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The impacts of new and old economy stock market valuations on private investment in South Africa.

Abstract

The investment - stock market relationship is captured by the q theory, however, the q variable performs poorly empirically. An alternative way to explain the relationship is to ascertain whether changes in new and old economy stocks are successful in predicting changes in investment. The new economy refers to the technology, media and telecommunications (TMT) sector of the economy, whereas all of the remaining sectors (non-TMT) are referred to as the old economy. This paper describes the impact that stock market capitalisation revaluations of the TMT and non-TMT sectors of the Johannesburg Stock Exchange have on private investment in South Africa. The analysis is particularly interesting as the TMT sector in South Africa has undergone significant changes during the period analysed. Using the vector autoregressive methodology for the period 1994 - 2004 it is shown that changes in TMT stock valuations cause a more pronounced effect in private investment than do changes in non-TMT stocks.

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I. INTRODUCTION

A considerable amount of research has been dedicated to building models that seek to establish what determines the levels of private investment in an economy. The stock market has been identified as playing a significant role in influencing investment behaviour. Although many approaches can be adopted to view the investment – stock market relationship, attention is focused on the effects of new economy stocks. In the context of this paper, the new economy refers to the technology, media and telecommunications (TMT) sector. The concept of a new economy became extensively developed during the 1990's – the decade during which stock markets worldwide underwent significant changes. The changes similarly affected the South African stock market, namely the Johannesburg Stock Exchange (JSE). The advent of the Internet becoming publicly available and the introduction of mobile telephones caused the pace of technological change to quicken. Firms which provided Internet and mobile phone services garnered much attention. In particular, the 1990's were characterised by numerous initial public offerings by TMT firms and by the subsequent surge in the prices of these stocks. Realised profits fell short of the levels required to justify the high prices. These firms proved difficult to value accurately because they were new and their assets were typically intangible, hence it became increasingly difficult to distinguish the true fundamental values. Perhaps this was the trigger of the significant fall in stock prices at the end of the decade. The wealth of those individuals who invested in TMT stocks would have been affected by the rise and fall of the stock prices. The change in personal wealth no doubt changed the path of future allocations in various investments.

This paper provides a framework to assess the extent to which private wealth is affected by changes in stock price valuations and how the subsequent changes in wealth will influence investment decisions. Thus, the principal objective is to use time series evidence to ascertain the impacts of changes in TMT and non-TMT stock market valuations on private investment in South Africa for the decade spanning the 1990's.

The paper proceeds as follows: Section II provides a literature review which explores both the direct and indirect theoretical effects of the stock market on investment. The investment – stock market link was formalised in the q ratio by Tobin (1969). Despite

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sound theoretical arguments which underpin the ratio, the empirical results obtained via the use of the ratio are disappointing. Consequently, this has led to the development of different types of models which attempt to identify other factors that can successfully explain the relationship between investment and the stock market.

Section III considers the possibility that stock prices are partly determined by the somewhat erratic behaviour of market participants who follow fashions and fads when selecting stocks. In particular, evidence is presented on the prevalence of a stock price bubble during the period 1990 – 2000. However, instead of attributing the high stock prices in the TMT sector to a bubble it could be argued that the economy underwent a structural change that was highly geared towards the technology and service orientated industries. This section includes a preliminary data analysis that serves to provide a feel for the characteristics and behaviour of the new and old economy sectors during the 1990's. In addition the wealth effect is discussed in some detail.

Section IV discusses the empirical approach that is used to test the investment equation which is defined as a function of wealth, income and user costs. Since the variables are all interrelated then the equation is estimated in the vector autoregressive (VAR) framework. The methodology employed is outlined in conjunction with a discussion regarding the appropriateness of using the VAR framework.

Section V presents the results of the estimated VAR model in the form of impulse response functions which plot the estimated coefficients within the bounds of confidence intervals. An external positive shock evokes a larger response in TMT market values than in non-TMT market values. Investment responds to changes in both the TMT and non-TMT market values. However, the response is larger for changes in TMT market values. The South African case is compared to the results obtained by Edison and Sløk (2003) for the OECD countries.

Section VI briefly investigates the robustness of the model and Section VII concludes and summarises the main findings. Appendix A provides various results from Edison and Sløk (2003) which are used to make direct comparisons with South Africa in the preliminary data analysis. Appendix B lists and describes the data used. Lastly, Appendix C provides the mathematical derivation of the equations of the VAR model.

II. THEORETICAL OVERVIEW

A firm can allocate funds in various investment opportunities. Financial securities, such as stocks and bonds, represent one type of investment. The other type refers to real investment such as buildings and equipment. A positive relationship exists between these two types, in the sense that stock price movements and changes in real investment may occur in the same direction. Traditional explanations for the existence of this relationship can be attributed to Keynes (1936) and Tobin (1969).

Keynes' (1936) version focuses on speculative behaviour amongst stock market participants. In principle, speculators attempt to buy low and sell high. Thus, rising stock prices are a signal to sell. The realised proceeds thereof are predominantly used to undertake real investment. A booming stock market is therefore associated with high levels of real investment.

Tobin (1969) on the other hand, suggested that the stock market is driven by fundamentals. This implies strong market efficiency whereby the stock price captures all relevant information about the firm. These concepts are reflected in Tobin's quotient or the so-called average q, which values a physical asset as:

$$q = \frac{\text{Current market value of an established asset}}{\text{Cost of reproducing/replacing the asset}}$$

A firm's stock price represents the market value of the underlying asset or so-called established asset. The cost of reproducing or replacing this asset would entail making an investment directly in the underlying asset. The ratio has an equilibrium value of one when the market value is equal to its fundamental value. The equilibrium therefore accords with market efficiency. The value of a firm and thus of the established asset is continually revised as is evidenced by the frequent buying and selling of stocks. Therefore at times the market value might not necessarily coincide with the cost of reproducing the asset. In fact, it is the difference between these values that determines the rate of investment (Brainard and Tobin, 1968 and 1977). For instance, increases in a stock price raise the ratio such that q takes on a value greater than one. In terms of the definition of the ratio, this would mean that market participants believe the firm will be profitable in the future and reflect this by valuing the firm in excess of its replacement cost. The implication is that it is cheaper

to reproduce the asset rather than to buy a stake in an existing firm hence real investment will increase. In summary, Tobin's q provides a link between investment and the stock market by valuing the firm directly using its stock market value (Abel, 1990). Additionally, the q theory is effectively a formal specification of Keynes' observation that "...there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; whilst there is an inducement to spend on a new project what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit."[1] Therefore, the conjectures of both Keynes and Tobin yield similar outcomes: real investment rises and falls in line with the stock market. Not surprisingly, investment is inherently volatile.

The q theory is widely used in studies which examine the relationship between investment and the stock market, however empirically it proves to be a particularly inadequate predictor of investment. The outcomes of various studies have brought to light certain deficiencies in using q models.

Barro (1990) finds that stock market returns are consistently better than the q variable at explaining variations in investment. This result is unexpected because the numerator of the q variable is the market value of equity and this in itself should render the variable highly significant. However, the market value is constructed, using for example dividends. This is the first source of difficulty as the constructed value only serves as a proxy for actual stock market value.

A second difficulty is that in the realm of the q theory it is marginal q that is the actual predictor of investment. It is defined as the ratio of the incremental market value relative to the investment to be undertaken. Hayashi (1982) derives the relationship between average and marginal q and shows that under certain circumstances the measures are equal. By so doing, the unobservable component - the marginal value of capital is transformed into an observable variable - the average market value. This is a useful tool which allows q models to be estimated. Yet once again the true predictor, marginal q, is being proxied by average q which, as discussed, is itself a flawed variable.

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[1] Keynes, J. (1936) The General Theory of Employment, Interest and Money, p.151

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The third difficulty relates to the required assumption of market efficiency where stock prices are always presumed to equal fundamental values. In reality market efficiency often does not hold. As pointed out by Shiller (1981), observed market prices are generally too volatile to be caused by corresponding changes in fundamental values, therefore they cannot accord with the efficient markets model. Hence the use of the q model could lead to false interpretations and conclusions.

Studies, such as Blundell et al. (1992), that manage to successfully attain a significant q variable can usually only do so in the presence of a vast number of assumptions relating to the properties of the q variable. However, even such a result proves to be fragile. The moment other determinants of investment are added to the equation, the explanatory power of q diminishes (Blundell et al., 1992 and Mullins and Wandhwani, 1989).

The shortcomings of the q model have led to the development of a new strand of literature which uses alternative methods to examine the link. Such studies have often discovered other factors, over and above the stock market, which influence investment. In general, either completely new models are developed or the original q model is augmented to include other possibilities.

An example of the latter can be found in Chirinko (1987) where it is suggested that the q model is restrictive as it does not capture and reflect the way a firm truly operates. In reality firms participate in many markets simultaneously and not just in the stock market. As a result the q variable on its own may be a misleading indicator of investment. Therefore, the model is respecified to include a firms debt and equity policies which are shown to exert an influence on investment.

A model in contrast to the q theory is the so-called flexible accelerator model developed by Jorgenson (1963). This mainstream model defines the demand for new capital as a function of a firm's production and demand functions. The firm equates the marginal product of capital to its marginal/user cost. Investment levels are therefore determined by real activity and the average return on capital. Accordingly a firm will expand its asset base, and hence investment, if its output increases whilst user costs decrease or at least remain unchanged. A slight variation of this model is the accelerator model whereby investment depends only on changes in output and not on user costs (Abel, 1990).

Fama (1981, 1990) adopts the flexible accelerator model to derive the relationship between the stock market and real activity, within which investment as a variable is included. The analysis reveals that stock returns are a leading indicator of real variables suggesting that the market rationally forecasts the real sector. The flexible accelerator model is often empirically more superior than the q theory (Mullins and Wandhwani, 1989). Regressions modeled on the flexible accelerator provide significant coefficients, allowing for various factors to simultaneously influence investment. The q model on the other hand is generally only significant when it appears on its own in regressions. In the presence of other variables it often has no independent effect.

Another model which deviates considerably from the q theory proposes that investment is determined by conditions in the credit market. Specifically, Bernanke *et al.* (1996) argue that the impact exerted by the financial accelerator on the credit market determines levels of investment. The concept of an accelerator refers to the situation whereby adverse shocks to the economy are amplified by worsening credit market conditions. This is observed when a small shock has large overall effects. The notion can be further explained in terms of the principal-agent framework. Negative shocks to the economy reduce an agents net worth making it more difficult to obtain additional finance. As a result investment and production are reduced, amplifying the initial shock. Additionally a flight to quality can ensue. The principal would rather invest in a safe technology with a guaranteed return than extend seemingly risky loans to firms.

Another strand of research, discussed below, examines the established relationship between investment and the stock market for any additional influences. Specifically, tests are conducted to determine whether factors that directly affect the stock market will by association also affect investment.

The susceptibility of stock prices to fads is a well-documented and supported fact (Poterba and Summers, 1988, Shiller, 1981). Galeotti and Schiantarrelli (1994) consider the standard q model in their analysis. In this case the market value of equity is split into fundamental and non-fundamental components, where the latter component is presumed to represent the fads or fashions that persist in the market. The significance of both components implies that investment does indeed respond to movements in stock prices, even if these movements are attributable to fads. Even though the fundamentals component exerts the stronger influence there is room for

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irrationality to affect investment decisions. These findings are confirmed by Morck *et al.* (1990) who evaluate whether investor sentiment is a potential channel through which investment can be affected. The observation that variations in stock prices may occur even though fundamentals remain unchanged leads to the conclusion that sentiment exerts an influence on prices. By deduction, sentiment influences investment.

Another branch of the literature follows a similar line of reason but takes the approach of isolating the effects of management behaviour and organisational structures in firms. Blanchard *et al.* (1993) examine whether managers' investment decisions are affected solely by fundamentals or whether stock market valuations have a role to play. This question is particularly interesting when the two valuations differ. The evidence suggests that although, once again, fundamentals assume the leading role in investment decisions the stock market does influence these decisions. It provides managers with information even if false signals are relayed. A common example of the market influence on investment decisions can be found in the case of new stock issues. A manager's decision to use the market as a source of financing for the purposes of an investment project will depend on the amount of proceeds that can be raised. This in turn directly depends on the markets valuation of the stock. Therefore, periods of high stock prices are usually coupled with numerous IPO's. Morck *et al.* (1990) concur that in the case of IPO's the financing channel is an important determinant of investment.

An example of the effects of a firm's internal structures can be found in Mullins and Wandhwani (1989). Utilising the flexible accelerator model the authors have identified that shareholder control; stock options as a part of remuneration and the predominance of fresh stock issues to finance projects are all factors which make the stock market an important consideration in the investment decision-making process. However, in those instances where the manager's decision-making process is autonomous stock prices are not as influential and investment rates tend to be higher.

In a similar manner, Dow and Gorton (1997) bring forth a conjecture that the stock market influences investment through the actions of shareholders. If shareholders believe that their capital will be used more efficiently elsewhere they will reveal their sentiments by selling their claim causing the share price to fall. In this case a manger is less likely to invest in new projects. On the other hand a price increase is

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likely to raise the rate of investment. Therefore, current prices clearly play a role in investment decisions. The features of the argument are in line with the q theory which uses the current market value of assets to determine investment.

Bond and Cummins (2000) propose yet another angle at which the investment - stock market relationship can be approached. They introduce the concept of a 'new economy' and place the emphasis on the key characteristic of new economy firms: intangible assets. The familiar q measure is used to empirically test the idea, in other words a q greater than one implies the presence of intangible assets. Since intangible assets are difficult to value the efficient markets model is employed and the intangible asset values are derived as being the difference between market capitalisation and the value of the tangible assets. Since market efficiency implies that the market value always equals the fundamental value then the authors' conjecture that any large deviations in price can be explained as the market pricing in changes in intangible assets. Empirically however, the model does not conform to the authors' argument. Stock price movements are not due to changes in the investment in intangible assets. On the contrary, the results suggest that business investment decisions are chiefly based on projected profits and not on share price behaviour.

In summary, Tobins Q provides the means for ascertaining how investment decisions are made. The ratio encapsulates the investment – stock market relationship and is based on the assumption of strong market efficiency. The value of the ratio indicates whether it is more profitable to invest in assets, such as buildings or equipment, rather than to purchase a stake in an established firm. Therefore the level of investment depends on the direction that stock market valuations follow. However, Tobins Q proves to be an inaccurate and poor predictive measure when used to test the investment - stock market relationship empirically. The q variable is almost always insignificant. Generally, significance is achievable only under a vast number of assumptions. The implementation of assumptions can be tedious and often they distort the true relationship between variables.

The use of the q-variable in empirical studies has highlighted particular deficiencies in the theory and assumptions backing the ratio. Hence, various different approaches have been developed to examine the investment – stock market relationship and to attain significant q coefficients. One of the approaches simply builds on the original q-theory in order to obtain results that reflect reality as closely

as possible. Alternatively, completely new models are built whereby it is ascertained that non-fundamental factors which partly determine stock prices will likewise exert a significant influence on investment decisions. The concept of new economy firms is explored in order to judge the impact of intangible assets on stock prices and thus on investment.

III. THE BASIC MODEL

Edison and Sløk (2003) continue with the thread of new and old economy stocks. In contrast to previous studies like Bond and Cummins (2000) the authors do not make use of the q theory in empirical evaluations but merely use it as a theoretical and general guide. The methodology employed in their paper involves splitting the stock market into two components and evaluating each individually. One component consists of technology, media and telecommunications (TMT) stocks only; the other component comprises all the remaining stocks (non-TMT) in the market. These components are referred to as new economy and old economy stocks respectively. The distinction between old and new economy firms is usually explained in terms of assets. A firm will belong to the old economy if its assets are mainly in the form of buildings, machinery and equipment. New economy firms are more difficult to define precisely but typical assets will include a brand name, human capital and intellectual property. The authors test the independent impacts of the new and old economy stocks on investment in various OECD countries for the decade 1990 – 2000. The motivation for the study stems from the particular changes observed in the behaviour and composition of worldwide stock markets during the 1990's.

In terms of behaviour, the 1990's were characterised by significant stock price increases. If the efficient market hypothesis is accepted, whereby the stock price of a company is always equal to its fundamental value, then these price increases could be attributed to the arrival of large amounts of new information regarding fundamentals (Blake, 2000). Sometimes however, in contrast to this hypothesis, a temporary breakdown between fundamentals and stock prices occurs whereby the fundamental factors do not justify the high prices. Such a breakdown often arises when certain stocks or sectors become fashionable. In addition, market participants could develop more flexible tastes and hence their appetite for risk increases (Black, 1988). The increased investor demand for the fashionable stocks causes the prices of these stocks to rise sharply. However, when these prices cannot be sustained at the new higher levels then the phenomenon is referred to as a bubble. As Stiglitz (1990) noted: "if the reason that the price is high today is *only* because investors believe that the selling price will be high tomorrow – when "fundamental" factors do not seem to justify such a price – then a bubble exists"[2].

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[2] Stiglitz, J. (1990) Symposium on bubbles, The Journal of Economic Perspectives, p.13

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Just as fashions and fads can cause prices to rise dramatically they can burst a bubble as well. The role of bringing stock prices back to fundamentals belongs to the arbitrageur. However, bubbles exist and persist because the uncertainty injected in the market coupled with various limits of arbitrage prevents prices from reverting to fundamentals. The risks an arbitrageur has to endure relate to not knowing what direction the prices will take in the future and whether the price truly is out of line with fundamentals (Schleifer and Summers, 1990). The activities of noise traders amplify these risks and hence the arbitrageur will resort to taking limited positions that do not have the desired effect of bringing prices back to their fundamental value (Black, 1986). An additional reason for the limited positions is attributable to capital constraints. The arbitrageur usually acts on behalf of individuals who supply the necessary capital. The amounts allocated are determined by the arbitrageur's performance. Positions that incur losses will result in capital withdrawals, even though during a bubble it is the large and aggressive positions which succeed in countering the mispricing (Schleifer and Vishny, 1997). Sometimes arbitrageurs will act like noise traders themselves as the gains from jumping on the "bandwagon" and trading like the noise trader outweigh the potential benefits of counter positions (Schleifer and Summers, 1990).

Aside from specific bubble periods when extreme pricing is the order of the day, De Bondt and Thaler (1985) find that the market generally tends to overreact. The authors discovered that US stock price movements often go through complete reversals within two years. Similarly, Page and Way (1992/93) find that the JSE experiences overreaction. Overreaction is not the behavioural domain of just the noise traders but arises in the professional spheres as well. For instance equity analysts are more often than not too optimistic in their forecasts of company earnings. Actual earnings generally prove to be more modest and fall short of analysts' expectations (De Bondt and Thaler, 1990). Moreover, professionals have admitted to spending time and effort trying to second guess what other investors are doing rather than analysing hard economic news (De Bondt and Thaler, 1990 and Shiller, 1990). In this way the professionals contribute to both the building of a bubble and to the severity and depths of the subsequent crash.

Along with various world market indices like the Nasdaq, the JSE experienced a bubble between 1996 and 2001. This particular bubble was driven by the enthusiasm shown for technology stocks. At the time, investment in technology was

significant and on the increase however it was difficult to realise the gains of these investments, hence a misevaluation of technology stocks occurred. This can easily be seen using the price to current earnings (P/E) ratio. The ratio represents the markets' expectations of the growth that can be achieved by a firm (Bodie *et al.*, 2002). Firms with high P/E ratios, namely those in the technology sector, were thought to have numerous growth opportunities and that the resulting future earnings would justify the high current prices. For instance the optimism surrounding Internet firms meant that they were valued in billions of dollars even though they had not yet earned a single dollar in profits. Some market participants, like Shiller, warned that the very high P/E ratios were misleading as the firms faced more risk than growth opportunities. These individuals predicted a sharp fall in stock prices and hence the bursting of the bubble (Barro, 2000). Shortly thereafter, in 2000, this indeed did happen. The market became more sceptical about the true growth opportunities and more realistic about how fast earnings could actually grow. TMT stock prices were additionally affected by the "Year 2000" scare at the end of 1999.

Figure 1 : Price earnings ratio of the TMT sector, Q4 1994 – Q4 2002.
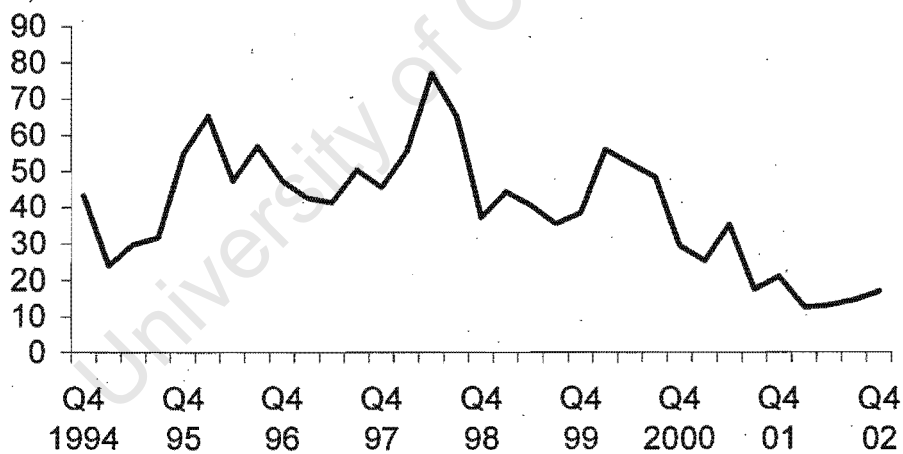
Source: Datastream

Figure 1 shows that during the 1990's the P/E ratio was on a steady increase with a sharp upward movement in early 1998, reaching a tremendous 77 that year. The average P/E ratio over this period was approximately 40 whereas in the non-TMT sector the average P/E ratio was approximately 15. The prices and earnings in the TMT sector were clearly not synchronised but this was corrected after the technology stock price crash in 2000.

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A. Evidence of a Bubble in the South African Stock Market

Shiller (1981) found that regardless of whether a stock market is experiencing a bubble, stock price movements in general are just too large and too volatile to be explained by changes in fundamentals such as dividends and earnings. Barsky and De Long (1993) suggest that perhaps changes in dividends can explain movements in stock prices in the long-term but certainly not in the short-term. Stock price volatility is developed further in Shiller (1990) whereby a simple test is used to ascertain whether stock prices are susceptible to fashions and fads. Essentially market efficiency is tested. The test involves regressing stock prices on dividends and using the R^2 to judge whether changes in stock prices can be explained by changes in dividends. For the purposes of this paper such a test, when applied to the South African stock market, provides an adequate indication of whether a bubble existed during the period 1990 - 2000.

As is the case with most macroeconomic time series variables non-stationarity is present in the variables. To deal with this, instead of detrending the series as Shiller does, cointegration is used. The benefit of this method is that the variables do not have to be transformed via, for example, taking the first difference of the variable. The true long-run relationship between the variables is thus retained. Therefore, despite the trend, cointegrated series can be used in regressions and any statistical inferences drawn from the results will be valid.

The raw data constitutes the dividend and earnings yields. These yields were adjusted by the market capitalisation in order to obtain the dividend and earnings series on their own. These, together with the stock price index were deflated by the consumer price index. Furthermore, the variables are expressed as logarithms. Stiglitz (1990) has pointed out that by nature bubbles are often short-lived, meaning there are too few data points available for the effective statistical testing of a bubble. As a result, the data used is monthly to ensure as many data points as possible.

The following correlation matrix (Table 1) reveals a very strong and positive relationship between the variables. At this stage however, there is uncertainty about whether these relationships are simply capturing a common trend or whether the variables are meaningfully related. The 98% correlation between earnings and dividends is expected as earnings are often thought of as indicators of dividends. The high correlations between stock prices and both dividends and earnings would

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be expected if the market were efficient whereby stock price changes mimic expected dividend/earnings changes.

Table 1: Simple correlations: stock prices, dividends and earnings.

	Log real stock prices	Log real dividends	Log real earnings
Log real stock prices	1.00	0.71	0.75
Log real dividends	0.71	1.00	0.98
Log real earnings	0.75	0.98	1.00

The first part of the testing requires establishing whether the variables are integrated of the same order. The number of times that a variable has to be differenced before it is rendered stationary determines its order of integration. For example if the variable has to be differenced twice then its order of integration is two. The commonly used formal test for the order of integration is the Augmented Dickey Fuller (ADF) test which uses the MacKinnon critical values to evaluate the following hypothesis:

H_0: The series is non-stationary (unit root present)
H_1: The series is stationary (no unit root)

The ADF test is performed in level terms and thereafter on successive differenced versions of the series until the null hypothesis is rejected. If the variables are integrated of the same order then the testing proceeds to the second part which establishes whether the variables are cointegrated. If the variables are cointegrated they can be used in regressions with the confidence that any results obtained will not be spurious.

The first ADF test is performed to test for a unit root on the logged real dividend, earnings and stock price series in level terms. A simple line graph of each series revealed a distinct upward trend thus the intercept and trend term options were chosen in addition to specifying a lag order of two. The results are as follows:

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Table 2: ADF test in level terms.

Variables	ADF test statistic	MacKinnon Critical Values		
		1%	5%	10%
Log real stock prices	-3.73			
Log real dividends	-2.31	-4.03	-3.44	-3.15
Log real earnings	-2.38			

Since the absolute value of the ADF test statistic is lower than the absolute value of all the critical values for the dividend and earnings series the null hypothesis cannot be rejected and thus the series have a unit root. In the case of the stock prices the ADF test statistic is lower than the critical values only at the 1% level. Therefore, if the 1% significance level is used overall then it can be concluded that all of the variables are integrated of an order of at least one. The ADF test is now performed on the differences of the same variables with the following results:

Table 3: ADF test in first differenced terms.

Variables	ADF test statistic	MacKinnon Critical Values		
		1%	5%	10%
Log real stock prices	-6.34			
Log real dividends	-8.14	-4.03	-3.44	-3.15
Log real earnings	-6.92			

The null is now clearly rejected in each case. Thus each of the variables are integrated of order one. The variables can now be tested for cointegration. Specifically this involves running cointegrating regressions and testing the residuals for stationarity, that is, the residuals must be integrated of order zero. The following cointegrating regressions are rearranged to obtain the residuals u_1 and u_2:

Regression 1: u_1 = Log real stock prices - β_1 - β_2 Log real dividends
Regression 2: u_2 = Log real stock prices - β_3 - β_4 Log real earnings

Once again the usual ADF test is performed. However when dealing with residuals the Engle-Granger critical values are appropriate. A line graph of the residuals revealed no trend in the series therefore only the intercept option was chosen. The lag order specified is still two.

Table 4: ADF test of the regression residuals in level terms.

Variables	ADF t-statistic	Engle-Granger Critical Values		
		1%	5%	10%
Regression 1	-3.40			
Regression 2	-3.42	-3.90	-3.34	-3.04

The null is rejected at both the 5% and 10% significance levels but not at the 1% level. Therefore, if the 5% significance level is used then it can be concluded that the residuals are stationary and thus the variables are cointegrated. Internationally, Campbell and Kyle (1993) provide similar evidence of cointegration for the S&P 500 and the respective dividend series.

When cointegrated variables are used together in a regression the trends effectively cancel out and thus the true nature of the relationship between the variables can be analysed. The regression of log real monthly stock prices on log real monthly dividends provides the following result:

Table 5: Regression results with log real stock prices as the dependant variable and log real dividends as the independent variable.

Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	-2.90	0.96	-3.02	0.0030
Log real dividends	0.75	0.06	11.93	0.0000
R^2	0.50			

The dividends series is significant at the 1% significance level. For every 1% increase in dividends, stock prices increase by approximately 0.75%. In line with Shiller's interpretations, the R^2 of 50% suggests that stock prices are reacting equally to dividends as they are to 'something else'. Hence for the period 1990 – 2000 the changes to fundamentals do not completely explain changes in stock prices. This leads to the conclusion that there was room for fads and fashion to play a role in determining the price and so a bubble did exist. However, this conclusion is made cautiously as dividends themselves are often subject to fads and fashions through the actions of the managers who decide on the dividend policy. Generally, managers are just as susceptible to the same optimism and pessimism that prevails in the market (Shiller, 1990). During the bubble the belief that the market held in the virtues

of technology could have led managers to issue higher dividends or to revise future dividends based on the growth they were hoping to achieve. Moreover, dividends cannot be the sole cause of price changes as some companies like Dimension Data have not declared dividends for many years yet their stock prices fluctuate regardless. Consequently, Shiller (1990) proposes that the same test be carried out but with earnings in place of dividends. Managers cannot easily control actual earnings and earnings forecasts are used in the absence of dividend payouts.

Table 6: Regression results with log real stock prices as the dependant variable and log real earnings as the independent variable.

Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	-0.46	0.68	-0.69	0.4925
Log real earnings	0.55	0.04	13.34	0.0000
R^2	0.56			

Similarly to the dividends variable, the earnings variable is highly significant in explaining movements in stock prices. A 1% increase in earnings will raise the stock price by 0.55%. Thus not even changes in earnings manage to fully explain stock price movements. The R^2 of 56% is marginally higher than in the previous regression. Hence, these results confirm that there is room for fads and fashions to cause movements in the stock price. On the whole repeating the test with earnings does not provide additional insight, as earnings are effectively indicators of future dividends and so similar regression results were expected.

An alternative explanation for the stock price increases observed during the 1990's can be given in terms of the changes in composition of world stock markets. Various economies are undergoing structural changes where certain sectors of the economy become more important. Specifically, the TMT sector has become more prominent and so perhaps not surprisingly TMT stock prices have increased more dramatically. The 1990's saw a rise of investment in technology and telecommunications on both the international and local arena. Gilchrist *et al.* (2004) found that in spite of the bubble and the large number of new stock issues, Nasdaq firms did have higher investment rates than those firms listed on the New York Stock Exchange. In light of this, the sharp increases in prices could have been rational. Moreover, the increased importance of the TMT sector brings with it the expectation of more volatile stock prices. Productivity gains are difficult to measure in this sector and therefore so are

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the growth opportunities (Barro, 2000). Perhaps these considerations change the original form of and accordingly the inferences drawn from the investment – stock market relationship previously described.

B. Preliminary Data Analysis

The Edison and Sløk (2003) paper sets the modelling paradigm within which the evidence for South Africa is presented. As noted previously, the existence of the relationship between the stock market and private investment is a crucial result as changes in this relationship have real effects on the macroeconomy. Since stock market fluctuations have real consequences, it is worthwhile to explore the question of what real effects the components have in their individual capacity. The specific focus is on how the value of stocks affects wealth and what response this evokes in investment behaviour. Conducting such an analysis is particularly important in the case of South Africa where the rates of investment are considered to be too low to achieve the required economic growth. Investment as such is desirable as it determines the rate of accumulation of physical capital. Physical capital is used to increase productivity which in turn is a means of raising long-run living standards. In addition, investment in new goods is what provides the link to improved technology and positive learning externalities. However, investment becomes undesirable when it is highly volatile; it then becomes a prime contributor to aggregate economic fluctuations. South Africa has felt the effects of these. As an emerging market it is especially sensitive to global impacts and market flows such as contagion effects, exchange rate effects or investor psychology. By identifying the main determinants of investment better forecasts and more desirable policy can be devised to insulate the real economy.

In analysing the important role that the TMT sector plays in determining investment, Edison and Sløk (2003) detect the influence that structural changes can have on the economy. Structural change in this context refers to the situation where various sectors of the economy become more or less important over time. Such changes will have implications for the type of labour and capital required. For example, the more dominant the agricultural sector is the more important land and labour will be. A structural change that is geared towards technology will be biased towards highly skilled labour. Thus, a technological change for a country like South Africa is not necessarily an advantage as most of the labour force is unskilled. The benefits of technology will raise GDP thereby raising the incomes of both the skilled and

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unskilled however the gains will be largely apportioned to those that are employed by the sector.

The following preliminary data analysis concentrates on South African macroeconomic and stock exchange data and draws extensively on the approach used by Edison and Sløk (2003). For comparative purposes the relevant tables containing results for the OECD countries from Edison and Sløk (2003) are included in Appendix A. Table 7 below confirms the existence of the investment - stock market relationship for South Africa where during the 1990's both private investment and the total stock market value increased.

Table 7: Changes in real GDP, investment, and market capitalisations.

	GDP	Investment	Total Market	TMT Sector	Non-TMT Sector
1990 - 2000	30%	20%	79%	8923%	73%

Note: Annual numbers are used. The change is calculated relative to 1994 for the TMT sector owing to the unavailability of data for prior years.

In the TMT sector the 1990's are characterised by explosive growth in the order of nearly 9 000%. This far exceeds the already high 73% growth recorded in the non-TMT sector. Figure 2 confirms that the stock price increases of TMT firms have outperformed the stock prices of the non-TMT firms. However, the observed changes in the TMT stock prices are more volatile (Table 8). The degree of volatility is important to consider since it may determine whether private investment itself is stable or volatile. For example, if the rate of investment is more sensitive to the relatively volatile changes in new economy stocks then the wealth arising from holding these stocks and consequently investment will be volatile. If on the other hand, investment is more responsive to movements in old economy stocks then owing to the relative stability of these stocks investment will be stable.

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Figure 2: TMT stock price index v non-TMT stock price index (1995 = 100)
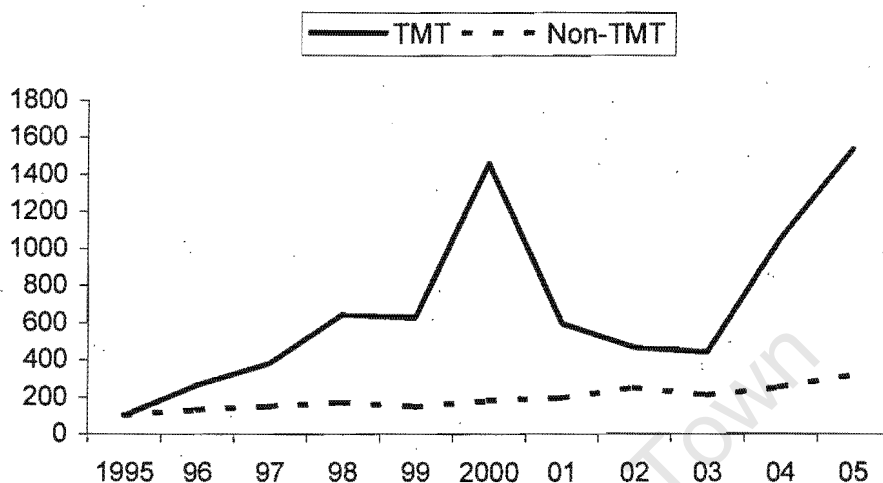
Table 8: Mean and standard deviation of the change in the logarithms of TMT and non-TMT price indices, 1990 to 2000.

	TMT	Non-TMT
Mean	23%	5%
Standard Deviation	17%	8%

Due to the remarkable performance of the TMT sector it is worth examining the developments in this sector in greater detail. The market capitalisation index starts at an actual value of R 622 million in 1994 but increases to R 76 757 million in 2000 (Figure 3). If certain striking features of the TMT sector are considered then such an increase can be deemed plausible.

Figure 3: TMT market capitalisation, Q4 1994 – Q1 2005.
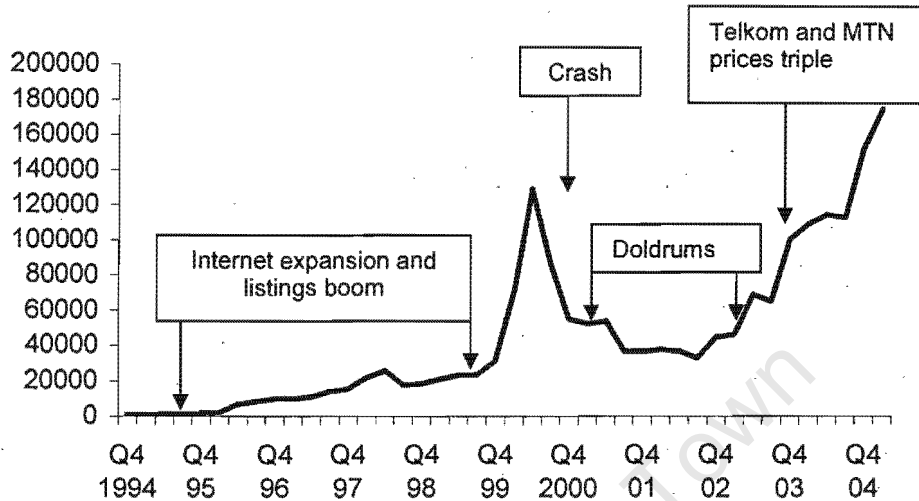
Source: Datastream

During the early 1990's the spreading reach of the Internet shaped the path followed by the index. At the time the Internet firm Dimension Data was virtually the only stock captured by the market capitalisation index, constituting 96% of the index in 1994. The company was also the darling of the market. This is evidenced by the fact that in Q1 1990 the stock price was ZAR 0.19 and by Q1 2000 it had increased to ZAR 61.50 (adjusted for stock splits), this translates to an increase of 323 times.

The major listings boom of 1990's further shaped the direction taken by the continually increasing index. The high stock prices of the period made raising funds through fresh stock issues an appealing and popular method for financing new investments. In the OECD countries the majority of such new listings originated in TMT sector. Figure 4 represents the amount of share capital raised on the JSE.

Figure 4: Total value of capital raised on the JSE, 1992 – 2003.
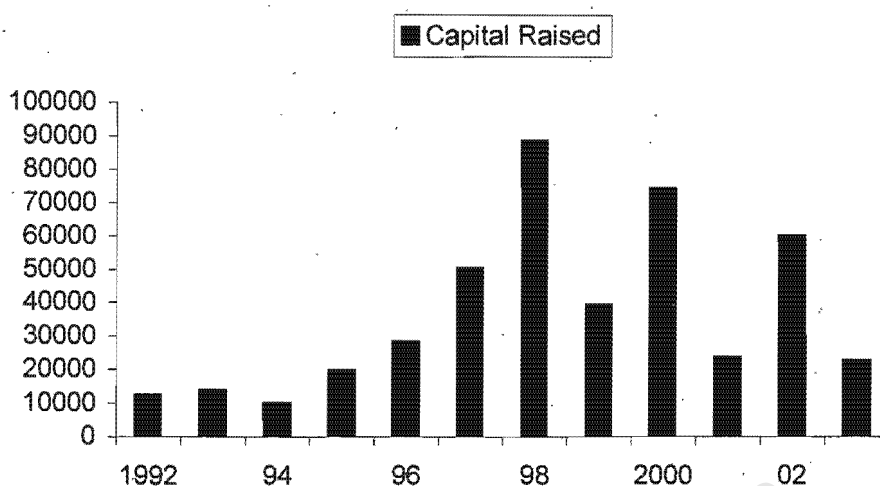
The amount of capital raised by firms on the stock market rose steadily from 1994 reaching a peak in 1998 with an actual number of 101 new listings. Within the TMT sector the same pattern is identified where the largest number of listings, approximately 22, occurred in 1998.

With the spreading contagion effects of the Asian crisis at the end of 1998, the listings frenzy in the entire market started to abate. Thereafter the technology crash in 2000 marked the beginning of a sharp decline in new listings, in fact, there were many de-listings. The highest number of which was recorded for 2001 with 85 de-listings taking place.

The introduction of mobile phones in 1994 and their continuous proliferation coupled with the public listing of the fixed-line operator in 2003 has further shaped the TMT sector. These events significantly increased the value of the TMT market capitalisation index. The telecommunication service firms, namely, Telkom and MTN, currently dominate the index of which the two stocks on their own constitute 80%. Thus, movements in these particular stocks will cause the overall index to change. The remarkable rise in the index since 2003 is the direct result of both the Telkom and MTN stock prices increasing threefold. Telkom listed in March 2003 at ZAR 29 and is now worth ZAR 115. Similarly, MTN increased from ZAR 12.95 to ZAR 44 in the same period.

The conclusion that the total stock market performed exceptionally well over the time period considered should be made cautiously. The market has largely been led by factors affecting certain dominant sectors of the economy and it has been strongly influenced by currency movements. The South African stock market has historically been dominated and driven by the resources sector. Currently, just three of the largest resource firms (in terms of market value), Anglo American, BHP Billiton and Sasol comprise 40% of the total market capitalisation. The main asset base of a typical resource firm consists of minerals. The value of minerals has steadily increased in Rand terms and thus it could easily be concluded that the performance of the resource firms was impacted positively as a result. However, this is not a true reflection of the reality. Since resources are priced in international markets both the prices and the exchange rate will affect the revenues and profitability of these firms. Resource prices and the US dollar have been relatively stable throughout the 1990's. Thus the actual values of the assets have remained unchanged. However, the Rand value of the assets is increasing but only because the Rand has depreciated. For instance, the stock market valued in US dollars was 100 in 1990 and 100 in 2002 therefore the assets retained their original value (Figure 5). In Rand terms the market rose as the Rand continued to depreciate. A remarkable change takes place from 2002 onwards. The market value continues to rise even though the Rand is now strengthening. Such behaviour can still be attributed to currency movements but this time to a weakening US dollar. The reliance of the South African stock market on currency movements may impact the inferences drawn from the results of the regressions conducted in Section V. Contrary to the usual interpretations, an increasing market value does not imply similar increases in the wealth of investors for South Africa. As can be seen below, if the market is viewed in dollar terms then investor wealth did not change at all until 2002.

Figure 5: Market value in both Rand and Dollar terms against the ZAR/USD exchange rate (1990 = 100).
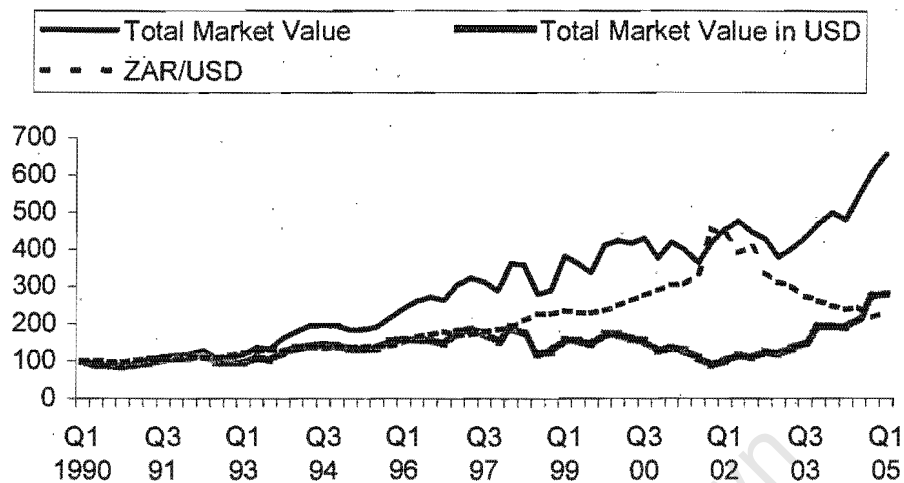
C. The Wealth Effect

This section provides a detailed account of the concept of wealth as it is one of the determinants of investment in the empirical model derived in Section IV. The focus is on how the wealth effect impacts both the individual and the firm. If an individual investors portfolio is mainly comprised of stocks with frequently changing values then these stocks will be a significant source of variation in wealth. For instance, higher stock prices boost wealth as the value of the asset held has appreciated. This in turn encourages individuals to increase both consumption and investment spending. This wealth effect aggregated across all individual investors will have implications for the economy as a whole, as increased spending will boost overall growth. Correspondingly, the wealth effect could have grave implications for an economy if stock prices swing the other way.

From the perspective of a listed firm, changes in the investment behaviour of individuals will affect the firm's earnings and consequently their market value. As a result the firms own investment and financing processes will be affected. All these considerations will once again exert an influence on the individual investors portfolio and hence augment their investment strategies. Therefore, changes in wealth have a feedback effect on investment (Barr and Kantor, 2002).

Another dimension of the wealth effect that is important to consider is the type of financial system, bank-based or market-based, that prevails in an economy. This will determine the extent to which stock market changes affect wealth and consequently the actions of firms and individual investors. Demirguc-Kunt and Levine (1999) use recent cross country data to examine the financial structure of various economies and construct a comprehensive classification system. Countries are classified as bank or market-based according to a score achieved for a composite index of financial structure. The index is based on various measures of size, efficiency and activity for both the banking sector and the stock market for each country.

With reference to the banking sector the measures used to determine size and the level of activity are liquidity, the asset base of banks and the amount of credit extended to the private sector. These measures are all taken relative to GDP. Mean values across countries are obtained for each ratio. In line with expectations countries like Japan and Switzerland have prominent banking sectors as these two countries achieve the highest ratios. Scores for South Africa are above the mean values for all the ratios suggesting a significant role played by the banking sector in the economy. In terms of the efficiency of the banking sector the measures considered are overhead costs, net interest earned and the portion of the total size of the banking sector that is taken up by the three largest banks. South Africa's banking sector achieves a score that is equivalent to the mean value for these efficiency ratios.

A similar approach is adopted for stock markets. The size and activity of the market is captured by the ratios of market capitalisation and the total value of stocks traded, both relative to GDP. Efficiency is measured via the ratio of the value of the stocks traded relative to the value of the market as a whole. Countries like the UK, the US and the Netherlands have well-developed markets as each country achieves high scores for these measures. South Africa has a relatively high ratio of market capitalisation to GDP but a relatively low ratio of total value of stocks traded to GDP. This suggests that the South African stock market is very large but illiquid.

It is difficult to use any one of the single measures mentioned to correctly classify a country therefore the composite index of financial structure is constructed. The measures which make up the index focus on the size, activity and efficiency of the banking sector relative to the stock market. The specific ratios used are bank assets relative to market capitalisation; credit extended by banks relative to the private

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sector to total value of stocks traded and the total value of stocks traded relative to overhead costs. Countries with index values higher than the sample mean are classified as market-based whereas countries with index values lower than the mean are classified as bank-based. South Africa achieves a score higher than the mean value for each ratio individually; hence it is classified as a financially developed country. It is further classified as market-based owing to its relatively large index value. This indicates that the level of stock market development has been higher than the banking sector development during the last decade. The selection of OECD countries used in Edison and Sløk (2003) are classified as follows: the UK, the US, Canada and the Netherlands are market-based whereas Japan, France and Germany are bank-based.

The two types of financial systems have very particular characteristics. Firms in market-based economies will typically use the stock market as a source of financing. Fresh stock issues are an advantageous way to raise funds quickly and easily, especially if the market is overvalued. Firms in bank-based economies will turn to the bank to supply their capital needs. Individuals in market-based economies tend to hold larger portions of their portfolios in stocks than if the economy were bank-based. Since information about firms is disseminated more widely and quickly into the public domain in market-based economies, individuals can react swiftly. In addition, the more developed a financial market is and the higher the number of available financial instruments the easier it is to access wealth. Consequently, the wealth effect arising from stock price movements is generally larger in the market-based economies.

Edison and Sløk (2002) have identified additional characteristics of the stock market which affect both wealth and investment. Firstly, the size of the stock market as a whole relative to GDP has changed in many countries. In general, the larger the stock market the more significant is the impact on investment resulting from movements in stock prices. In the OECD countries TMT market capitalisation is taking up a larger portion of the stock market as a consequence of both more TMT firms and the increasing values of these firms. The importance of the TMT sector is highlighted by the fact that during the 1990's TMT stock price growth far exceeded that of the old economy stocks. Despite this however, TMT stock prices tend to be more volatile and are thus a riskier investment alternative. The higher risk factor of uncertain gains and losses implies that investors are less inclined to undertake investments using wealth generated from TMT stocks. In contrast, non-TMT stock

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prices are relatively more stable thus it can be expected that non-TMT wealth will have a larger impact on investment.

In South Africa, as shown in Table 9, the size of the stock market relative to GDP has increased with ratios similar to those obtained for the OECD countries. Throughout the period total stock market capitalisation remains at relatively high levels, never falling below 68% of GDP.

Table 9: Market capitalisations as a share of GDP[3], of the total market and of the TMT and non-TMT sectors.

	Q4 1994	Q4 1997	Q1 2000	Q1 2001
Total	0.81	0.85	1.02	0.89
TMT	0.001	0.2	0.08	0.06
Non-TMT	0.80	0.83	0.94	0.89

Source: Market capitalisation is from Datastream and GDP is from the Reserve Bank Quarterly Bulletin.

The main difference between the stock market trends in South Africa and the OECD countries lies in the portion of the total market that is taken up by the TMT sector. In South Africa, unlike in other parts of the world, the TMT sector is relatively small, reaching only 15% of GDP at its highest market value in 2000. In the United Kingdom for instance the TMT sector on its own exceeded GDP.

The second aspect affecting wealth and investment relates to the increasingly widespread use of stock options. These form considerable portions of remuneration packages especially in the TMT sector. In this case wealth depends heavily on the movements of stock prices as stock returns are now a form of income. The uncertainty in income generated by stock prices is bound to alter investment behaviour.

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[3] Nominal GDP and market values are used. A 12-month rolling GDP is calculated in order to adjust the GDP figures which are simply snapshots of the economy at a particular moment in time whereas the market values are cumulative.

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IV. THE ESTIMATED MODEL AND METHODOLOGY

As has been previously mentioned, although the usual approach to modelling private investment is to use Tobin's q, its poor performance in the empirical realm leads Edison and Sløk (2003) to use the q measure merely as a theoretical tool to identify broad changes in the economy. During the 1990's rising market values of TMT firms and declining replacement costs of computers, equipment, software and the like, resulted in an increasing q. According to the formula for average q this suggests that investment increased. Since most firms are aiming to become more hi-tech much of this investment has been apportioned to the acquisition of technology goods. The increased demand for technology goods impacts positively on the profitability of the TMT firms which supply them thereby increasing the stock prices. Therefore, the q approach has enabled the authors to confirm their belief in the significant impacts of TMT stocks.

The actual empirical approach adopted tests the investment equation defined as:

$$\text{Investment} = F(\text{Wealth, Income, Usercost})[4]$$

This specification is a slight variation on the standard formulation of investment which defines the demand for new investments as being a function of income, expected income and user costs. Therefore, the equation above replaces expected income with wealth. Generally, a positive relationship exists between income, wealth and investment. As income and wealth rise, disposable income increases and so more can be devoted to investment. There is a negative relationship between investment and user costs. As user costs rise so does the opportunity cost of investment. In the presence of high user costs, many planned projects become unviable as the cost of borrowing increases. In fact there is more of an incentive to save.

The investment equation contains variables which are interrelated, for example wealth and income independently affect investment but at the same time income will affect wealth. Brainard and Tobin (1968) recognised that most macroeconomic systems are made up of many interrelated markets. Often the variables in these systems are jointly determined and thus a number of interdependent relationships will

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[4] Edison, H. and Sløk, T. (2003) The Impact from Changes in Stock Market Valuations on Investment: New Economy Versus Old Economy, *Applied Economics* **35** (9), 1015-1023, p.1018

arise. A situation like this would call for a simplification of these dependencies so that an empirically testable model is created. However, Brainard and Tobin (1968) discourage simplifications because it is in fact important to recognise the relationships individually. Various structural models can be used to estimate and capture the numerous relationships in large macroeconomic systems. Usually these models are heavily laden with restrictions and conditions which lead to estimates that are a clouded version of the true relationship between variables.

In light of this, Edison and Sløk (2003) appropriately use vector autoregressions (VARS) to estimate the investment equation. VARS were originally developed by Sims (1980) as a statistical framework within which the dynamic interactions between variables are systematically captured but where the estimation process is free from any significant restrictions. In essence, a multivariate linear VAR model regresses each non-lagged current variable on all the remaining variables lagged a specified number of times. Each regression in the VAR model contains the same explanatory variables. In addition, all the variables in the system are endogenous. The VAR methodology successfully captures co-movements and feedback effects between the variables which are detected with difficulty by other standard models.

In practice certain restrictions do have to be imposed on the model. These include specifying the number of variables and the lengths of the lags. Another requirement is that the data must be stationary since only variables with fixed underlying parameters can be modelled. The aim of using these restrictions is to ensure that the model remains manageable and can be feasibly estimated. Moreover, these types of restrictions are still consistent with the notion of an unrestricted VAR model in the sense that they are not based on any *a priori* knowledge (Charemza and Deadman, 1997). An example of where *a priori* knowledge is required is during the exercise of segregating the variables in a system based on whether they are exogenous or endogenous.

A. Investment in South Africa

The approach taken to estimate the investment equation for South Africa follows the methods employed by Edison and Sløk (2003). Specifically, a reduced form VAR is obtained. This involves representing each variable as a linear function of both its own past values and those of all the other variables in the model. Therefore, there are no current values of the variables on the right hand side of the regression

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equations. In addition, the error terms in the equations are assumed to be contemporaneously but not serially correlated. The error terms essentially take into account the past values of each variable and capture any unexpected movements thereafter.

A VAR model effectively has two dimensions, the number of variables included and the maximum lag length. In order to estimate the investment equation empirically the number of variables used is five and they are proxied by the following time series data:

Variable	Proxy
Investment	Real gross fixed capital formation by private business enterprises (I)
Wealth	TMT (TMT) and non-TMT (NTMT) stock market capitalisation
Income	Industrial production[5] (P)
User cost	Real short interest rate (R)

Note: Appendix B lists the source and a more detailed definition of each proxy.

Financial and economic magnitudes tend to rise over time partly as a result of inflation and so are non-stationary. In order to ensure that the system is rendered stationary each variable, excluding the interest rate, is logged. Logs linearise variables thereby removing the trend. In addition, the resulting log-linear model has the convenient feature that the coefficients are interpreted as elasticities.

With regard to the lag length the following selection test is used to determine the appropriate number of lags to be included:

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[5] The composite industrial production index contains data that is seasonally adjusted.

Table 10: Lag order selection

Sample: 1994Q4 2004Q4
Included observations: 37

Lag	LogL	LR	FPE	AIC	SC	HQ
0	16.77474	NA	3.64e-07	-0.636472	-0.418781	-0.559726
1	139.2052	205.1538	1.91e-09	-5.902986	-4.596837*	-5.442507
2	167.0644	39.15347	1.77e-09	-6.057538	-3.662930	-5.213326
3	209.8024	48.51332*	8.37e-10*	-7.016344	-3.533278	-5.788400
4	241.9588	27.81098	9.00e-10	-7.403179*	-2.831655	-5.791503*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

As is often the case with a lag order selection test the criteria yield conflicting results. Depending on what the objective of a VAR model is certain criteria are given priority. The FPE and AIC criteria are similar measures as they are both constructed to minimise the forecast error variance. The use of the lag length indicated by these criteria will ensure that the VAR model will produce accurate forecasts. The HQ and SC statistics are most appropriately used when the consistency of criteria dominates in importance. For each of the four criteria mentioned the appropriate lag length will be the one corresponding to the smallest value of each criterion. In the case of a small sample the AIC and FPE criteria tend to choose the correct lag length more often than the SC and HQ statistics (Lütkepohl, 1993).

The more commonly used statistic and the one most relevant in small sample cases is the likelihood ratio (LR). The LR statistic is based on values obtained for estimators that are subject to *a priori* restrictions and those that are unrestricted. The test is initialised at the longest lag length of four. Thereafter successively shorter lag lengths are chosen until the null hypothesis can be rejected. At this point the test stops and the corresponding lag is chosen. Therefore the relevant hypothesis tested is:

H_0: The coefficients on lag one are jointly zero

H_1: The coefficients on lag one are different from zero

From Table 10 it can be seen that at a lag of four the hypothesis cannot be rejected whereas at a lag of three it is rejected. This result is in accordance with the lag length used in Edison and Sløk (2003). A lag of three translates to nine months and this is a plausible time frame during which investment strategies, market capitalisation, industrial production and the interest rate can all change. For some of the variables a change will be instantaneous. If for example, the interest rate changes then market participants react immediately by buying or selling stocks accordingly. However, a variable such as industrial production is only expected to change after some time has passed as there are bound to be equipment and labour constraints.

Edison and Sløk (2003) estimate the VAR equations using quarterly data for the decade of 1990 – 2000. In the case of South Africa, data for the TMT sector is available only as of Q4 1994. As a result the estimation period is shifted forward to the ten-year period spanning Q4 1994 – Q4 2004. Thus, the number of data points available for analysis is merely 200, however, new economy firms have only been established relatively recently.

The VAR is estimated using a constant and three lags. The variables in each equation are ordered as follows: (1) the log of real gross private capital formation, (2) the log of real TMT stock market capitalisation; (3) the log of real non-TMT stock market capitalisation; (4) the log of industrial production and (5) the real interest rate. Appendix C contains the full mathematical derivation of the summarised representation listed below:

A. $I_t = a_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{1t}$

B. $TMT_t = b_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{2t}$

C. $NTMT_t = c_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{3t}$

D. $P_t = d_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{4t}$

E. $R_t = f_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{5t}$

Each equation contains an error term that is often referred to as an innovation. These capture the movements in the dependant variable which are not predicted by the lagged values of the variable (Sims, 1980). Since by definition, the lagged variables are not correlated with the error term then the equations can be consistently estimated using the multivariate form of the ordinary least squares procedure. Moreover the error terms of the VAR model shown above are not in fact serially correlated. The standard Lagrange multiplier (LM) test of autocorrelation in the residuals of the VAR is used to test for serial correlation with the following hypothesis:

H_0: There is no serial correlation at a lag order of three
H_1: Serial correlation is present

From Table 11 below it can be seen that the null hypothesis cannot be rejected at any of the lag lengths.

Table 11: Serial correlation test of the VAR residuals

Sample: 1994Q4 2004Q4
Included observations: 38

Lags	LM-Stat	Prob
1	32.08541	0.1556
2	22.78350	0.5902
3	24.60516	0.4847

Note: Probabilities are from chi-square with 25 degrees of freedom.

The VAR methodology is particularly appealing for its advantages. The first advantage relates to the use of lagged variables. The effect that one variable has on another is rarely instantaneous thus lags are useful to use. In addition they tend to capture natural economic momentum. Moreover, it is often the lagged and not the contemporaneous variables which are the strong predictors (Barro (1990), Dow and Gorton (1997), and Morck *et al.* (1990)). Secondly, the VAR methodology does not impose any *a priori* divisions between endogenous and exogenous variables. This renders the methodology simple to apply as all the variables used in the model are treated as endogenous. Thirdly, there are no zero restrictions. Such restrictions make the parameters of certain variables equal to zero with the aim of *a priori* excluding these variables. The VAR technique allows the data to determine which variables should be included and which excluded. Lastly, there is no requirement to supply an economic theory, regarding the expected relationships between the variables, to support the model to be estimated.

The VAR approach is not without its disadvantages. The requirement of stationarity entails undertaking data transformations at the outset. For instance, differencing is commonly used to render variables stationary. However, most transformations tend to eliminate the underlying relationship that might exist between the variables. Such an outcome is undesirable when the detection of these relationships is the prime objective of a study. Furthermore, VARS results are sensitive to the inclusion of other variables, to the choice of lag lengths and to the ordering of the VAR equations. Lastly, this method has been critised for being atheoretical because the model is backed by a theory where "everything causes everything else"[6]. Critics therefore

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[6] Charemza, W. and Deadman, D. (1997) New Directions in Econometric Practice, p. 157

claim that the results obtained have little economic content in them. For instance, Enders (1995) noted that the VAR is likely to be overparametrised because many of the estimated coefficients will be insignificant. However, he concurred that the goal of VAR analyses is not to attain precise parameter estimates but to determine the nature of the relationships that emerge from the estimation procedure. To identify these relationships it is necessary that as much information as possible be included in the model. To this end the VAR method serves its purpose. Moreover, Charemza and Deadman (1997) find that the results obtained from VAR models are actually consistent in cases where a very particular theory is tested.

V. THE RESULTS

The complicated dynamics and feedback effects between the equations in a VAR system lead to difficulties in examining and interpreting the individual coefficients, especially if their signs alternate. However, since the coefficients themselves are not the focus but the general relationships are, then impulse response functions prove to be a more useful descriptive device. These functions trace the response of a variable over time to a hypothetical, completely random, unexpected and positive exogenous shock experienced by another variable in the system. In other words, the function depicts the likely response of current and future values of a particular variable to a unitary change in the error term of another variable that experiences the shock. Since the variables in this model are in log form the relevant unit measurement is the percentage.

To illustrate the exact functioning of an impulse response function equation B of the VAR equations listed in Section IV is considered. A shock will have both direct and indirect influences. A change in the error term ε_{2t} by one percent will cause an immediate change in TMT_t. This effect is direct because all the lagged variables in the equation are predetermined and therefore are not subject to change. Although the effect is immediate on TMT_t, I_t in equation A responds only after one lag. The change in ε_{2t} will affect the future values of all the variables over subsequent quarters because of the presence of lagged TMT_t in each of the equations. The shock further influences I_t through its impacts on $NTMT_t$, P_t and R_t due to the contemporaneous correlations that exist between ε_{2t} and ε_{3t}, ε_{4t} and ε_{5t}. The contemporaneous correlations render it impossible to assess the isolated impact of the shock to TMT_t on I_t. A remedy for this is to transform all the errors terms via orthogonal innovations. This process involves breaking down the errors into uncorrelated components. It is now possible to trace out the dynamic response of a specific variable to a shock in one of the error terms.

Estimated coefficients are used to plot the response functions. By definition these are just estimates and not precise parameters meaning the response functions will contain some error. Confidence intervals are thus constructed around the response functions to take this uncertainty into account. The dotted lines in the graphs below indicate an approximately two standard error band that shows that over the two-year period the true response is confirmed within a 95% confidence interval. The width of

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the standard error bands corresponds the actual size of the standard errors of the coefficients. The larger the standard errors are the wider the confidence interval becomes. For example, in Figure 6 the error bands widen rather quickly as time passes, therefore indicating that the uncertainty of estimating the true value of the coefficient increases.

The impulse responses of I_t to innovations in the TMT_t and the $NTMT_t$ market capitalisations are the only responses considered since these variables are the focus of this study. All the graphs are generated using the default Cholesky one standard deviation innovations as this representation uses orthogonalised error terms. Figure 6 illustrates the effects of shocks to ε_{2t} and ε_{3t} on the variables TMT_t and $NTMT_t$ respectively. Figure 7, on the other hand, captures the cumulated behaviour of the sequence I_{t+i} in response to a one percent change in ε_{2t} and ε_{3t} in the TMT_t and $NTMT_t$ equations respectively. The estimated response parameters are used to trace out the impulse response functions with the following trajectories:

Figure 6: Impulse response functions for TMT and non-TMT market capitalisations

Response of TMTMV to a One Percent TMTMV Innovation
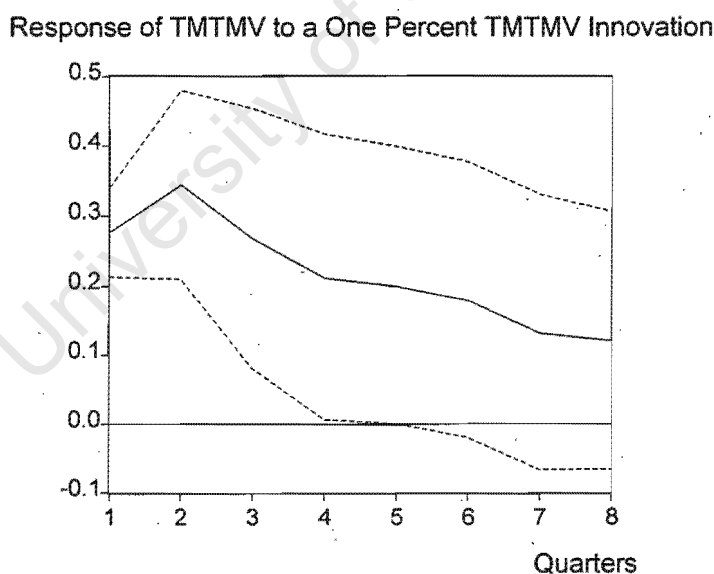
Quarters

This graph represents the immediate effect of a shock to TMT_t on TMT_t itself. A one percent shock to TMT_t will generate the largest response of 0.34% after two quarters. The effect declines to 0.12% after two years.

Response of NTMTMV to a One Percent
NTMTMV Innovation
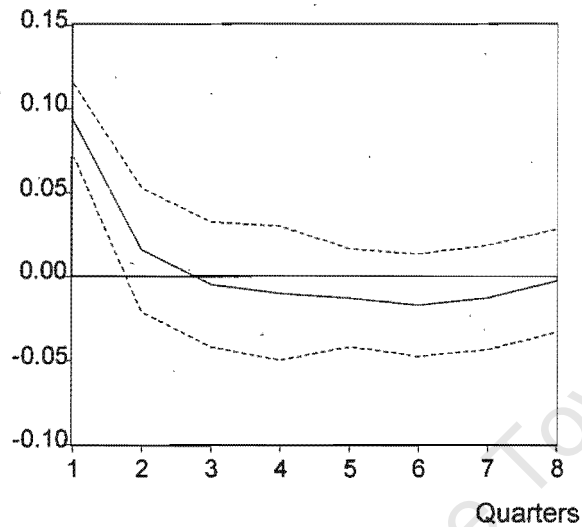
The maximum response of $NTMT_t$ is in the order of 0.09% and occurs in the first quarter following a one percent shock to $NTMT_t$ itself. This effect declines, becoming negative between quarters three and seven eventually diminishing to almost zero (-0.003%) after two years.

The above impulse response functions show that on the whole, a positive shock evokes a much larger response in TMT_t market capitalisation than it does in $NTMT_t$ market capitalisation for every quarter.

Investment does not respond instantaneously to changes in TMT and non-TMT market values, as is shown in Figure 6. This is an expected result as a certain period of time will elapse before market participants are able to change their longer-term investment strategies in reaction to changes in the stock market variables. However, immediately after the first quarter the impacts are clearly discernible.

Figure 7: Impulse response functions for investment

Response of I to a One Percent TMTMV Innovation
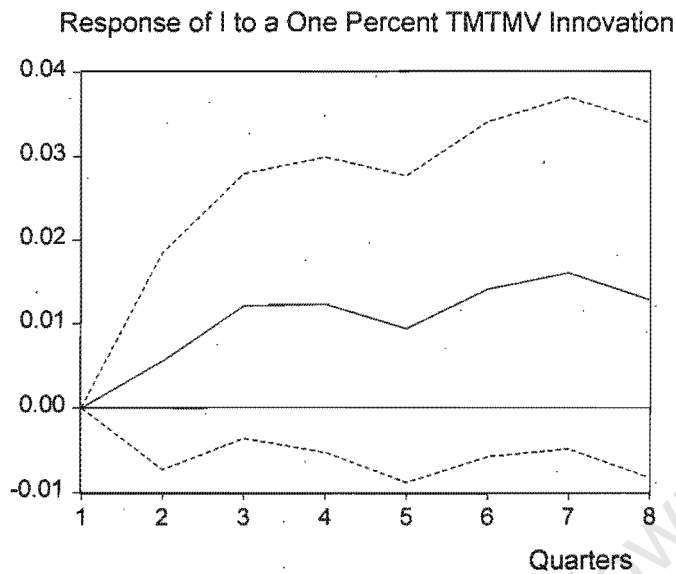
Investment responds positively to a shock in TMT_t, increasing steadily over time. The maximum response to a one percent shock in terms of magnitude occurs after seven quarters and is in the order of 0.016%. Specifically, the one percent shock in ε_{2t}, that causes a change in TMT_t of 0.12%, adds a maximum increase in investment of 0.016% after seven quarters. The effect is somewhat less pronounced after the full two-year period is considered as it amounts to only 0.013%. The South African case is not dissimilar to the time paths followed by investment in the United States, Canada and France. Although the time paths share the same pattern the magnitudes differ. The response evoked in South African investment is much lower. For example, in the United States the response of investment is in the order of 0.2% after two years. The United Kingdom, Germany, the Netherlands and Japan all experience negative responses in investment in certain quarters.

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Response of I to a One Percent NTMTMV Innovation
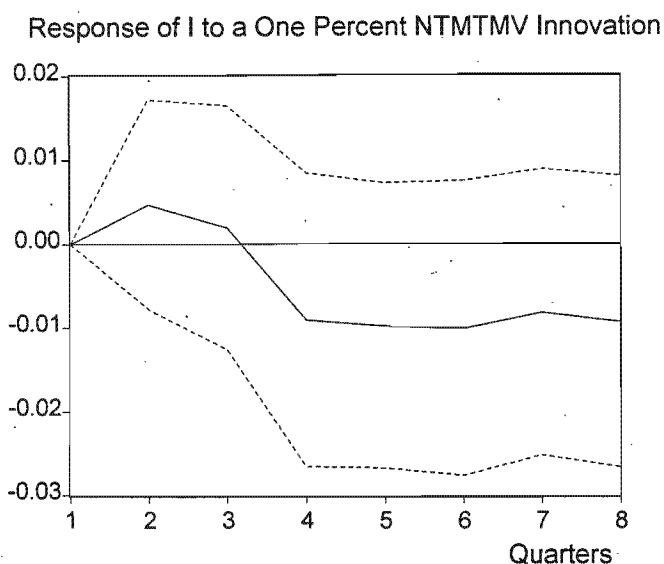
The effects of the non-TMT sector present a different picture. Although investment initially responds positively the effect is largely transitory as it becomes negative by the third quarter and remains so for the rest of the time period. A one percent increase in $NTMT_t$ evokes the largest positive response in investment in quarter two of 0.005%. The shock to $NTMT_t$ resulted in an overall decrease in the variable of 0.003% after two years. This in turn translates to a decrease in investment by -0.009% over the same period. Thus a positive shock to $NTMT_t$ causes a persistent decline in investment. In France investment responds similarly to a shock in $NTMT_t$ where the effect is negative from the first quarter. All the other countries experience positive responses. In the USA, Canada and the UK the response is stable whereas in Germany, Japan and the Netherlands it is more volatile.

The time paths of the investment responses eventually converge to zero. The exact time period at which this occurs is obtained by simply re-estimating the impulse response functions but with specifying a longer time horizon over which the response is to be estimated. The process is repeated in this manner until the coefficients of investment are equal to zero. For a TMT_t shock this occurs after a period of approximately six years whereas for an $NTMT_t$ shock this occurs after three and a half years for from the date of the initial shock. The convergence to zero coupled with the absence of explosive responses to the shocks reflects the stability of the estimated model. Stability in turn implies stationarity.

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The impulse response functions in Figure 7 are subsequently used to measure a ten percent impact on investment after a two-year period (Table 5). The elasticities of the response of investment differ substantially between the two sectors.

Table 12: Response of investment after two years to a ten percent shock in the TMT and non-TMT market capitalisations.

	TMT	non-TMT
	0.13%	-0.09%

Using the t-test confidence interval approach these coefficients are tested for significance where the hypothesis is stated as:

H_0: The coefficients are equal to zero after two years
H_1: The coefficients are different from zero

At both the 5% and 10% probability levels the null hypothesis cannot be rejected for neither the TMT nor the non-TMT market capitalisation changes. Therefore, the magnitude of the response of investment is not significantly different from zero.

The results obtained by Edison and Sløk (2003) for the OECD countries can be summarised as follows: on average investment in the European countries responds more to changes in TMT than non-TMT market values. The reverse is true for Canada, the USA, the UK and Japan where investment is more sensitive to changes in non-TMT market values. Therefore, there is evidence of the strong relationship between private investment and the TMT sector of the economy. Investment behaviour in South Africa is similar to the investment patterns observed in continental Europe. Changes in TMT market values cause a larger response in private investment in comparison to the response evoked by non-TMT market values. This is in spite of the fact that South Africa is market-based whereas the countries in continental Europe are largely bank-based.

VI. ROBUSTNESS OF THE MODEL

The model is briefly evaluated for how robust the variables are to definitional changes. The alternative specifications of the investment equation that are considered are: (a) replacing stock market capitalisation with actual stock prices; (b) changing the sample period and (c) using aggregate stock prices instead of the separate components of TMT and non-TMT stock prices.

Firstly, the VAR is re-estimated using TMT and non-TMT stock price indices as a measure of wealth. In this case, the response path outlined by investment is virtually the same as the response in the graphs of Figure 6 above. Table 13 below confirms that the difference in the results is negligible. As noted by Edison and Sløk (2003) this should be expected "as much of the variation in the capitalisation figures comes from changes in stock prices."[7]

Table 13: Coefficients of the one percent impulse response functions for the TMT and non-TMT market values and price indices.

Period	TMT Market Value	TMT Price Index	Difference	non-TMT Market Value	non-TMT Price Index	Difference
1	0.000	0.000	0.0%	0.000	0.000	0.0%
2	0.006	0.004	0.1%	0.005	0.010	-0.5%
3	0.012	0.010	0.3%	0.002	0.009	-0.7%
4	0.012	0.005	0.8%	-0.009	-0.002	-0.7%
5	0.009	0.006	0.4%	-0.01	-0.008	-0.1%
6	0.014	0.007	0.7%	-0.010	-0.011	-0.1%
7	0.016	0.013	0.3%	-0.008	-0.013	0.5%
8	0.013	0.012	0.1%	-0.009	-0.016	0.7%

The next robustness test is concerned with the sample period. Since new economy firms are a relatively recent phenomenon it is worthwhile to examine how the elasticities in the two sectors have changed during the last few years. The ten percent impacts after two years are reported below (Table 14).

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[7] Edison and Sløk (2003) The Impact from Changes in Stock Market Valuations on Investment: New Economy Versus Old Economy, *Applied Economics* **35** (9), p.1022

Table 14: The response of investment after two years to a ten percent change in the TMT and non-TMT market values.

Period	TMT	non-TMT
1994:4 – 2000:4	0.2%	0.2%
1994:4 – 2001:4	0.08%	0.02%
1994:4 – 2002:4	0.02%	0.04%
1994:4 – 2003:4	0.05%	-0.05%
1994:4 – 2004:4	0.13%	-0.09%

During the last four years the elasticities in both sectors have fallen, with the exception of the TMT sector where the elasticity regains its original value of 0.13%. Over this period stock prices in the TMT sector fell substantially hence it is expected that investment would decrease. In contrast, the non-TMT sector experienced stable and gradually increasing stock prices, however, investment fell regardless.

The last robustness test involves the use of total stock market prices as a measure of wealth. The ten percent impact on investment of a change in the total stock market prices after two years is –0.16%. Using this result it can be concluded that overall stock market changes have a negative impact on investment in South Africa.

VII. CONCLUSION

The broad aim of this paper has been to establish the extent to which private wealth is affected by changes in TMT and non-TMT stock price valuations. The primary goal, however, is to ascertain the impact these stock price revaluations have on private investment via the resultant changes in wealth.

Owing to certain peculiarities present in the South African stock market the results obtained in this study in all likelihood do not reflect the true impacts with precision. For example, the behaviour of the South African stock market is largely shaped by the actions of South African financial institutions, which hold the majority of shares listed on the JSE. Furthermore, the largest shareholding is concentrated in the hands of just a small number of the total institutions, where Old Mutual is considered to be the most prominent. Such a shareholding structure tends to introduce additional volatility in the market. For instance, if an Old Mutual fund manager were to readjust their portfolio by selling certain shares then this action causes significant ripple effects. Fund managers as a group tend to follow each others actions thus Old Mutual selling the stock of a particular firms serves as a signal to the remaining institutions who subsequently place sell orders on the same stock. In an attempt to avert such behaviour fund managers often trickle feed their transactions through a number of brokers so as not to alert the market to their intentions.

In comparison to major world stock markets like those in the US, the South African market is relatively illiquid and this prohibits market players from buying and selling with ease. The illiquidity coupled with the fact that most of the market is held in just a few hands means that there are bound to be misprisings. Hence the market cannot be as efficient as the US market which is highly liquid and where stocks are held equally by institutions as they are by private individuals. Another cautionary note is that South African data has certain oddities thus the results obtained are not as significant as those that would be obtained with the use of US data which is collected with greater accuracy.

Furthermore, evidence of a TMT equity price bubble in the South African market taints the period considered in this study. The implications of the bubble for investment were that more money was allocated to the investment in TMT stocks rather than to real investment. The bursting of the bubble left many market

participants with significantly reduced wealth and hence little or no proceeds from which to undertake real investment. The TMT stock price crash at the end of 2001 did cause a slump in private investment.

However, if the question looked at is simply whether stock market changes influence investment in South Africa then the answer is clearly yes. Major changes in the TMT and non-TMT sectors of the stock market have caused pronounced changes in investment, both positive and negative. Therefore the results do provide an overall indication of the investment – stock market relationship.

Specifically, the TMT sector market capitalisation responds more to a positive external shock than the non-TMT sector. The response of investment to a shock in TMT market capitalisation is of a typical market-based economy, whereas the response of investment to shocks in non-TMT market capitalisations is of a typical bank-based economy. This suggests that the South African stock market responds differently to changes in old and new economy stocks. Changes in TMT market values cause a larger response in private investment than the response evoked by non-TMT market values. Since private investment is more susceptible to TMT changes and since the TMT sector is far more volatile than the non-TMT sector this signifies that private investment will be volatile as well as the wealth arising from holding these stocks is volatile. In a country like the US the reaction of investment is more or less the same for both TMT and non-TMT market capitalisation shocks. Investment behaviour in South Africa displays similar patterns to those observed in continental Europe. This is in spite of South Africa being classified as a market-based economy whereas countries in continental Europe are classified as bank-based.

The results obtained are somewhat surprising. At the outset of this study it was expected that investment is more sensitive to old economy stock valuations since old economy firms dominate the market capitalisation on the JSE. Changes in South Africa's new economy stock valuations were expected to exert an influence on investment that would be similar to what has been observed for the OECD countries. This stemmed from the notion that TMT firms generally have a global reach and that the TMT sector functions similarly across countries.

The evidence presented by Edison and Sløck (2003) for the OECD countries allowed comparisons to be drawn between South Africa and various first world countries.

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There is scope for future studies to explore the investment - stock market link for other emerging markets. Since South Africa's market performance often follows the emerging market index it would be of interest to ascertain how South Africa performs in comparison to the other emerging markets.

APPENDIX A

Table 15. Change in real investment, income, and market capitalization, 1990 – 2000 (%).

	GDP	Investment	Total Market	TMT Market	Non-TMT Market
Canada	30.6	52.7	146.5	223.8	116.0
France	19.1	15.5	194.5	296.3	177.7
Germany	14.8	15.6	131.7	329.1	110.7
Japan	14.3	-10.7	-34.7	62.5	-56.3
Netherlands	33.4	36.1	175.7	269.9	165.7
United Kingdom	24.5	58.7	125.6	206.7	106.7
United States	38.9	97.9	159.7	233.7	131.2

Source: Edison and Sløk (2003)

Table 16. Mean and standard deviation of TMT and non-TMT stock prices, 1990m1 – 2000m10^2 (%).

	USA	Canada	UK	Japan	Germany	France	Netherlands
Mean							
TMT	2.0	2.6	1.7	1.0	2.5	2.5	1.9
Non-TMT	1.2	1.2	0.8	-0.2	1.4	1.4	1.6
Standard dev.							
TMT	5.6	7.0	5.9	6.9	7.8	7.3	7.3
Non-TMT	3.2	3.3	3.2	4.1	3.8	3.8	4.2

Source: Edison and Sløk (2003)

Table 17a. Total Market Capitalisation as a share of GDP.

	December 1994	December 1997	March 2000	March 2001
Canada	0.38	0.70	1.03	0.82
France	0.25	0.42	1.03	0.88
Germany	0.18	0.35	0.65	0.48
Japan	0.69	0.53	0.92	0.67
Netherlands	0.65	1.30	1.90	1.50
UK	0.86	1.40	1.89	1.62
USA	0.48	0.98	1.40	1.17

Source: Edison and Sløk (2002)

Table 17b. TMT Market Capitalisation as a Share of GDP.

	December 1994	December 1997	March 2000	March 2001
Canada	0.07	0.14	0.48	0.20
France	0.02	0.07	0.34	0.24
Germany	0.01	0.05	0.20	0.08
Japan	0.08	0.09	0.33	0.16
Netherlands	0.09	1.17	0.47	0.18
UK	0.11	1.16	0.68	0.35
USA	0.10	0.22	0.62	0.33

Source: Edison and Sløk (2002)

APPENDIX B

Consumer Price Index

Source: International Financial Statistics, IMF

Code: 19964...ZF

Dividend and Earnings Yields

Source: Inet Bridge

Code: Dividend yield   CI01

               Earnings Yield   J203

Exchange Rate (ZAR/USD)

Source: Datastream

Code: USSARCM

Gross Domestic Product

Nominal expenditure on gross domestic product is used.

Source: South African Reserve Bank Quarterly Bulletin

Code: RB6006

Industrial Production

This composite index is constructed using data for mining and manufacturing production.

Source: South African Reserve Bank Quarterly Bulletin

Codes: Mining   – RB6632

               Manufacturing   – RB6634

JSE Listings and De-listings

The TMT sector on the JSE is comprised of the following sectors:

- Computer Hardware
- Computer Services
- Electrical Equipment
- Electronic Equipment
- Fixed Line Telecommunication Services
- Media Agencies
- Publishing and Printing
- Television and Filmed Entertainment
- Subscription Entertainment Networks

- Software

- Wireless Telecommunication Services

The number of new listings and de-listings for the TMT sector were derived from McGregor's Who Owns Whom in South Africa, 2001 – 2004. The number of new listings and de-listings for the market as a whole was obtained directly from the Johannesburg Stock Exchange.

In addition the total value of share capital raised was obtained.

Source: South African Reserve Bank Quarterly Bulletin

Code: RB2043

Private Investment

Private investment = gross residential fixed capital formation + gross non-residential fixed capital formation.

For South Africa, data pertaining to residential investment is unavailable. As a result private investment is proxied by gross fixed capital formation by private business enterprises (non-residential). The model can still be reasonably estimated but suffers the shortcoming that a large and influential portion of the economy is ignored.

Source: South African Reserve Bank Quarterly Bulletin

Code: RB6109

Short Interest Rate

The relevant interest rate is the 3-month Treasury Bill Rate.

Source: International Financial Statistics, IMF

Code: 199060C..ZF

Stock Market Variables

The South African stock market is the Johannesburg Stock Exchange (JSE). The TMT time series are only available from Q4 1994.

Source: Datastream

Codes:

Non-TMT price index	– TOTXTSA(PI)
TMT price index	– TLMITSA(PI)
Non-TMT market capitalisation	– TOTXTSA(MV)
TMT market capitalisation	– TLMITSA(MV)

Total Stock Market capitalisation	– TOTMKSA(MV)
Total Stock Market price index	– TOTMKSA(PI)
Total Stock Market capitalisation in US$	–TOTMSA$(MV)
Anglo American (Mining and Natural Resources)	– 923904(MV) or (P)
BHP Billiton (Mining and Natural Resources)	– 895185(MV) or (P)
Dimension Data (Technology Services)	– 315419(MV) or (P)
MTN (Cellular Telecommunications)	– 871044(MV) or (P)
Sasol (Oil and Gas Exploration)	– 982545(MV) or (P)
Telkom (Fixed-Line Telecommunications)	– 26714J(MV) or (P)

Abbreviations: MV – Market Value

PI – Price Index and

P – Current Stock Prices (previous day's closing price)

OECD Countries

The specific OECD countries referred to in the text are Canada, France, Germany, Japan, Netherlands, United Kingdom and the United States. The complete list of member countries can be found at www.oecd.org.

APPENDIX C

The unrestricted vector autoregressive system is described with the following general formula:

$$Z_t = A_0 + \sum_{i=1}^{k} A_i Z_{t-i} + \varepsilon_t \ [8]$$

Z_t is a column vector containing the current values of all the variables in the model. A_0 is a column vector of the constant terms that appear in each equation. The summation is in reference to the number of lags. The matrix A_i contains the coefficients and does not have any zero elements. Z_{t-i} is a matrix of the variables lagged a specified number of times. ε_t is the column vector of random error terms.

Each equation in the VAR system can be written as:

A. $I_t = a_0 + a_1 I_{t-1} + a_2 I_{t-2} + a_3 I_{t-3} + b_1 TMT_{t-1} + b_2 TMT_{t-2} + b_3 TMT_{t-3} + c_1 NTMT_{t-1} + c_2 NTMT_{t-2} + c_3 NTMT_{t-3} + d_1 P_{t-1} + d_2 P_{t-2} + d_3 P_{t-3} + f_1 R_{t-1} + f_2 R_{t-2} + f_3 R_{t-3} + \varepsilon_{1t}$

B. $TMT_t = b_0 + a_1 I_{t-1} + a_2 I_{t-2} + a_3 I_{t-3} + b_1 TMT_{t-1} + b_2 TMT_{t-2} + b_3 TMT_{t-3} + c_1 NTMT_{t-1} + c_2 NTMT_{t-2} + c_3 NTMT_{t-3} + d_1 P_{t-1} + d_2 P_{t-2} + d_3 P_{t-3} + f_1 R_{t-1} + f_2 R_{t-2} + f_3 R_{t-3} + \varepsilon_{2t}$

C. $NTMT_t = c_0 + a_1 I_{t-1} + a_2 I_{t-2} + a_3 I_{t-3} + b_1 TMT_{t-1} + b_2 TMT_{t-2} + b_3 TMT_{t-3} + c_1 NTMT_{t-1} + c_2 NTMT_{t-2} + c_3 NTMT_{t-3} + d_1 P_{t-1} + d_2 P_{t-2} + d_3 P_{t-3} + f_1 R_{t-1} + f_2 R_{t-2} + f_3 R_{t-3} + \varepsilon_{3t}$

D. $P_t = d_0 + a_1 I_{t-1} + a_2 I_{t-2} + a_3 I_{t-3} + b_1 TMT_{t-1} + b_2 TMT_{t-2} + b_3 TMT_{t-3} + c_1 NTMT_{t-1} + c_2 NTMT_{t-2} + c_3 NTMT_{t-3} + d_1 P_{t-1} + d_2 P_{t-2} + d_3 P_{t-3} + f_1 R_{t-1} + f_2 R_{t-2} + f_3 R_{t-3} + \varepsilon_{4t}$

E. $R_t = f_0 + a_1 I_{t-1} + a_2 I_{t-2} + a_3 I_{t-3} + b_1 TMT_{t-1} + b_2 TMT_{t-2} + b_3 TMT_{t-3} + c_1 NTMT_{t-1} + c_2 NTMT_{t-2} + c_3 NTMT_{t-3} + d_1 P_{t-1} + d_2 P_{t-2} + d_3 P_{t-3} + f_1 R_{t-1} + f_2 R_{t-2} + f_3 R_{t-3} + \varepsilon_{5t}$

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[8] The methodology employed follows Charemza, W. and Deadman, D. (1997) New Directions in Econometric Practice, p.157

The equations can be described more succinctly in matrix notation:

$$
\begin{bmatrix} I_t \\ TMT_t \\ NTMT_t \\ P_t \\ R_t \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \\ c_0 \\ d_0 \\ f_0 \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ b_{11} & b_{12} & b_{13} \\ c_{11} & c_{12} & c_{13} \\ d_{11} & d_{12} & d_{13} \\ f_{11} & f_{12} & f_{13} \end{bmatrix} \begin{bmatrix} I_{t-i} \\ TMT_{t-i} \\ NTMT_{t-i} \\ P_{t-i} \\ R_{t-i} \end{bmatrix} + \begin{bmatrix} a_{21} & a_{22} & a_{23} \\ b_{21} & b_{22} & b_{23} \\ c_{21} & c_{22} & c_{23} \\ d_{21} & d_{22} & d_{23} \\ f_{21} & f_{22} & f_{23} \end{bmatrix} \begin{bmatrix} I_{t-i} \\ TMT_{t-i} \\ NTMT_{t-i} \\ P_{t-i} \\ R_{t-i} \end{bmatrix} +
$$

$$
\begin{bmatrix} a_{31} & a_{32} & a_{33} \\ b_{31} & b_{32} & b_{33} \\ c_{31} & c_{32} & c_{33} \\ d_{31} & d_{32} & d_{33} \\ f_{31} & f_{32} & f_{33} \end{bmatrix} \begin{bmatrix} I_{t-i} \\ TMT_{t-i} \\ NTMT_{t-i} \\ P_{t-i} \\ R_{t-i} \end{bmatrix} + \begin{bmatrix} a_{41} & a_{42} & a_{43} \\ b_{41} & b_{42} & b_{43} \\ c_{41} & c_{42} & c_{43} \\ d_{41} & d_{42} & d_{43} \\ f_{41} & f_{42} & f_{43} \end{bmatrix} \begin{bmatrix} I_{t-i} \\ TMT_{t-i} \\ NTMT_{t-i} \\ P_{t-i} \\ R_{t-i} \end{bmatrix} +
$$

$$
\begin{bmatrix} a_{51} & a_{52} & a_{53} \\ b_{51} & b_{52} & b_{53} \\ c_{51} & c_{52} & c_{53} \\ d_{51} & d_{52} & d_{53} \\ f_{51} & f_{52} & f_{53} \end{bmatrix} \begin{bmatrix} I_{t-i} \\ TMT_{t-i} \\ NTMT_{t-i} \\ P_{t-i} \\ R_{t-i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix}
$$

The matrix representation can be summarised with the following equations:

A. $I_t = a_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{1t}$

B. $TMT_t = b_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{2t}$

C. $NTMT_t = c_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{3t}$

D. $P_t = d_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{4t}$

E. $R_t = f_0 + \sum_{i=1}^{3} a_i I_{t-i} + \sum_{i=1}^{3} b_i TMT_{t-i} + \sum_{i=1}^{3} c_i NTMT_{t-i} + \sum_{i=1}^{3} d_i P_{t-i} + \sum_{i=1}^{3} f_i R_{t-i} + \varepsilon_{5t}$

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