ matrix</td>
<td>0.950</td>
<td>-0.00768</td>
</tr>
<tr>
<td></td>
<td>-0.125</td>
<td>0.921</td>
</tr>
<tr>
<td>Σ matrix</td>
<td>1.961</td>
<td>-0.450</td>
</tr>
<tr>
<td></td>
<td>-0.450</td>
<td>6.405</td>
</tr>
</tbody>
</table>

Perfect correlation (13)

<table>
<thead>
<tr>
<th>CEFs</th>
<th>Volume</th>
<th>Log-likelihood: -963.597</th>
</tr>
</thead>
<tbody>
<tr>
<td>μ₀</td>
<td>7.0156</td>
<td>25.427</td>
</tr>
<tr>
<td>μ₁</td>
<td>7.401</td>
<td>48.768</td>
</tr>
<tr>
<td>ρ matrix</td>
<td>0.948</td>
<td>-0.0114</td>
</tr>
<tr>
<td></td>
<td>-0.0719</td>
<td>0.931</td>
</tr>
<tr>
<td>Σ matrix</td>
<td>2.247</td>
<td>-0.573</td>
</tr>
<tr>
<td></td>
<td>-0.573</td>
<td>6.435</td>
</tr>
</tbody>
</table>
As is presented in Table 20, for the CEFs discount and IPO returns vector Markov-switching model, one can reject the hypothesis that the Markov process driving the switching regimes are perfectly correlated and that the CEFs discount process leads or lags the returns process. However, the hypothesis that the two processes are independent cannot be rejected. This implies that the Markov-switching process driving the CEFs discount regimes is independent of the Markov-switching process driving the IPO returns regimes. The independence of the two processes is made evident in Figure 15 where the filter probability measures from the baseline model are plotted. From this figure one notices that there is no congruence of the timing of the respective premium or high regimes. Table 19b shows that the low-and high-mean value of the baseline or the independent model are not very dissimilar from the individual single equation estimates presented in Section 4.5 for the IPO returns and in Subsection 4.7.1 for the CEFs process. Inspection of the $\rho$ matrix for either model shows that the series have an autocorrelation of 0.954 and 0.631 respectively for the CEFs process and the volume process. This again is not far from their individual single equation two-state measure of autocorrelation measure of the respective processes.
### Table 19b

Results of the vector CEFs-Returns estimation

<table>
<thead>
<tr>
<th>Baseline model</th>
<th>CEFs</th>
<th>Volume</th>
<th>Log-likelihood: -1056.121</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition matrix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \mu_a )</td>
<td>3.601</td>
<td>13.221</td>
<td></td>
</tr>
<tr>
<td>( \mu_i )</td>
<td>10.549</td>
<td>60.343</td>
<td></td>
</tr>
<tr>
<td>( \rho ) matrix</td>
<td>0.954</td>
<td>-0.0119</td>
<td>0.000 0.000 0.993 0.00656</td>
</tr>
<tr>
<td></td>
<td>-0.171</td>
<td>0.631</td>
<td>0.000 0.000 0.956 0.0443</td>
</tr>
<tr>
<td>( \Sigma ) matrix</td>
<td>1.933</td>
<td>-0.157</td>
<td>0.00685 0.0772 0.0206 0.895</td>
</tr>
<tr>
<td></td>
<td>-0.157</td>
<td>12.876</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent model (12)</th>
<th>CEFs</th>
<th>Volume</th>
<th>Log-likelihood: -1062.121</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition matrix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \mu_a )</td>
<td>3.579</td>
<td>13.471</td>
<td></td>
</tr>
<tr>
<td>( \mu_i )</td>
<td>10.470</td>
<td>61.468</td>
<td></td>
</tr>
<tr>
<td>( \rho ) matrix</td>
<td>0.955</td>
<td>-0.0128</td>
<td>0.957 0.043 0.425 0.575</td>
</tr>
<tr>
<td></td>
<td>-0.157</td>
<td>0.632</td>
<td>0.469 0.531 0.067 0.933</td>
</tr>
<tr>
<td>( \Sigma ) matrix</td>
<td>1.947</td>
<td>-0.0729</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.0729</td>
<td>13.046</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 15

CEF's Discount and IPO Returns
To sum up, the evidence supporting the "noise trader" model of asset pricing put forward by De Long et al. (1990a) is mixed. The hypothesis of perfectly correlated regimes is not rejected for the CEFs-Volume vector model as well as the hypothesis that the processes are independent. Also the there is no evidence to support the perfect correlation of the CEFs discount and IPO initial return processes. One then can conclude that there is weak evidence that the appearance of "windows of opportunity" for firms deciding to go public is caused by swings in investor sentiment as posited by De Long et al. (1990a).

4.8 Summary and Conclusion

Though the empirically observed cyclical patterns of the IPO market presents itself as an intriguing anomaly, there has been little study, in detail, of the statistical characteristics of the IPO data. By utilizing the techniques developed by Hamilton (1989), this chapter highlights certain ill understood features of the IPO data. Specifically, the results provide an ex-post characterisation of the statistical properties of the IPO initial returns and volume processes that are useful in directing attention to dynamic classes of models for future research on the public equity offering process. Evidence suggests that the series are characterised by means and variances that shift over time. This evidence is consistent with the informal "windows of opportunity" explanation that firms take advantage of investor overvaluations that occurs in certain periods.

An additional innovation in the empirical study of IPOs, is to use an added
regressor specification for the Markov-switching model. This allows for the investigation of whether or not economic variables have some explanatory power for the IPO series. The findings indicate that the economic variables chosen do not have much explanatory power (after controlling for switching). The poor predictive ability of these variable may be in part due to the possibility that they were ill chosen or possibly due to the strong dependence of the IPO stochastic processes on the unobservable state variable. Further work in determining which is the case may require a formal theoretical model explaining which economic variables are more likely important factors in the firm’s decision to go public over time.

In assessing the predictive ability of these economic variables for the timing of regime changes in the IPO volume process, the results show that lagged IPO initial returns and the log level of the S&P500 stock market index are important. As for the IPO returns regimes, the results show that the growth rate of the stock market and money supply are important. However the money supply growth rate is of the opposite sign than posited. Evidence indicating that some measure of the market index is important in the timing of the IPO regime changes, supports the “windows of opportunity” explanation of the observed cyclical patterns in the IPO data and is in concurrence with the Lerner’s (1994) findings that firms tend to time IPOs with sectoral market peaks.

The implication derived from De Long, Schleifer, Summers, and Waldmann’s (1990a) “noise trader” model, that investor sentiment is systematic across assets in which noise traders are the principal players is also examined within a stochastic regime switching framework. By modelling the interdependence of the pairings of the volume, returns, and CEFs data within a vector autoregressive Markov-switching model, the implication that the cycles in IPO volume or returns are correlated with cycles in CEFs is tested. This framework allows one to test whether or not the IPO processes are correlated with the shifts in the CEFs discount process which is shown to be itself, best described as a regime shifting process. The findings indicate that there is mild support for the investor sentiment model of asset mis-pricing which underpins the “windows of opportunity” hypothesis of the cyclical incentive to go public.
Appendix 4.1

A. Davies' Bound Test

Davies proposed a procedure that is useful when there is a q dimensional vector \( \mathbf{v} \) a subset of some parameter space \( \mathcal{P} \), present only under the alternative hypothesis. Davies defines the likelihood ratio statistic as a function of \( \mathbf{v} \):

\[
LR(v) = 2(\ln(L_1(v)) - \ln L_0^*).
\]

where \( L_1(v) \) denotes the likelihood function evaluated at \( v \) present under the alternative hypothesis and \( L_0^* \) the maximized value obtained under the null hypothesis where \( v \) is not included. Let \( v^* \) be the argmax of \( L_1(v) \). The likelihood function under the alternative evaluated at \( v^* \) is then denoted as \( L_1^{*} \). Then one defines \( LR^* = \sup_{v} LR(v) = 2(\ln L_1^{*} - \ln L_0^*) \). Denoting \( M \) as the empirically value of \( LR^* \), Davies derives an upper bound for the significance of \( M \):

\[
\Pr[\sup_{v \in V} LR(v) > M] \leq \Pr[\chi^2_q > M] + DM \frac{q - 1}{2} \exp \frac{M}{2} \frac{q}{2} \Gamma\left(\frac{q}{2}\right).
\]

where \( \Gamma(\cdot) \) denotes the gamma function. Davies also introduces a quick rule \( D = 2M^{1/2} \), which is obtained upon making the assumption that the likelihood ratio has a single peak. The testing procedure applied in this paper uses this quick rule. \( L_1^{*} \) is obtained by estimated the likelihood for the model with the higher number of states (the alternative) which in turn allows for the estimate of the bound for the significance level.
B. Gallant’s Test Procedure

Consider the following models under the null and alternative hypotheses:

\[ H_0: y_t = h(x_t, \theta) + e_t, \]
\[ H_1: y_t = h(x_t, \theta) + \alpha f(x_t, \theta) + e_t. \]

If the true value of \( \alpha \) is equal to 0, the parameter vector \( \theta \) becomes unidentified. This is basically the situation observed in testing the number of significant states of the switching regressions.

Gallant shows that by letting \( z_t \) be a vector of variables which do not depend on the unknown parameters \( \theta \) or \( \theta \), one can test the significance of the values of the vector \( \delta \) without recourse to the calculation of non-standard asymptotic values. If \( \alpha_0 \) the true value of \( \alpha \), is equal to 0, then the parameters least squares estimator of \( \delta \) in the following regression:

\[ y_t = h(x_t, \theta) + z_t/\delta + e_t \]

is estimating the zero vector since the true model does not have any other variables that are important. Gallant shows that the best choice of variable in the vector \( z_t \) would be variables that maximize the power of the test when \( H_1 \) is actually true. The rest of this description follows closely the summary of Gallant’s procedure presented in Garcia and Perron (1996) applied to a switching regression problem.

Let \( \beta = (\alpha_0, \omega_0, \alpha_1, \omega_1, p, q) \) be the vector of parameters in the two-state model. The Gallant procedure applied to determine the number of states in a Markov-switching model follows these four steps:

a) For a given set of values for \( \beta \) (say k) indexed by j, calculate the fitted values \( \hat{y}_j \) for the model with the larger number of states.
b) When the matrix \( \hat{Y} = (\hat{y}_1, \ldots, \hat{y}_k) \) is too large, extract a few principal components, say m.
c) Add these principal components, denoted as the \( z_t \) vector of dimension m, to the model with the lower number of states. In other words estimate (b.1) where the function \( h(x_t, \theta) \) represents the model with the lower number of states.
d) Compute the following residual sums of squares:

\[ H_1: \sigma^2 = \sum_{t=1}^{T} (y_t - h(x_t, \hat{\theta}) - \hat{\delta}z_t)^2. \]
\[ H_0: \sigma^2 = \sum_{t=1}^{T} (y_t - h(x_t, \hat{\theta}))^2. \]
Then the likelihood ratio test, with size $\alpha$, rejects the null if:

$$\frac{\hat{\sigma}^2}{\sigma^2} > 1 + \frac{dF_{\alpha}}{(T-m-\omega)}$$

where $\omega$ is the number of parameters estimated under the null hypothesis, $m$ is the dimension of the vector $z$, and $F_{\alpha}$ denotes the $\alpha$ percentage point of a $F(m, T-m-\omega)$ distributed random variable.
Appendix 4.2

Solid lines represent the bound of $2/T^{1/2} = 0.099$

Sample ACF AR(1)

Sample ACF AR(2)

Sample ACF AR(3)

Figure 5 Sample ACF of the Residuals of different AR models of the IPO returns from 1960:1-1993:12.
Figure 8 Sample ACF of the residuals of different AR models of the IPO volume process from 1960:1-1993:12
Figure 9
Figure 10
Chapter 5

An Optimal Stopping Model of A Firm’s Decision to Go Public

5.1 Introduction

Privately owned corporations face the option of either financing their capital requirements privately or financing their capital requirements by going public and carrying out an initial public equity offering. Over the “life span” of a firm, equity infusions are likely to occur periodically as the firm grows. It is not uncommon to observe young and rapidly growing firms secure several rounds of equity financing.\(^1\) Interestingly, on a yearly basis approximately one third of the capital requirements raised through common equity are raised through initial public offerings (IPOs). Also, an IPO is usually the largest equity issue that a firm will ever make. These facts are an indication that the IPO is an important channel through which a company can raise capital. It is also an important channel for entrepreneurs and venture capitalists to receive the rewards for their efforts in producing a viable and growing company.\(^2\) Therefore an understanding of what affects the decision or the likelihood of “going public” is important in attempting to ease access to equity financing and stimulate entrepreneurial activities and economic growth.

This chapter presents a dynamic, infinite horizon, optimal stopping model of the

\(^1\) Lerner (1994) gives an indication of the average number of equity infusions required by young firms before going public. He finds that firms in the biotechnology industry in the U.S. require, on average, three private equity infusions before going public.

\(^2\) As part of the entrepreneurs reward, the entrepreneurs are able to diversify their portfolios and reduce their investment risks.
firm's decision to go public in an environment in which the distribution of the offering proceeds that the firm receives by going public fluctuates stochastically. One implication derived from the model is that IPOs are more likely to occur during some period than others, a prediction borne out by the empirical evidence documented in Chapter 4 of this thesis and in Ibbotson, Sindelar, and Ritter (1994). Secondly, the model predicts that periods of high IPO volume are correlated with sectoral stock market peaks. This implication is consistent with the empirical evidence presented in Pagano, Panetta, and Zingales (1995) and Lerner (1994). The optimal stopping model is then extended to allow for firm heterogeneity. Specifically firms are assumed to be differentiated on the basis of the available public information about the firms themselves. Established firms are assumed to engender a reduction in the divergence of investor beliefs about the firm's intrinsic value. A third implication of the model is that more established firms, such as larger and/or older firms, are more likely, other things being equal, to go public.3

The idea behind the proposed model is as follows. Suppose that a private firm is continually waiting for the right moment to go public. As it waits, it receives a sequence of offer prices from an underwriter. The offer prices calculated by the underwriter depend on the investors' valuation of the firm given it goes public during that period. The market valuations of the IPO and, in turn, the offer prices received from the underwriter are viewed as draws from a distribution of offers that is dependent on investor beliefs about the IPO's intrinsic value. These investor beliefs are assumed to shift in a stochastic manner. The firm's decision problem under these conditions involves the selection of a criterion that determines when a received offering price is "acceptable." Once an acceptable offer is received, the firm stops waiting and goes public. Throughout this analysis the firm is assumed to know the state of investor beliefs and, in turn, the distribution of offer prices that it receives. Also, it is assumed that there are two types of firms differentiated by their public information characteristics.

---

3Pagano, Panetta, and Zingales (1995) provide empirical evidence that larger firms, as measured by their sales revenue, are more likely to go public. Lerner (1994) shows that firms backed by more experienced venture capitalists are more proficient at timing the IPO than firms backed by less experienced venture capitalists.
Technically this model differs considerably from previous models of the IPO process. Past models of the firm’s decision to go public focused on the pricing aspect of the offering in order to explain the presence of positive initial returns, the so-called “underpricing” phenomena. These models, under the assumption that IPO shares are “efficiently” priced in the aftermarket, assume that the positive initial returns arise because of the adverse selection problem engendered by the asymmetric information between the investors and the owners of the firm going public. Examples of this work include Rock (1986), Welch (1989), Leland and Pyle (1977), Grinblatt and Hwang (1989), and Chemmanur (1991) to name a few (see Chapter 3 of this thesis for other examples). In summary, these models are primarily concerned with the price at which firms go public rather than modelling what affects the probability of firms going public. This study is believed to be the first to model explicitly the firm’s decision to go public in a stochastic environment and explain why firms tend to go public in clusters, the so-called “hot issues” market phenomena. Also, because of its explicit stochastic structure, the model formalizes various aspects of the “windows of opportunity” hypothesis described in Chapter 3.

The rest of the paper proceeds as follows. Section 5.2 presents an overview of the information environment assumed in previous IPO pricing models and the information environment postulated to account for the observed cycles in IPO volume model here. This section is a useful starting point for readers who are unfamiliar with the IPO market’s information environment. Section 5.3 describes the financial or investment environment of the model. In this section, the interaction between the firm, the underwriter, and the investors is described. Specifically, Section 5.3 describes how the offering proceeds, or “bids,” received by the firm are determined and how fluctuations in investor beliefs affect these offering proceeds. Section 5.4 presents the basic optimal stopping model for a firm deciding to go public in an environment in which their offer

---

In these models, there is no modelling of the timing of the firm’s decision to go public and thus there is no explanation of the observed cycles in the number of IPOs. Also, the environment in which the agent interacts is a static one. The information on which the agents base their decisions does not vary.
distribution varies stochastically over time. An analysis of the sensitivity of the results derived in Section 5.4 is presented in Section 5.5. In Section 5.6 the model is extended to allow for heterogeneity between firms. With this added flexibility, the model explains why certain types of firms are more likely to go public. Some concluding remarks are offered in Section 5.7.

5.2 An Overview of the Information Environment Surrounding an IPO and IPO Pricing Theory

In this section a review of the information-based explanations of IPO underpricing and IPO long-run investment underperformance is presented. The focus is on the role that informational asymmetries play in explaining these anomalies. This section describes how some degree of discrepancy between market valuation and the owner's valuation of the firm, as well as some degree of investor heterogeneity, lead to the overvaluation of the IPO stock in the aftermarket, positive initial returns and poor long-run investment performance. This section also introduces and motivates some basic assumptions that underlie the optimal stopping model of the firm’s decision to go public. The consistency of these assumptions with the empirical evidence characterising the IPO market is also discussed.

5.2.1 Information's Role in the IPO Process: An Overview

It is easy to see why investors have imperfect information about the firm’s intrinsic value. First, no past stock price history for investors to judge the merits of the offering price exists. Second, these firms often do not possess a long publicly observable operating history.

The development of adverse selection models based on the presence of

---

4The firm’s intrinsic or fundamental value is assumed to be measured by the expected net present value of the firm’s future cash-flow/dividend stream.
asymmetric information between the owners and investors is the most actively researched aspect of the IPO process. In these models the owners' private information gives them a superior ability to value the firm's common stock. This information advantage over the investors creates an adverse selection problem since firms have an incentive to exploit valuation errors by the investors. As highlighted by Rock (1986) and others, low-quality firms have the greatest incentive to exploit these valuation errors, which in turn adversely affects the IPO offering price (downward).

The adverse selection problem can be thought of in the following terms. Given that the firm goes public, the investors' valuation (the market valuation) of the firm immediately prior to the listing \( V^M \), is equal to the market expectation (over the investors' information set \( \Omega \)) of the firm's intrinsic value, \( v \), denoted \( E[v] = E[v|\Omega] \)

\[
V^M = E[v].
\]

From the owners perspective, the value of their public firm is given by

\[
V^o = v
\]

where \( v \) is known to the owners of the firm and to "informed" investors. In adverse selection models of the IPO process, the "informed" investors believe they are more likely to end up purchasing shares in low-quality firms at the offering. Under these beliefs, uniformed investors hold low average \( E[v] \) values compared with the true average (across all firms) \( v \) value. Under these circumstances the offering price is set at \( V^M \), which is below \( V^o \) in order to entice all potential buyers to purchase shares at the offering.\(^6\) The assumption that stock markets are efficient, in turn, implies IPO shares will trade at their intrinsic value, \( V^o \), in the aftermarket. This implies that the adverse selection argument is consistent with the fact that offering prices for IPOs are typically

\(^6\)Informed investors, since they know the intrinsic value of the firm, also know whether the firms offering price is above or below the intrinsic value and thus only invest in firms whose offering price is set at or below the intrinsic value. Uniformed traders do not have this luxury and thus will assume that they are buying firms that are overvalued. For more details see Chapter 3 for a summary of Rock's (1986) model.
below the first day closing price: *i.e.*, the so-called "underpricing" phenomena
documented by many authors (see Ibbotson Sindelar, and Ritter (1994)). Viewed in this
manner, the adverse selection problem experienced by IPOs is a cost to going public since
the firms must "leave money on the table" in the amount of $V^o - V^M = v - E[v] > 0$ to
achieve a successful offering. Less severe informational asymmetries between the initial
owners and investors should reduce the adverse selection costs of going public since $E[v]$
will be closer to $v$. For example, younger, smaller, or more "information-poor" firms
should incur higher adverse selection costs since the disparity between informed and
uniformed investors is greater for these firms.7 Private firms needing equity can reduce or
avoid these adverse selection costs by financing projects with their (limited) internal
funds, issuing debt or raising funds privately, or by timing their IPOs during periods when
the asymmetric information problem is less severe.

The empirical evidence suggests that there is a cyclical pattern in the magnitude of
positive initial returns. If asymmetric information models are to explain this fact, they
must assume that asymmetric information costs vary over time to account for these
fluctuations in underpricing. This requires the informational content of the public
offering to vary. Ritter (1984) extends Rock’s (1986) model to account for this by
allowing the composition of the firms going public to vary over time. Specifically, Ritter
suggests that, since riskier issues (issues for which there is greater informational
asymmetry) tend to be underpriced more than informationally symmetric issues,
fluctuating risk *composition* of the firms going public (*i.e.*, more risky type firms going
public) may account for the cyclical pattern in initial returns. A more straightforward
explanation of the swings in initial returns put forth by Myers and Majluf (1984) is that
there is an inter-temporal variation in the level of asymmetric information between the
owners and the investors. Though variable asymmetric information levels have not been

7 This prediction is consistent with the empirical evidence found in Dark and Carter
(1993), Ritter (1991), and Ibbotson, Sindelar, and Ritter (1994). Dark and Carter find that firms
that have larger offerings and use more prestigious underwriters will incur less underpricing.
Ritter finds older firms experience less underpricing. Ibbotson, Sindelar, and Ritter show that
larger firms, as measured by sales, incur less underpricing.
formally modelled for IPOs, it is easy to construct examples for which this may be the case for certain sectors, industries or even firms. Informational symmetry can occur if the value of the firm, or the value of firms in a certain sector, is dominated by factors that both the owners and the investors observe (see Berkovitch and Narayanan (1993) for situations in which this may occur).

Recent empirical evidence of long-run investment underperformance for IPO firms is an indication that the early aftermarket may not be "efficiently" pricing IPO shares. Specifically, studies by Ritter (1991), Dark and Carter (1993), and Loughran and Ritter (1995) document the existence of positive first day returns followed by strongly negative returns over an extended period following the IPO. The long-run underperformance evidence is an indication that this initial overvaluation of the IPO in the early aftermarket is subsequently corrected over the long-run as the market value of the firm approaches its fundamental value. These recent findings indicate that the early aftermarket price is $V^m$ (not $V^o$, as in the adverse selection models above), and may be a reflection of overpricing by the investors with $v < \mathbb{E}(v)$ and $V^m > V^o$. In summary, the initial market price of the IPO tends to be high relative to the long-run (efficient) market price, $V^o$ (the intrinsic value of the firm). One should note that it is no longer necessarily the case that the firm's offering price is set strictly below its intrinsic value, $V^o$, as was assumed under adverse selection. However, the observed positive initial returns suggest that the offering price is still set below the early aftermarket price. An explanation for why firms may not receive the full market value for the shares sold at the offering is discussed in the Appendix to this chapter.

How does this high (initial) expectation of the IPO firm's value arise? Two complementary hypotheses have been put forward to explain this result. These are considered in turn. The first is suggested by Morris (1995), who develops a micro-theoretical model of asset valuation and learning. In this model, a "speculative premium" may arise when traders have heterogeneous but "reasonable" prior beliefs. Morris provides necessary and sufficient conditions to show that the asset's price will always be "strictly" greater than every trader's estimate of the fundamental value of the asset, and
that both the price and the traders' valuations will converge to the fundamental value of
the asset as traders learn over time.\footnote{Morris' model is basically an extension of the Harrison and Kreps (1978) model of
investor speculation due to heterogeneous investor belief of an asset's fundamental value. Morris
adds learning to this model to investigate the dynamics of the speculative premium. He is
mystified as to why Harrison's and Kreps' results have been largely ignored. He presumes that the
assumption of "unmodelled" heterogeneity is the contributing factor to the professions disdain for
this model. Morris also argues that allowing differences in prior beliefs affects economic models
the same way as does allowing for differences in utility functions across agents. However, he
concludes that the economic profession remains, nonetheless, only interested in explaining
phenomena with heterogeneous utility functions without explicitly modelling this type of
heterogeneity. He finds that heterogeneity in beliefs is a victim of some sort of double standard
within the economic profession.} Morris shows that this phenomenon can explain the
long-run underperformance paradox documented for IPOs. To further elaborate, Morris
provides a formal explanation of why speculative premia may occur in an environment
where, without historical data such as past prices or returns, traders must form beliefs
about the traded asset's future returns. He finds that this is particularly relevant for IPO
shares. Morris argues that even in an environment of ample public information (about
firm characteristics for example), the lack of historical data allows for the possibility that
different traders initially have diverse beliefs based on the same information.

His model predicts that the speculative premium is reduced to zero over time as
more information becomes available about the fundamental value and beliefs become less
diverse. Therefore, Morris' model predicts that IPOs will be overpriced the most at the
new issue date when information is at minimum and divergence of beliefs is greatest. As
time goes on, IPO shares develop a price history, information increases, and overpricing
decreases as beliefs converge. Morris' model is also consistent with Ritter's (1991)
finding that initial returns and investment underperformance decreases monotonically
with the IPO firm's age. Morris argues that traders are less likely to have heterogeneous
beliefs for old firms that have accumulated a long public history. His model thus predicts
that older firms have lower initial returns and experience less investment
underperformance than younger, smaller, less well-known firms.

A second explanation of the apparent overvaluation of IPO shares is the "noise
trader” model developed by De Long, Schleifer, Summers, and Waldmann (1990a) (DSSW hereafter). In their model, some less than rational traders calculate the value of a risky asset with an error. Because of the assumed limited arbitrage and the assumed stochastic variance of the noise traders’ valuation error (or beliefs), the price of the risky asset will be stochastic and systematically different from the efficient market price. In fact, due to the stochastic nature of the noise traders’ valuation error, the risky asset may be overvalued relative to its fundamental value in certain periods. Morris’ model can explain, at a fundamental level, how these errors (beliefs) may be non-zero across investors, thus dispelling the ad hoc nature of these exogenous errors. The implications of the “noise trader” model are consistent with several empirical characteristics of the IPO market, including the clustering of IPOs in certain periods. Specifically, if stocks are overpriced in certain periods, as suggested by DSSW, firms that realize that other seasoned firms in their sector are overvalued have an incentive to go public. This is the so-called “windows of opportunity” hypothesis based on investor mis-pricing. It is consistent with the long-run underperformance (Ritter (1991) and Loughran and Ritter (1995)) of IPOs. It is also consistent with the cross-sectional clustering of IPOs near sectoral stock price peaks (Lerner (1994)) and sectoral median market-to-book ratios (M/B hereafter) (Pagano, Panetta, and Zingales (1995)). In this case, investors are not simply overvaluing the individual IPOs but also overvaluing other (similar) firms in their sector as a whole, thus resulting in the observed correlation of IPOs with sectoral measures of firm value.

5.2.2 Formal Summary

A more formal treatment of the various aspects of the informational content of the IPO process is now presented. To start, some additional notation is introduced. Let \( v \) denote the true intrinsic or fundamental value of the firm (usually defined as the net

---

\(^9\)See the Appendix to this chapter for an explanation of how the extraneous “irrational” beliefs in the DSSW “noise trader” model can be explained at a fundamental level with Morris’ (1995) model.
present value of the future stream of cash flow dividends). Let $\mathcal{Q}_i$ be the information set representing the publicly available information about the firm at time $t$, and $\mathcal{Q}_i^0$ be the information set held by the original owners with $\mathcal{Q}_i \subset \mathcal{Q}_i^0$. As previously discussed, a natural assumption is that the public information set, $\mathcal{Q}_i$, is positively related to the age and size of the firm. Let $\Lambda$ represent the level of asymmetric information between the investors and the owners of the firm (i.e., older/larger firms are assumed to possess a larger information set, $\mathcal{Q}_i$, than younger/smaller firms). As Myers and Majluf (1984) argue, the degree of asymmetric information is assumed to be negatively related (or inversely proportional) to the difference between the public information set $\mathcal{Q}_i$ and $\mathcal{Q}_i^0$. In circumstances where $\mathcal{Q}_i$ and $\mathcal{Q}_i^0$ are identical, $\Lambda$ will be zero. Let $\Pi$ represent the level of heterogeneity of beliefs between investors. Morris (1995) predicts that as the size of $\mathcal{Q}_i$ increases, $\Pi$ should decrease. As in DSSW, the investors are assumed to mis-value fundamentals with an error $\mu_i$ in certain periods (i.e., if the true expected value of the firm is $v$, then DSSW's model predicts that investors will value the firm at $v + \mu_i$). DSSW assume that this value is exogenous and stochastic with $\mu_i \sim \text{iid } N(\mu^*, \sigma^2)$.

Having introduced some notation, it is now possible to summarise succinctly and compare the differences in the role information plays in the IPO process. Let $E[v|\mathcal{Q}_i]$ be the market's expectation of the firm's intrinsic value. The expectation is over the set of investors who condition their valuations of the firm on the information set $\mathcal{Q}_i$.

(i) Adverse Selection (Rock (1986)):

$$E[v|\mathcal{Q}_i] = \gamma(\Lambda(\mathcal{Q}_i)) \leq v$$

and as $\mathcal{Q}_i \rightarrow \mathcal{Q}_i^0 \rightarrow \Lambda \rightarrow 0$ and $E[v|\mathcal{Q}_i] = \gamma(\Lambda(\mathcal{Q}_i)) \rightarrow v$.

Here $\gamma$ is some function of the level of asymmetric information, $\Lambda$, which is in turn some function of the public information set $\mathcal{Q}_i$. In adverse selection models, it is assumed that as public information becomes equivalent to the owner's private information (and the informed investors' information) about the intrinsic value of the firm (with $\mathcal{Q}_i \rightarrow \mathcal{Q}_i^0$) the level of asymmetric information $\Lambda$ goes to zero. This implies that the market valuation of the firm, $E[*]$, converges to the intrinsic value of the firm, $v$. 
(ii) Speculative Premia (Morris (1995)):

\[ E[v | \Omega_t] = \gamma(\Pi(\Omega_t)) \geq v \text{ and as } t \rightarrow \infty, \Omega_t \rightarrow \Pi - 0 \text{ and } E[v | \Omega_t] = \gamma(\Pi(\Omega_t)) \rightarrow v. \]

Here \( \gamma \) is some function of the heterogeneity among investors, \( \Pi \), which is in turn some function of the public information set \( \Omega_t \). In the speculative premia model proposed by Morris, it is assumed that as time goes on (after the offering), the public information set increases, which in turn reduces the investor heterogeneity, \( \Pi \). This implies that the market valuation of the IPO stock (which is greater than the intrinsic value of the firm due to the heterogeneity of investor beliefs) converges to the intrinsic value of the firm.

(iii) Misvaluation (De Long, Schleifer, Summers, Waldmann (1990a)):

\[ E[v] = v + \mu_t \]

where \( \mu_t \) is iid N(\( \mu^*, \sigma^2 \)) in DSSW’s original formulation. Since DSSW simply assume that \( \mu_t \) is exogenous and stochastic, the market expectation, \( E[v] \), is an unconditional expectation in this case. Evidence indicating that the median sectoral M/B is high in some periods and is correlated with clusters of IPOs is consistent with the model’s prediction that \( \mu_t \) is high for that sector for a certain period with M/B=M/B(\( \mu_t \)). In other words, a high median M/B in a sector may be an indication of some sector wide overvaluation rather than a reflection of high fundamentals.

Alternatively, \( \mu_t \) may be a function of the median sectoral M/B, with \( \mu_t = \mu_t(M/B) \).

This may arise as investors overreact to recent news about the sector's earnings or future growth potential as suggested by the “overreaction” hypothesis put forward by DeBondt and Thaler (1985) or by the “fads” hypothesis put forward by Shiller (1990). In this case, the market expectation of the firm’s value can be viewed as conditional on sectoral valuation measures such as the median M/B of the sector, with

---

10 A recent example is the case of Internet IPOs. The recent belief that the Internet presents itself as a large untapped growth market for any firm that produces products related to the Internet has allowed the IPOs from Internet firms to raise vast amounts of capital before having produced a positive earnings history (Netscape is a prime example of such a firm). However, recent Internet IPOs have not had the same success as earlier IPOs. Some firms have had to withdraw their plans for a public equity offering, possibly due to a change in the investors’ perceptions of the Internet’s growth or investment potential.
\[ E[v|M/B] = v + \mu_t(M/B). \]

However, evidence presented in Lee, Schleifer and Thaler (1991) shows that the difference between the median market price of closed-end funds and the directly observable median fundamental value of the closed-end funds sector varies stochastically and is on average negative. They indicate that this evidence is consistent with the "noise trader" model's implication that the market value of certain assets is dependent on the investors' stochastic beliefs \( \mu_t \), and not conditional \( M/B \).

The following section of this study develops a model of a firm seeking to go public that uses various aspects of the above competing (and partly overlapping) explanations of the IPO market anomalies. As opposed to the majority of IPO pricing models (see Chapter 3), the model described in this chapter is consistent with all anomalous aspects of the IPO market. The model is developed to be consistent with the observed cyclical patterns in the IPO volume. Extensions of the model, presented in the Appendix to this chapter, have predictions that are consistent with both the observed cyclical patterns in the positive initial returns and the long-run underperformance of IPOs.

5.3 The Environment of the Model

In this section, the environment of the model and the nature of the offer distribution, which the firm (in deciding to go public) takes as given is described in some detail. The structure of the model is as follows. The firm receives a sequence of "bids" or offers from the underwriter for the sale of a fixed percentage of the firm to the public. These bids are simply the total amount received at the offering. However, the amount offered to the original owner is assumed to be an independent draw from a known (to the owners) distribution of offers, the offer distribution. This offer distribution is derived from the market valuation of the firm which, because of stochastic heterogeneous investor beliefs about the intrinsic value of the firm, is a random variable. In this section the stochastic offer distribution is derived given the stochastic nature of the investors. In the Section 5.4, the stochastic offer distribution is taken as given in deriving the optimal
stopping model of the dynamic decision-making process of the firm.

5.3.1 The Firm

The firm is either a private entity or a public entity. Let \( d_i \) be an indicator function denoting the firm's status such that

\[
d_i = \begin{cases} 
0 & \text{if firm stays private} \\
1 & \text{if firm goes public.} 
\end{cases}
\]

The intrinsic or true value of the firm, \( V \), is equal to the intrinsic value of the firm given that it goes public, \( v_1 \), otherwise it is equal to the intrinsic value, \( v_0 \), given that the firm remains private, such that

\[
V(d_i) = v_{d_i} \text{ where } d_i = \{0, 1\}. \quad (1)
\]

Here it is assumed that \( v_1 \neq v_0 \) and \( v_1, v_0 \geq 0 \).\(^{11}\) The IPO will be overvalued in the aftermarket if the market estimate of \( v_1 \) is greater than \( v_1 \). The market estimate of \( v_1 \) is derived in the following subsection.

Firms are run by risk-neutral owners/managers who maximize their lifetime wealth derived from the firms' assets. In what follows, the decision-making entity will be referred to as the firm or the owners. The owners exogenously set the fraction of equity in the firm to sell, \((1 - \alpha)\), such that \((1 - \alpha) \in (0, 1]\). Owners are assumed to invest the net proceeds from the IPO — the offering proceeds, \( D_\alpha \),\(^{12}\) minus project investment \( K \) — in

\(^{11}\) Setting \( v_1 > v_0 \) addresses the case where the purpose of the IPO is to fund a project that is growth enhancing and thus increases the intrinsic or fundamental value of the firm given it goes public.

\(^{12}\) The offering prices that the firm receives fluctuates with the offering proceeds, \( D_\alpha \), since the offering proceeds are assumed to be the product of the offering price and the number of shares sold at the offering. By assuming the number of shares to be sold at the offering is exogenously set at the same time as the proportion of the firm to take public, \((1 - \alpha)\), the offering price will fluctuate with the fluctuations in the offering proceeds received. Alternatively, the focus of attention could be on dilution of ownership rather than the offering proceeds. This is
a risk-free asset which yields a rate of return normalised to zero. The offering proceeds, \( D_t \), are based on the investors' valuation of the firm and are calculated by the underwriter. Though the intrinsic value of the firm, \( V \), does not vary over time, the offering proceeds are assumed to vary as investor valuations of the firm vary over time. The derivation of \( D_t \) is described in subsection 5.3.3 below. From the owners perspective, the value of their net asset holdings, \( V^o \), conditional on taking the firm public is

\[
V^o(d_t = 1) = \alpha v_t + D_t - K. \tag{2}
\]

The owners of the firm are also assumed to enjoy a pecuniary benefit to sole ownership that is measured as \( B \). The value of the owners' holdings in the firm given that it is private is:

\[
V^o(d_t = 0) = v_0 + B \tag{3}
\]

### 5.3.2 Investors

Investors are assumed to be risk neutral. Each investor seeks to maximize the expected value of a stream of cash flow dividends that will accrue to them through their ownership of assets. If the investors' valuation of the firm's intrinsic value (or equivalently, the net present value of the firm's future stream of cash flow dividends) exceeds the dividend stream from a riskless asset, the investor invests in the firm. As opposed to the owners of the firm, investors do not know \( V \). Under an information scarce environment each investor makes a valuation error of the firm's intrinsic value given that it goes public, \( v_t \), based on their own beliefs, \( y_i \), at \( t \). Investor \( i \)'s valuation of the firm at

accomplished by holding fixed the offering price while varying the number of shares sold and, in turn, the fraction of equity in the firm to sell \((1 - \alpha)\).

\(^{11}\) Setting \( K = 0 \) addresses the case where the only purpose for the IPO is to diversify the owners' portfolio, divest part of its ownership in the firm, and raise no extra capital for the firm.
time period $t$ is:

$$v_{it} = v_1 \cdot y_{it}.$$  

The value of the investor specific belief, $y_{it}$, is assumed to be a composite of two types of beliefs. One belief is common to all investors, and can be thought of as arising from the investors’ assessment of the firm’s industry’s prospects.\(^{14}\) For example, investors may believe that firms producing goods related to the Internet will bring them good financial fortune. The idea that investors have a common belief (or error) about an asset’s value is formalised in the DSSW “noise trader” model and is defined as $\mu_i$. Here $\mu_i$ is assumed to be driven by an unobservable discrete state variable.\(^{15}\) Specifically, $\mu_i$ is assumed to be dependent on the value of a state variable $S_i \in \{0, 1\}$ which is an indicator of the state of the investors’ common beliefs. Therefore $\mu_i = \mu_i(S_i)$ such that:

$$\mu_i = \mu_i(S_i) = \begin{cases} 
\mu_0 & \text{if } S_i = 0 \\
\mu_1 & \text{if } S_i = 1
\end{cases}$$

where $\mu(1) > \mu(0)$ since investors are assumed to hold more “optimistic” beliefs in state 1.

The other type of belief is investor specific, and arises because each investor assesses public information about the firm’s potential in an investor specific manner, and thus yields a different valuation of the firm’s intrinsic value.\(^{16}\) The idea that investors

\(^{14}\)More generally, common investor beliefs may be thought of as arising from some common extrinsic “psychological” or “societal” factor that may be described as herd-behaviour (Welch (1992)) or fads (Shiller (1990)).

\(^{15}\)In DSSW, $\mu_i$ is assumed to be stochastic with $\mu_i \sim N(\mu^*, \sigma^2_\mu)$.

\(^{16}\)Investors may form different opinions even when they have the same substantive information if one takes into consideration the investors’ heterogenous characteristics such as preferences, education, age, work experience, religious beliefs, etc. Investors are simply assumed to react to information differently based on their individual characteristics. See Russel and Thaler (1985) for a model of how economic agents may react differently when choosing between bundles of goods that are identical but presented differently; this model may be able to explain why agents seem to behave irrationally in asset markets.
hold *heterogeneous* beliefs about an asset’s value is formalised at the micro-theoretical level in Morris (1995). In this study, each investor, i, is assumed to hold beliefs, \( \varepsilon_i \), about the intrinsic value of the firm, where \( \varepsilon_i \) is a random variable with cumulative distribution function \( \Psi \). The distribution \( \Psi \) is invariant over time, and the \( \varepsilon_i \)’s are mutually independent with mean equal to 0 and variance equal to \( \sigma^2 \). Let the investor beliefs, \( y_{it} \), now be defined as:

\[
y_{it} = \mu(S_t) + \varepsilon_i \tag{4}
\]

This implies that \( y_{it} \) has a mean of \( \mu(S_t) \) and variance equal to \( \sigma^2 \). The time subscript for \( y_{it} \) arises from the fact that \( \mu(S_t) \) is state-dependent. If the mean of \( y_{it} \) was state-independent with \( \mu(S_t) = \mu \), \( y_{it} \) could simply be viewed as a cross-sectional random variable, \( y_t \).

In this study, the individual investor’s valuation of the firm is a random variable, \( v_{it} \), and is defined as:

\[
v_{it} = v_i + \mu(S_t) + \varepsilon_i \tag{5}
\]

Given the state variable, \( S_t \), \( v_{it} \) is assumed to vary in a stochastic manner with the following state-dependent distribution:

\[
\text{PDF}(v_{it} | s_t) = \begin{cases} f_0(v_{it}) & \text{with } \text{E}(v_{it}) = v_i + \mu(0) \text{ and } \text{Var}(v_{it}) = \sigma^2 \quad \text{if } S_t = 0 \\ f_1(v_{it}) & \text{with } \text{E}(v_{it}) = v_i + \mu(1) \text{ and } \text{Var}(v_{it}) = \sigma^2 \quad \text{if } S_t = 1 \end{cases}
\]

This implies that when common investor beliefs are in state 1 (the optimistic state), the individual investor’s valuation of the firm (conditional on the firm going public), \( v_{it} \), is assumed to have been drawn from a distribution with mean \( v_i + \mu(1) \) and variance \( \sigma^2 \). If investor beliefs are in state 0, the investor’s valuation of the firm is assumed to be drawn from a distribution with mean \( v_i + \mu(0) \) and variance \( \sigma^2 \).17

---

17 Recall that \( \mu(1) > \mu(0) \) is assumed. Setting \( \mu(1) > \mu(0) = 0 \) addresses the case where investors are on average correctly assessing the firm’s intrinsic value at the offering while in state 0, but are on average optimistic about the firm’s potential in state 1. Symmetrically, setting \( \mu(1) = 0 > \mu(0) \) addresses the case where investors are on average correctly assessing the firm’s value in
The variable $S_t$ is a discrete valued state variable specified as a first-order Markov process with the transition $P$ matrix defined as

$$
P = \begin{bmatrix}
p & (1-p) \\
(1-q) & q
\end{bmatrix},
$$

where $p = \Pr[S_t = 0 | S_{t-1} = 0]$ and $q = \Pr[S_t = 1 | S_{t-1} = 1]$.

To sum up, the individual investor's valuation of the firm's prospects in period $t$ is given as:

$$v_{t+1} = v_t + \gamma_{t+1} = v_t + \mu(S_t) + \epsilon_t,$$

where $\mu(S_t)$ represents the investor-wide perception and $\epsilon_t$ the individual perception (belief) about the firm's intrinsic value, $v_t$. With $\mu(S_t)$ stochastic, the amount investors are willing to offer for a $(1 - \alpha)$ share of the firm will fluctuate.

Since a key assumption of the model is that $\mu(S_t)$ is stochastic and non-zero, a few words on the exogenous nature of these investor beliefs are in order at this time. Here, as in the DSSW "noise trader" model, investors are assumed to be affected by exogenous, stochastic swings in non-fundamentally-based beliefs or sentiment. Though these beliefs are assumed exogenous in this model, there is a growing literature modelling the microeconomic foundation of the asset trading process that can account for these "perceived" irrational beliefs of the traders.\textsuperscript{18} As shown in the Appendix to this chapter, state 1 but are on average pessimistic in state 0. Naturally, having $\mu(1) > 0 > \mu(0)$ implies that investors are on average incorrectly assessing the value of the firm in either state.

\textsuperscript{18} A sample of other models that explain, at a fundamental level, the perceived irrationality of investors follows. Kurz (1992) develops a model in which asset mis-pricing arises from heterogenous beliefs of rational economic agents reacting to the same information. Here rational beliefs are defined as beliefs that cannot be contradicted by the data generated within the economy. A related theoretical model of learning and rationality that helps explain the evidence of investor overreaction to news, documented by DeBondt and Thaler (1985), is put forward by Russell and Thaler (1985). A model of the micro-structure of herding behaviour which can be characterised as informational cascades is presented by Welch (1992) and Bikhchandani, Hirschleifer and Welch (1992). Grossman (1988), Bulow and Klemperer (1994), Caplin and Leahy (1994), and Romer (1993) put forward models that contend that the dispersion of asymmetric information between investors, the trading process itself, and the frictions involved in aggregating information overtime.
Morris' (1995) model seems particularly well suited to explain both how \( \mu(S) \geq 0 \) in certain periods, which helps explain the clustering of IPOs, and why these speculative beliefs decline as more information becomes available (thus resulting in poor long-run investment performance for IPOs).

### 5.3.3 The Underwriter's Calculation of the Offering Proceeds

Recall that the investor specific valuation of the firm (given \( d_i = 1 \)) derived in the previous subsection is:

\[
v_{ii} = v_i + \mu(S_i) + \epsilon_i.
\]

The underwriter, in calculating the market's valuation of the firm, is assumed to take a sample of the investors' valuation, \( v_{iti} \). Specifically, the underwriter calculates the sample mean of \( v_{iti} \) defined as \( v^*_i \):

\[
v^*_i = v_i + \mu(S_i) + \epsilon^*_i
\]

which is the same as \( v_{iti} \) in equation (5) except that \( \epsilon_i \) is now replaced by its sample mean \( \epsilon^*_i \) at \( t \) and has a cumulative distribution function \( \Psi^* \) with mean equal to 0 and variance equal to \( \sigma^2/N \) where \( N \) is the sample size.\(^{19}\) Given \( v^*_i \), the underwriter performs the following calculation to derive the net proceeds from the offering, denoted \( D_i \). Investors will provide a total of \( D_i \) at the offering in return for a \((1-\alpha)\) share of the firm such that:

---

across the investor community, play an important part in the perceived speculative or "inefficient" behaviour of investors.

\(^{19}\) As the number of investors sampled by the underwriter is very small in relation to the universe of investors interested in IPOs, there is little reason to believe that the distribution of the sample mean for \( D_i \) will be much different than the distribution of \( v_{iti} \) itself. In fact, there is good reason to believe that the estimate of the mean of \( v_{iti} \) will in fact be biased upwards since it is likely that the underwriter will sample investors who come forward with some interest in investing in the firm in the first place (what is called a selection bias). The possibility of selection bias is not modelled here.
\[ D_t = (1 - \alpha)v_i^* = (1 - \alpha)[v_i + \mu(S_i) + \epsilon_i^*]. \tag{7} \]

In every period that the firm remains private, the underwriter undertakes this calculation, which is passed on to the firm in the form of a bid. In reality, the underwriter will only start sending a sequence of offers, \( D_t \), to the private firm after the firm has initiated the IPO process. The model abstracts from the firm's initial decision to participate in the IPO process itself. For the time being, the parameter values are assumed to be set such that the return to the firm for participating in the IPO process is at least as large as the return for not participating in the IPO process. The assumption is relaxed in subsection 5.6.3 below.

The owner's holdings in the firm in accepting the bid (offer) and going public, \( V^o(d_i=1) \), is calculated by substituting \( D_t \) into equation (2). This yields:

\[ V^o(d_i=1) = \alpha v_i + (1 - \alpha)[v_i + \mu(S_i) + \epsilon_i^*] - K = v_i - K + (1 - \alpha)[\mu(S_i) + \epsilon_i^*]. \tag{8} \]

This implies that \( V^o(d_i=1) \), the firm's income derived in accepting the bid and going public, is a stochastic random variable. Therefore from the firm's perspective, the bids received are viewed as a random sample from a distribution, which is defined in the following subsection.

Note that the model's predictions are consistent with the long-run investment underperformance evidence; this is shown in the Appendix to this chapter. This is accomplished by relaxing the assumption of time invariant investor heterogeneity so that variance of \( \epsilon_i \), which is the measure of the investors heterogeneity, is time dependent and equal to \( \sigma_i^2 \). In Section 5.6 of this study, the degree of investor heterogeneity is assumed to be firm dependent with the variance of \( \epsilon_i \) firm dependent and equal to \( \sigma_i^2 \) such that an established firm (\( j = r \)) will experience a smaller divergence in beliefs about its intrinsic value than a less established firm (\( j = p \)) with \( \sigma_p^2 \geq \sigma_r^2 \).
5.3.4 The Offer Distribution

In the optimal stopping model presented in the next section, the owners decision to go public is based on a comparison of the owners income derived from going public and the one period income derived from remaining private. However, \( V^o(d_t) \) from equation (3) and (8) is a measure of the present value of the stream of income received by the owner conditional on \( d_t \) rather than the per period income. Let the per-period income derived from the owners holdings, the "annuitized" value of their holdings in the firm, \( Z(d_t) \), be a linear function of \( V^o(d_t) \) and the owners discount factor \( \beta \). Under the assumption that the owners discount factor is fixed over time, the "annuitized" period \( t \) value of the owners holdings given the firm has gone public is given as:

\[
Z(d_t = 1) = (1 - \beta) V^o(d_t = 1) = (1 - \beta) [v_t - K + (1 - \alpha)(\mu(S_t) + \epsilon^*_t)].
\]

If the owners accept the underwriters offer and take the firm public they are assumed to receive \( Z(d_t = 1) \) in each period forever after. If the owners reject the offer, they are assumed to receive

\[
C = Z(d_t = 0) = V^o(d_t = 0)(1 - \beta) = (1 - \beta) [v_0 + B]
\]

in period \( t \), the per-period earnings from remaining private. Since the intrinsic value of the firm if it remains private is time invariant, the income received while waiting for the right offer to come along is \( C \), which is constant. To simplify the notation let \( Z_t = Z(d_t = 1) \) and \( C = Z(d_t = 0) \) with

\[
Z_t = a + \gamma(\mu_t + \epsilon^*_t)
\]

where \( a = (1 - \beta)[v_t - K] \) and \( \gamma = (1 - \beta)(1 - \alpha) \). The density, \( \theta \), of the random variable \( Z_t \) is a linear function of the density for \( \epsilon^*_t \) and is given by

\[
\theta(z_t; S_t) = \begin{cases} 
\theta_{S_t = 0}(z_t) \text{ with mean } E(z_t) = \zeta_0 = a + \gamma \mu(0) \text{ and } \text{Var}(z_t) = \sigma^2 = (\gamma \sigma)^2/N & \text{if } S_t = 0 \\
\theta_{S_t = 1}(z_t) \text{ with mean } E(z_t) = \zeta_1 = a + \gamma \mu(1) \text{ and } \text{Var}(z_t) = \sigma^2 = (\gamma \sigma)^2/N & \text{if } S_t = 1
\end{cases}
\]
where \( E[z_t] \) is the annuity value of \( E[V^o(d_t=1)] \) and \( \text{Var}(z_t) \) is the annuity value of \( \text{Var}[V^o(d_t=1)] \) such that \( \zeta_t \geq \zeta_0 \) and \( z \in \mathbb{R}^+ \). Therefore the firm will receive an offer, \( z_t \), each period from the underwriter that is drawn from a state-dependent distribution \( \Theta_{st} \). If \( S_t = 1 \), the offers received by the owners to go public will be drawn from the high mean distribution.

To ensure that the high mean state is preferred to the low mean state, the following assumption is made.

**Assumption 1:** Let \( \Theta(z_t) \) be the cumulative distribution function associated with the probability density of \( Z_t \). It is assumed that the distribution \( \Theta(z_t) \) belongs to a class of distributions with the following properties. First, \( \Theta_i(z_t) \) is assumed to be a translation of \( \Theta_0(z_t) \) with

\[
\Theta_i(z_t) \leq \Theta_0(z_t) \quad \forall Z_t,
\]

where \( \Theta_i(z_t) \) is said to first-order stochastically dominate \( \Theta_0(z_t) \).\(^{20}\)

In order to study how the changes in the divergence of beliefs affect the decision-making environment of the firm, it is convenient to analyse the changes in variance of the distribution (introduced in Section 5.5 and 5.6) within the standardized notion of "mean preserving spread." To do so, the following assumption is made.

**Assumption 2:** Let \( \Theta(z_t, \sigma_t) \) be the "mean preserving spread" of \( \Theta(z_t, \sigma_0) \), given that both distributions are defined over \( \mathbb{R}^+ \) and satisfy the following two properties:

(i) \[
\int_0^\infty [(\Theta(z_t, \sigma_t) - \Theta(z_t, \sigma_0))dz_t = 0
\]

and

(ii) \[
\int_0^x [(\Theta(z_t, \sigma_t) - \Theta(z_t, \sigma_0))dz_t \geq 0 \quad 0 \leq x \leq \infty.
\]

In what follows, \( Z_t \) is assumed to have a log-normal density such that \( W_t = \ln(Z_t) \)

\(^{20}\) Assumption 1 guarantees that \( \zeta_t \geq \zeta_0 \).
has a normal distribution, $\Phi(w_i; S_i)$, and density, $\Phi(w_i; S_i)$, defined as

$$
\Phi(w_i; S_i) = \begin{cases} 
\Phi_{S_i=0}(w_i) \text{ with mean } E(w_i) = \omega_0 \text{ and } \Var(w_i) = \sigma_w & \text{if } S_i = 0 \\
\Phi_{S_i=1}(w_i) \text{ with mean } E(w_i) = \omega_1 \text{ and } \Var(w_i) = \sigma_w & \text{if } S_i = 1.
\end{cases}
$$

where $\omega_1 \geq \omega_0$. Any reference to the offer $w_i$ is assumed to be a reference to the natural log ($\ln$) of the offer $z_i$. Let $c = \ln(C)$.

5.4 Decision-Making Process of the Firm

The subsequent theoretical analysis of the firm’s decision to go public is a novel application of the sequential optimal “stopping” approach used in statistical decision theory (see Eckstein and Wolpin (1989)). This is the first study that models the firm’s decision process under the assumption that the firm decides to go public after sampling a sequence of potential offers (offering proceeds) from the underwriter. Since the sequential job search theory of unemployment is also based on the optimal stopping approach, the following firm decision model resembles in many ways the “standard” job search models found in the labour economics literature. However, it differs in one important aspect. The structural stopping model presented below is nonstationary.

---

21Following much of the job search literature referenced in Section 5.4, the log of the offers received is often assumed to be distributed normally. Since it is naturally assumed that firms, like unemployed individuals, only receive offers that are positive, $Z_i \in \mathbb{R}^+$, the log of $Z_i$ is assumed to be distributed normally. This means that the density of the random variable $\epsilon_i$ is log-normal since $Z_i$ is a linear function of $\epsilon_i$. Allowing $\epsilon_i$ to be log-normal has the desirable property that the majority of offers received by the firm accumulate near the reservation bid (the critical acceptance level, discussed in the next section). That is, the probability of drawing an offer near the reservation bid of the firm is high. This implies that most of the investors come close to correctly valuating the firm at or near its intrinsic value. This also reflects the efficiency of the stock market because it would be non-optimal for investors to hold, on an ongoing basis, investor specific beliefs that are very much higher than the intrinsic value of the firms. If this were the case, these investors would continually be holding overpriced assets yielding poor investment returns and would be driven out of the market. If agents held beliefs that were always too low, they would never be purchasing assets.
Because the offer distribution is assumed nonstationary, the critical acceptance bid, or the "reservation wage" using the job search terminology, is found to be nonstationary in the model derived here. Few studies published in the job search literature allow for nonstationarity in the offer distribution (see van den Berg (1990) for one of the more general analyses of nonstationarity in search models). Of these studies, all use rather restrictive assumptions that are undesirable or not plausible in the finance environment studied here. These assumptions are elaborated upon in Subsection 5.4.2. This section of the chapter has two subsections. In the first, the model of a firm which sequentially samples offers from an underwriter is presented. The second numerically solves this model.

5.4.1 The Optimal Stopping Model

In each period the firm receives an offer \( w_t \in W_t \) from the time varying density \( \phi(w_t | S_t) \) defined above (in what follows the firm is used as a reference to the original owners). The firm has the option of rejecting the bid offered to it in which case it receives the per-period income derived from being private, \( I_t = c \), and then waits until next period to receive another offer from \( \phi(w_t | S_t) \). Otherwise the firm can accept the bid, \( w_t \), and receive \( I_t = w_t \) per period forever. A linear utility function is assumed for the owners of the firm with \( U(I_t) = I_t \). The firm is assumed to remain public in perpetuity.

The firm devises a strategy to maximize \( \mathbb{E}[\sum \beta^t I_t] \) where \( \beta \) is a discount factor. Let the value function, \( m(S_t, w_t) \), be the expected value of \( \sum \beta^t I_t \) for a firm who is offered \( w_t \) and is deciding whether to accept or reject it, and who behaves optimally. Because the distribution \( \phi(w_t | S_t) \) is in fact state-dependent, the value function \( m \) depends on two state variables \( (S_t, w_t) \), where \( S_t \) is the state of investors beliefs and \( w_t \) is the current offer received from the underwriter. To reduce notation, let \( S_t = k \) where \( k \in \{0, 1\} \) and let \( \Phi_k(w_t) = \Phi(w_t | k) = \Phi(w_t | S_t) \) denote the state-dependent cumulative offer distribution. Also, in what follows, the time subscript for the random variable \( w_t \) is omitted to reduce notation. The Bellman's functional equation can then be written as:
$$m(k,w) = \max \{ w/(1-\beta), c + \beta \sum_{r \in \{0,1\}} p_{kr} \int m(r,w') d\Phi_r(w') \} \forall k \in \{0,1\}. \quad (12)$$

where $w'$ is the offer received next period and where $p_{kr}$ are the transition probabilities from the matrix $P$ (that governs the state of investor beliefs) defined in Section 5.3 with $P_{00} = p$ and $P_{11} = q$.

Throughout the following analysis the owners of the private firm are assumed to know the offer distribution, the state of investor valuation beliefs, and the Markov transition probabilities found in matrix $P$. Any possible adaptive behaviour of the firm, as it learns about the state of the offer distribution, is not modelled here. Let $r_0$ be defined as the minimum level bid that the firm is willing to accept in state $k \in \{0,1\}$. Specifically, there exists a critical number while investors are in state 0, known as the "reservation bid," $r_0$, defined as:

$$\frac{r_0}{1-\beta} = c + \beta \sum_{r \in \{0,1\}} p_{0r} \int m(r,w') d\Phi_r(w') \}$$

such that:

$$m(0,w) = \begin{cases} \frac{r_0}{1-\beta} = c + \beta \int m(0,w') d\Phi_0(w')p + \beta \int m(1,w') d\Phi_1(w')(1-p) & \text{ if } w < r_0 \\ \frac{w}{1-\beta} & \text{ if } w > r_0. \end{cases} \quad (13a)$$

Symmetrically there also exists a critical number $r_1$ (the reservation bid for state 1) defined as:

$$\frac{r_1}{1-\beta} = c + \beta \sum_{r \in \{0,1\}} p_{1r} \int m(r,w') d\Phi_r(w')$$
such that:

\[
m(1, w) = \begin{cases} 
\frac{r_i}{1 - \beta} \cdot c \cdot \beta \int m(y, w') d\Phi_i(w') = q \cdot \beta \int m(0, w') d\Phi_0(w')(1 - q) & \text{if } w \leq r_i \\
\frac{w}{1 - \beta} & \text{if } w > r_i.
\end{cases}
\tag{13b}
\]

The firm finds it an optimal strategy to reject all offers \( w \leq r_k \) and accept all offers \( w > r_k \) \((k \in \{0, 1\})\). Using (13a, b), one can convert the functional equation (12) into ordinary symmetric equations of the state-dependent reservation bids \( r_k \). Evaluating \( m(0, r_0) \) and using (13a), one finds:

\[
\frac{r_0}{1 - \beta} = c + \beta \left( \frac{\Pr(r_0 > w')}{1 - \beta} \cdot \frac{r_0}{1 - \beta} + \frac{1}{1 - \beta} \Pr(r_0 \leq w') E(w' | w' > r_0) \right) p \\
+ \beta \left( \frac{\Pr(r_i > w')}{1 - \beta} \cdot \frac{r_i}{1 - \beta} + \frac{1}{1 - \beta} \Pr(r_i \leq w') E(w' | w' > r_i) \right) (1 - p).
\tag{14}
\]

Note that \( r_i \) is defined symmetrically. Given the offer distribution, \( \Phi(w | S_k) \), defined in Section 5.3, the expected bid received by the firm in the next period is \( E(w' | S' = k) = \omega_k \). The expected bid accepted is given by \( E(w' | S' = k, w' > r_k) = \omega_k + \sigma_w g_k(r_k) \) \((k \in \{0, 1\})\) where \( \omega_k \) and \( \sigma_w \) are the means and variance of the density of \( W \) and

\[
g_k(r_k) = \frac{\Phi_k \left( \frac{r_k - \omega_k}{\sigma_w} \right)}{1 - \Phi_k \left( \frac{r_k - \omega_k}{\sigma_w} \right)}.
\]

Thus with \( \Pr(r_k > w') = \Phi_k(r_k) \), one can rewrite (14) as:
\[
\frac{r_0}{1 - \beta} = c + \beta \left( \Phi_0(r_0) \frac{r_0}{1 - \beta} + \frac{1}{1 - \beta} (1 - \Phi_0(r_0)) (\omega_0 + \sigma_w g_0(r_0)) \right) p \\
+ \beta \left( \Phi_1(r_1) \frac{r_1}{1 - \beta} + \frac{1}{1 - \beta} (1 - \Phi_1(r_1)) (\omega_1 + \sigma_w g_1(r_1)) \right) (1 - p)
\] 

(15a)

and symmetrically for \(r_1\)

\[
\frac{r_1}{1 - \beta} = c + \beta \left( \Phi_0(r_0) \frac{r_0}{1 - \beta} + \frac{1}{1 - \beta} (1 - \Phi_0(r_0)) (\omega_0 + \sigma_w g_0(r_0)) \right) (1 - q) \\
+ \beta \left( \Phi_1(r_1) \frac{r_1}{1 - \beta} + \frac{1}{1 - \beta} (1 - \Phi_1(r_1)) (\omega_1 + \sigma_w g_1(r_1)) \right) q.
\]

(15b)

The major difference between (15a) and (15b) are the transition probabilities that multiply each bracket. The values inside each bracket are identical for \(r_1\) and \(r_0\). This implies that one of the important factors that affects the level of the state-dependent reservation bids (and in turn the difference between reservation bids) is the value of the Markov transition probabilities \(p\) and \(q\). The importance of the transition probabilities to the decision-making process is elaborated upon in the Section 5.5 of this study.

Let \(h_k\) be defined as the state-dependent probability of receiving and accepting a bid when the investor beliefs are in state \(k \in \{0, 1\}\). Specifically, given the reservation bid \(r_k\), the state-dependent probability that the firm goes public is defined as:

\[
h_k = 1 - \Phi_k \left( \frac{(r_k - \omega_k)}{\sigma_w} \right). \] 

(16)

5.4.2 Numerical Solution to Optimal Stopping Model

Because the derived reservation bids are state-dependent, the optimal "stopping" model of the firm's decision to go public presented above is nonstationary. As previously mentioned, van den Berg (1990) analysed the consequences of nonstationarity in job
search models in a rather general setting. He assumes that one cause of nonstationarity in the reservation wage is due to a nonstationary wage offer distribution. In his study, the wage offer distribution is assumed to be constant over the interval $t \in (T, \infty)$ and nonstationary over the interval $t \in (0, T)$. Here too, the offer distribution, $\phi(w)$, is assumed to be nonstationary. Empirical evidence presented in Chapter 4 of this dissertation indicates that the behavior for the monthly IPO volume process is consistent with the behavior of a process driven by an unobservable recurring discrete state process. van den Berg's assumption that the offer distribution is constant (after time $T$), as well as his derived results, are therefore undesirable for the firm decision model considered here since in reality the nonstationarity of the offer distribution is ever present.

Lippman and McCall (1976) put forward a job search model that comes closest in replicating the features of the approach taken here in modeling the firm's decision to go public. They too assume that the offer distribution is driven by a first-order Markov switching process. They are able to analytically solve for the state-dependent reservation wage given this nonstationary wage offer distribution. However, in order to do so, they assume that the high mean offer distribution, $\phi_h(w)$ in this model, is more persistent than the low mean distribution. In other words, Lippman and McCall make the assumption that the transition probabilities from matrix $P$ are such that $q > p$. This assumption is deemed too restrictive since it is inconsistent with the evidence presented in Chapter 4 where the high mean state for the IPO volume process is shown to be less persistent than the low mean state with $q < p$ instead. Without Lippman and McCall's restrictive assumption it is not obvious that an analytical solution exists for the state-dependent dynamic programming problem. However, because the assumed utility function is real valued, continuous and concave, this dynamic programing problem can be solved numerically via an iterative procedure. More precisely, the reservation bids, $r_1$ and $r_0$, can be solved numerically by way of an iterative procedure.\(^{22}\)

---

\(^{22}\) After setting the 2 by 1 vector of reservation bids $r' = [r_0, r_1]$ to an arbitrary value to start the iteration of equation 15, the iteration continued until the Ordinary Euclidean $R^2$ metric of the difference between the original value of $r'$ and the iterated (next value) of $r'$ was less than $10^{-13}$. 
Before solving for the state-dependent reservation bids, parameter values for equation (15) must be chosen. The choice of the transition probabilities, \( p \) and \( q \), is based on Chapter 4 of this thesis. In that chapter, empirical evidence based on the IPO volume data suggests that the transition probabilities, \( p \) and \( q \), are above 0.9. As previously mentioned, the empirical evidence shows that, \( q \), the probability of staying in the high mean state (state 1 here) given that the distribution was in the high mean state in the last period, is smaller than that transition probability, \( p \), the probability of staying in the low-mean state. Given these empirical findings, the values of \( q \) and \( p \) are set in the range (0.6, 1) with \( q < p \). \( \beta \) is set at an economically plausible 0.9 while \( c \), the one period income the owners derive in rejecting the offer and remaining private, is set to the low mean value (of the offer distribution). The means of the state-dependent offer distribution \( \omega \) are such that \( \omega_1 \geq \omega_0 = 2 \) where \( \omega_1 \) is the mean of the offer distribution when investors are in the optimistic state.\(^{23}\) The variance of the offer distribution \( \Phi_i(w) \) is assumed constant across states and is simply set at \( \sigma^2_w = 1 \). Finally, \( \Phi_i(w) \), as mentioned in the previous section, is assumed to be normally distributed for either state.

Given the above range of values for the parameters, the numerical results show that \( r_i \geq r_0 \). Finding that the reservation bid in state 1, \( r_i \), is higher than the state 0 reservation bid implies that the firms will, given their complete knowledge of the offer distribution and the state of the investor beliefs, accept an offer to go public in state 1 that is on average higher than the offer accepted when in state 0. No that in the above specification of the model, it was assumed that the firms received an offer in each period with probability 1. As previously mentioned, \( h_i \) is the probability of receiving and accepting a bid when the investor wide beliefs are in state \( i \). Given the above range of values for the parameters, the results show that \( h_i \geq h_0 \). This implies that firms experience a higher probability of going public while investor beliefs are in state 1. In other words, firms are more likely to go public during periods in which the investors hold

\(^{23}\)The range of values chosen for \( \omega \) had a finite upper bound that, in relation to the other parameters, was of an order of magnitude larger than the low mean state (e.g. \( \omega_1 = 10,000 \) if \( \omega = \omega_0 = 2 \)).
optimistic beliefs.

In the "standard" job search models, an increase in the reservation wage (the reservation bid, $r$, in this framework) caused, for example, by an increase in the (unemployment) benefits to search for employment results in a corresponding decrease in the acceptance probability, $h$. This is because the acceptance probability is negatively related to the reservation wage (bid) as is clear from (16). However, the opposite is predicted in this model. The reservation bid $r$ is greater than $r_0$ due to the fact that the offer distribution in state 1 has a greater mean than the offer distribution for state 0. However, the increase in the reservation bid from state 0 to state 1 is less than the increase in mean from state 0 to state 1. Since the acceptance probability is dependent on the mean of the offer distribution and the reservation bid, this implies that the increase in the mean between states increases the acceptance probability because the reservation bid increases by less than the increase in the mean.

Define $h^j_k$ as the firm $j$ specific probability of going public in state $k$ and $r^j_k$ the firm $j$ specific reservation bid in state $k$. In aggregate, assuming that all firms waiting for an acceptable IPO offer are affected by the same shifts in investor sentiment, these findings imply that the average probability, $H_k$, and the average reserve bid, $R_k$, across firms waiting to go public are defined as:

$$R_k = \sum_{j=1}^{N} \frac{r^j_k}{N} \quad \text{and} \quad H_k = \sum_{j=1}^{N} \frac{h^j_k}{N} \quad \forall k \in \{0, 1\}$$

where $N$ is equal to the number of firms waiting to go public. Both $R_k$ and $H_k$ are increasing as investor sentiment swings from state 0 to 1. What is more important, $H_1 \geq H_0$, which implies that the probability of going public for the average (or typical) firm is increasing as investor beliefs become more optimistic. Note that firm heterogeneity is not explicitly modelled in the section, but is introduced in the following section. In the present specification of the model, firms are assumed to be identical with $R_k = r^j_k = r$ and $H_k = h^j_k = h_k$ for each state $k$ and for all firms $j$. This assumption is relaxed in Section 5.6.
The first of the model’s predictions is that the probability of going public will fluctuate as investor beliefs about the firm’s value fluctuate. In aggregate this implies that the number of firms going public will increase during periods of investor optimism. The model’s prediction that the number of firms going public will fluctuate over time is consistent with the well documented IPO volume fluctuations. The model also predicts that the average level of the offering proceeds raised at the offering should also fluctuate with investor beliefs. If \( R_k \) is reflected in the median market-to-book equity values, as asserted in Pagano, Panetta, Zingales (1995), then the model predicts that these market measures of firm value should be significantly correlated with the probability of a firm going public, \( h_k \). This prediction is also consistent with the empirical evidence that the probability of a firm going public is significantly (positively) related to the median market-to-book equity values of the firm’s industry presented in Pagano, Panetta, and Zingales (1995).

5.5 Sensitivity Analysis

The optimal stopping model of a firm deciding to go public took as given a set of parameter values to solve numerically the state-dependent reservation bids, \( r_k \), and the firm’s probability of accepting the offer and going public, \( h_k \). Though some motivation was provided for the values of the parameters used in solving for the reservation bids, there was no discussion on the sensitivity of the reservation bids and acceptance probabilities to the assumed parameter values. This section of the study investigates the sensitivity of the state-dependent reservation bids to various values of these parameters by calculating reservation bids for a range of plausible parameter values. Specifically, state-dependent reservation bids and probabilities of going public are calculated for each parameter value of interest in a specified range (holding other parameter values constant).

The results of the sensitivity analysis are presented in Figures 1 to 5. It is interesting to note that the results in these graphs often resemble the results derived from the partial derivative analysis presented in Mortensen’s (1986) job search study.
Mortensen finds that in a stationary job search model where the reservation wage is stationary over time (or in this framework this would imply that the reservation bids are equal across states, with \( r = r_i = r_0 \)), the partial derivatives with respect to the mean of the distribution from which the wage offers are drawn is positive. He also finds the derivative of the reservation wage with respect to a mean preserving spread in the offer distribution to be positive. For the stationary probability of escape from unemployment (\( h = h_i = h_0 \)) the sign of the partial derivative is positive with respect to the mean of the offer distribution and ambiguous with respect to a mean preserving spread.\(^{24}\)

This study is the first to perform a sensitivity analysis of the reservation bids derived from an optimal stopping model with a nonstationary Markov switching offer distribution. Unless otherwise stated, the parameter values used for the sensitivity analysis remain fixed at:

\[
q = 0.8, \ p = 0.9, \ \phi_k(w) - N(\omega_k, \ \sigma^2_w), \ c = 2, \ \beta = 0.9, \ \sigma^2_w = 1, \ \omega_1 = 3 \text{ and } \omega_0 = 2.
\]

First, consider what the effects are on the state-dependent reservation bids of changes in the transition probability \( q \), the probability of being in the high-mean offer distribution state given that the last period offer distribution was the high-mean distribution. Figure 1 shows that as \( q \to 0 \), \( r_i - r_0 \) decreases and eventually becomes negative. This implies that if \( q \) is small enough, \( r_0 > r_i \) despite the fact that the offer distribution of state 1 has a higher mean. This result is opposite to the result found in Mortensen's study; he found that a higher mean implies a higher reservation bid. The intuition behind this result is made clear by setting \( q = 0 \) in equation (15b). Here, the second term in the square brackets of equation (15b) becomes approximately zero. The reservation bid for state 1 is then a function of the reservation bid in state 0 plus a

\(^{24}\)van den Berg's (1990) results are qualitatively similar to Mortensen's, however, unlike Mortensen, he allows the offer distribution and the unemployment benefits to be nonstationary. In this study, the offer distribution is allowed to shift repeatedly throughout the lifetime of the private firm.
function of the low mean value of the distribution (the first term in the square brackets).

On the other hand, since the transition probability \( p \) is such that \( 0 < p < 1 \), the value of the state 0 reservation bid (in 15a) remains a function of both the low mean and the high mean values. This implies that the firm, in calculating its reservation bid while in state 0, understands that there is a positive probability that it will receive offers from the high mean state next period. This is not the case in calculating the reservation bid while in state 1. The firm sees little probability of receiving other offers from the high mean state and thus calculates a lower reservation bid for this state.

This intuition is strengthened by comparing the results in Figures 1 and 2. In Figure 1, \( p = 0.9 \) and in Figure 2, \( p = 0.6 \). As \( q \) becomes small when \( p = 0.6 \), \( r_0 \) becomes greater than the high mean state reservation bid, \( r_1 \), at a much higher value of \( q \) than when \( p = 0.9 \). Note that these findings are also naturally dependent on how different the means of the state-dependent distributions are from each other. As the high mean, \( \omega_1 \), becomes increasingly greater than the low mean, \( \omega_0 \), the value of \( q \) for which \((r_1 - r_0)\) becomes negative decreases. Allowing the transition probability for the persistence of the low state, \( p \), to go to zero is an uninteresting experiment since this
simply increases the positive spread between \( r_1 \) and \( r_0 \). This analysis of the effects of changes in the transition probabilities illustrates the firm's decision process is critically dependent on the persistence of the states of investor beliefs and on the means of the state-dependent offer distributions.

Figure 3 illustrates how a mean preserving spread also affects the difference between the state-dependent reservation bids. In this case, the variance of the offer distribution is assumed to be state-dependent with \( \sigma^2_w \) now equal to \( \sigma^2_{kw} \) for \( k \in \{0, 1\} \). Let state 1 be a mean preserving spread of state 0 such that \( \sigma^2_{1w} \geq \sigma^2_{0w} = 1 \). Also let the means of the state-dependent distribution, \( \omega_k \), be equal across states \( (\omega_1 = \omega_0) \) in order to concentrate on both the affect the mean preserving spread has on the reservation bids, and the probability that the firms accept an offer between states. In this case, \( r_1 - r_0 \) will monotonically increase as \( \sigma^2_{1w} \) increases. When both means are equal \( (\omega_1 = \omega_0 = 2) \), the findings replicate Mortensen's findings that a mean preserving spread has a positive effect on the reservation bid. This finding is reinforced when \( \omega_1 > \omega_0 \). Though not shown here, this result is robust to the situation with \( \omega_1 < \omega_0 \). In this case, \( r_1 - r_0 \) will be negative for values of \( \sigma^2_{1w} \) near \( \sigma^2_{0w} \). However, as \( \sigma^2_{1w} \) becomes increasingly greater than \( \sigma^2_{0w} \), \( (r_1 - r_0) \) increases until it eventually reaches positive values. Therefore, even if the offers received by the firm in state 1 are on average smaller than the offers received in state 0, if state 1 has a greater divergence of offers, the reservation bid for state 1 may in fact be greater than that of state 0.

Recall that the greater divergence of offers, \( w \), (due to larger \( \text{Var}(w) = \sigma^2_w \)) is the result of a greater divergence of heterogeneous beliefs among investors. Specifically,
\( \text{Var}(w) = \sigma^2_w \) depends on the variance of the random variable \( \epsilon_1^* \), denoted as \( \sigma^2/N \), as presented in equation (9). As emphasised in Sections 5.2 and 5.3, the variance is assumed to be a measure of the degree of investor heterogeneity. Specifically, \( \text{Var}(\epsilon) \) is assumed to measure the divergence of prior beliefs about the firm's intrinsic value held by the investors. Following Morris (1995), it is assumed that "information poor" firms engender a greater divergence of beliefs about their expected value among investors. As shown in the following section of this study, this firm level characteristic has important implications for calculating the firm specific probability of going public. The sensitivity of the probability of becoming a publicly traded firm to this measure of investor heterogeneity is presented in Figure 4 where \( \omega_1 = 4 > \omega_0 = 1 \). These state dependent probabilities are shown to be a decreasing function of \( \sigma^2_{1w} \), though the state 1 probability of going public \( h_1 \) is strictly larger than \( h_0 \) for all values of \( \sigma^2_{1w} \) due to the greater mean for the state 1 offer distribution. This implies that "information poor" firms are less likely to go public than larger, established firms.

Figure 5 plots the difference in the probability between states of going public, \( (h_1 - h_0) \), given that the means of the offer distributions are equal (at \( \omega_1 = \omega_0 = 2 \)) as \( \sigma^2_{1w} \) increases. When \( \sigma^2_{1w} = \sigma^2_{0w} \) (and with the state-dependent means equal) there is naturally no difference in the probability of going public between states \( (h_1 = h_0) \). However, as \( \sigma^2_{1w} \) increases and the difference in variance between state increases, the probability of going public is greater in state 1 (the higher variance state) than state 0. The reason for this is that a larger divergence of beliefs in state 1 not only increases the reservation bid for state 1, \( r_1 \), but also increases the
reservation bid in state 0 (though to a lesser degree than depicted in Figure 3). The interdependence of the state-dependent reservation bids, as shown in equation (15), is the reason behind the increase in \( r_0 \) as \( r_1 \) increases. This implies that the probability of going public in state 0 is smaller the greater the difference between \( \sigma_{i,w}^2 \) and \( \sigma_{0,w}^2 \) since \( h_0 \) is negatively related to \( r_0 \). Though \( r_1 \) is also increasing as \( \sigma_{i,w}^2 \) increases, which, on its own would decrease the probability of going public in state 1, the higher variance counteracts this effect since changes in \( \sigma_{i,w}^2 \) have a positive affect on \( h_1 \). Therefore, \( h_1 \) decreases at a lesser rate than \( h_0 \) as \( \sigma_{i,w}^2 \) increases. In summary, \( (h_1 - h_0) \leq 0 \) as long as \( \sigma_{i,w}^2 \geq \sigma_{0,w}^2 \).

5.6 Heterogeneous Firm Types

In this section, the model's assumptions are relaxed to allow for two types of firms differentiated by their public information content and costs incurred in participating in the IPO process. Information content heterogeneity is specified by classifying a proportion of the firms looking to go public as established, large, “information rich” firms (denoted by 'r'), while classifying the rest as young, small, “information poor” firms ('p').\(^2\) The heterogeneity between the firms is parameterised in three different ways.

\(^2\) A firm is “information rich” if there is a large pool of information available to investors that enables them to calculate more easily or with greater precision the expected net present value of the dividend stream for the firm (or the intrinsic value of the firm). The reverse is true for “information poor” firms. Carter and Dark (1993) show that older and/or larger firms engender a reduced degree of heterogeneity in investor beliefs. See also Morris (1995) and Pagano, Panetta, and Zingales (1995) for similar arguments.
First, the nature of the relationship between information availability (information richness) and investor demand for the public offering is assumed to be discrete. Specifically, firms are assumed to require a minimum level of information richness before investors are willing to calculate the firm’s intrinsic value. Therefore, in certain periods, an underwriter will be unable to sample investor opinions about the firm’s value and thus will not give the firm an offer during this period. Here, information poor firms are assumed to receive bids in each period with probability $\lambda$ rather than with probability 1, while established firms receive an offer with certainty in every period. Secondly, information poor and information rich firms will be differentiated by the difference in variance of the variable $\epsilon$, which is a measure of the divergence of beliefs among investors of the firm’s intrinsic value. Thirdly, a participation cost is introduced to the model that captures the idea that there are costs associated with the IPO process itself and that these costs may be proportionally higher for smaller firms. These firm specific participation costs imply that it is more likely that information poor firms will rationally decide not to undergo the IPO process and “drop out” since the income it receives while not participating in the IPO process exceeds the reservation bid it has calculated when participating. Each type of firm heterogeneity is modelled in three separate extensions of the basic model.

5.6.1 Heterogenous Probability of Receiving an Offer

In this framework there are two groups of firms (deciding to go public) which are identical in all respects except one group of firms receives a bid in period $t$ with probability $\lambda<1$ while the other type of firm receives a bid with certainty in each period. The value function for firms that receive an offer with probability $\lambda$ is written as:

$$m(k,w) = \lambda \max \left\{ \frac{w}{(1-\beta)}, \ c + \beta \sum_{i=0}^{1} P_{ui} \int m(t',w') \phi_i(w') \right\} \cdot (1-\lambda) \left[ c + \beta \sum_{i=0}^{1} P_{ui} \int m(t',w') \phi_i(w') \right] k.$$

An approach similar to that used in Section 5.4 is undertaken to solve for the state-
dependent reservation bids. Given the current bid, $w$, received, the value function can be rewritten as

$$
m(k, w) = \begin{cases} 
c + \beta \sum_{t=0}^{1} m_{t}(w') d\Phi_{t}(w') P_{kt} & \text{if } w \leq r_k \\
\lambda \frac{w}{1-\beta} + (1-\lambda)(c + \beta \sum_{t=0}^{1} m_{t}(w') d\Phi_{t}(w') P_{kt}) & \text{if } w > r_k
\end{cases} \forall k. \quad (17)
$$

Using (17) and evaluating $m(k, w)$ at $r_k$, one then obtains.

$$
r_k = c(1-\beta) + \beta \left[ \{ Pr(r_0 > w') r_0 + Pr(r_0 \leq w') \times [\lambda E(w'|w') r_0] + r_0 (1-\lambda) \} P_{k0} + \right. \\
\left. \{ Pr(r_1 > w') r_1 + Pr(r_1 \leq w') \times [\lambda E(w'|w') r_1] + r_1 (1-\lambda) \} P_{k1} \right] \forall k. \quad (18)
$$

where $P_{k0} = p$ and $P_{k1} = q$ from the transition matrix $P$ defined in Section 5.3. (18) can be rewritten as:

$$
r_k = c(1-\beta) + \beta \left[ \Phi_0 r_0 + (1-\Phi_0)(\lambda(\omega_0 + \sigma g_0) + (1-\lambda)r_0) \right] P_{k0} + \\
\beta \left[ \Phi_1 r_1 + (1-\Phi_1)(\lambda(\omega_1 + \sigma g_1) + (1-\lambda)r_1) \right] P_{k1} \forall k. \quad (19)
$$

Let $r'(k)$ and $r''(k)$ be the reservation bids (given state $k$) for the information rich and poor firms, respectively, while $h'(k)$ and $h''(k)$ are the respective probabilities of going public in each period for the information rich and poor firms. Define $\lambda < 1$ as the probability that the information poor firm receives a bid in any period. The probability of going public for the information poor firms is now defined as:

$$
h''(k) = \lambda \left( 1 - \Phi_k \left( \frac{(r''(k) - \omega_k)}{\sigma_w} \right) \right). \quad (20)
$$

Since the information rich firms receive a bid in each period, they use (15) to solve for the reservation bid while the information poor firms' reservation bids are calculated using
An iterative procedure is used to solve for $r^b(k)$ and $r^c(k)$ given a set of parameters. The parameter set used in solving for the reservation bids is the same as in Section 5.4. Specifically, $q$ and $p$ are set in the range $(0.6, 1)$ with $q = p$. The discount factor, $\beta$, is set at an economically plausible 0.9 while $c$ is set to equal the low mean value where $\omega_1 = \omega_0 = 2$ and $c=2$. The variance of the state-dependent offer distribution $\phi_4(w)$ is simply set at $\sigma^2 = 1$. The findings show that within the range of parameters, $r_1 \geq r_0$ for both the types of firms. This is the same result as for the base model. However, $r^b(k) \geq r^c(k)$ for $k=\{0,1\}$ which implies that the reservation bid (in each state) for the information poor firm will be lower than an "identically in all other respects" information rich firm. This result is not surprising. Intuitively, a firm that receives bids with a higher probability in each period can afford to be choosier since over time it will receive a greater number of bids. In calculating the state-dependent probabilities of going public, $h^j(k)$, for each type of firm ($j \in \{p, r\}$), the findings indicate that both types of firm are more likely to go public during the high-mean state such that $h^1(1) \geq h^0(0)$ and $h^0(1) \geq h^0(0)$. However, $h^1(k) > h^0(k)$ for $k=\{0,1\}$ implying that the information poor firms are less likely to go public in either state of investor beliefs. The intuition behind this result is rather straightforward.

Heuristically, a lower probability of receiving an offer in any period for information poor firms means that the reservation bid for information poor firms is lower as well, but by a proportionally smaller amount; this implies that any positive affect that the lower state-dependent reservation bids, $r^b(k)$, have on the probability of going public, $h^b(k)$, is more than offset by the direct and proportionally greater negative affect of having $\lambda \leq 1$.

Finding that information rich firms are more likely to go public, ceteris paribus, than information poor firms is consistent with the empirical evidence presented in (Pagano, Panetta, and Zingales) (PPZ) (1995) and lends support to the validity of the model.

How sensitive is the information poor firm's decision process to changes in the state in investor beliefs relative to the information rich firm's? This is answered by comparing the differences between the state-dependent values for the reservation bid, $r^b(k)$, and the acceptance probability $h^j(k)$ for firm type $j \in \{p, r\}$ and investor state $i \in \{0, 1\}$. For the above set of parameter values the results indicate that $(h^p(1) - h^p(0)) > (h^1(1) - h^0(1))$. 

h'(0)) and (r^p(1) - r^p(0)) \leq (r'(1) - r'(0)) when \lambda \leq 1. This implies that more established
(information rich) firms are more sensitive to the changes in investor beliefs (i.e., are
more sensitive to switches in the state of investor beliefs). In aggregate, this implies that
during "hot issues" markets (periods in which investor beliefs are assumed to be in the
optimistic state, state 1) information rich firms will comprise a greater proportion of the
firms going public. Testing empirically this derived implication of the model would be
interesting. This would require a data set that not only indicates the number of firms
going public in each period but also identifies some firm specific characteristics in order
to be able to classify which firms are considered "information rich."

Of some interest is the possibility that \lambda^p may be state dependent. It is likely that,
as investors become more optimistic, they lower their required minimum level of
information richness criterion mentioned above. In this situation, as investors become
more optimistic about all firms contemplating an IPO, they are less worried about their
lack of information. As the minimum information criterion decreases with the increase in
investor optimism, the probability that the information poor firm receives a bid will
increase. Now \lambda is defined as \lambda(k) and is state-dependent with \lambda(1) \geq \lambda(0). Given the
above parameter values, the numerical findings show that \Delta h^p = (h^p(1) - h^p(0)) and \Delta r^p =
(r^p(1) - r^p(0)) are increasing functions of \Delta \lambda = (\lambda(1) - \lambda(0)). Also, it is no longer the case
that the difference in the reservation bids and the acceptance probabilities (h'(k)) between
states for information poor firms is less than that for the group of established firms.
Therefore an implication of the model is that swings in investor sentiment may affect not
only the distribution of bids received, but also the probability of receiving a bid in each
period.

5.6.2 Heterogenous Divergence of Beliefs

For information poor firms it is assumed that there is a greater divergence of
beliefs among investors about the firm's actual intrinsic value. Because the information
poor firms represent firms for which there is relatively less information available,
assuming that investors will have greater difficulty assessing the actual value of the firm
seems reasonable. Since information is scarce, it is likely that the heterogenous beliefs among the investors will be more diverse for this type of firm. This greater divergence of beliefs about the true value of the firm can be modelled by assuming that $\sigma^2$ from the distribution of $\epsilon_i$ is an increasing function of the divergent beliefs. As shown in Section 5.3 of this study, the variance of $W$, $\sigma_w$, is an increasing function of $\sigma^2$, the variance of investor specific beliefs $\epsilon_i$. The divergence of beliefs among investors for each type of firm is modelled by allowing the variance of the offer distribution to be firm specific; established firms receive bids from an offer distribution that has a smaller variance than the offer distribution of the less established firms. Define $\sigma^2_{pw}$ and $\sigma^2_{rw}$ as the variance of $W$ for the information poor and rich firms respectively, with $\sigma^2_{rw} \leq \sigma^2_{pw}$.

Assuming that the two types of firms are identical in every other respect, the state-dependent reservation bids for the information poor and rich firms are $r^p(k)$ and $r^r(k)$, respectively. The parameter set used here is the same as in Section 5.4. Specifically, $q$ and $p$ are set in the range (0.6, 1) with $q \leq p$. $\beta$ is set at an economically plausible 0.9 while $c$ is set to equal the low mean value where $\omega_1 = \omega_0 = 2$ and $c=2$. However, the variance of the state-dependent offer distribution $\Phi_i(w)$ is firm specific in this case with $\sigma^2_e \neq \sigma^2_r = 1$. The state-dependency of the reservation bids documented in Section 5.4 remains unaltered with $r^p(1) \geq r^p(0)$ ($j \in \{p, r\}$). However, $r^p(k) \geq r^r(k)$ for $k = \{0, 1\}$. This implies that information poor firms going public will receive higher offering proceeds (higher offering prices) than identical, in all other respects, information rich firms across states. This result should not be surprising since $\Phi^p_i(w)$ is a mean preserving spread of $\Phi_i^r(w)$. As Mortensen (1986) explains for a stationary offer distribution, this result is the consequence of the fact that the (information poor) firm has a higher probability of receiving a bid from the tails of the density $\Phi(w)$. Since the firms only care about the truncated part of the distribution (with $w \geq r(k)$), the mean of the truncated distribution increases.

Calculating the probability of going public, $h^p(k)$, indicates that $h^p(k) < h^r(k)$ for
k = \{0, 1\}.\footnote{This implies that information poor firms are less likely to go public than identical information rich firms. This result is consistent with the empirical evidence showing that more established firms, as measured by size (or age), are more likely to go public than smaller less established firms (see Pagano, Panetta, and Zingales (1995)). What is also interesting is the result that 0 \leq (h'(1) - h'(0)) \leq (h'(1) - h'(0)). These results imply that the difference in the number of information poor firms going public is less sensitive to swings in investor beliefs than the difference in the number of more established information rich firms going public. The result is the same as the one calculated for the heterogenous probability of receiving an offer specification in the model above. This is a testable implication that has not been empirically investigated.}

5.6.3 Heterogeneous Participation Costs

Recall that c from equation (12) above is simply the income received by the firm while waiting for the optimal bid offer to go public. In this subsection, c is redefined to allow for an environment where firms incur a participation cost in the IPO process, such that C = Z(d,=0) is no longer simply equal to (1-\beta)(v_0 + B) (from Section 5.3 with c=ln(C)) but now is defined as C = (1-\beta)(v_0 + B) - x, where x is some positive per-period participation cost.\footnote{This allows one to look into the participation of private firms in the going public process itself. If they are not actively participating in the IPO process, it is assumed that these firms are not receiving any offers from the underwriters in this case. After introducing a participation cost to the original framework, this implies that the income earned while not participating (1-\beta)(v_0 + B) is greater than the income earned while participating while remaining a private firm (C). Since the reservation bids are a function of c = ln(C), it is easy to find parameter values for \omega_1, \omega_0, and C such that r_1 \cdot (1-\beta)(v_0 + B) \geq r_0 > (1-\beta)(v_0 + B) - x. This implies that income received from not

\footnote{Some of the direct costs incurred in going public are the underwriting fees. auditing fees, registration fees, etc. Many expenses do not increase proportionally with the size of the IPO and therefore weigh relatively more on small firms.}
participating in the IPO process exceeds \( r_m \), the reservation bid while the investor beliefs are in state 0. If investors are in state 0, then the optimal policy for the firm is to "drop out" and not participate in the IPO process. As the investor beliefs shift to the optimistic state, this decision to drop out must be reconsidered, and since \( r_L < r_m \), the firm may decide to re-enter the IPO process.

When younger, smaller firms incur proportionally higher participation costs, \( \lambda \), than the established firms, information poor firms will then be disproportionately represented in the pool of firms not searching to go public. This implies that as investor sentiment for IPOs increases, there will be a disproportionate increase in information poor firms joining the group of firms deciding to go public, which in turn would lead to a disproportionate increase in the number of younger firms going public during that period (all other things being equal). This testable implication of the model is at odds with the empirical evidence presented in Pagano, Pagano, and Zingales (1995) (for the Italian stock markets) where they show that larger firms are more likely to go public. It also contradicts the findings derived from the previous two firm heterogenous specifications of the model. However, there may be some subtle explanation for this. The stock markets in Italy are not as advanced as the U.S. capital market for example. It is possible that the IPO participation costs are proportionally large enough in the Italian stock markets that the smaller, less established firms never find themselves voluntarily participating in the IPO process. In a more advanced capital market, such as in the U.S., these costs may represent a relatively smaller burden for the less established firms and thus are more likely to go public in certain periods.

5.7 Concluding Remarks

The model described in this chapter yields a number of interesting predictions. Most significantly, it relates the market's stochastic valuation of a firm's intrinsic value to the firm's "going public" decision-making process. Equally important, it focuses on the timing of initial public offerings by assuming that owners of a private firm receive an
offer (an offering price at which to go public) in each period. Given this offer, they must decide whether to accept it and go public, or reject the offer and remain private and continue their search for the right offer at which to undertake an initial public offering. The discrete choice dynamic programming model described in this chapter provides, at a fundamental level, a description of the firm's behaviour that incorporates dynamic elements into the firm's discrete choice set. Because of its explicit dynamic structure, the model formalizes the "windows of opportunity" hypothesis.

One implication of the model presented in this chapter is that the probability that a firm goes public will fluctuate in a manner reflecting the shifts in investor beliefs about the firm's intrinsic value. Specifically, as market valuations for firms deciding to go public increase, the probability that these firms receive an acceptable offer increases. In aggregate, this model predicts that IPOs will be clustered during certain periods which is consistent with the well-documented periods of above-average IPO volume known as "hot issues" markets. The model analysed here also predicts that the expected offering price at which the firm goes public is state dependent and thus varies with fluctuations in investor beliefs. If shifts in investor beliefs about the firm's value are systematic, and affect not only the firm's offering proceeds but also the market valuation of firms in the same industry, as suggested by the DSSW "noise trader" model, then the model also predicts that these IPO clusters should coincide with market peaks. The prediction is borne out by the empirical evidence presented by Lerner (1994), and Pagano, Panetta, and Zingales (1995).

An interesting feature of the model is that it offers an explanation of the IPO decision-making process that takes into account some firm specific characteristics. This is desirable because empirical work such as Lerner (1994), Pagano, Panetta, and Zingales (1995), and Dark and Carter (1993) show that firm characteristics are important in explaining the likelihood that a firm will go public. For example, Pagano, Panetta, and Zingales show that a firm's size (as measured by their sales) is a significant factor affecting the probability that the firm goes public. Here, the firm specific extensions of the model focus on the interaction of the firm's publicly available information, the
individual investor’s beliefs, and the likelihood that the firm goes public. It is assumed that the age and size of the firm are the characteristics that influence the availability of public information about the firm’s intrinsic value. The heterogeneous information content of the firm (due to heterogeneous firm size and/or age) is assumed first to have an affect on the divergence of investor beliefs about the firm’s value and secondly to influence the firm’s probability of getting an offer. A third extension of the model allows the costs of participating in the IPO process to vary across firms. The implication derived from these (heterogeneous firm) extensions of the model are as follows.

First, when the public information content of the firm influences the divergence of investor beliefs, the model predicts that established firms are more likely to go public and at a lower offering price than less established firms. Also, this extension of the model predicts that more established firms are more sensitive to shifts in investor beliefs. More precisely, the difference in the likelihood of going public between states is greater for the information rich firms than for the information poor firms. Secondly, when the public information content of the firm affects the firm’s probability of receiving an offer, the model predicts that established firms are more likely to go public at higher offering prices. This implication is consistent with the empirical evidence presented in Pagano, Panetta, and Zingales (1995) where they show that the size of the firm has a positive influence on the probability that the firm goes public. This extension of the model also predicts that information rich firms are more sensitive to shifts in investor beliefs.

Thirdly, when heterogenous participation costs are modelled, information poor firms are found to comprise a larger proportion of the firms going public during a “hot issues” market period.

As mentioned in the introduction, many of the model’s predictions are consistent with existing empirical evidence. However, at the firm level, the model’s predictions are shown to be dependent on whether participation costs are more important than the public information content of the firms. Determining which type of firm heterogeneity plays a more important role in the firm’s decision-making process is essential in order to help increase access to capital markets. Empirical evidence documenting the number of
"information rich" or established firms carrying out IPOs during a "hot issues" market period relative to the number of IPOs from their "information poor" counterparts would allow one to calculate the proportion of firms going public during these periods. Finding that the IPOs that go public during a "hot issues" market period consists largely of established firms would imply that the informational aspects of the IPO play an important role in the firm's decision to go public. Data that includes the size, age and a few other characteristics of the IPO is becoming increasingly easy to access for North American stock markets and thus would enable one to investigate the "sensitivity" predictions of the model. However, if one is interested in understanding what characteristics of the market and what characteristics of the firms themselves affect the decision to go public, one requires information on firms that have not gone public as well. Specifically, it is important to observe a large proportion of firms that can go public, rather than simply have a sample of the firms that have gone public. Any empirical results derived from a data set that consists of only IPOs would suffer the consequences of sample selection bias that is present in the data. Therefore, any support found for the model with the empirical investigation of IPO data proposed above would imply that the model is, at best, consistent with some observable stylised facts.\footnote{The data utilised in Chapter 4 are simply the aggregated observation on the IPO market. Information on firm level characteristics is not included in this data set. Because of this, firm level stylised facts cannot be calculated here.}

The optimal stopping model of the firm's decision-making process presented in this chapter is a special case of a discrete choice dynamic programming model. There exists a growing literature on the methods for solving and estimating dynamic stochastic discrete choice models. The "structural" approach to estimating a dynamic discrete choice model, as outlined in Eckstein and Wolpin (1989), uses an exact solution to an approximation of the value function \( m(S_i, W_i) \) from equation (12) in this study). This estimation procedure seems like the most fruitful method to study whether it is possible to identify some variables that predict the firm's decision to go public. With this estimation procedure, one can predict the firm's behavioural response to i) changes in any
of the parameters in the model's objective function, and ii) changes in the parameters that enter into the firm's participation costs and the firm's offer distribution, both of which are assumed to depend on firm level characteristics. Therefore, the empirical estimation of the dynamic programing model of the firm's decision to go public would be an interesting avenue for future research.

Unfortunately, the type of individual firm data that would be required for the suggested estimation procedure is not easily available for private North American firms. Specifically, the estimation procedure requires data on private firm characteristics that may affect the likelihood of it going public. Some of these characteristics have already been outlined in the study (i.e., the firm's size, age, the offering price at which a firm goes public, and the firm's sectoral median market-to-book ratio). Other characteristics which may affect the firm's decision to go public include the firm's degree of leverage, measures of the firm's capital expenditures, and the firm's earnings or growth performance. This would require data on the balance sheets and income statements, and stock market prices (for the offering price) for a pool of firms that can potentially go public during the sample period of interest. This type of data is difficult to acquire for North American firms that are not listed on a stock exchange. It would also be of interest (though not necessary) to have this type of data for a sample period that overlapped with an observed "hot issues" market period in order to evaluate the prediction that firms are sensitive to changes in investor sentiment.  

---

29 See Pagano, Panetta, and Zingales (1995) for a summary of the various reasons why these factors may affect the firm's decision-making process.

30 This type of data set is available in many European countries since the central banks of various countries have undertaken to build data sets containing the financial statements for a large proportion of the countries corporate community (private and public) (see Pagano, Panetta, and Zingales for the Italian version of this type of data set). Though the European data is a rich source of firm financial characteristics, it does not contain stock market data for the publicly traded firms in the data set. Since data on the offering price at which the firms go public is essential for the estimation procedure suggested above, this would require one to splice the financial statements data with some stock market data (if available). This may be problematic since the financial statements data set is tabulated on an anonymous basis. Without the corporation's name, matching up the stock market data with the firm characteristic data would be difficult.
In summary the model described in this chapter yields a large number of predictions about the firm's reaction to changes in the incentive to go public brought about by changes in the market's valuation of the firm. Several predictions are consistent with existing empirical stylised facts while other predictions have yet to be empirically tested. The model presented here is a special case of a dynamic programming discrete choice model that can be "structurally" estimated. Identifying the factors that may be significant determinants of the firm's decision to go public from the estimated model would then be possible. Conditional on the availability of the data, the estimation of the model presents itself as an avenue of future research.
Appendix 5.1

Though the focus of this study is to explain how and why IPOs tend to be clustered in certain periods it is important that the model be consistent with other observed empirical anomalies of the IPO market, specifically the observed cyclical pattern in positive initial returns and long-run investment underperformance. Two extensions of the model may explain these other IPO market anomalies.

In Section 5.3, the endogenous speculative premia modelled in Morris' (1995) work is not modelled in the proposed formulation of the market's valuation of the firm. Only the investors' heterogeneity is modelled. Any speculative premia engendered is due to the extraneous investor beliefs (as described in DSSW) modelled as \( \mu_i \). Specifically, under the formulation presented in Section 5.3, the market's valuation (calculated by the underwriter if it were to sample the whole market) of the value of the firm would be \( E[v_i + \mu(S_i) + \varepsilon_i] = v_i + \mu(St) \) since \( E[\varepsilon_i] = 0 \). Here, the offering price is set at the firm's fundamental value plus a common (to all investors) belief (error), \( \mu(S_i) \). If \( \mu(S_i) = 0 \), investors value the firm at its true value and the market efficiently prices the offering. If, on the other hand, \( \mu(S_i) > 0 \), then the market is willing to pay a premium for the firm. Morris shows that with divergent beliefs, the market price of the asset will (endogenously) strictly exceed every investor's valuation of the asset and that the dispersion of these beliefs affects this speculative premium. Therefore Morris' model may explain, at a fundamental level, how the common investor beliefs, \( \mu(S_i) \), assumed here to be exogenous, may be greater than zero. As previously mentioned, the only characteristic of Morris' asset valuation model embodied in this model is investor heterogeneity. To model Morris' prediction of a speculative premia due to investor heterogeneity would require that \( \mu_i \) be some function of the investors' divergence of beliefs with \( \mu(S_i) = \varphi(\text{var}(\varepsilon_i)) = \varphi(\sigma_i^2) \).

With this formulation of investor beliefs, it is possible to show the affect that learning and increased information about the firm's value have on the market valuation of the firm. Following Morris, it is assumed that the dispersion of investor beliefs, \( \sigma_i^2 \), is
dependent on the information qualities of the firm. Early in the aftermarket, \( \sigma_i^2 \) is assumed to be large due to the large divergence of beliefs caused by the lack of information about the firm's potential. As time goes by, information about the firm becomes public and investor heterogeneity, \( \sigma_i^2 \), goes to zero. As information becomes available, the traders' valuation and the market price will converge to the firm's fundamental value. In this case, the early aftermarket price of the IPO's shares, \( V_t \), will be given by:

\[
V_t = v_t + b(\sigma_i^2) \text{ (with } \mu(S_t) = b(\sigma_i^2))
\]

with the following properties:

\[
as t \to \infty, \sigma_i^2 \to 0 \Rightarrow \mu(\sigma_i^2) \to 0 \text{ and } V_t \to v_t.
\]

Since the market valuation of the firm converges from above to the true value of the firm, long-run investment performance will be poor. This prediction is consistent with the observed long-run investment underperformance. By letting \( \sigma_i^2 \) be firm specific, this extension of the model is also able to predict that more established firms experience a less degree of long-run underperformance than younger firms. Using the notation introduced in Section 5.6, let \( \sigma_{pi}^2 \), the measure of divergence of beliefs among investors about the information poor firm's potential, be greater than that of the established firm's, \( \sigma_{pi}^2 \), at the offering. Therefore, as time goes on the older established firm will underperform to a lesser degree than younger firms. This is consistent with the empirical evidence presented in Ritter (1991).

A second extension of the model is able to explain the occurrence of positive initial returns. This extension relies on adverse selection being a problem encountered by the underwriter in pricing the offering. This is accomplished by introducing the possibility that the intrinsic or fundamental value of the firm, \( v_t \), is dependent on the type of firm going public such that \( v_{1g} \in \{ v_{1a}, v_{1b} \} \) with \( v_{1g} > v_{1b} \). Here, b and g denote the two types of firms differentiated by their intrinsic value, given they go public. A bad type firm, b, is assumed to have a lower intrinsic value than a good type firm, g. The market valuation of the firm (if the type is known with certainty), \( V_t \), under Morris' speculative premia hypothesis is then calculated as:
\[ V_i^g = E(v_{1g} + \beta(\sigma_i^g) + \epsilon_i) = v_{1g} + \beta(\sigma_i^g) \text{ or } V_i^b = E(v_{1b} + \beta(\sigma_i^b) + \epsilon_i) = v_{1b} + \beta(\sigma_i^b) \]

As explained in Section 5.2, adverse selection cost, as predicted in Rock (1986), arises in this situation since some investors are not able to distinguish the type of firm going public. Here, the underwriter will calculate an offering price below the market trading price that takes into account the adverse selection problem. The difference between this formulation of IPO pricing under adverse selection and Rock's (1986) formulation is that the aftermarket price is not necessarily set efficiently (which is assumed in Rock's) but at a market price reflecting some degree of investor beliefs. This explanation of positive initial returns requires that the investors have their information sets partitioned in a manner that would allow them to distinguish information about the type of firm going public from information about the intrinsic value of the firm, given firm type. Such a possibility is envisioned if investors valuate the intrinsic value, \( v_{1j} \in \{b, g\} \), as a function of the returns derived from a growth enhancing investment project of type \( g \) or \( b \).

Investors who do not observe directly the project type must evaluate the probability that the firm has a project of type \( g \) or \( b \). Also, the investors may be required to assess the firm's prospects that are unrelated to the type of project that it undertakes. For example, the industry that the firm operates in may be on the verge of technical innovation that would change the investment prospects for all firms, regardless of the type of project the firm is thinking of undertaking.
Chapter 6

Summary and Conclusion

The underlying theme of this thesis is that economic agents' beliefs play an important role in both monetary and financial settings. In a monetary setting, beliefs are shown to be critical to the existence of money as a medium of exchange. In a financial setting, stochastic beliefs are shown to influence the firm's decision to go public.

Chapter 2 of this thesis studies that interaction between price level fluctuations, the economic agent's beliefs, and money's medium of exchange function. It begins by reviewing some of the ideas put forward by early theorists, such as Menger and Simmel, on the origin of money and its continued existence as a medium of exchange, as well as some of the recently developed search theoretic models of money. In doing so, this study demonstrates that the recent search theoretic models of money are the first to formalize the early theorists' idea that money's acceptability as a medium of exchange hinges on the agent's belief that other agents will in turn accept it. While the monetary search models are able to capture the idea that beliefs are important for the existence of money, this chapter shows that they have yet to model Simmel's idea that price fluctuations may have detrimental effects on these beliefs, and thus may be welfare reducing.

This study highlights that Walrasian models which focus on money's store of value function invariably find that monetary policy plays a minimal role in the economic well-being of agents. However, the recent search theoretic models which focus on money's medium of exchange function are able to capture money's institutional aspects, hence these models could be used to formalize the ideas put forward by the early theorists.

Chapter 3 of this thesis reviews the defining characteristics of the initial public
offerings (IPOs) market and provides some background on the institutional aspects of the IPO process. Some of the academic literature concerned with the IPO process is reviewed; it is evident from this review that most of the literature concentrates on the pricing aspect of IPOs, specifically the so-called “underpricing” anomaly. This chapter reveals that the implications drawn from the “underpricing” models are not consistent with the observed cyclical patterns in the IPO data. Moreover, this part of the thesis shows that little research has been carried out investigating the anomalous “hot issues” market phenomena, which is described as recurring periods of abnormally high IPO initial returns and volume.

Chapter 4 seeks to rectify the dearth of empirical studies on the IPO “hot issues” market phenomena. The empirical study presented in this chapter is one of the first studies to characterize explicitly the cyclical properties of the IPO initial returns and volume processes. Using Hamilton’s Markov-switching approach, the study tests the implications derived from the “windows of opportunity” hypothesis. The results of the tests suggest that the IPO volume and initial return processes can be described as stochastic regime switching processes, thus supporting the explanation that firms take advantage of “windows of opportunity” in certain periods. By extending Hamilton's approach to a vector setup, this empirical study also tests one of the implications derived from the De Long, Schleifer, Summers and Waldmann (1990a) “noise trader” model. In doing so, this study reverses one of the criticisms of the theoretical “noise trader” model, which is that the model’s predictions are not empirically testable. The findings of this study lend some support for the “noise trader” model of asset pricing. Since the findings provide an ex-post characterization of the statistical properties of the IPO initial returns and volume processes, future theoretical work on the public equity offering process should be directed to models that focus on the stochastic interaction between investor beliefs and the firm’s decision making process.

In Chapter 5 a model is developed which analyses a firm’s decision to go public in an environment where investors hold heterogeneous, stochastic beliefs. Specifically, this study develops a theoretical optimal stopping model of the firm’s decision to undertake an
IPO that is similar to the "standard" job search model that is predominant in the labour economics literature. However, as opposed to the "standard" job search model, the optimal stopping model is nonstationary in nature due to the stochastic nature of investor beliefs. The model identifies important factors contributing to the firm's decision to go public. It also provides several testable (aggregate and firm specific) implications of the firm's decision to raise equity and issue publicly traded shares for the first time. The model shows that firms are more likely to go public during periods when investors hold optimistic beliefs and thus overvalue the shares of firms issuing stock for the first time. This prediction is consistent with the well-documented clustering of IPOs in certain periods (the "hot issues" market phenomena). This stopping model is extended in order to be able to analyse the interaction between heterogeneous firm characteristics and the firm's decision to go public.

A number of directions for future research are suggested by the studies contained in this thesis. The empirical analysis undertaken in Chapter 4 proved to be a fruitful approach in characterizing the dynamic properties of the IPO processes. It would therefore be useful to extend this type of approach to other assets which display evidence of regime shifts. Since Loughran and Ritter (1995) present evidence that seasoned equity offerings (SEO) (secondary offerings of shares from publicly traded firms) are afflicted by many of the anomalies that characterize the IPO processes, it seems natural to apply this approach to SEOs. As is the case for the empirical academic studies on IPOs, the empirical research conducted on SEOs does not analyse, in any detail, the stochastic characteristics of the SEO volume process.

As discussed in the conclusion of Chapter 5 of this thesis, the empirical studies estimating the job search models found in the labour literature are a growing research field in economics. Because these studies have advanced to a point where they can estimate dynamic programming models, it seems logical to use their techniques to estimate the optimal stopping model in Chapter 5. The estimation of the model would

---

1They show that SEOs display poor long run investment performance and undergo cyclical variations in volume.
provide a better understanding of what influences the firm's decision to go public. This type of empirical research would not only allow one to test the implications derived in Chapter 5, it would also provide empirical evidence to guide the development of other theoretical models that build on the analysis of the firm's decision making process presented here.
BIBLIOGRAPHY


