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SCHREYER HONORS COLLEGE

DEPARTMENT OF FINANCE

EVOLVING MARKET EFFICIENCY AND ITS IMPLICATIONS

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Thesis Supervisor
Honors Adviser

* Signatures are on file in the Schreyer Honors College.
ABSTRACT

The efficient market hypothesis is a financial theory that investors should not be able to outperform markets consistently because all information about a security is already reflected in its price. In examining literature regarding market efficiency, I stumbled across a quote from Warren Buffet’s will. As one of the most successful investors of all time, I was curious to discover what investment plans he made. In his will he requested that the trustee “put 10% of the cash in short-term government bonds and 90% in a very low-cost S&P 500 index fund… I believe the … results from this policy will be superior to those attained by most investors.” There can be many reasons for doing this considering his tremendous net worth and current level of risk aversion. However, I decided to investigate this concept further to see if the returns produced by managed funds were changing. Using the returns produced by Berkshire Hathaway, I designed a proxy consisting of the CAGR differential between the fund and the S&P as a function of time. The first data point was the CAGR differential from the S&P starting at the fund’s inception in 1965 to present. (Appendix A) The following point is the same calculation from 1966 to present, and so on. According to this method, the fund seemed to be outperforming the S&P by less and less each year. The questions of this thesis are to determine whether or not this is a trend across managed funds, if it is continuing, and why. Though the results of this research are not definitive, there is strong support for evolving market efficiency from an analysis of behavioral finance and mutual fund returns.
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Chapter 1

Relevant Implications of an Efficient Market

Markets are efficient when all relevant information about a security is reflected in its price. The mechanism behind this is as follows. If a security is overvalued, it will not produce a return as high as that of another security. This causes demand for the security to fall, resulting in a lower price. Then, if a security is undervalued, investors will see the security will produce an abnormally high return and buy it, causing an increase in price. In theory this process will repeat itself with diminishing deviations until price oscillates closely around the objective value.

Graphical Explanation of Market Efficiency

The blue line represents the theoretical objective value of a security, and the black line represents the actual price. The returns are seen in the slope of the lines.

Figure 1. Market Efficiency Graph
Some of the biggest questions in the world of finance are regarding market efficiency. More appropriate than attempting to determine if markets are efficient would be analyzing how efficiency is changing over time. Critics of market efficiency point to the numerous factors influencing market trends and many realized inconsistencies and abnormalities going against the theory. Additionally, testing the validity of this theory is difficult, as some versions of it are not falsifiable.

Part of the issue with testing efficiency is in defining what to test. There are varying levels of efficiency, all with different implications. Further complicating matters is the idea that markets have not always been operating at a constant level of efficiency. This means that using historic data can only provide moderate evidence regarding the current efficiency of a market. This is why it may be a better approach to examine the direction in which the strength of the implications is trending.

Currently, there is no way to directly test the efficiency of a market. Instead, we must test its implications. While plenty of testing has been done on these implications to determine efficiency, the literature seems to be lacking in the way it defends the idea that the aforementioned implications really are indicative of an efficient market. The general force behind semi-strong market efficiency is the idea that all relevant public information is priced into a stock. All implications of market efficiency must extend from this idea. These have included ideas that: anticipated announcements should not affect stock prices, prices should follow a random walk, there should not be long-term excess return generation or opportunities for excess profit outside of chance or crime. However, not all of these assumptions truly extend from the concept of market efficiency.
Implications

The Risk Premium and The Random Walk

There is a concept in economics called the risk premium that voids the implication that anticipated announcements should not affect stock price. The risk premium suggests risk averse agents derive less utility from a lottery with any positive expected value than they would from the same expected value with absolute certainty. The aforementioned lottery will have a corresponding level of wealth that, when obtained with certainty, provides the same level of utility, and this utility-equivalent level of wealth with certainty will be less than the expected value of the lottery. The difference between the expected value of the lottery and a level of wealth with certainty, that provides the same utility as the lottery, is called the risk premium. The following graph illustrates this concept.

Figure 2. Utility Curve
The blue line represents the utility function \( \ln(x) \). A utility function for risk averse agents has a second derivative less than 0 to represent diminishing marginal utility. A simple way to think about this is that an additional $100 will bring a greater change in utility, or happiness, to a poor person than a rich person. The curvature in the graph creates the risk premium, as illustrated by the difference between the red vertical line and the black vertical line.

For risk averse agents, this implies that even if expectations about a given security are perfectly realized, the security will be worth more at the time expectations are realized than when they were only expectations. It then follows that the price of a security should still be rising if expectations regarding its performance remain constant. Supposing this is the case, anticipated announcements should do one of two things. The first possibility is that these announcements will still increase stock price, if only slightly. The second is that these announcements will not affect the rate at which the stock is increasing in value, which is still different from them not affecting the price at all.

The risk premium suggests a random walk model could be applied to returns. A random walk applied to returns, allows for fluctuations around a constant rate of change. Later, I will discuss other variations of this model and how well they might match the data.

**Excess Returns and Noise**

Long-term excess return generation is also possible in an efficient market. In a world where markets are efficient, it is still possible for investors to generate excess returns through chance. However, for the practical purpose of providing rejectable hypotheses, frequently repeated “chance” occurrence should be treated with more respect than just chance. Fischer
Black (1986) attributed the above to “noise,” and while he may be correct, an inability to test his theory unfortunately renders it less useful.
Chapter 2
Evolving Market Efficiency

In regards to the time aspect intrinsic to a long-term analysis, it becomes more difficult to determine the level or existence of market efficiency if it is in fact changing over time.

“The true underlying market structure of asset prices is still unknown. However, we do know that, for a period of time, it behaves according to the classical definition of an efficient market; then, for a period, it behaves in such a way that researchers are able to systematically find anomalies to the behavior expected of an efficient market.” (Self and Martur 2006)

The above quote reflects the belief that markets are oscillating about efficiency. Markets can still trend toward or away from efficiency as measured by the variation in the magnitude of each set of theoretical oscillations, with greater deviations from equilibrium, or true objective value, construed as less efficient. That said, the notion that it can change and that there is evidence to support it changing reflects the idea that it has the capacity for evolution, which would entail the deviations from equilibrium shrinking in magnitude.

The adaptive market hypothesis is a much more flexible interpretation of market behavior than a constant particular form of market efficiency. Lo (2004) suggests “the dynamics of evolution—competition, mutation, reproduction, and natural selection—determine the efficiency of markets and the waxing and waning of financial institutions, investment products, and ultimately, institutional and individual fortunes.” One could say that market efficiency is changing because the things that drive markets are changing. These relevant variables can be
broken down into three primary groups: macro variables, investor behavior, and an interaction term.

**Changing Macro Variables**

“At the macro level, it is not unreasonable to expect market efficiency to evolve over time due to changes in macro institutions, market regulations and information technologies.” (Lim & Brooks 2011) Thus it is important to consider the changes in these variables as well.

Changes in macro institutions and market regulation are two variables that are difficult to operationalize and do not necessarily follow a pattern that would strictly increase market efficiency, at least not as directly as technology. The complicated nature of the collective of variables influencing market efficiency do not suggest that markets will definitively increase in efficiency from one period to the next. Politics specifically play an incredible role in defining market behavior. “We see risks and potential opportunity in volatility stemming from political and policy uncertainty.” (Political Risk and Returns 2017)

Our technological capabilities however are consistently increasing. Since technology plays a role in our learning and decision-making processes, it can be inferred this is a driver of market efficiency. This happens through two primary ways. First, investors are getting better and more information about everything around them at a faster rate. Second, facilitating the ability to trade increases its frequency, resulting in more liquid markets. The increase in liquidity allows investors to run more “tests” on the market with what could be interpreted as less commitment or perceived risk. Consequently, the advances in technology alone should have the
effect of increasing market efficiency, because technology disperses information and enables people to make faster and more advanced calculations.

**Changing Behavior**

Much of the work done in the realm of the adaptive market hypothesis has been theoretical. These theories have been derived in part from behavioral economics, psychology, and biology. The human tendency to be learning and reacting certainly supports the concept that markets should be evolving, given they are a product of human behavior. Furthermore, Lo (2004) argues that some seemingly irrational behaviors within markets are simply part of this learning process. “Behavioral finance—that is, finance from a broader social science perspective including psychology and sociology—is now one of the most vital research programs, and it stands in sharp contradiction to much of efficient markets theory.” (Schiller 2003)

However, it is also possible that a better understanding of behavioral finance is driving markets toward efficiency. In other words, if excess returns can be obtained from a superior understanding of behavioral finance, the investors obtaining those returns will cause the opportunity to disappear. Effectively, they would be tempering the blows of overreactions.

**Implicit Learning**

“Modern economies can be characterised as ‘learning economies’ in which knowledge is the crucial resource and learning is the most important process.” (Lundvall & Johnson 2006)

One of the primary ways we learn is through the trial and error process. It is an effective, and occasionally superior, means of learning about new, unfamiliar environments. As the amount of
uncertainty in a system increases, rationality becomes much more complicated. The theory of rational inattention implies what could potentially be an evolutionary mechanism that allows us to explore uncertain territory until it becomes familiar. However, this means of acquiring knowledge does not produce perfectly linear results as a function of time, and while it may have a positive trend, this alone does not necessarily support a continuous drift toward greater efficiency in markets. It could however support the concept of noise.

It is plausible that market noise is simply investors learning about the market, running test after test regardless of their perceived intentions for doing so. Whether or not investors are fully cognizant of this process is another issue. The mechanism that causes the trial and error process could in fact operate through a falsity of confidence, in which case the investors would not even consider the idea that they are trying to learn or are performing a test on their environment. From an article by Arthur Reber in The Journal of Experimental Psychology,

“implicit learning [is] the process by which knowledge about the rule-governed complexities of the stimulus environment is acquired independently of conscious attempts to do so… the conclusions reached are as follows: (a) Implicit learning produces a tacit knowledge base that is abstract and representative of the structure of the environment; (b) such knowledge is optimally acquired independently of conscious efforts to learn; and (c) it can be used implicitly to solve problems and make accurate decisions about novel stimulus circumstances.” (1989)

This implicit learning implies there is a possibility for market participants to make optimal investing decisions without necessarily understanding the reasons behind their actions. In
theory, even a relatively small number of market participants with this tacit knowledge could be capable of establishing increasing levels of efficiency. “Not everyone in a financial market must be well informed about a security or have rational expectations for its price to be driven to the point at which the efficient market condition holds.” (Mishkin & Eakins 2009)

Greater Awareness of Psychological Factors

Psychological factors play a great role in influencing human behavior and decision making. According to a study on traders from City of London investment banks, researchers were able to “conclude that emotions and their regulation play a central role in traders' decision making.” (Thinking, feeling and deciding: The influence of emotions on the decision making and performance of traders) A greater awareness of these factors and how they work should consequently afford investors greater control over them, which should produce less “noisy” valuations. Before looking at the details of such specific factors, two questions to consider are: how is our awareness changing over time and are people capable of self-correcting their biases if given sufficient information.

To address the first issue, one means of operationalizing a variable for societal awareness of the influence of psychological factors on cognition would be the number of degrees awarded in Psychology. It is presumed that the number of degrees awarded is positively related to the long-term quantity and quality of research produced and the prevalence of the material throughout the general public.
Considering the recent increase in the number of psychology degrees awarded, it can be assumed that our awareness of psychological factors as a society will be improving.

This leads to the follow-up question, are people capable of self-correcting their biases. To answer this question, I constructed an experiment to determine if participants could regulate a natural aversion to loss. (See Chapter 3) The small sample size and variation unfortunately made it difficult to conclude anything definitively, so more research should be done on this in the future.

Mental Illness and Irrational Behavior

According to data from the Substance Abuse and Mental Health Services Administration, or SAMHSA, in 2015, roughly 18% of Americans aged 18 and older had some sort of mental illness, defined as any mental, behavioral, or emotional disorder that met DSM-IV criteria.
is likely to be reflected in abnormal utility functions. Utility functions that reward excessive risk, for example, have the potential to lead an individual to ignore costs.

Roughly half of those with any mental illness had some type of substance use disorder.

“According to a 2001 paper by Harvard Medical School’s Hans Breiter and colleagues, "the activations seen in the NAc, SLEA, VT, and GOb in response to monetary prospects and outcomes overlap those observed in response to cocaine infusions in subjects addicted to cocaine." (Those abbreviations, if you were curious, mean nucleus accumbens, sublenticular extended amygdala, ventral tegmental and orbitofrontal cortex, respectively.) In other words, a fat line is to a coke addict what a fat win is to a trader (or gambler).” (Floyd 2017)

Given the prevalence of mental illness and the addictive elements associated with investing, it is possible this can be influencing entire markets. Furthermore, psychiatrists are continually improving their understanding of mental illness. “The Bulk of mental illness in any community never comes to their attention at all. The reason as Professor Goldberg and Dr. Huxley point out in this book is that psychiatrists base their concepts of mental illness on the highly selected sample of patients who are referred to them.” (Mental Illness in the Community) Like many elements of behavior and personality, mental illness also consists of a spectrum. It can be inferred that more than 18% of Americans could be negatively affected by psychological factors even if it does not necessarily qualify as mental illness as we see it today. Our awareness of and ability to treat these issues improves should eventually reduce the prevalence of mental illness. However, over the past few years, the prevalence has remained about the same. (National Survey on Drug Use and Health 2015)
Stress should also be considered in behavioral finance. The following model from Ganster and Rosen (2013) on the allostatic load framework for understanding stress outlines some of the negative effects of stress.

**Figure 4. Allostatic Load**
It has been proven that stress can have serious physical and psychological effects, and stress is particularly prevalent in the financial industry.

“Four industries accounted for the bulk of occupational stress cases: Services (35 percent), manufacturing (21 percent), retail trade (14 percent), and finance, insurance, and real estate (12 percent) … White-collar occupations had a higher proportion of stress cases than both blue-collar and service occupations combined.” (U.S. Bureau of Labor Statistics 2017)

Reducing stress could be a necessary step in moving markets toward efficiency. “Research examining the relationship between work stress and well-being has flourished over the past 20 years. At the same time, research on physiological stress processes has also advanced significantly.” (Ganster & Rosen 2013) It can be assumed that an increase in our understanding of stress will lead to a more adept way of dealing with allostatic load.

**Desire to Restore Balance**

Research on the way humans perceive fairness has revealed some interesting concepts that may be relevant to this discussion. In game theory styled experiments,

“subjects were willing to pay to punish those who acted selfishly, even though there was an individual cost to inflicting such punishments… Engaging in such punishment appears to make the subjects happy: it activates an area of the brain, the dorsal striatum, that “lights up” in anticipation of many different types of rewards.” (Animal Spirits 2010)

In some models of utility functions, shame and envy have been included, operationalized by differences between an individual’s payoff or wealth and that of others. The findings that individuals are willing, if not biologically programmed, to restore a sense of balance, even at a
cost to themselves, indicate people care very much about finding and sustaining long-term equilibria. This trait could make investors more willing to “place their bets” in a way that points to a security’s value rather than their perceptions of future sentiment. From an incredibly optimistic perspective, this desire to restore balance also has the potential to drive an institutional desire for transparency and fairness, which could contribute to market efficiency.

Desire for Novelty

“In information theory, the words ‘uncertainty’, ‘surprise’ and ‘information’ are identical. Before a message indicating the occurrence of an event originating from a given distribution of probable events, there is the amount of (statistical) uncertainty associated with the event. At the event’s occurrence there is the amount of surprise. Afterward, there is the gain in information.” (Middleton 1986)

This is a precise way of saying there is a payoff for exploring uncertainty and learning about an environment. As this applies to finance, investors will continue to explore new strategies to maximize profit, even if there is a cost to doing so, if this is outweighed by the payoff from accumulating new information. Behavioral finance is revealing an entire set of opportunities to obtain excess profit, and as people explore and exploit them, they will disappear.
Interactions

Rational Inattention

Rational inattention is the inability to make an optimal decision because of limited time and resources and imperfect information. In this context, resources also refer to intelligence and mental energy. This behavior can best be seen in decisions when an agent is faced with stress, exhaustion, or time constraints. (Sims 2003) It can be inferred that as we continue to outsource exhausting tasks to technology, we will be capable of making more rational decisions. This interaction effect should be considered when analyzing what is driving the theoretical rate of change of efficiency.

Recessionary Cycles

Considering our tendency to learn and our increasing accessibility to information, people might realize market overreactions at a progressively faster rate. They might even be less likely to overreact in the first place. In “Tony Robbins Says Don’t Fear a Stock Market Crash” he urges investors to do just that. Recessionary periods are followed by recovery periods, and if people are not panicking as much during these swings, their intensity should begin to decrease. Increasing anecdotal evidence regarding this should eventually moderate the magnitude of these steep deviations.
Chapter 3

Testing Self-Correction

The Status Quo Bias

To test this concept, I constructed an experiment modeled after the work of Kahneman, Knetsch, and Thaler on the endowment effect, loss aversion, and status quo bias. One of the findings from their research was that valuations of trivial objects like pens and mugs are dependent upon whether an individual is buying, selling, or choosing between an object and a sum of money. The results of their experiments showed that sellers valued their objects more than the other groups. The explanation for this difference is that losses have a stronger psychological impact than gains of the same magnitude.

![Figure 5. Psychological Effect of Gains Vs. Losses](image)
The figure illustrates this difference, as the slope in the loss domain is steeper than the slope in the gains domain. According to the graph, individuals in a selling position would need to be compensated more to part with their object than individuals in a buying position would want to pay, if the two had the same state-dependent valuations.

49 students at Penn State’s Smeal College of Business were asked to value a Penn State keychain. To determine whether individuals are capable of effectively self-correcting their biases, I divided subjects into two groups. The first was presented information about status quo bias and risk aversion to prior to giving valuations as a buyer or seller. The second group was not presented with any framing prior to giving valuations, although they were presented with the information after selecting their valuations and asked if they would like to pick a different value. Details of the experiment are noted in Appendix B. It was hypothesized there would be a greater discrepancy between valuations from the group that was not exposed to the framing. It was also hypothesized buyers without framing would increase their initial valuations while sellers without framing would decrease them. Evidence supporting ability to self-correct valuation bias would entail closer valuations of the objects among members exposed to the framing. Graphically, this would consist of the above figure curving into a perfect reflection across the x and y axes.
Results

Actual price: $7

Table 1. Experiment Results

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std Deviation</th>
<th>Variance</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No Framing) Buyer Valuations</td>
<td>2</td>
<td>6.51</td>
<td>3.97</td>
<td>1.53</td>
<td>2.35</td>
<td>9</td>
</tr>
<tr>
<td>(No Framing) Seller Valuations</td>
<td>2</td>
<td>7.45</td>
<td>4.7</td>
<td>1.49</td>
<td>2.23</td>
<td>10</td>
</tr>
<tr>
<td>Framing Buyer Valuations</td>
<td>2.06</td>
<td>6.99</td>
<td>4.3</td>
<td>1.56</td>
<td>2.43</td>
<td>12</td>
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<tr>
<td>Framing Seller Valuations</td>
<td>1</td>
<td>8.06</td>
<td>5.56</td>
<td>2.21</td>
<td>4.9</td>
<td>13</td>
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Table 2. Mean Differences

<table>
<thead>
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<th>Buying</th>
<th>Selling</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Framing</td>
<td>$3.97</td>
<td>$4.70</td>
<td>$0.73</td>
</tr>
<tr>
<td>Framing</td>
<td>$4.30</td>
<td>$5.56</td>
<td>$1.26</td>
</tr>
</tbody>
</table>
Buyer Willingness to Change

Figure 6. Buyer Change

Seller Willingness to Change

Figure 7. Seller Change
Analysis and Future Research

In accordance with the hypothesis, a higher percentage (33% > 30%) of buyers reported they would pay more upon reflection whereas a higher percentage of sellers reported they would accept less (20% > 10%). Contrary to expectations, the mean difference between valuations was greater between participants exposed to framing than between those who were not ($1.26 > $0.73). This could be for several reasons:

- Framing could have led to participants thinking they were supposed to move their valuation further from the middle if it was perceived to be the “normal” thing to do
- There was only a picture of the object, so assigning a value could have been challenging in itself
- Misunderstanding the questions and design of the experiment could have led participants to give obscure valuations

In the future, a larger sample size in conjunction with tangible rewards and consequences for the experiment might yield more decisive results. Also, it should be examined whether participants are more prone to change their valuations if the information about biases is instead presented as a social pressure.
Chapter 4

Testing if Returns Are Consistent with the EMH

At this point, the question becomes how to test for changes in market efficiency over time, so as to provide more substantial evidence for or against these theories. Two ways to assess these changes include exploring the changes in compounded annual growth rates, or CAGRs, for mutual fund returns over time and designing and testing an instrument that could model patterns of efficient markets.

Previous studies have found evidence supporting the idea that long-term excess returns should not occur outside of chance. “They tend to become marginal or disappear when exposed to different models for expected (normal) returns or when different statistical approaches are used to measure them. Thus, even viewed one-by-one, most long-term return anomalies can reasonably be attributed to chance.” (Fama 1998) However, there are investor portfolios that have outperformed the market substantially since their inception. Notably Berkshire Hathaway has averaged a return of nearly 10% in excess of the S&P 500 since 1965. Probability dictates that even if markets are efficient, it is still possible to earn an excess return from chance alone, and yet, the consistency of their performance suggests an ability to predict market behavior. However, the following table demonstrates an interesting complication.
The aforementioned table shows a calculation of the CAGR differential between Berkshire Hathaway and the S&P 500 from 2003 to 2013 (these are also defined as excess returns). When restricted to more recent data, the excess returns disappear. The fact that Berkshire Hathaway went from beating the market by nearly 10% annually to hardly beating it at all (.154% annual difference) supports the notion of markets trending towards efficiency.

This alone is not enough data to determine anything about entire markets with certainty, but it is interesting enough to prompt investigation. To determine the prevalence of this “trend,” I started with the same proxy for calculating changes in Berkshire Hathaway’s excess returns on mutual funds that have been around since the 1960s and 1970s. Retrieving data from Wharton Research Data Services, I was able to find monthly returns for 5 mutual funds.

I had three calculations I was interested in examining. The first I denoted as Shrinking CAGR. This was calculated as CAGR including data points from the year plotted to the most recent data available.
recent data. The earliest point was therefore the standard CAGR since inception, with each subsequent point calculated with 1 less return. Additionally, I calculated Growing CAGR. This was calculated as CAGR from inception to date. Each data point was the CAGR of that year since inception. The final calculation was an average of the two to see how every year’s return affected the overall CAGR. The CAGR from the full data set was also plotted as CAGR ALL.

It was hypothesized that the average of these CAGR calculations would have a negative slope.

Results

![American Century Investment Management Inc](image)

Figure 8. American Century
Figure 9. Fidelity

Figure 10. Neuberger Berman
Figure 11. Morgan Stanley

Figure 12. Lord Abbet
Table 4. Slopes of Averages

<table>
<thead>
<tr>
<th>Fund</th>
<th>Average Slope</th>
<th>Annualized</th>
<th>*100</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Century Investment Mgmt Inc</td>
<td>-0.0001341</td>
<td>-0.001610288</td>
<td>-0.1610</td>
</tr>
<tr>
<td>Fidelity Management &amp; Research Company</td>
<td>-0.0000738</td>
<td>-0.000886665</td>
<td>-0.0887</td>
</tr>
<tr>
<td>Neuberger Berman Management LLC</td>
<td>-0.0000412</td>
<td>-0.000495537</td>
<td>-0.0496</td>
</tr>
<tr>
<td>Morgan Stanley Investment Management Inc</td>
<td>-0.0000899</td>
<td>-0.001079722</td>
<td>-0.1079</td>
</tr>
<tr>
<td>Lord Abbett &amp; Co LLC</td>
<td>-0.0000423</td>
<td>-0.000508101</td>
<td>-0.0508</td>
</tr>
</tbody>
</table>

Slopes were calculated as change in average CAGR per month, multiplied by 12 for annualization, and then by 100 for ease of comparison. The graphs revealed consistent directionality and surprisingly similar slopes (Min -.161, Max -.049). These slopes might be indicative of a trend towards market efficiency.
Chapter 5

Models

Another means of testing evolving market efficiency involves constructing a model that would reflect these patterns. The random walk model is a good starting point. Some studies trying to test its application to finance have transformed it by adding a drift term.

\[ y_t = y_{t-1} + \epsilon_t \]

\[ y_t = y_{t-1} + \alpha + \epsilon_t \]

The first equation entails the normal random walk. As applied to finance, the first equation states that a return \( Y \), is a function of a return from the previous period plus an error term. The error term is defined to have a mean of 0 and take on realized values of 1 and -1 with a probability of .5 each. The standard deviation of a security’s returns is input here. The second equation adds a drift term, \( \alpha \).

If it is constant, the drift term can be redistributed inside the error term. For example, if the drift term was -.5, once redistributed in the error term, the values would be .5 and -1.5, each with probability .5. This term might be a fitting place for the slopes found from the CAGR analysis. An even more precise model might not see this term as a constant, but as a variable that decreases in magnitude to 0 as markets get closer to efficiency.

There does exist another way to transform the random walk model. Changing the realization values along with the probabilities assigned to each can produce different results. For
example, instead of the possible steps having equal probability, one can occur more often than the other. This model is called a biased random walk, and it has primarily been used to model chemotaxis, a process in which organisms with limited senses find food. A slightly more relevant application has been used to model social endeavors like network and community expansion. (Vinko, Gabrielli, and Caldarelli 2010) It has yet to be determined whether this may or may not effectively model market behavior.
Chapter 6

Now What?

This research is not arguing that markets are efficient. Rather, it supports the idea we are progressively approaching it. If this is the case, the financial community should be mindful of the effects of varying levels of efficiency.

Many have argued behavioral finance contradicts market efficiency. It is possible, however, that our understanding of behavioral finance and micro factors will drive out anomalies. If markets are becoming efficient, they are becoming less volatile. If they are safer, there will be a higher demand for them, which could lower their returns. If returns are decreasing over time, which was supported by the mutual fund data, this could have drastic implications for long-term investors. Specifically, this could be bad for everyday individuals who are investing for retirement and trying to plan accordingly. If the rate of return is assumed to be relatively stable over “the long run” but it is actually slowly declining, people could be overestimating the amount of money they will have at retirement. There should be a greater analysis of changing CAGR. This research only examined a handful of mutual funds. Applying a similar analysis to other companies and industries could reveal Knowing when and where this change happens could establish greater market insight and provide investors of all kinds with better expectations for the future.
Appendix A

Berkshire Hathaway Excess CAGR
Appendix B

Survey Flow & Questions
INTRO PAGE

Q26 Please read all descriptions and questions carefully. Some pages cannot be submitted until sufficient time has passed.

Q8 For the following questions, you will be asked to provide honest valuations of a product. You will select a value between $0.00 and $10.00. In this hypothetical, a computer will randomly generate the transaction value between 0.00 and 10.00. If the transaction value provides you with a payoff greater than or equal to 0 (based on the difference between your valuation and the transaction value), the transaction will go through. If otherwise, there will not be a transaction. This design is implemented to give participants the incentive to provide honest valuations.

Block A

Q9 At what amount would you value the following item if you are BUYING?
Q7 Use the slider to select a value.

_____ $ (1)

Q16 Prior research has found that Buyers and Sellers, on average, have different honest valuations of a product. Independent of trading strategies to maximize surplus, buyers tend to have lower honest valuations and sellers tend to have higher honest valuations of identical products. An explanation for this difference is that losses have a stronger psychological impact than gains of the same magnitude. Considering this information, would you change your valuation?

☐ Yes, I would value the product I'm Buying at a higher price. (1)
☐ No (2)
☐ Yes, I would value the product I am BUYING at a lower price. (3)
Q10 At what amount would you value the following item if it was given to you and you are SELLING?

Q18

Q6 Use the slider to select a value.

______ $ (1)
Q15 Prior research has found that Buyers and Sellers, on average, have different honest valuations of a product. Independent of trading strategies to maximize surplus, buyers tend to have lower honest valuations and sellers tend to have higher honest valuations of identical products. An explanation for this difference is that losses have a stronger psychological impact than gains of the same magnitude. Considering this information, would you change your valuation?

- Yes, I would value the product I am SELLING at a higher price (1)
- No (2)
- Yes, I would value the product I am SELLING at a lower price (3)

Block C

Q11 Prior research has found that Buyers and Sellers, on average, have different honest valuations of a product. Independent of trading strategies to maximize surplus, buyers tend to have lower honest valuations and sellers tend to have higher honest valuations of identical products. An explanation for this difference is that losses have a stronger psychological impact than gains of the same magnitude.

Q13 Considering the aforementioned value discrepancy, at what amount would you value the following item if it was given to you and you are SELLING?
Q12 Prior research has found that Buyers and Sellers, on average, have different honest valuations of a product. Independent of trading strategies to maximize surplus, buyers tend to have lower honest valuations and sellers tend to have higher honest valuations of identical products. An explanation for this difference is that losses have a stronger psychological impact than gains of the same magnitude.
Q14 Considering the aforementioned value discrepancy, at what amount would you value the following item if you are BUYING?

Q20

Q4 Use the slider to select a value.

_____ $ (1)
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EDUCATION

The Pennsylvania State University
Smeal College of Business | Bachelor of Science in Finance
College of the Liberal Arts | Bachelor of Science in Economics, Minor in Psychology
Eberly College of Science | Minor in Mathematics

Graduation May 2017

PROFESSIONAL EXPERIENCE

Puleo & Gimple Attorneys at Law
Legal Assistant
- Analyzed over 100 legal documents, including court orders and summaries of court hearings, some of which totaled over 100 pages, in a malpractice suit against Dewey and Leboeuf to find elements of fraudulent activities
- Eliminated $500,000 worth of risk by opting to postpone the lawsuit against the firm until after the funds in their possession were distributed, saving 1,400 victims roughly $360 each
- Discovered fraud in billing by utilizing simple math and noted suspicious trends through extensive research

Wienken and Associates Financial Advising Firm
Correspondence Intern
- Utilized Morningstar Analytics, Fieldnet, and Streetscape to produce reports for the clients of David Becker and William Martin reflecting current and hypothetical allocations and operated Papervision to scan and index client files
- Accompanied advisors on client meetings and information sessions on mutual funds hosted by companies including Franklin Templeton, BlackRock, and American Funds to better understand the accounts in client portfolios
- Instructed new staff members on how to utilize programs, leading to more frequent correspondence

Consultant Training Program
Graduate, Winning team in program’s case competition
- Selected from over 150 students to participate in a comprehensive training program that prepares graduates for careers in the financial services industry
- Strengthened core consulting skills through hands-on case study analysis with industry professionals
- Collaborated with a team of four to consult mock clients and construct revenue models and sensitivity analyses

LEADERSHIP EXPERIENCE

Alpha Kappa Psi Co-Ed Professional Business Fraternity
Inductee class competition participant, Fundraising Committee of Pledge Class
- Participated in case competition with pledges to better develop their analytic and problem solving skills
- Endeavored with a pledge class of 18 to host professional and philanthropic events for a brotherhood of 98 members and achieved fundraising goal of $2,500 through bake sales, clothing drives, and restaurant fundraisers
- Developed professional, networking, and interviewing skills through mock interviews, resume workshops, professional presentations and information within the brotherhood

Penn State IFC/Panhellenic Dance Marathon (THON)
OPPerations, Team Building Chair
- The mission of the Penn State IFC/Panhellenic Dance Marathon is to conquer pediatric cancer by providing emotional and financial support to the children, families, researchers, and staff of the Four Diamonds Fund
- Established unity among a committee of 37 students to facilitate the performance of duties required by our captain, in addition to working with each other to make sure our events ran smoothly during THON weekend
- Trained in advance to ensure optimal levels of cleanliness during THON weekend, prepared necessary materials by moving stages and cleaning mats, and completed the set up and tear down in the Bryce Jordan Center for the event

The Boy Scouts of America
Senior Patrol Leader
- Educated younger scouts on survival training, environmental awareness, and leadership as Senior Patrol Leader
- Worked at the Uschak Farm by planning a schedule to feed steers and maintain fields, and carried out those daily tasks
- Trained in advance to ensure optimal levels of cleanliness during THON weekend, prepared necessary materials by moving stages and cleaning mats, and completed the set up and tear down in the Bryce Jordan Center for the event
- Trained in advance to ensure optimal levels of cleanliness during THON weekend, prepared necessary materials by moving stages and cleaning mats, and completed the set up and tear down in the Bryce Jordan Center for the event

SKILLS, AWARDS, & INTERESTS

- Won first place out of 15,000 competitors at “The” (a national acting competition in Phoenix, AZ) and signed with Frederick Levy of Management 101 after being offered to work with over thirty agencies
- Performed in four short films and appeared on television, developing skills in communication, improvisation, and public speaking
- Worked at the Uschak Farm by planning a schedule to feed steers and maintain fields, and carried out those daily tasks
- Trained six hours a week for nine years to earn the rank of Cho Dan, first degree black belt, in Tang Soo Do
- Recited poetry and presented the Distinguished Artist of the Year Award at the Governor’s Awards for the Arts in Pennsylvania
- Worked knowledge in Microsoft Excel, Morningstar Analytics, Hysales, Stata
- Won the John A. Pidgeon Award at The Kiski School for best exemplifying the school’s values, 1st place at States for Poetry Out Loud
- Interests include: guitar, piano, singing, swimming, wrestling, skiing, dirtbiking, wakeboarding, backpacking