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Timber Investments

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Summary

In recent years, institutional and individual investors have increased their portfolio allocations to alternative investments, including timberland. The aim of this dissertation is to provide an overview of the timber asset class and to explore the effects that timber investments may have on well diversified portfolios using modern portfolio theory.

Timber investments possess some unique characteristics that differentiate them from investments in other asset classes, the most significant one being biological growth of trees. The value gain from biological growth is two-dimensional, as trees do not only grow in volume with age, but they also grow exponentially in value as their diameter increases.

Using historical return data for various different asset classes, a theoretical investment universe was created to assess the impact that timber investments have on the portfolio frontier. The study clearly reveals that timber investments offer significant diversification benefits. When timber is added to the set of available risky assets, the portfolio frontier shifts and changes shape, reflecting improved risk-return combinations. Whether the maximum allocation to timber investments is restricted or not, results indicate that the standard deviation of the portfolio, for various fixed return targets, falls significantly, in most cases by several percentage points. In sum, results suggest that there are substantial benefits to be achieved by including timber investments in a portfolio.

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1. Introduction

Alternative investments, such as hedge funds, private equity funds and artwork, to name only a few, have gained popularity over the last several years as both institutional and individual investors seek new ways to mitigate risk and improve returns on investment portfolios. The gradual increase in institutional investors' allocations to alternative investments is the result of over two decades of abundant liquidity and low interest rates in most major developed economic areas around the world. Under such economic circumstances, several investors find it hard to achieve their return targets and thus turn to alternative asset classes – that is, alternatives to publicly traded securities – in their search for yield. Globalization is also a force behind the surge in alternative investments as it has caused more traditional financial markets, such as stock markets and bond markets, around the world to become more interconnected. The same events and news now affect stocks and bonds globally and thus in order to mitigate risk and fully diversify their portfolios, investors now must look beyond the realm of stocks and bonds.

Although there is no formal definition of the term *alternative investment*, it is generally seen as encompassing investments in most or all asset classes that are not traded in traditional, liquid markets, such as the stock market or the bond market. The spectrum of alternative investments is therefore a very broad one, ranging all the way from investor shares in venture capital funds to rare postage stamps.

The whole universe of alternatives may be divided into two broad categories: financial instruments and real assets. Financial instruments include assets such as hedge funds, private equity funds and mortgage-backed securities, to name only a few examples. Real assets, on the other hand, include natural resources such as precious metal mines and oil

fields, as well as real estate and other physical assets, including timberland, on which the remainder of this dissertation will focus.

In this paper, the term *timber investments* refers to the direct ownership and management of timberlands. The definition thus assumes that investors purchase and hold timberland directly, either alone or in collaboration with other investors, and that the property is then actively managed, which includes the harvesting and sale of timber products. There are of course other (and perhaps easier) ways to gain exposure to timber assets, such as the purchase of stocks of paper companies, but these clearly expose the investor to a wide range of additional risks which are unrelated to timber assets.¹

Although investing in timberland is certainly not a new phenomenon, it was only in the mid-1980s that institutional investors in the United States, such as pension funds and university endowments, began exploring this asset class as a potential alternative investment. Before this time, most timberland in the U.S. was owned either by national and state forests or by forest-product companies.² The growth in timber investments by institutional investors was spurred in the mid-1980s when pulp and paper companies sought to divest their forest assets to reduce debt.

The creation of specialized asset managers, called Timberland Investment Management Organizations (TIMOs), also facilitated institutional investor participation in the timber asset class by collecting institutional and private money to purchase the forest assets that were being divested.³ Since the establishment of the first TIMO in the United States in 1981, institutional timberland investments have grown substantially. It is estimated that institutional investments in timber have grown from a mere one billion USD in 1990 to roughly 50 billion as of early 2008.⁴

¹ Throughout this dissertation the terms *timber investments* and *timberland investments* will be used interchangeably.

² Goar, Jinny St., "Into the Woods", *Bloomberg Wealth Manager*, 2001/2002.

³ Laplante, Julien. "Timberland Investments: Once a US territory, now a global one", *Bfinance*, 2006.

⁴ Merrill Lynch. "Timber Survey: What will institutional investors do next?", 2007.

Timber is a renewable resource with a relatively stable product demand and as an investment it possesses several desirable characteristics for asset allocation purposes. Timber assets possess a unique and attractive return structure and, from a portfolio theory perspective, there are substantial benefits to be achieved by investing in the timber asset class. In fact, historical timber returns are higher than for other traditional asset classes such as equities.⁵ The potential benefits of including the timber asset class in an institutional investment portfolio are further strengthened by the fact that timber investments exhibit a low or negative correlation with other traditional asset classes, such as stocks and bonds, but a relatively high correlation with inflation, which suggests that it can serve as a natural hedge against inflation.

The reasons for including timber assets in a portfolio can also reach beyond potential financial gains, as investors who are inclined toward socially responsible and environmentally friendly investing will find even more to like in timber. Trees, for example, replenish the earth's oxygen by taking greenhouse gases out of the atmosphere as they grow. Also, if properly managed, a forest is a sustainable natural resource. For some investors, these are important intangible benefits which do not show up on the books as additional revenue.

This dissertation focuses on timber investments and attempts to shed light on how such investments affect institutional investment portfolios. The following chapter provides a general introduction to timber investments and provides an analysis of the most important aspects of the timber asset class, such as its growth characteristics, return drivers and risk factors. The third chapter takes a look at timber investments' historical performance and discusses how returns from timber assets are measured and assessed. The fourth chapter explores timber investment performance relative to that of other asset classes and analyses the effects of including timber investments in an institutional investment portfolio using modern portfolio theory. This study is carried out by constructing a theoretical U.S. portfolio using real return data for various different asset

⁵ Over the past two decades, the NCREIF Timberland Index, which measures the return on timber assets, has delivered a higher cumulative return than both U.S. and global equities, as measured by the S&P500 index and the MSCI World index, respectively.

classes, including - but not limited to - domestic and international equities, government bonds and real estate. The aim is to determine how the portfolio frontier shifts and changes shape to reflect different risk-return combinations when timber investments are added to a portfolio. All data used to carry out the study are provided in appendices. Results are summarized in the final chapter followed by concluding remarks.

2. On Timber Investments

This chapter provides an introduction to timber investments. The growth characteristics of timber are explored in the first section, followed by an analysis of the major return drivers and the unique return structure of timber investments in sections two and three. The last section takes a look at some of the major risks associated with the timber investment class.

2.1 Growth Characteristics of Timber Investments

The value of timber and therefore the return earned from holding timber investments is, as for any other commodity, in part a function of supply and demand. However, timber assets are different from other commodities - and perhaps from all other investments – due to a combination of two different but related factors: (1) constant biological growth of trees and (2) a term called product class “step-ups”⁶, sometimes referred to as in-growth, which describes the fact that large trees are worth significantly more than small trees due to the fact that they can be transformed into higher value products.⁷

As trees grow, they add both volume and value. They add volume as there is quite simply more wood; and they add value because increasingly higher value products can be created from increasingly larger trees (class step-ups). Simply put, a tree that is twice the volume of another tree of the same kind can be several times more valuable as higher value products that can be made from it.

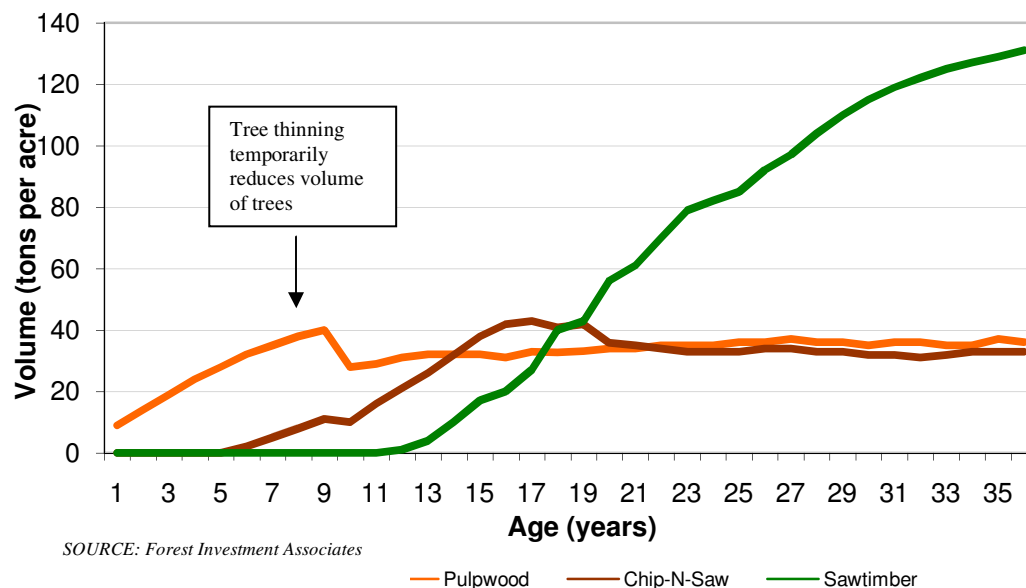
⁶ Corriero, Timothy, Thomas Healey and Rossem Rozenov. “Timber as an Institutional Investment”. *The Journal of Alternative Investments*, vol. 8 (winter 2005), pp. 60.

⁷ Fund Evaluation Group (FEG). “Investing in Timber”, 2004.

As a result of biological growth, timberland can easily increase in value even if timber prices and land prices remain constant because the volume of timber on the land will increase. This volume increase can also help timberland maintain its value in an environment where timber prices and land prices are falling. Consequently, it is clear that if timber is harvested at the same rate trees grow, timberland can – assuming other factors remain constant - generate constant income without loss in value to the asset. Biological growth can therefore be viewed as a sort of natural hedge against the economic factors that affect both timber and land prices, or as one timber investor puts it: “Trees don’t read the Wall Street Journal. They do not concern themselves with events like the war in Iraq, or statements from the Federal Reserve Chairman”.⁸

In figure 2.1, wood volume over time on a hypothetical Southern pine plantation (one acre) has been drawn.⁹ The volume has been split into three categories of timber in this market: pulpwood (5-8” in diameter), chip-n-saw (8-12” in diameter) and sawtimber (12”+ in diameter).

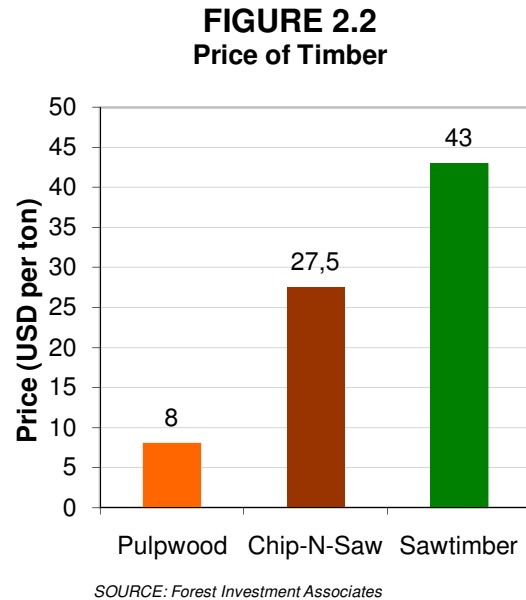
FIGURE 2.1
Wood Volume Over Time



⁸ Laplante, Julien. “Timberland Investments: Biological growth pays off”, *Bfinance*, 2006.

⁹ The figures used are based on real prices for Southern pine in the U.S South from *Forest Investment Associates*. <http://www.forestinvest.com/>.

Pulpwood is timber grown with the principal purpose of making wood pulp for paper production. Chip-n-saw trees are large enough to make small-dimension lumber and they can also be used to create various wood-based products. Sawtimber consists of larger (and older) trees, which can be used to create large, high-end wood products such as furniture. As the chart shows, tree volume drops suddenly in year 9. This is due to a process called tree thinning, whereby low quality trees are removed to create better growth conditions for the remaining trees.



Sawtimber is significantly more valuable than pulpwood and chip-n-saw, as higher value products can be made from it. Figure 2.2 displays recent average prices for each of the three categories for pine wood in the southern United States. These prices clearly reflect how significant the in-growth characteristic of timber really is: sawtimber, for this particular species, is roughly five times more valuable than pulpwood.

In figure 2.3, by combining the aggregate volume information in figure 2.1 and the average prices in figure 2.2, a chart illustrating total value growth of one acre over time has been created. This is done by multiplying the volume for each product by the average price and then aggregating the value for the three product classes.

FIGURE 2.3
Aggregate Value Over Time

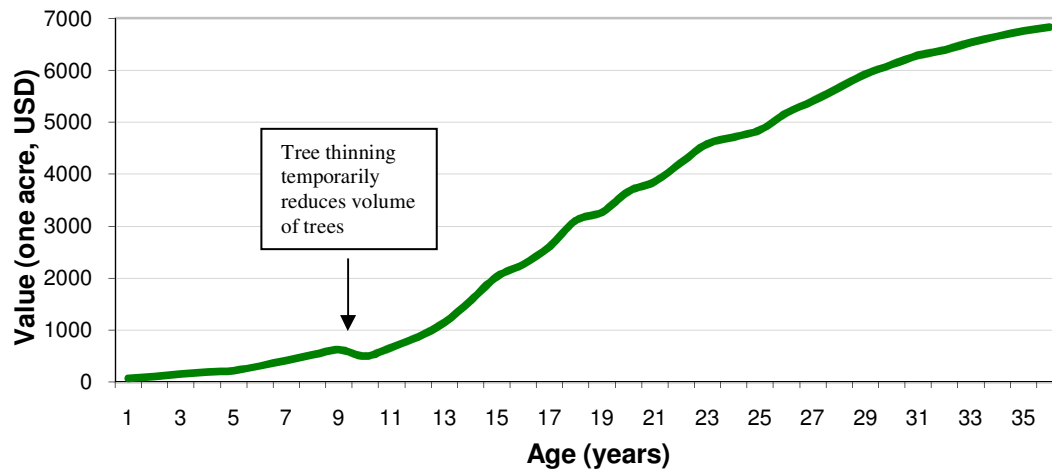
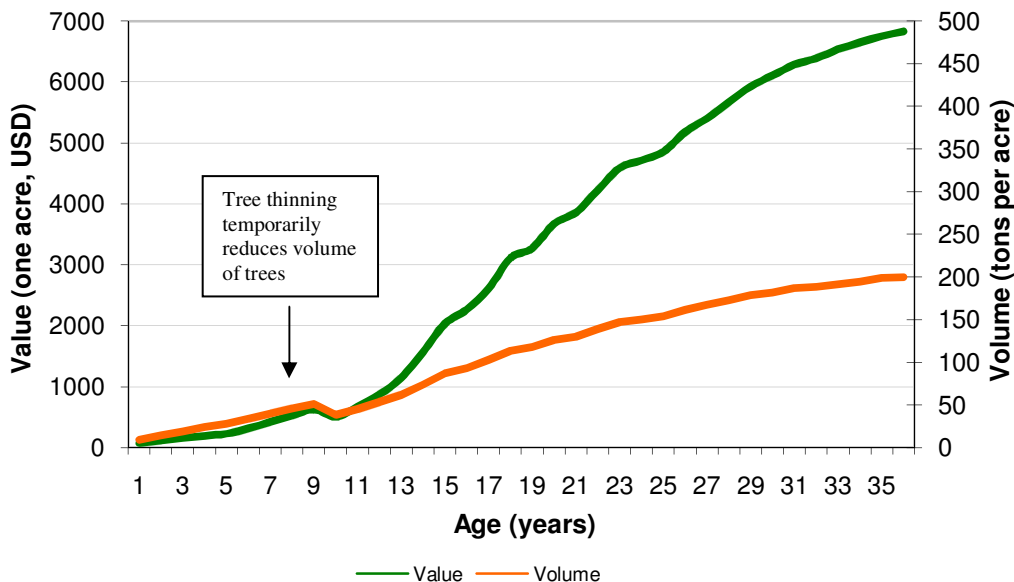


Figure 2.3 shows that the value of the acre does indeed grow faster as the trees grow larger and older (time scales in figures 2.1 and 2.3 are the same). To further emphasize the difference between volume growth and value growth, information from figures 2.1-2.3 has been combined in figure 2.4 below. The value per one acre (left axes) and the volume per one acre (right axes) have been plotted on the same chart. It clearly reveals that over time growth in value is significantly steeper than growth in aggregate volume. Simply put, over a period of several years, a tree that grows twice in volume will appreciate far more than twice in value.

EXHIBIT 2.4
Value and Volume Over Time



This unique natural growth pattern exhibited by forests is clearly a very important driver of investment returns for timber investments. These returns – the growth rates of forests – vary according to a wide range of variables, including soils, silvicultural treatments, species composition, wildlife patterns, pest control and fertilization, to mention only a few. Biological growth is also not constant throughout the lifetime of a tree. Old trees grow slower than younger ones. Very young trees put most of their growth into height, adding little volume; whereas older trees will put less growth into height and more into diameter, contributing more volume to the stand.¹⁰

For the timber investor (or his forest manager) these patterns in biological growth, which are highly predictable, form the basis for developing very precise forest management plans in order to maximize the asset’s value. Precise mathematical growth models have been developed for all commercially important tree species, and since most of the variables that affect growth rates of trees can be controlled - or at least heavily influenced

¹⁰ Lutz, Jack. “Biological Growth Rates and Rates of Return”, *Forest Research Notes*, Vol. 2, No. 3 (3rd quarter 2005).

– by the forest manager, these variables appear as control variables in the value-maximizing optimization problem.¹¹

This suggests that intense management of timberlands can vastly improve returns on timber investments. In fact, research shows that the difference in growth between an actively managed forest and a natural stand of timber can be tremendous; perhaps twice as much timber can be produced in half the time in intensively managed plantations than in an unmanaged plantation.¹² Evidence that intense management pays off when it comes to timber investments is therefore irrefutable, which is certainly not the case with many other asset classes such as stocks, where the value of active management is still subject to heated debate.

2.2 Sources of Returns

There are three primary drivers of timberland investment returns: (1) biological growth, (2) timber prices and (3) changes in land value. Of these factors, biological growth is by far the most significant one. John Caulfield, a professor at the University of Georgia School of Forest Resources, has conducted a detailed study on the relative importance of timber investment return drivers. His findings indicate that biological growth has typically generated 61% of total investment returns on timberland investments, 33% is related to timber prices and the remaining 6% stem from changes in land prices.¹³

Each of the three return drivers will now be discussed in more detail.

Biological Growth

This component is by far the most important factor driving timberland returns and it is the one that separates timberland investments from most other investments in natural resources. Biological growth has a two-dimensional effect on returns as trees do not only

¹¹ See for example Heikkinen (2003), Wear & Parks (1994) or Berck (1979).

¹² Corriero, Healey & Rozenov (2005), pp. 62-63.

¹³ Caulfield, Jon. “Timberland Return Drivers and Investing Styles for an Asset that Has Come of Age”. *Real Estate Finance*, Vol. 14, No. 4 (1998).

grow in volume over time, but they also turn into higher value products (in-growth), as explained in the previous section.

Biological growth is a very attractive feature from an investment perspective as it is highly predictable, unidirectional and independent of all macroeconomic and most microeconomic factors (“trees do not read the Wall Street Journal”). This return factor therefore presents itself as a stabilizing, positive return component for the timber asset class. It provides a natural hedge against non-natural economic events. This helps account for the almost consistently positive annual returns of timber investments over the past two decades, as well as the low volatility and low correlation with other asset classes that timber exhibits.

Timber Prices

About a third of timberland investment returns can be traced to changes in timber product prices. However, the volatility of timber product prices contributes the greatest risk to timberland investments.¹⁴ This is because timber prices, unlike biological growth, are affected by various macro- and microeconomic factors:

- Macroeconomic factors include but are not limited to:
 - New housing activity
 - Long-term interest rates
 - Population growth
 - GDP growth
 - Exchange rates
 - Unemployment levels

- Microeconomic factors include but are not limited to:
 - Environmental/legislative issues
 - Regional timber processing capacity

¹⁴ Mercer Investment Consulting. “Timberland as an investment for institutional portfolios”. *Perspective*, July 2006.

- Prices of substitute products, such as plastic and metals
- Ease of harvesting and transport

Since timber price changes depend on numerous different and non-natural factors, they can be hard to predict and are obviously not always positive. Indeed, timber prices can be quite volatile over the short-term, but, when viewed over long periods, their increase has trended above inflation.¹⁵

It should be noted, however, that during periods of declining timber prices, biological growth, which is always positive, counters the impact of falling timber prices. The timber investment asset class therefore has a natural built-in hedge against timber price volatility. Also, as will be discussed in more detail in the next section, management has a significant degree of flexibility when it comes to timing the harvesting of trees, which allows them to postpone harvesting when timber prices are unfavorable (harvest option).

Land Value

The value of the land on which the timber grows only comprises around 6 percent of the returns on timber investments. Land prices are partially affected by local demand and supply conditions and can therefore vary geographically. They are far less volatile than timber prices and they tend to change slowly, which means that they tend to buffer downside volatility.¹⁶

The potential for alternative uses of timberland – uses other than growing timber – also has a bearing on land values. In areas near growing cities, or areas bordering lakes or rivers, for example, the land could potentially be worth more for development than for growing trees. However, if there are no real options for alternative uses, then the land value closely reflects the long-term outlook for timber prices. In fact, research studies

¹⁵Thomson, Thomas A.. “Long-Term Portfolio Returns from Timber and Financial Assets”. *Journal of Real Estate Portfolio Management*, Vol. 3, No. 1 (1997).

¹⁶ Mercer (2006), pp. 8.

have confirmed that value appreciation of the underlying land is correlated with timber prices over the long-term.¹⁷

Other Factors

Although biological growth, timber prices and changes in land value are the principal drivers of returns on timber investments, there are of course some other factors that can have a material impact on returns. One factor deserves particular mention: forest management intensity.

As mentioned earlier, the forest manager can time the harvest in order to take advantage of market opportunities and therefore improve returns. In addition to that, a skillful manager can vastly improve returns by applying the proper silvicultural treatments, such as fertilizer use, tree thinning and pest control. Evidence that intensive forest management pays off when it comes to timberland investments is compelling: it is estimated that active management of forest assets can produce long-term return gains approaching 400 basis points.¹⁸ The skill levels of individual forest managers can therefore be a partial return driver.

2.3 Asymmetric Return Structure

Timber investments do not have a symmetric return structure like many other investments. The reason is that managers have significant control over the investment and can therefore affect returns as was explained in previous sections. In fact, the managerial flexibility associated with timberland investments, as opposed to other traditional securitized investments (e.g. stocks), can be regarded as acquiring two important timing options: an entry/exit option and a harvest option.¹⁹

¹⁷ Larson, Keville. "The Southern Timberland Market in Perspective", 1997.

¹⁸ Blair, Craig. "In Search of Alternatives". *GROWTH Magazine*, Winter 2003, pp. 5.

¹⁹ International Woodland Company, The (IWC). "Timberland investments in an institutional portfolio", 2006, pp.6-7.

Entry/exit option – The value of a timberland property is related to several factors, of which timber price developments and presence of timber industry are very important. A timberland investor can take advantage of timberland market conditions when either entering or exiting the investment and thus affect the investment's return.

Harvest option – If timber prices in a certain period are unattractive, a timberland manager can decide to postpone harvest until a later period. If timber prices are particularly attractive in a certain period, the manager can decide to harvest more than initially planned in order to take advantage of favorable prices. The harvest option thus allows the manager to positively affect the return on the investment through timing.

These two options are examples of real options or, more precisely, flexibility options.²⁰ Such options permit the manager to alter operations depending on how conditions change during the life of the investment.²¹ If it is assumed that the timber investor wishes to maximize the return from his investments, then it is clear that he will utilize these options optimally. Consequently, as option theory suggests, the return structure of the investment will be changed.²²

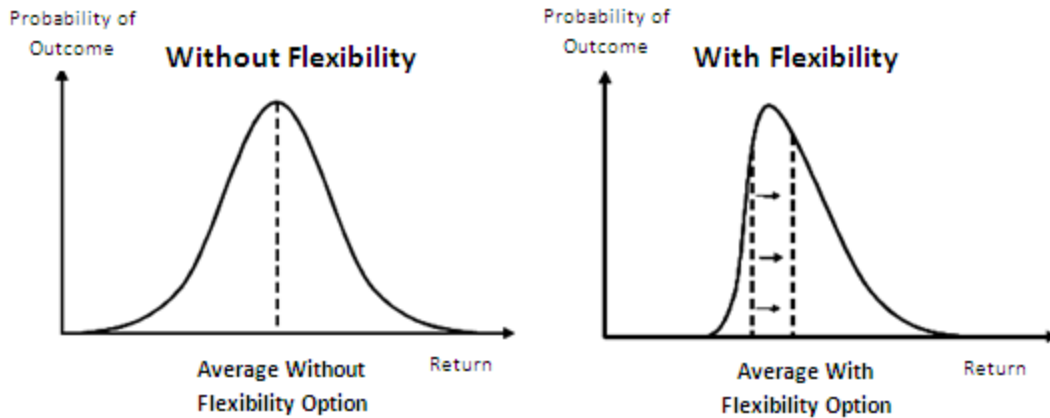
Figure 2.5 illustrates how the flexibility option alters the return structure of timber investments. The options allow management to reduce the occurrence of unfavorable outcomes and increase the occurrence of favorable ones. This causes the weighted average return to increase, thereby increasing the total return on the investments over a certain time period.

²⁰ In option theory, options are generally classified as either real options or financial options.

²¹ Brigham, Eugene F. and Joel F. Houston. *Fundamentals of Financial Management*. Mason, Ohio: South-Western, 2004, pp. 464.

²² See for example Hull (2006) or Hirschey & Nofsinger (2008).

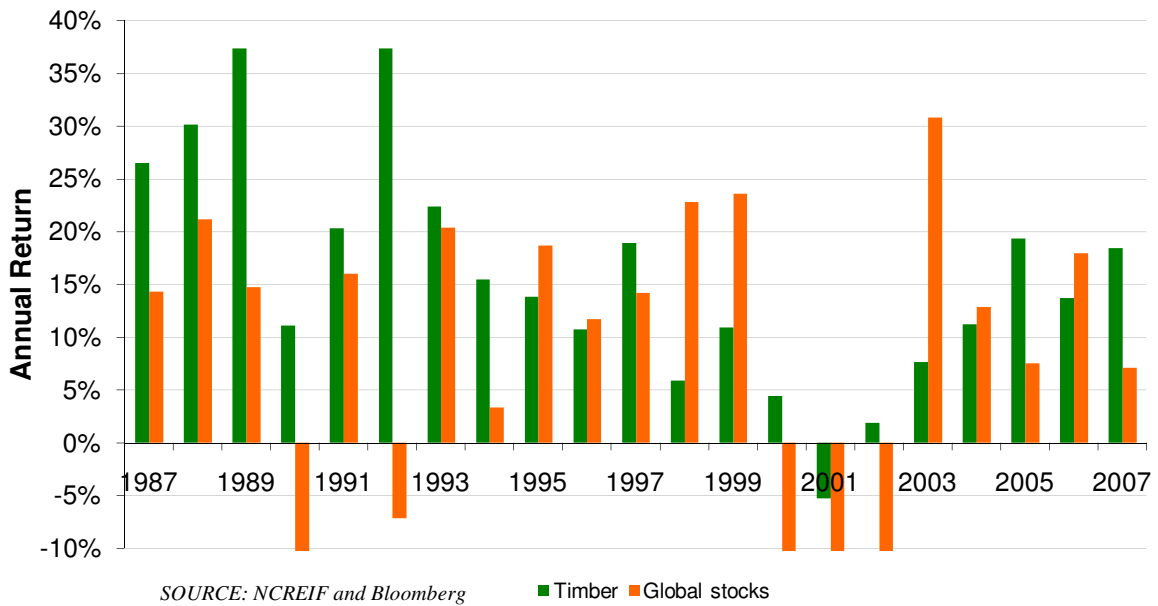
FIGURE 2.5
Return Structure with and without
Flexibility Options



Due to the inherent flexibility in timberland investments, as the figure clearly demonstrates, unfavorable outcomes can be reduced, which results in higher volatility on upsides than on downsides – an asymmetric or positively skewed return structure.

Historical data for timber returns confirm this theoretical observation. Over the last two decades, timber investments have exhibited greater volatility on the upside than on the downside. Figure 2.6 shows annual returns for timber investments as measured by the NCREIS Timberland Index and for global stocks as measured by the MSCI World Index. The data series for both indices are provided in Appendix 1.

FIGURE 2.6
Annual Returns of
Timber and Global Stocks



Volatility on the upside can be roughly approximated by the magnitude of positive bars and volatility on the downside by the magnitude of negative bars. Looking at the chart, it is clear that the magnitude of positive green bars far exceeds that of negative green bars, indicating that timber investments are significantly more volatile on the upside than on the downside. Also, when timber is compared with stocks, the magnitude of positive green bars is about the same as the magnitude of positive orange bars, which indicates that upside volatility for timber and equities is similar. Negative volatility however, as measured by the magnitude of negative bars, differs materially. The magnitude of negative orange bars far exceeds that of green bars, indicating that downside volatility of timber is lower than for stocks. In sum, timber returns appear to be highly elastic on the upside, but very inelastic on the downside, which is an ideal return characteristic from an investment perspective, as it suggests that the probability of high returns is greater than the probability of low returns.

2.4 Risk Factors

As with any investment, there are risks associated with timber investments that can affect financial performance. The majority of risk factors that timber investors may face can be grouped into four categories: (1) Supply and demand risks, which can also be referred to as price risks, (2) natural and environmental risks, (3) regulatory risks and (4) illiquidity risks. Each risk category will now be discussed in greater detail.

Price Risk

As previously mentioned, the volatility of timber prices contributes the greatest risk to timber investments. Timber prices are affected by supply and demand for timber, which in turn are affected by a broad range of macro- and microeconomic factors. Timber prices are thus subject to cyclical fluctuations.

The demand for wood is primarily affected by the level of new construction activity and, to a lesser extent, repair and remodeling activity. In the United States, for example, it is estimated that almost 40% of the wood consumed is used for new residential home construction and about 30% is used for home repairs and remodeling.²³ The remaining 30% is used to produce various wood-based products such as paper, packaging and newsprint. These activities are in turn subject to fluctuations from factors such as interest rates and population growth, to name only a couple.

Natural and Environmental Risks

Timber investments are exposed to a wide variety of natural hazards such as wildfires, hurricanes, pest infestation, disease outbreaks and drought. These are all physical risks that can potentially affect the volume and the quality of timber.

Even though these risks are often high-profile and receive significant media attention, especially in the case of wildfires and hurricanes, their economic implications for timberland investments are usually minimal. In fact, financial losses associated with

²³ FEG (2004), pp. 6.

natural risks reported by large-scale TIMOs²⁴ and forest industry companies only average around 20 basis points per year.²⁵ Furthermore, most of the timber exposed to fire or other catastrophic damage can be salvaged, with salvage rates of up to 80% of the undamaged value.²⁶ As loss rate associated with physical risks is so low, timberland managers generally do not even take out insurance to protect against them.²⁷

Regulatory Risks

Timber returns can be positively or negatively affected by changes in regulatory and environmental issues. Government policies and regulations can for example restrain or prohibit certain management activities, such as the harvesting of certain timber species.

An example of a government action that has affected timber returns in the U.S. is the placement of the northern spotted owl on the endangered species list. This action prohibited the harvesting of certain tree species in federal forests, which resulted in an increase in the value of private timberland.²⁸ Another example is the Clean Water Act in the U.S. International trade policies that affect imports and exports of timber and timber products can also affect timber returns.

Illiquidity Risk

As there is no organized timber market that continually prices timber investments, the asset class suffers from a certain degree of illiquidity risk. This can be a function of both a limited buyer universe and the substantial amount of time that is often required to negotiate and close a timberland transaction.²⁹ However, the fact that timber assets trade in relatively imperfect and inefficient markets can present itself as an opportunity for some investors. Inefficiencies in prices may in fact allow experienced and skilled forest managers to produce superior returns.³⁰

²⁴ TIMO, Timber Investment Management Company.

²⁵ Mendell, Brooks C. "Managing Timberland Investment Risk". *Timberland Report*, Vol. 6, No. 4 (4th quarter 2004).

²⁶ Corriero, Healey & Rozenov (2005), pp. 72.

²⁷ FEG (2004), pp. 7.

²⁸ Ibid, pp. 8.

²⁹ Corriero, Healey & Rozenov (2005), pp. 71-72.

³⁰ Blair (2003), pp. 5.

3. Timber Investment Performance

The previous chapter provided a general introduction to timber investments and explored the major factors that affect the return on timber assets. It is now time to take a closer look at the historical performance of timber investments and how this performance is assessed. The first section introduces the major return index used to measure timber returns and the second section looks at the asset class' historical performance. The last section explains why focusing on return figures from the United States is appropriate.

3.1 Measuring Timberland Investment Returns

As for most illiquid alternative investments, measuring the historical investment performance of timberland assets can be complicated because there is no centralized auction market which continuously prices timberland assets.

The most widely used index for the purpose of measuring historical timberland returns is the National Council of Real Estate Investment Fiduciaries (NCREIF) Timberland Index. The index was first published in 1995 with data constructed back to 1987. It is a property-based index which reports returns before fees from various regions in the United States in U.S. dollars.³¹ The returns are broken into two components: income and capital gains.

The income component, also referred to as the EBITDA³² component, mainly measures the proceeds from the sale of timber, but it can also include income from other activities such as hunting and fishing licenses, and sometimes from royalties and the sale of

³¹ IWC (2006), pp. 10.

³² EBITDA, Earnings Before Interest, Tax, Depreciation, and Amortization.

development rights. The capital gains component of return reflects the increased volume and value of trees on the property and the change in value of the land. It may also include proceeds from the sale of land.

The number of participating members reporting information has historically ranged from two to nine, but the number is expected to grow in the future.³³ The index currently accounts for 8.7 million acres of forestland and the value of all the properties included is approximately 15 billion dollars, which is a substantial share of total institutional investment in the United States.³⁴

No index is flawless and the NCREIF Timberland Index is certainly no exception. There are four limitations to the index which deserve particular mention:³⁵

1. The index covers a relatively short period as returns are only available since 1987. This limitation will however be of less concern over time as more periods are added.
2. The index only covers investments in the United States even though this is not the only market for timberland investments. It is however still by far the most significant one.
3. The index currently has only nine contributors, which are all Timber Investment Management Organizations.
4. The index only reports quarterly returns. In quarters where certain properties are not appraised, the appreciation is reported as zero. The return series may therefore report higher volatility than there actually is.

³³ Mercer (2006), pp. 3-5.

³⁴ IWC (2006), pp.11.

³⁵ Lutz, Jack. "Measuring Timberland Performance". *Timberland Report*, Vol. 2, No. 2 (1999).

Despite these limitations, the NSCREIF Timberland Index is the best available measure of timberland returns and the most widely employed. In the next section, historical returns and the volatility of timber investments are explored.

3.2 Historical Return of Timber Investments

Although there is limited reason to assume that the future will be like the past, it is still instructive to find out what the past was like. The following table and figure display annual timber investment returns from 1987–2007 as measured by the NCREIF Timberland Index. All performance figures are net of management fees.

TABLE 3.1
NCREIF Timberland Index

Year	Annual return	Year	Annual return
1987	26.51%	1998	5.88%
1988	30.12%	1999	10.92%
1989	37.35%	2000	4.41%
1990	11.06%	2001	-5.25%
1991	20.27%	2002	1.88%
1992	37.31%	2003	7.66%
1993	22.37%	2004	11.20%
1994	15.45%	2005	19.35%
1995	13.84%	2006	13.68%
1996	10.73%	2007	18.43%
1997	18.91%	Mean	15.81%

SOURCE: NCREIF

FIGURE 3.1
NCREIS Timberland Index
Annual Returns

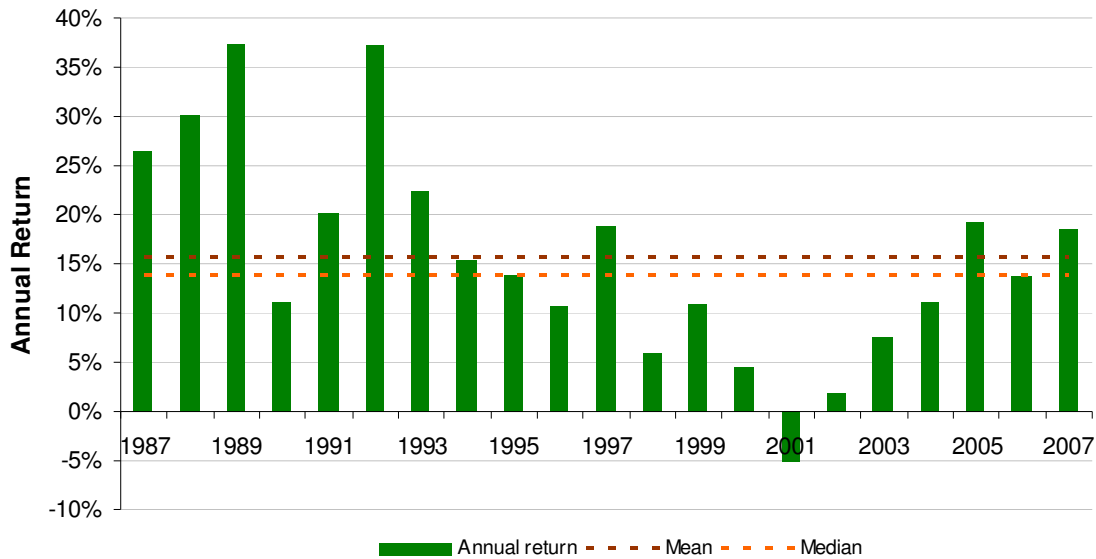
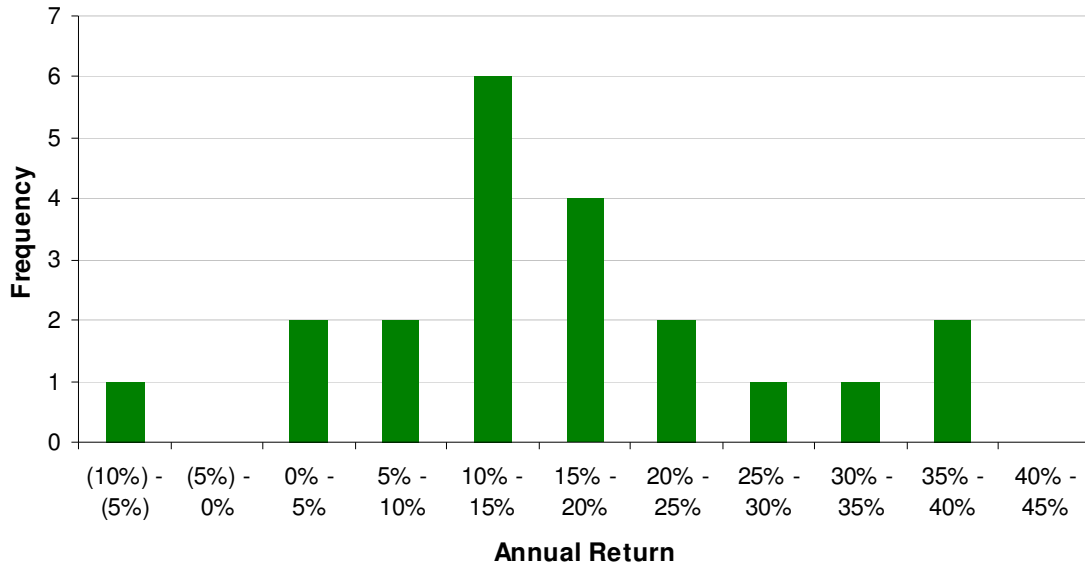


Table 3.1 and figure 3.1 imply that timber investments have indeed delivered a high risk-adjusted return over the last two decades. The return was negative only once, in 2001, the year in which the U.S. became victim of a terrorist attack, putting downward pressure on asset prices globally. The mean rate of return is 15.7% over the period, whereas the median return is 13.7%.

The fact that the median lies below the mean indicates positive skewness in the return distribution, which means that a large negative return is less likely than a large positive return. Over the past two decades, this is certainly the case: large positive returns have occurred frequently but large negative ones have not. A histogram of annual returns is provided in figure 3.2 here below. Despite the low number of periods, the histogram still provides further evidence for positive skewness in the return distribution. This fits the theoretical discussion about timberland return distributions in section 2.3.

FIGURE 3.2
NCREIS Timberland Index
Histogram of Annual Returns



3.3 Emphasis on North America

As mentioned earlier, one of the shortfalls of the NCREIS Timberland Index is that it only measures performance of timber assets in the United States. Since institutional investors, however, can of course invest in timberland internationally, it is worth justifying using only U.S. return figures when considering timberland investments. There are three important reasons why focusing on the U.S. is the most appropriate way to go:

1. The United States is the world leader in producing and consuming wood products and it accounts for the largest private timberland base in the world. The market for timber from timberland investments is therefore particularly strong and developed in the U.S.³⁶
2. Research suggests that the benefits from geographical diversification in timberland investments are limited. There is no clear indication that

³⁶ Lutz, Jack. "Why Focus on the US?". Forest Research Notes, Vol. 5, No. 1, (1st quarter 2008).

investing in a geographically diversified timberland portfolio will provide better overall performance.³⁷ This is due to the homogeneity of timberland investments.

3. The third reason, and perhaps the most obvious one, is that reliable return data is only available for the U.S. The NCREIF Timberland Index reports returns for properties in the U.S. only. Until such return data for non-US properties becomes available, it will difficult to discuss timber returns without a heavy emphasis on North America.³⁸

The Hancock Timber Resource Group has estimated returns from timberland investments in various regions outside of the U.S. since 1987. Their estimates are very rough and therefore not particularly reliable, but they suggest that timberland returns outside the U.S. have in fact been higher than in the U.S. over the past two decades.³⁹ This implies that focusing on the U.S. when analyzing the effects timber investments have on portfolios is, if anything, a cautious approach.

³⁷ Lutz, Jack. "Regional Diversification in Timberland". Forest Research Notes, Vol. 1. No. 3 (3rd quarter 2004).

³⁸ Lutz (2008).

³⁹ Hancock Timer Resource Group, <http://www.htrg.org>.

4. Timberland Investments in an Institutional Portfolio

The analysis thus far already indicates that timber assets possess favorable diversification characteristics. In this chapter, the benefits of including timber investments in risky portfolios will be quantified and analyzed through the use of Modern Portfolio Theory (MPT), which is principally based on the Markowitz Portfolio Selection Model.⁴⁰ The first section introduces the basic methodology of modern portfolio theory, but readers who require a more thorough discussion of the subject may require additional literature.⁴¹

4.1 Rudiments of Modern Portfolio Theory

The principal idea behind modern portfolio theory is that diversifying investments leads to portfolios with higher expected returns and lower standard deviation (less risk) if the assets' returns are not perfectly correlated. In other words, if the correlation between assets is anything but perfect, by suitably combining them, the investor can create portfolios with higher expected returns and less risk than if he were to hold only one of the assets.

The first step of the selection model is to identify the different risk-return combinations available from the whole set of risky assets. To do this, estimates for the expected returns of each security and a set of estimates for the covariance matrix are required as inputs. The expected returns are usually based on historical data, as will be done in this study, but they may also be based on forecasts. The covariances among the rates of return on

⁴⁰ Harry Markowitz published a formal model of portfolio selection in 1952, thereby paving the way for his 1990 Nobel Prize for economics. See Markowitz, "Portfolio Selection", *Journal of Finance*, March 1952.

⁴¹ See for example Bodie, Kane & Marcus (2005) or Hirschey & Nofsinger (2008).

the analyzed securities (variance-covariance matrix) are usually estimated from historical data.

The variance-covariance matrix is defined as follows for a total of n different risky investments:

$$\mathbf{V} = \begin{bmatrix} \sigma_1^2 & \sigma_{1,2} & \cdots & \sigma_{1,n} \\ \sigma_{2,1} & \sigma_{2,2} & & \vdots \\ \vdots & & \ddots & \sigma_{n-1,n} \\ \sigma_{n,1} & \cdots & \sigma_{n,n-1} & \sigma_n^2 \end{bmatrix}$$

where the n diagonal elements are estimates of the variances of the individual investments, σ_i^2 , and the $n^2 - n = n(n-1)$ off-diagonal elements are estimates of the covariances between each pair of asset returns, $Cov(r_i, r_j)$. Each covariance measure appears twice in the matrix; once as the covariance between assets i and j and once as the covariance between j and i .

Once these estimates have been compiled, it is possible to calculate the expected return and variance of any risky portfolio with weights w_i for each investment. This can be calculated from the matrix \mathbf{V} or, equivalently, using the following formulas for expected return of a portfolio, $E(r_p)$, and portfolio variance, σ_p^2 :

$$E(r_p) = \sum_{i=1}^n w_i (r_i)$$

$$\sigma_p^2 = \sum_{i=1}^n \sum_{j=1}^n w_i w_j Cov(r_i, r_j)$$

The next step is to identify the efficient set of portfolios. Here, the principal idea is that the investor is only interested in portfolios that minimize the variance for a given return target, or, alternatively, only portfolios with the highest expected return for a given risk

level. It follows that there are two feasible optimization procedures that can be used to construct the portfolio frontier. The first one is to maximize expected return, $E(r_i)$, for fixed levels of risk, σ_p^2 , by changing the weights, w_i . The second one is to minimize the risk level (variance) for fixed return targets by changing the weights. The two methods are equivalent and in this study the latter one is employed.

Mathematically the optimization problem for a given return target may be expressed as follows:

$$\begin{aligned} \text{Min } \sigma_p^2 &= \sum_{i=1}^n \sum_{j=1}^n w_i w_j \text{Cov}(r_i, r_j) \\ \text{subject to } \sum_{i=1}^n w_i &= 1 \quad (\text{all funds are invested}) \end{aligned}$$

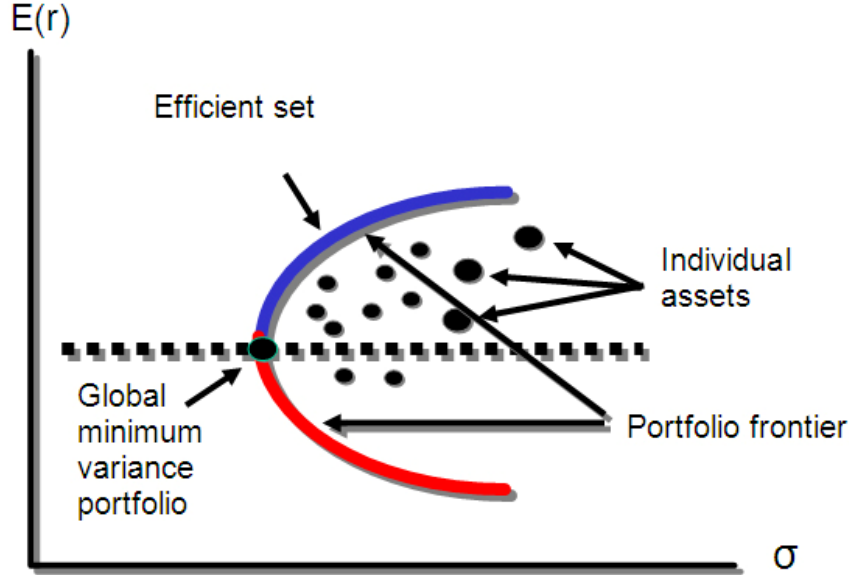
The solution will be a vector of weights, \mathbf{w} , showing the allocation to each asset required to achieve the minimum variance for each return target. Note that if the practice of selling short is prohibited, as is generally the case for many institutional investors⁴², the additional constraint that all weights be greater than or equal to zero must be imposed, that is $w_i \geq 0, \forall i$.

Solutions for all different return targets will yield the minimum-variance frontier, usually referred to more casually as the portfolio frontier. If short-selling is permitted, the portfolio frontier will be a hyperbola, but, if short-selling is not permitted, it will generally have a more parabolic shape⁴³. Figure 4.1 below depicts a portfolio frontier.

⁴² Institutional investors such as university endowments and pension funds generally do not sell assets short, except in rare cases for hedging purposes.

⁴³ Although the frontier usually has a parabolic shape when short sales restrictions are imposed, it may have kinks when two or more assets have the same expected rate of return.

FIGURE 4.1
Portfolio Frontier



All the individual assets or investments lie to the right, inside the frontier.⁴⁴ This illustrates how diversification among different assets leads to portfolios with higher expected returns and lower risk. Only portfolios that lie on the upper part of the portfolio frontier, that is from the global minimum-variance portfolio and upward, make up the efficient frontier. This is because they offer the best risk-return combinations.

For any portfolio on the lower part of the portfolio frontier, there is a portfolio with the same standard deviation but a higher expected return directly above it. Hence the bottom part of the portfolio frontier is inefficient and an investor would never choose any of the portfolios there. In this study, the focus will therefore be on the efficient frontier.

The final step in the portfolio selection model is to identify the optimal risky portfolio. This is done by finding the point of tangency between the efficient frontier and the capital allocation line (CAL) so that the slope of the CAL is maximized.⁴⁵ However, this last step is not directly relevant when the objective is to analyze the effects that adding an

⁴⁴ This is the case when short-selling is permitted; when it is not, all individual assets lie inside or on the frontier.

⁴⁵ The slope of the CAL is the reward to variability ratio, $\frac{E(r_p) - r_f}{\sigma_p}$.

investment has on the efficient frontier. The major concern in this study is how the efficient frontier shifts and changes to reflect different risk-return attributes of portfolios when timber is added to the set of available assets. This last step will therefore not be formally undertaken.

4.2 Allocation Model: A Theoretical Portfolio

In this section, the diversification benefits of including timber in a theoretical U.S. institutional portfolio will be explored. The asset classes available in this theoretical investment universe are U.S. stocks, global stocks, emerging markets stocks, U.S. government bonds (short-term, medium-term and long-term), U.S. real estate, timberland, inflation and a risk free rate. Since this is a theoretical U.S. portfolio, all of the data are based on real historical U.S. figures and their respective benchmarks are all denominated in U.S. dollars.

All historical data are based on reported quarterly returns between the first quarter of 1990 and the second quarter of 2008. The asset classes that comprise the universe of available risky assets in this study, along with their respective benchmarks, are tabulated in table 4.1. All data series are provided in Appendix 2.1.

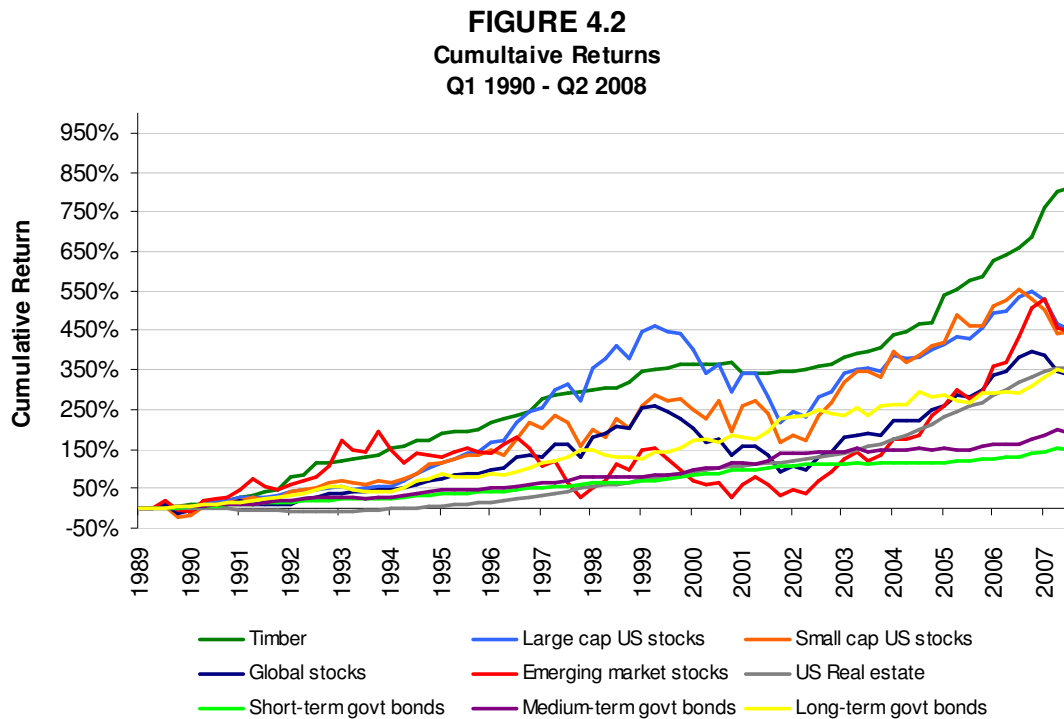
TABLE 4.1
Asset Classes Available in Study

Asset Class	Index / Benchmark**
Large cap US stocks	S&P 500 Index*
Small cap US stocks	Russell 2000 Index*
Global stocks	MSCI World Index*
Emerging market stocks	MSCI Emerging Markets Index*
Short-term govt bonds	Bloomberg USG1TR Index
Medium-term govt bonds	Bloomberg USG3TR Index
Long-term govt bonds	Bloomberg USG5TR Index
Real estate	NCREIF Property Index
Timberland	NCREIF Timberland Index
Inflation	US Consumer Price Index
Risk-free rate	4.5%; average LIBOR USD 3 Month from 1990-2008
* Total return indices (dividends reinvested) ** Data obtained via Bloomberg and NCREIF.org	

The NCREIF Timberland index was obtained through NCREIF's website.⁴⁶ All other indices were obtained via Bloomberg Terminal.

Return and Volatility

Figure 4.2 below shows the cumulative return of timberland investments since Q1 1990, as measured by the NCREIF Timberland Index, relative to the other asset classes available in the investment universe. The data is provided in Appendix 2.2.

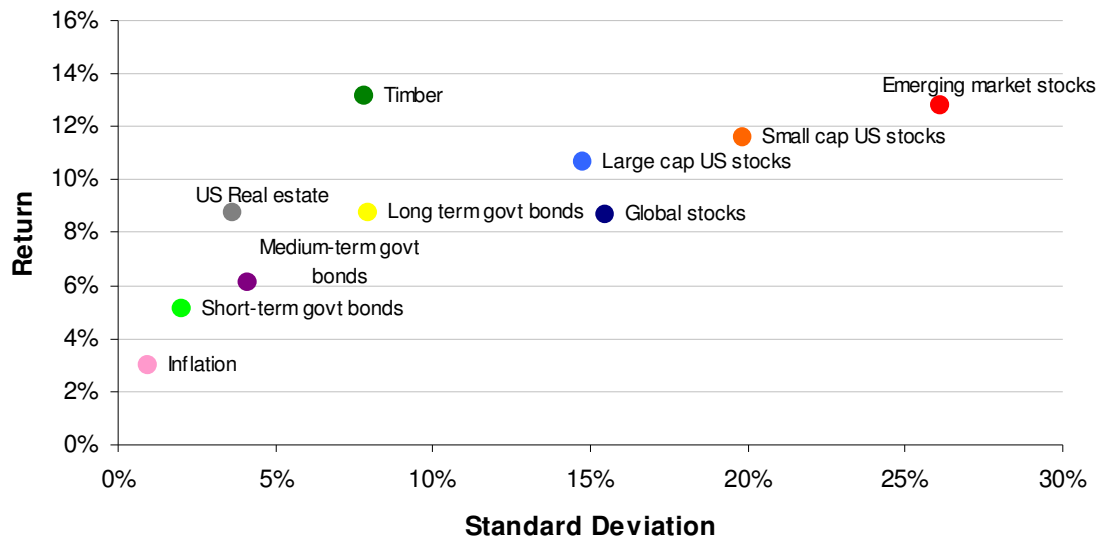


The figure reveals that timberland investments have yielded the highest cumulative return since 1990. Both domestic and emerging market stocks have also appreciated significantly, but they clearly exhibit more volatility than timber. Bonds and real estate have shown a steady but limited appreciation, which is in line with the characteristics of those asset classes.

⁴⁶ NCREIF, National Council of Real Estate Investment Fiduciaries, <http://www.ncreif.org/indices>.

To further illustrate timberland investments' historically attractive returns in terms of variability, a chart of the rates of return versus standard deviations for the assets included in the study has been prepared. Figure 4.3 shows annualized returns versus volatility, as measured by the standard deviation of returns.

FIGURE 4.3
Returns VS Volatility
Q1 1990 - Q2 2008



Looking at the chart, it is clear that timberland investments possess attractive historical performance and risk characteristics. Annualized timber returns have been materially higher than U.S. and global stock returns for example and, judging by the difference in standard deviations, the timber asset class is also significantly less risky. Historically, timber investments therefore appear to have produced a high risk adjusted return.

There are several ways of quantifying risk adjusted returns. One method is to use the coefficient of variation (CV). This coefficient is a normalized measure of dispersion, which is useful because a distributions' standard deviation should always be understood

in the context of its mean.⁴⁷ The coefficient of variation expresses the standard deviation as a percentage of the mean:

$$CV = \frac{\sigma}{\mu} \times 100\% \quad \text{for } \mu > 0$$

where σ is that standard deviation of and μ is the mean.

The coefficient of variation thus makes it possible to compare the relative risk of different assets. Table 4.2 displays the CV for the asset classes included in the present study based on annual returns and standard deviations for the period under investigation.

TABLE 4.2
Coefficients of Variation

Asset class	μ	σ	CV
Short-term govt bonds	5,1%	2,0%	39,6%
US Real estate	8,7%	3,6%	41,6%
Timber	13,1%	7,9%	59,8%
Medium-term govt bonds	6,1%	4,1%	66,9%
Long term govt bonds	8,8%	7,9%	90,3%
Large cap US stocks	10,7%	14,8%	138,5%
Small cap US stocks	11,6%	19,8%	170,9%
Global stocks	8,7%	15,5%	178,0%
Emerging market stocks	12,8%	26,1%	204,0%

Of the assets included in the study, as measured by the coefficient of variation, only short-term government bonds and real estate offer more attractive returns to variability than timber. However, when compared with all the other asset classes, particularly stocks, timber compares extremely favorably. This suggests that timberland investments do indeed exhibit high returns and low risk relative to other investments.

Another useful measure of relative or risk-adjusted performance is the Sharpe ratio (SR), sometimes referred to as Sharpe's measure. Although this measure is usually employed

⁴⁷ Newbold, Paul, William L. Carlson and Betty Thorne. Statistics for Business and Economics. New Jersey: Prentice Hall, 2007, pp. 57.

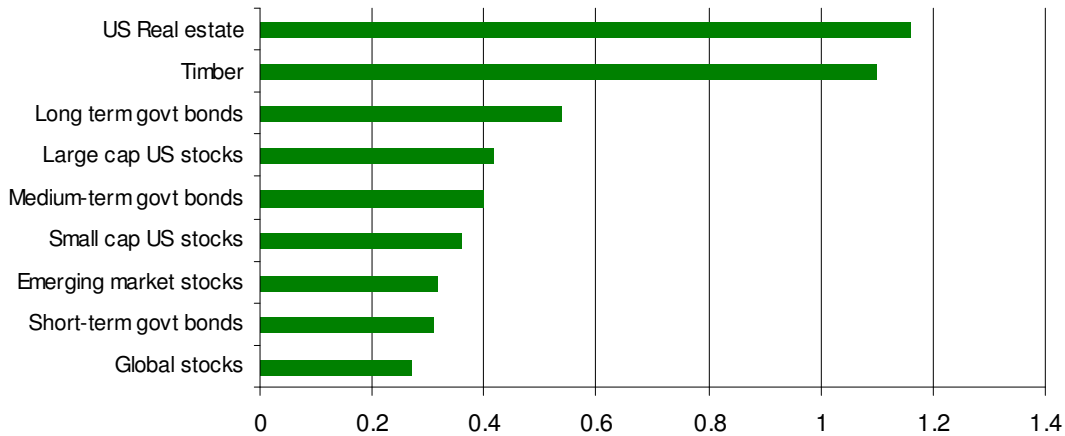
to provide rankings of different portfolios, it may also be used when comparing individual asset classes. The Sharpe ratio is calculated by dividing the mean excess return⁴⁸ of an asset over the sample period by the standard deviation of returns over that period:⁴⁹

$$SR = \frac{\bar{r}_i - \bar{r}_f}{\sigma_i} \quad \text{for } \sigma_i > 0$$

where \bar{r}_i is the average return of an individual asset, \bar{r}_f is the average risk free rate and σ_i is the standard deviation of returns.

It follows that poor relative performance exists if the Sharpe ratio is negative (<0) or positive but small. Very good relative performance is indicated if the Sharpe ratio is positive and large in magnitude. Figure 4.4 below illustrates the result of the analysis.⁵⁰

FIGURE 4.4
Sharpe Ratios



The figure clearly shows that the excess return to variability from both timberland and real estate, which are both real asset classes, is very attractive. Particularly compelling is

⁴⁸ The excess return is found by subtracting the risk-free rate from the mean return, $\bar{r}_i - \bar{r}_f$.

⁴⁹ Bodie, Zvie, Alex Kane and Alan J. Marcus. *Investments*. New York: McGraw-Hill, 2005, pp. 868.

⁵⁰ As displayed in table 2, the average risk-free rate for this study is taken to be 4.5%, which is the average LIBOR USD 3 month rate from 1990-2008.

the fact that timberland has, according to the Sharpe ratio, delivered excess returns that far exceed those of stocks.

The reason for historically high and steady average returns of timber investments can first and foremost be attributed to the biological growth of trees, which was discussed in detail in sections 2.1 and 2.2. Biological growth is the most important driver of timberland returns and this component is, of course, entirely independent of all macroeconomic events – events that heavily affect the returns of other asset classes. Biological growth significantly reduces the volatility – and therefore the risk - of timber investments.

The fact that timber assets have historically yielded high risk adjusted returns already implies that adding the asset class to a diversified portfolio can potentially carry significant benefits. However, before proceeding to the actual portfolio allocation model, it is important and instructive to explore the historical correlations that timberland returns have exhibited with the returns of other asset classes.

Timber Correlations

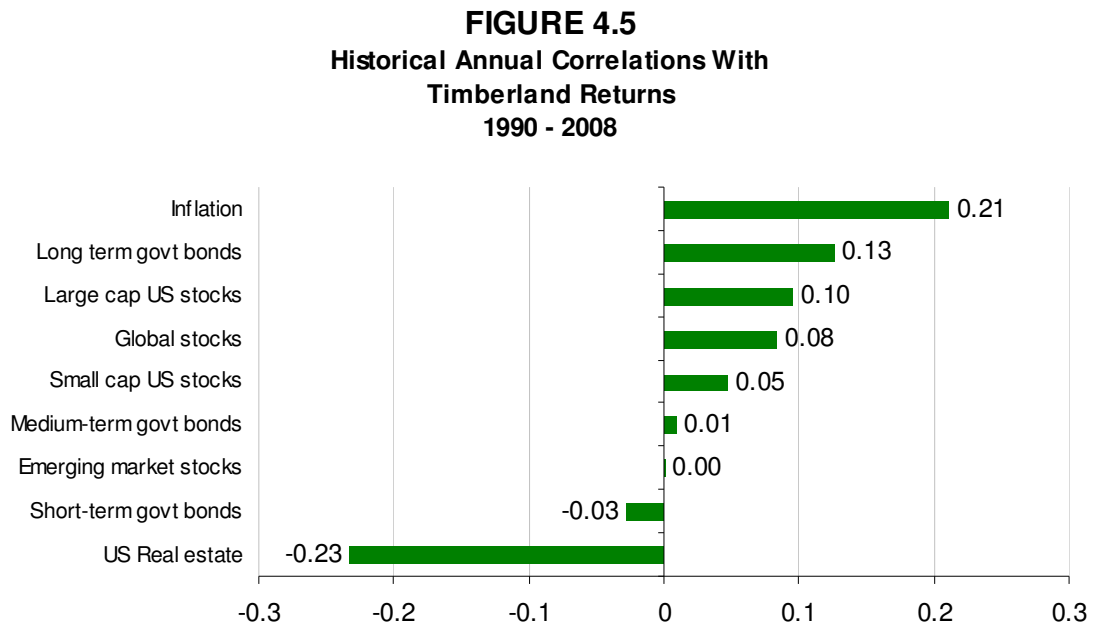
Low or negative correlations between different asset classes are highly beneficial when a portfolio of assets is created. When individual assets exhibit low or negative correlations with each other, combining them can increase potential returns and significantly reduce risk. One of the primary attractions of timberland investments is its low to negative correlation with traditional asset classes.

The correlation coefficient scales the covariance between two variables to a value between -1 (perfect negative correlation) and +1 (perfect positive correlation). The correlation coefficient is calculated by dividing the covariance between the two variables by the product of their standard deviations:

$$\rho = \frac{Cov(r_a, r_b)}{\sigma_a \sigma_b}$$

where $Cov(r_a, r_b)$ is the covariance between assets a and b, and σ_a and σ_b are their individual standard deviations.

Figure 4.5 below shows the correlation coefficient between timberland returns and the returns of other asset classes for the period 1990 – 2008.



The correlation analysis shows that timber returns have historically correlated fairly well with inflation, which indicates that timber investments may, to a certain extent, provide a hedge against inflation. However, the fact that two data series are highly correlated does not necessarily suggest that there is a direct cause and effect relationship. The correlation coefficient simply measures the change in direction of each data series and the magnitude of those changes, but does not provide any information on how the two series may be related. It simply suggests that there may or may not be a linear relationship between two variables.

In the case of inflation and timber returns, it should be noted that inflation in the U.S. has been positive over the last several decades and that timberland returns have also usually been positive. This, however, does not necessarily indicate a direct cause and effect relationship: since both series are almost always positive, they are likely to exhibit a high positive correlation simply because calculating the correlation coefficient between two positive data series will yield a positive coefficient.

Dr. Jack Lutz, a forest economist with The Forest Research Group and a renowned authority in the field of forestry economics, has done extensive research on timber returns. His findings have led him to conclude that timberland returns are highly correlated with inflation because timber prices contribute to the inflation rate in the following year.⁵¹ Simply put, timber returns and inflation correlate well because timber prices in year t affect the inflation rate in year $t + 1$. His research therefore supports the view that timberland investments may serve as an efficient hedge against inflation.

Figure 4.5 also reveals that timberland is negatively correlated with U.S. real estate prices and quite significantly so. This is an interesting result as timberland is frequently categorized as an alternative to investments in real estate. Further analysis reveals that it was particularly during the three-year period 1990-1993 that there was a strong negative correlation between timber and real estate. This was a period during which real estate prices in the U.S. dropped significantly between quarters but timber assets delivered stellar returns. Although this three-year period heavily influences the correlation coefficient between timber and real estate over the entire period under investigation, 1990-1993, the correlation analysis still suggests that there are substantial benefits to be achieved by including timber assets in a portfolio including real estate assets.

Finally, the correlation analysis reveals that timberland returns are only slightly positively correlated with stocks and bonds, which shows yet again that the timber asset class is a very desirable one from a portfolio diversification perspective. In fact, in one of his recent studies, Dr. Jack Lutz claims, after having examined timber correlations with

⁵¹ Lutz, Jack. "Inflation and Timberland Returns". *Forest Research Notes*, Vol. 4, No. 3 (3rd quarter 2007).

other assets over various different time intervals, that timber returns are neither positively nor negatively correlated with stocks and bonds. His research indicates that timberland is simply not correlated with stocks and bonds at all.⁵² The reason, of course, is biological growth, which, as has been mentioned several times in this dissertation, is entirely independent of – and therefore not correlated with – all the factors that drive the returns of stocks and bonds.

Efficient Frontiers With and Without Timber

As the analysis thus far indicates, timber returns have been competitive with other asset classes and have low risk (volatility) as well as attractive correlation attributes for portfolio diversification. The issue that remains is to measure the impact that timber investments have in a portfolio. This will be done using portfolio frontiers, where the focus is on the efficient frontier as was explained in section 4.1.

As was outlined in section 4.1, the first step of the selection model is to find estimates for the expected returns of each asset class as well the variance-covariance matrix. In this study, these estimates are based on historical return data and they are provided in Appendix 2.⁵³ The next step of the selection model is to construct the portfolio frontier by mathematically minimizing variance for various fixed return targets. The optimization model was constructed and solved with Microsoft Excel and this procedure is outlined in Appendix 2.6.

Two portfolio frontiers have been produced on two different charts in figures 4.6 and 4.7.⁵⁴ In both charts, the green-colored curve is the portfolio frontier when timber investments are allowed in the portfolio; the orange curve is the portfolio frontier when timber investments are not allowed in the portfolio. Since most institutional investors will generally not sell assets short, except for hedging purposes, figure 4.6 displays

⁵² Lutz, Jack. “The Anti-Correlation Heresy”. *Forest Research Notes*, Vol. 1, No. 4 (4th quarter 2004).

⁵³ The data series are provided in Appendix 2.1 and the estimates for mean annual returns and the annual standard deviation are provided in A2.4.

⁵⁴ Inflation and the risk free rate are not included in the set of available assets when the frontiers are constructed.

portfolio frontiers where short-selling restrictions are imposed whereas figure 4.7 displays frontiers where no such restrictions are imposed.

FIGURE 4.6
Portfolio Frontier With and Without Timber
Short sales restriced

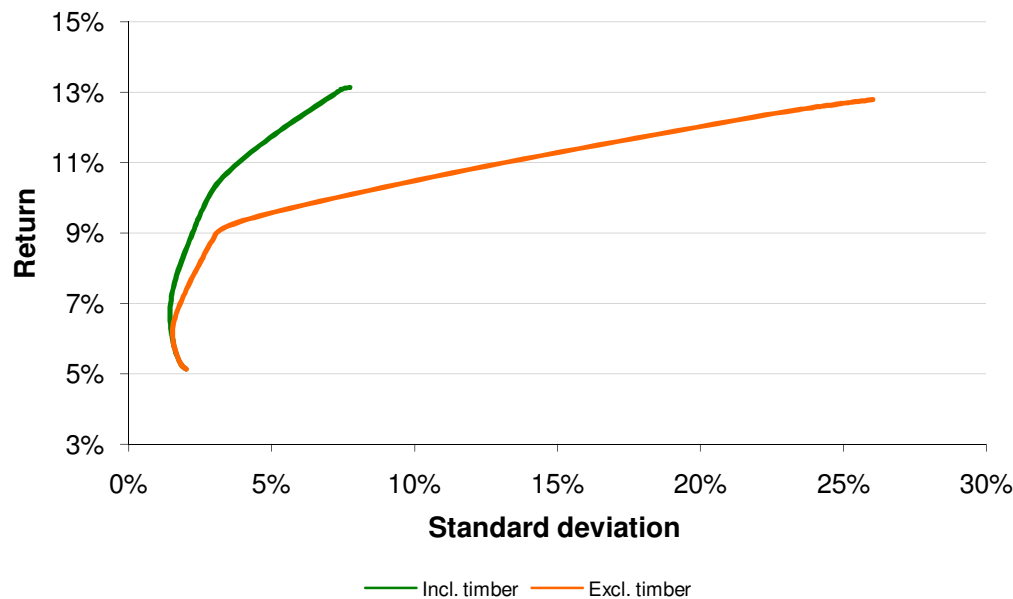
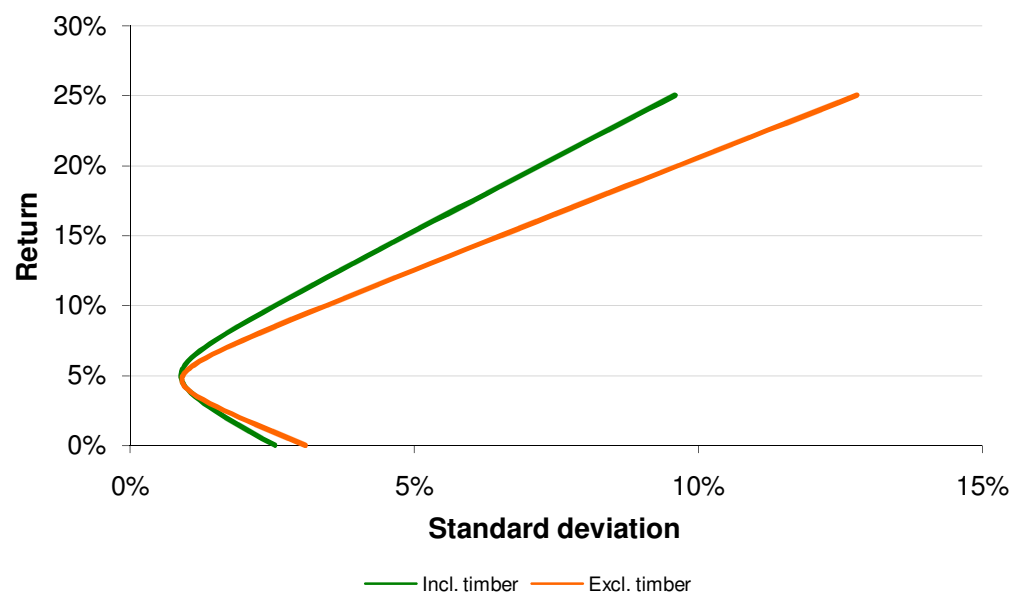


FIGURE 4.7
Portfolio Frontier With and Without Timber
Short sales permitted



As previously mentioned, the focus is on the efficient frontier, the part of the portfolio frontier extending from the global minimum variance portfolio and upward. Looking at the charts, the impact that timber investments have on the efficient frontier of a portfolio is evident: an opening of a range of new investment possibilities with significantly higher returns and a lower standard deviation (less risk). The efficient frontier shifts and changes shape when timber investments are included, reflecting higher potential returns and lower risk. In the case where short-selling is not permitted (figure 4.6), the difference is especially significant as the risk level can be reduced substantially for most return targets. This implies that a portfolio with timberland will be superior to a portfolio without timberland.

The frontiers in figures 4.6 and 4.7 vary significantly in size and shape depending on whether short sale restrictions are imposed or not and whether timber is included or not. The frontier including timber (green) in figure 4.6 extends only a short distance to the right, whereas the frontier without timber (orange) extends to the far right. This is because timber has the highest expected return of all the assets included in the study. The only way to achieve a 13.5% return target, which is the expected return of timber, is to allocate 100% of the funds to that asset class. The endpoint of the green frontier in 4.6 therefore reflects a portfolio with all funds allocated to timber, with an expected return of 13.5% and a standard deviation of 7.8%, which corresponds to the historical return and standard deviation of timber from 1990 - 2008. When short sales are permitted however, any return target can theoretically be achieved, whether timber is included or not, as long as the investor can sell an unlimited amount of assets short and there is no limit on the size of individual positions.

Attentive readers will also notice that there is a kink on the frontier without timber when short sales are restricted (figure 4.6). At first this may seem odd as the frontier is generally expected to be smooth (i.e. to be differentiable everywhere), even when there are short sale restrictions. However, in this study, two assets – U.S. real estate and global stocks - have the same expected return, 8.71%. When this is the case, there may or may not be a kink at some point on the frontier where the asset composition of the efficient

portfolio changes.⁵⁵ The frontier including timber in 4.6 (green) also has a slight kink for the same reason. When short sales are permitted, however, the portfolio frontier is always smooth.

To further illustrate the effects timber assets have on the portfolio, the incremental benefits of including timberland in the portfolio for a few different return targets are summarized in table 4.3 (short sales restricted).

TABLE 4.3
Incremental Benefits of Allowing Timber Allocation in the Portfolio

	Target Return	Risk Level	Risk Reduction from Including Timber	Optimal Allocation to Timber
Incl. Timber	7.0%	1.48%	0.33%	9%
Excl. Timber		1.81%		
Incl. Timber	8.0%	1.77%	0.63%	16%
Excl. Timber		2.40%		
Incl. Timber	9.0%	2.24%	0.84%	21%
Excl. Timber		3.08%		
Incl. Timber	10.0%	2.79%	4.45%	26%
Excl. Timber		7.24%		
Incl. Timber	11.0%	3.85%	9.30%	47%
Excl. Timber		13.15%		
Incl. Timber	12.0%	5.46%	14.38%	69%
Excl. Timber		19.84%		

The table shows the subsequent risk reduction when allowing an allocation to timberland investments in a diversified portfolio. The results are very positive indeed: for all return targets, allowing an allocation to timber decreases the risk substantially. For example, with a target return of 11%, an unrestricted allocation to timber reduces risk (standard deviation) by 9.30%.

This analysis is however somewhat unrealistic as it suggests very high optimal allocations to timber assets. For a target return of 11%, for example, the optimal allocation to timberland is close to 50%. This is almost counterintuitive to the fundamental idea of asset management, which is to diversify among different asset

⁵⁵ Dybvik, Philip H. "Short Sales Restrictions and Kinks on the Mean Variance Frontier". *The Journal of Finance*, Vol. 39, No. 1 (March 1984), pp. 239-244.

classes to mitigate risk. It is also unlikely that an institutional investor would be allowed to put so many eggs in one basket. Even though the mathematics of portfolio management suggest extreme allocations to timber, it is unlikely that any institutional investor holding a diversified portfolio would ever allocate more than 20% of total assets to a single alternative investment however attractive that investment may be, as is the case with timber. It is therefore instructive to examine the effects timber investments have on portfolios when the maximum allocation to timber may not exceed a reasonable maximum level, say 20%.

In figures 4.8 and 4.9, two different frontiers have been produced on two different charts in the same way as in figures 4.6 and 4.7. The only difference is that the maximum allocation to timber has now been capped at 20% of the total portfolio. The figures therefore illustrate the effects of including timber in a well diversified portfolio when the allocation to timber may not exceed 20%.

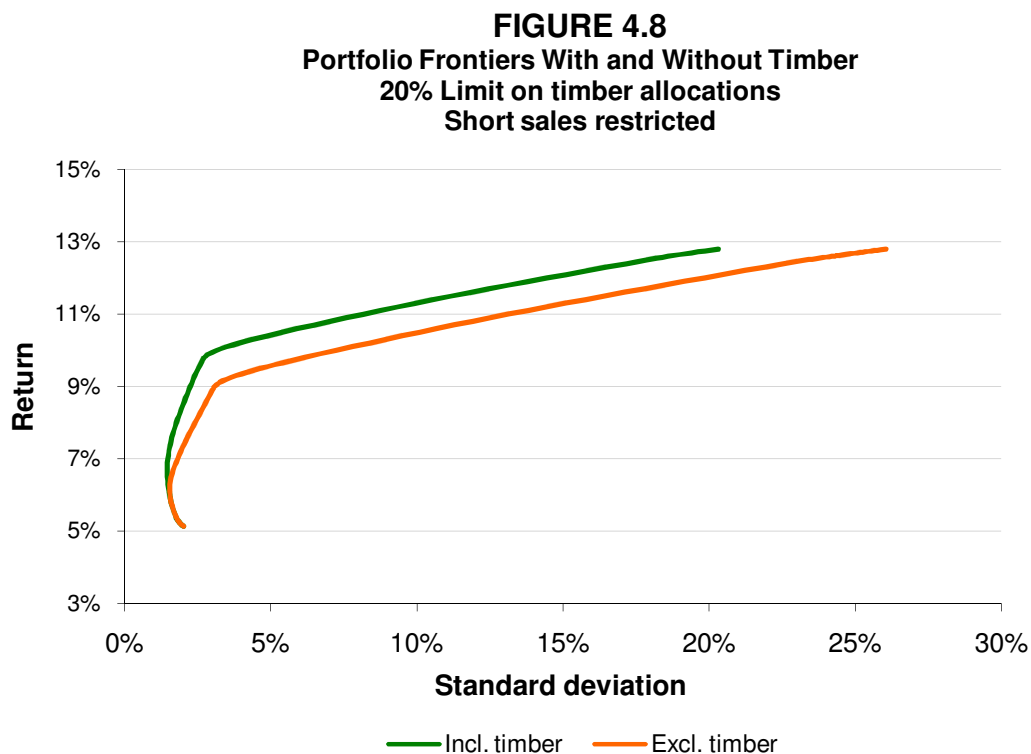
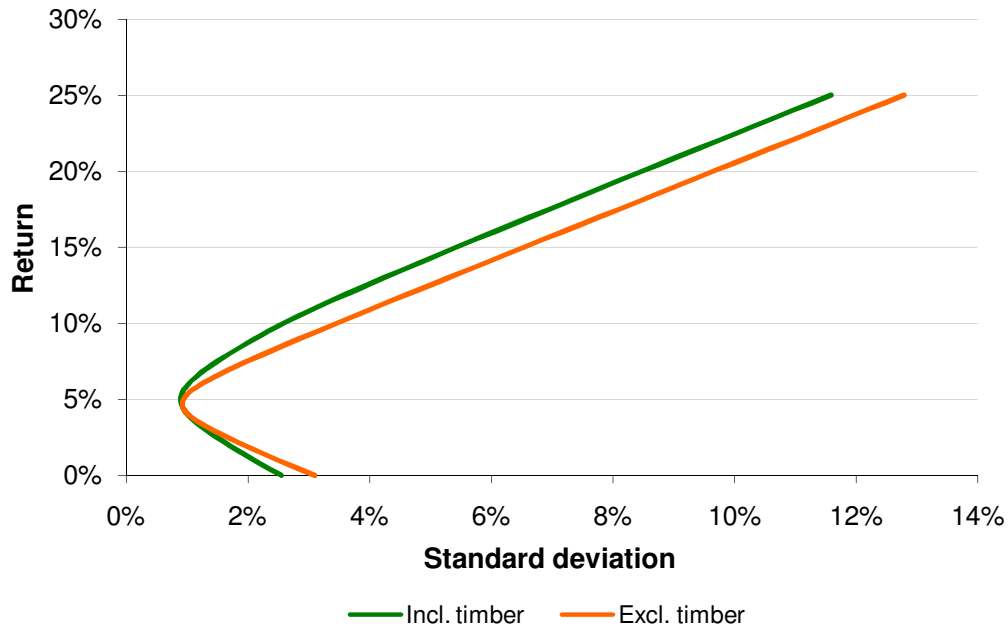


FIGURE 4.9
Portfolio Frontiers With and Without Timber
20% Limit on timber allocations
Short sales permitted



Even after imposing the additional constraint that allocation to timber may not exceed 20%, as the charts clearly demonstrate, the optimization model still reveals that there are sizable benefits to be achieved by including timber in the portfolio. When timber is included but capped at 20%, the frontiers still shift and change in shape to reflect higher returns and lower risk. In fact, the charts reveal that any portfolio on the efficient frontier including timber will always be superior to any portfolio that does not include timber, whether short-selling is restricted or not. This confirms yet again that there are sizable benefits to be achieved by including the timber asset class in a well diversified portfolio.

In table 4.4 below, the incremental benefits of including timber in the portfolio for a few return targets are summarized (short sales restricted) in the same way as in table 4.3, the only difference being that timber allocations are now capped at 20%.

TABLE 4.4
Incremental Benefits of Allowing 20% Timber Allocation in the Portfolio

	Target Return	Risk Level	Risk Reduction from Including Timber	Optimal Allocation to Timber
Incl. Timber	7.0%	1.48%	0.33%	9%
Excl. Timber		1.81%		
Incl. Timber	8.0%	1.77%	0.63%	16%
Excl. Timber		2.40%		
Incl. Timber	9.0%	2.24%	0.84%	20%
Excl. Timber		3.08%		
Incl. Timber	10.0%	3.13%	4.11%	20%
Excl. Timber		7.24%		
Incl. Timber	11.0%	8.16%	4.99%	20%
Excl. Timber		13.15%		
Incl. Timber	12.0%	14.43%	5.41%	20%
Excl. Timber		19.84%		

When timber exposure is capped at 20%, the risk reduction for different target returns is obviously lower than when timber allocations are not restricted. Still, the risk reduction potential is material. When the target return is 10%, for example, the standard deviation of returns is reduced by roughly 4% when a maximum exposure of 20% to timber is permitted. The table shows that for target returns of 9% or higher, the optimal allocation to timber is the maximum, 20%. In fact, when short sales are restricted, the optimal allocation to timber for all return targets of 8.8% or more is the maximum allowed or 20%.

In sum, this section has demonstrated that the addition of a timberland component to a U.S. institutional investment portfolio can yield highly positive results, even when exposure to the asset class is limited to 20%. The fact that the standard deviation (risk) decreases for all return targets along the efficient frontier when the timber asset class is added to an already well diversified portfolio, suggests that a portfolio including timber will always be superior to a portfolio that does not include timber.

The results of this study strongly suggest that institutional investors, who have not already explored the possibility of investing in timber, may want to do so. By adding timber investments to their portfolios, they can improve returns and reduce risk, and that is a very compelling proposition for all investors.

5. Conclusion

In recent years, institutional and individual investors have increased their portfolio allocations to alternative investments, including timberland. Timber investments possess some unique characteristics that differentiate them from investments in other asset classes, the most significant one being biological growth of trees. The value gain from biological growth is two-dimensional, as trees do not only grow in volume with age, but they also grow exponentially in value as their diameter increases. Larger trees can be turned into higher value products, a phenomenon called in-growth.

The growth characteristic of trees is the most significant return driver of timber investments, typically accounting for over 60% of returns from timber investing. The other return drivers are changes in timber prices and changes in land values. Biological growth is unidirectional (always positive) and completely independent of all the macro- and microeconomic factors that can affect the returns on other asset classes. As such, it serves as a natural hedge against timber price volatility, which is obviously not independent of the broader economic environment. Also, biological growth can be heavily affected by active forest management, allowing the timber investor to influence returns.

Timber investments have yielded average annual returns of 15.7% since 1987, making the asset class very competitive with other investments such as stocks and bonds. Furthermore, timber investments have exhibited low volatility, particularly on the negative side, when compared with other asset classes. This is due to the fact that the manager has the ability to choose between harvesting timber today and allowing it to grow larger in response to price expectations. This harvest option may be treated as a real

option and as such it skews the return structure of the investment. The positively skewed return structure of timber investments is ideal from an investment perspective as it implies that large negative returns are far less likely to occur than large positive ones.

Historically, timber investments have provided a high risk-adjusted return and have exhibited low or even negative correlations with returns of other asset classes, making it an attractive asset class for portfolio allocation purposes. Like real estate, timber is also a real asset and should therefore, in line with such assets, tend to hold its value in an inflationary environment. In fact, historical correlations of timberland returns with inflation suggest that timber can serve as an effective hedge against inflation.

When a timberland component is added to a diversified portfolio of risky assets, the impact on the portfolio frontier is clear: significantly higher returns with lower risk. The frontier shifts to the left and changes its shape, reflecting significantly better risk-return tradeoffs. When the maximum allocation to timber is unrestricted, results show that the standard deviation of the portfolio, for various fixed return targets, falls substantially; in most cases by several percentage points. Even when the maximum allocation to timber is capped at 20% of the total portfolio, which is perhaps closer to a more realistic scenario, results still indicate that there are substantial benefits to be achieved by including timber in the portfolio: the standard deviation falls significantly for all return targets and the model implies that the optimal allocation to timber investments is, in most cases, the maximum allowed. In sum, the results suggest that the addition of a timberland component to an investment portfolio can carry significant benefits. Thus, the study reveals that in terms of risk-return tradeoffs, a portfolio that includes timber is superior to a portfolio that does not include timber.

The rewards from investing in timber – at least for some investors – also involve more than pure financial gains. Investors who are inclined towards socially responsible and environmentally friendly investing will clearly find much to like in timber. Trees, for example, rid the atmosphere of carbon dioxide, and, if properly managed, a forest is a sustainable natural resource. In the near future, some of these benefits might even begin

to carry direct financial gains, as timberland owners, under the provisions of the Kyoto Protocol on Climate Change, are set to receive carbon credits which they could trade in an open market.

As with any investment, investors must of course weigh a host of factors before adding timber investments to their diversified portfolios. These factors include, among others, the potential financial gains and the principal risks associated with the investment. However, this dissertation strongly suggests that there are benefits to be achieved by holding timber investments. The addition of even a modest timberland component to an investment portfolio can yield highly positive results in the form of higher returns and less risk. It seems safe to say that this is a compelling proposition.

Appendix 1

The data series below display annual returns for the NCREIF Timberland Index and the MSCI World Total Return Index from 1987 – 2007. These series were used to create figure 2.6. The NCREIF Timberland Index was obtained from the National Council of Real Estate Investment Fiduciaries.⁵⁶ The MSCI World Index was obtained via Bloomberg.

The NCREIF Timberland Index measures the return earned from holding timberland assets from various regions in the United States. The MSCI World Index is a stock market index of global stocks. The index includes stocks from various developed countries around the world.

	NCREIF Timberland	MSCI World		NCREIF Timberland	MSCI World
1987	26.51%	14.34%	1998	5.88%	22.78%
1988	30.12%	21.19%	1999	10.92%	23.56%
1989	37.35%	14.75%	2000	4.41%	-14.05%
1990	11.06%	-18.65%	2001	-5.25%	-17.83%
1991	20.27%	16.00%	2002	1.88%	-21.06%
1992	37.31%	-7.14%	2003	7.66%	30.81%
1993	22.37%	20.39%	2004	11.20%	12.84%
1994	15.45%	3.36%	2005	19.35%	7.56%
1995	13.84%	18.70%	2006	13.68%	17.95%
1996	10.73%	11.72%	2007	18.43%	7.09%
1997	18.91%	14.17%	Mean	15.81%	8.50%

⁵⁶ <http://www.ncreif.org/indices>.

Appendix 2

This appendix provides all data and calculations that were used to carry out the study in Chapter 4.

A2.1 Time Series

The lists of available risky assets, along with their respective benchmarks, are tabulated here below.

Asset Class	Index / Benchmark**
Large cap US stocks	S&P 500 Index*
Small cap US stocks	Russell 2000 Index*
Global stocks	MSCI World Index*
Emerging market stocks	MSCI Emerging Markets Index*
Short-term govt bonds	Bloomberg USG1TR Index
Medium-term govt bonds	Bloomberg USG3TR Index
Long-term govt bonds	Bloomberg USG5TR Index
Real estate	NCREIF Property Index
Timberland	NCREIF Timberland Index
Inflation	US Consumer Price Index
Risk-free rate	4.5%; average LIBOR USD 3 Month from 1990-2008
* Total return indices (dividends reinvested) ** Data obtained via Bloomberg and NCREIF.org	

The NCREIF Timberland Index was obtained from the National Council of Real Estate Investment Fiduciaries. All other indices were obtained via Bloomberg. The equity indices are all total return indices; they are based on calculations of the performance of a group of stocks assuming that all dividends and distributions are reinvested. The raw time series display index values on a quarterly basis between the first quarter of 1990 and the second quarter of 2008.

TIME SERIES: RETURNS OF INVESTMENT CLASSES

	Timber	Large cap US stocks	Small cap US stocks	Global stocks	Emerging market stocks	US Real estate	Short- term govt bonds	Medium- term govt bonds	Long term govt bonds	Inflation
29.12.1989	226.11	379.41	555.48	145.87	214.70	100.00	90.47	88.77	80.66	126.30
30.3.1990	232.13	368.00	543.02	125.10	197.85	101.38	91.61	90.10	82.27	128.60
29.6.1990	239.23	391.14	563.61	135.52	235.14	102.92	92.76	91.45	83.92	129.90
28.9.1990	242.63	337.39	425.73	111.07	193.09	103.79	93.93	92.83	85.59	132.50
31.12.1990	251.12	367.63	447.29	121.83	185.16	102.30	95.11	94.22	87.31	134.20
29.3.1991	255.26	421.03	580.29	134.36	238.23	102.35	96.31	95.63	89.05	134.80
28.6.1991	269.81	420.07	571.08	130.27	247.27	102.36	97.53	97.07	90.83	136.00
30.9.1991	276.48	442.53	617.80	139.67	253.84	102.02	98.76	98.52	92.65	137.00
31.12.1991	302.03	479.63	653.24	146.09	288.80	96.59	100.00	100.00	94.50	138.20
31.3.1992	307.13	467.52	702.17	135.42	346.58	96.56	100.03	98.52	96.39	139.10
30.6.1992	332.74	476.41	654.11	137.42	305.52	95.56	102.91	103.02	100.41	140.10
30.9.1992	339.00	491.43	672.94	139.75	294.07	95.14	106.00	108.37	106.86	141.10
31.12.1992	414.73	516.18	773.50	139.91	314.93	92.47	106.23	107.52	107.96	142.30
31.3.1993	422.70	538.72	806.56	151.96	331.30	93.18	108.35	111.69	114.05	143.30
30.6.1993	496.16	541.34	824.24	161.54	354.82	92.96	109.55	114.00	120.28	144.30
30.9.1993	501.42	555.33	896.32	169.82	407.47	93.98	111.10	116.58	127.65	145.00
31.12.1993	507.49	568.20	919.53	174.72	539.34	93.75	111.93	116.86	126.52	146.30
31.3.1994	520.02	546.65	895.04	175.36	489.21	94.97	111.42	114.33	119.92	147.10
30.6.1994	535.57	548.96	860.02	180.32	479.18	96.44	111.46	113.33	116.38	147.90
30.9.1994	543.50	575.80	919.77	186.39	577.29	97.89	112.53	114.02	115.69	149.30
30.12.1994	585.89	575.71	902.76	183.50	492.58	99.73	112.54	113.54	118.03	150.10
31.3.1995	602.18	631.76	944.44	190.01	429.80	101.84	116.33	118.97	125.54	151.20
30.6.1995	627.71	692.07	1032.98	199.14	471.38	103.96	119.98	125.32	139.51	152.40
29.9.1995	633.17	747.07	1135.00	209.82	466.41	106.10	121.64	126.95	142.31	153.10
29.12.1995	666.98	792.04	1159.60	219.21	458.37	107.25	124.91	132.15	156.13	153.90
29.3.1996	681.25	834.55	1218.77	228.48	484.80	109.83	125.36	131.00	146.86	155.50
28.6.1996	682.07	872.01	1279.74	235.59	501.04	112.34	126.65	131.57	146.83	156.70
30.9.1996	695.65	898.97	1284.07	238.06	480.62	115.30	128.65	133.39	148.87	157.70
31.12.1996	738.57	973.90	1350.87	248.15	476.31	118.31	131.08	136.65	155.59	159.10
31.3.1997	759.91	1000.00	1281.02	250.63	514.61	121.07	131.92	136.31	150.74	159.80
30.6.1997	783.62	1174.59	1488.68	288.15	554.12	124.49	134.83	140.22	158.91	160.20
30.9.1997	802.04	1262.56	1710.24	294.98	502.05	128.70	137.50	144.27	168.01	161.20
31.12.1997	878.23	1298.82	1652.97	285.36	412.46	134.76	139.78	147.58	178.43	161.80
31.3.1998	897.90	1480.00	1819.23	324.89	436.02	140.34	141.87	150.04	181.64	162.00
30.6.1998	906.34	1528.87	1734.42	327.50	330.52	146.22	144.00	152.76	189.81	162.80
30.9.1998	912.69	1376.79	1385.01	287.32	254.87	151.28	148.51	161.06	205.04	163.50
31.12.1998	929.84	1670.01	1610.89	348.04	298.97	156.65	149.60	161.04	202.81	164.40
31.3.1999	943.23	1753.21	1523.51	361.82	334.75	160.70	150.50	160.20	194.08	164.80
30.6.1999	943.80	1876.78	1760.44	382.75	413.81	164.91	151.39	159.72	189.86	166.00
30.9.1999	967.02	1759.59	1649.13	376.57	391.07	169.55	153.30	161.51	188.90	167.80
31.12.1999	1031.42	2021.40	1953.31	441.47	489.42	174.45	154.07	160.84	184.82	168.80
31.3.2000	1048.34	2067.76	2091.68	446.60	499.40	178.64	156.00	163.63	199.85	171.00

30.6.2000	1055.67	2012.83	2012.62	430.00	445.52	184.08	158.68	166.66	201.95	172.20
29.9.2000	1081.75	1993.33	2034.87	406.62	386.03	189.50	162.17	170.81	207.12	173.60
29.12.2000	1076.88	1837.37	1894.30	379.86	333.79	195.81	166.59	177.97	222.26	174.60
30.3.2001	1082.16	1619.54	1771.07	332.68	313.14	200.43	171.22	183.61	225.70	176.10
29.6.2001	1082.70	1714.32	2024.12	342.12	322.89	205.38	173.13	183.81	220.35	177.70
28.9.2001	1091.79	1462.69	1603.32	291.91	251.40	208.66	179.05	193.76	235.55	178.10
31.12.2001	1020.39	1618.98	1941.39	319.41	317.40	210.06	180.49	193.22	231.48	177.40
29.3.2002	1025.90	1623.43	2018.73	322.31	351.43	213.23	180.33	192.23	227.41	178.50
28.6.2002	1027.23	1405.94	1850.12	293.47	319.75	216.67	184.75	200.59	241.31	179.60
30.9.2002	1032.37	1163.04	1454.19	239.99	266.11	220.54	189.27	213.14	270.19	180.80
31.12.2002	1039.60	1261.18	1543.73	258.80	292.09	224.23	190.95	214.65	270.54	181.80
31.3.2003	1045.94	1221.46	1474.39	245.91	272.27	228.44	192.27	216.93	274.67	183.90
30.6.2003	1063.41	1409.48	1819.76	288.90	332.68	233.22	193.82	220.88	288.24	183.10
30.9.2003	1078.83	1446.77	1984.95	304.25	377.63	237.81	194.63	220.58	280.31	185.10
31.12.2003	1119.28	1622.94	2273.20	348.43	442.78	244.38	194.91	219.79	277.26	185.50
31.3.2004	1142.11	1650.42	2415.52	359.02	482.06	250.63	196.86	225.58	291.92	187.10
30.6.2004	1151.94	1678.83	2426.93	360.88	432.20	258.48	194.80	219.33	277.51	188.90
30.9.2004	1174.63	1647.48	2357.60	359.11	464.15	267.32	196.56	224.49	294.18	189.80
31.12.2004	1244.64	1799.55	2689.86	403.32	542.17	279.77	196.61	224.38	298.37	191.70
31.3.2005	1267.17	1760.89	2546.25	399.87	548.69	289.59	196.07	221.66	300.05	192.90
30.6.2005	1314.05	1784.99	2656.19	403.13	565.17	305.06	198.31	227.09	323.79	193.60
30.9.2005	1326.53	1849.33	2780.80	434.31	661.32	318.60	198.41	225.14	313.50	198.80
30.12.2005	1485.45	1887.94	2812.35	449.19	706.48	335.90	199.72	225.96	317.09	198.20
31.3.2006	1519.77	1967.38	3204.37	481.01	787.80	348.06	200.48	224.83	305.60	199.60
30.6.2006	1572.81	1939.03	3043.37	478.07	747.54	362.02	201.77	225.40	301.83	201.90
29.9.2006	1586.18	2048.89	3056.75	500.07	778.17	374.73	205.73	232.22	321.41	202.90
29.12.2006	1688.64	2186.13	3328.90	545.90	912.65	391.63	207.58	233.93	322.91	203.30
30.3.2007	1720.05	2200.12	3393.70	560.00	929.03	405.80	210.52	237.95	326.58	205.10
29.6.2007	1759.79	2338.25	3543.53	601.55	1059.69	424.43	212.03	237.54	320.29	207.25
28.9.2007	1828.42	2385.72	3433.95	623.03	1204.90	439.54	217.51	246.63	335.70	208.51
31.12.2007	1999.92	2306.23	3276.77	612.41	1245.59	453.65	222.90	257.03	355.56	211.68
31.3.2008	2089.92	2088.42	2952.45	556.22	1104.58	460.91	229.77	270.10	370.37	213.30
30.6.2008	2111.03	2031.47	2969.68	548.65	1087.12	463.49	227.49	262.88	361.63	217.40

A2.2 Cumulative Returns

The data that was used to draw the cumulative return chart in figure 4.2 is provided below. These time series were calculated from the original time series in A2.1.

CUMULATIVE RETURNS OF INVESTMENT CLASSES

	Timber	Large cap US stocks	Small cap US stocks	Global stocks	Emerging market stocks	US Real estate	Short-term govt bonds	Medium- term govt bonds	Long term govt bonds
30.3.1990	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
29.6.1990	3.06%	6.29%	3.79%	8.33%	18.85%	1.52%	1.26%	1.50%	2.00%

28.9.1990	4.52%	-8.32%	-21.60%	-11.22%	-2.41%	2.37%	2.54%	3.02%	4.04%
31.12.1990	8.18%	-0.10%	-17.63%	-2.61%	-6.41%	0.91%	3.83%	4.57%	6.12%
29.3.1991	9.97%	14.41%	6.86%	7.40%	20.41%	0.96%	5.14%	6.14%	8.24%
28.6.1991	16.23%	14.15%	5.17%	4.14%	24.98%	0.97%	6.46%	7.73%	10.41%
30.9.1991	19.11%	20.25%	13.77%	11.65%	28.30%	0.64%	7.80%	9.34%	12.62%
31.12.1991	30.11%	30.34%	20.30%	16.78%	45.97%	-4.73%	9.16%	10.98%	14.87%
31.3.1992	32.31%	27.04%	29.31%	8.25%	75.17%	-4.76%	9.19%	9.34%	17.17%
30.6.1992	43.34%	29.46%	20.46%	9.85%	54.42%	-5.74%	12.34%	14.34%	22.05%
30.9.1992	46.04%	33.54%	23.93%	11.71%	48.63%	-6.15%	15.71%	20.28%	29.89%
31.12.1992	78.66%	40.27%	42.44%	11.84%	59.18%	-8.79%	15.96%	19.33%	31.22%
31.3.1993	82.10%	46.39%	48.53%	21.47%	67.45%	-8.09%	18.28%	23.96%	38.63%
30.6.1993	113.74%	47.11%	51.79%	29.13%	79.34%	-8.31%	19.59%	26.52%	46.20%
30.9.1993	116.01%	50.91%	65.06%	35.74%	105.95%	-7.30%	21.28%	29.38%	55.16%
31.12.1993	118.62%	54.40%	69.34%	39.66%	172.60%	-7.53%	22.19%	29.69%	53.78%
31.3.1994	124.02%	48.55%	64.83%	40.18%	147.26%	-6.32%	21.62%	26.89%	45.76%
30.6.1994	130.72%	49.17%	58.38%	44.14%	142.19%	-4.88%	21.67%	25.78%	41.46%
30.9.1994	134.14%	56.47%	69.38%	48.99%	191.78%	-3.44%	22.84%	26.54%	40.63%
30.12.1994	152.40%	56.44%	66.25%	46.68%	148.97%	-1.62%	22.85%	26.01%	43.46%
31.3.1995	159.42%	71.68%	73.92%	51.89%	117.24%	0.45%	26.99%	32.03%	52.60%
30.6.1995	170.41%	88.06%	90.23%	59.18%	138.25%	2.54%	30.97%	39.08%	69.58%
29.9.1995	172.77%	103.01%	109.02%	67.72%	135.74%	4.65%	32.79%	40.90%	72.98%
29.12.1995	187.33%	115.23%	113.55%	75.23%	131.68%	5.79%	36.35%	46.67%	89.78%
29.3.1996	193.48%	126.78%	124.44%	82.64%	145.03%	8.33%	36.84%	45.39%	78.51%
28.6.1996	193.83%	136.96%	135.67%	88.32%	153.24%	10.81%	38.25%	46.03%	78.48%
30.9.1996	199.68%	144.29%	136.47%	90.30%	142.92%	13.73%	40.43%	48.04%	80.96%
31.12.1996	218.17%	164.65%	148.77%	98.36%	140.74%	16.70%	43.08%	51.66%	89.12%
31.3.1997	227.37%	171.74%	135.91%	100.35%	160.10%	19.43%	44.01%	51.28%	83.23%
30.6.1997	237.58%	219.19%	174.15%	130.33%	180.07%	22.79%	47.18%	55.63%	93.15%
30.9.1997	245.51%	243.09%	214.95%	135.79%	153.75%	26.94%	50.10%	60.12%	104.22%
31.12.1997	278.34%	252.95%	204.40%	128.10%	108.47%	32.92%	52.58%	63.80%	116.89%
31.3.1998	286.81%	302.18%	235.02%	159.70%	120.38%	38.43%	54.86%	66.52%	120.78%
30.6.1998	290.45%	315.46%	219.40%	161.79%	67.06%	44.23%	57.19%	69.54%	130.71%
30.9.1998	293.18%	274.13%	155.06%	129.67%	28.82%	49.22%	62.11%	78.75%	149.23%
31.12.1998	300.57%	353.81%	196.65%	178.21%	51.11%	54.51%	63.31%	78.73%	146.51%
31.3.1999	306.34%	376.42%	180.56%	189.22%	69.19%	58.52%	64.28%	77.80%	135.90%
30.6.1999	306.59%	410.00%	224.19%	205.95%	109.15%	62.67%	65.25%	77.27%	130.78%
30.9.1999	316.59%	378.16%	203.70%	201.01%	97.66%	67.24%	67.35%	79.25%	129.61%
31.12.1999	344.33%	449.30%	259.71%	252.90%	147.37%	72.07%	68.18%	78.50%	124.66%
31.3.2000	351.62%	461.90%	285.19%	257.00%	152.41%	76.20%	70.29%	81.61%	142.91%
30.6.2000	354.78%	446.97%	270.63%	243.73%	125.18%	81.58%	73.21%	84.97%	145.47%
29.9.2000	366.01%	441.67%	274.73%	225.04%	95.11%	86.92%	77.03%	89.57%	151.75%
29.12.2000	363.92%	399.29%	248.85%	203.64%	68.71%	93.14%	81.85%	97.51%	170.16%
30.3.2001	366.19%	340.10%	226.15%	165.93%	58.27%	97.70%	86.90%	103.78%	174.34%
29.6.2001	366.42%	365.85%	272.75%	173.48%	63.20%	102.58%	88.99%	104.00%	167.84%
28.9.2001	370.34%	297.48%	195.26%	133.34%	27.07%	105.82%	95.45%	115.05%	186.31%
31.12.2001	339.58%	339.95%	257.52%	155.33%	60.42%	107.20%	97.02%	114.44%	181.36%
29.3.2002	341.95%	341.16%	271.76%	157.64%	77.62%	110.33%	96.85%	113.35%	176.42%
28.6.2002	342.53%	282.05%	240.71%	134.59%	61.61%	113.72%	101.67%	122.62%	193.32%
30.9.2002	344.74%	216.05%	167.80%	91.83%	34.50%	117.54%	106.61%	136.55%	228.42%
31.12.2002	347.85%	242.72%	184.29%	106.87%	47.63%	121.18%	108.45%	138.23%	228.85%
31.3.2003	350.59%	231.92%	171.52%	96.57%	37.61%	125.33%	109.89%	140.76%	233.86%
30.6.2003	358.11%	283.02%	235.12%	130.93%	68.15%	130.04%	111.58%	145.14%	250.36%

30.9.2003	364.75%	293.15%	265.54%	143.21%	90.87%	134.57%	112.46%	144.81%	240.72%
31.12.2003	382.18%	341.02%	318.62%	178.52%	123.80%	141.05%	112.77%	143.93%	237.01%
31.3.2004	392.02%	348.49%	344.83%	186.98%	143.65%	147.22%	114.89%	150.36%	254.83%
30.6.2004	396.25%	356.21%	346.93%	188.48%	118.45%	154.96%	112.64%	143.42%	237.32%
30.9.2004	406.03%	347.69%	334.16%	187.06%	134.60%	163.68%	114.56%	149.14%	257.58%
31.12.2004	436.18%	389.01%	395.35%	222.40%	174.03%	175.97%	114.62%	149.03%	262.67%
31.3.2005	445.89%	378.51%	368.91%	219.64%	177.33%	185.65%	114.04%	146.01%	264.71%
30.6.2005	466.09%	385.06%	389.15%	222.24%	185.66%	200.91%	116.47%	152.04%	293.57%
30.9.2005	471.47%	402.54%	412.10%	247.17%	234.25%	214.27%	116.59%	149.87%	281.06%
30.12.2005	539.93%	413.03%	417.91%	259.07%	257.08%	231.33%	118.02%	150.78%	285.43%
31.3.2006	554.71%	434.62%	490.10%	284.50%	298.18%	243.32%	118.85%	149.53%	271.47%
30.6.2006	577.56%	426.92%	460.45%	282.15%	277.83%	257.09%	120.25%	150.15%	266.88%
29.9.2006	583.32%	456.77%	462.92%	299.74%	293.31%	269.63%	124.58%	157.73%	290.68%
29.12.2006	627.46%	494.06%	513.03%	336.37%	361.28%	286.30%	126.60%	159.63%	292.50%
30.3.2007	640.99%	497.87%	524.97%	347.64%	369.56%	300.28%	129.80%	164.09%	296.96%
29.6.2007	658.11%	535.40%	552.56%	380.85%	435.60%	318.65%	131.46%	163.64%	289.31%
28.9.2007	687.67%	548.30%	532.38%	398.03%	509.00%	333.56%	137.44%	173.72%	308.05%
31.12.2007	761.56%	526.70%	503.43%	389.54%	529.56%	347.47%	143.32%	185.26%	332.19%
31.3.2008	800.33%	467.51%	443.71%	344.62%	458.29%	354.63%	150.82%	199.76%	350.19%
30.6.2008	809.42%	452.04%	446.88%	338.57%	449.47%	357.18%	148.32%	191.76%	339.56%

A2.3 Quarterly Returns

Quarterly returns of all asset classes included in the study are provided below. The expected annual returns and the variance-covariance matrix, which are used to determine the portfolio frontiers, are calculated from these data series. The quarterly returns are calculated as the percentage changes between quarters in the indices from A2.1.

QUARTERLY RETURNS OF INVESTMENT CLASSES

	Timber	Large cap US stocks	Small cap US stocks	Global stocks	Emerging market stocks	US Real estate	Short-term govt bonds	Medium- term govt bonds	Long term govt bonds	Inflation
30.3.1990	2.66%	-3.01%	-2.24%	-14.24%	-7.85%	1.38%	1.26%	1.50%	2.00%	1.82%
29.6.1990	3.06%	6.29%	3.79%	8.33%	18.85%	1.52%	1.26%	1.50%	2.00%	1.01%
28.9.1990	1.42%	-13.74%	-24.46%	-18.04%	-17.88%	0.84%	1.26%	1.50%	2.00%	2.00%
31.12.1990	3.50%	8.96%	5.06%	9.69%	-4.11%	-1.43%	1.26%	1.50%	2.00%	1.28%
29.3.1991	1.65%	14.53%	29.73%	10.28%	28.66%	0.05%	1.26%	1.50%	2.00%	0.45%
28.6.1991	5.70%	-0.23%	-1.59%	-3.04%	3.79%	0.01%	1.26%	1.50%	2.00%	0.89%
30.9.1991	2.47%	5.35%	8.18%	7.22%	2.66%	-0.33%	1.26%	1.50%	2.00%	0.74%
31.12.1991	9.24%	8.38%	5.74%	4.59%	13.77%	-5.33%	1.26%	1.50%	2.00%	0.88%
31.3.1992	1.69%	-2.53%	7.49%	-7.30%	20.01%	-0.03%	0.03%	-1.48%	2.00%	0.65%
30.6.1992	8.34%	1.90%	-6.84%	1.47%	-11.85%	-1.03%	2.88%	4.58%	4.17%	0.72%
30.9.1992	1.88%	3.15%	2.88%	1.69%	-3.75%	-0.44%	3.00%	5.19%	6.42%	0.71%

31.12.1992	22.34%	5.04%	14.94%	0.12%	7.09%	-2.81%	0.21%	-0.79%	1.03%	0.85%
31.3.1993	1.92%	4.37%	4.27%	8.62%	5.20%	0.77%	2.00%	3.88%	5.64%	0.70%
30.6.1993	17.38%	0.49%	2.19%	6.30%	7.10%	-0.24%	1.11%	2.07%	5.46%	0.70%
30.9.1993	1.06%	2.58%	8.75%	5.12%	14.84%	1.10%	1.41%	2.26%	6.13%	0.49%
31.12.1993	1.21%	2.32%	2.59%	2.89%	32.36%	-0.25%	0.75%	0.24%	-0.89%	0.90%
31.3.1994	2.47%	-3.79%	-2.66%	0.37%	-9.29%	1.31%	-0.46%	-2.16%	-5.22%	0.55%
30.6.1994	2.99%	0.42%	-3.91%	2.82%	-2.05%	1.54%	0.04%	-0.87%	-2.95%	0.54%
30.9.1994	1.48%	4.89%	6.95%	3.37%	20.47%	1.51%	0.97%	0.61%	-0.59%	0.95%
30.12.1994	7.80%	-0.02%	-1.85%	-1.55%	-14.67%	1.88%	0.01%	-0.42%	2.02%	0.54%
31.3.1995	2.78%	9.74%	4.62%	3.55%	-12.75%	2.11%	3.36%	4.78%	6.37%	0.73%
30.6.1995	4.24%	9.55%	9.38%	4.80%	9.67%	2.08%	3.14%	5.34%	11.13%	0.79%
29.9.1995	0.87%	7.95%	9.88%	5.36%	-1.05%	2.06%	1.38%	1.30%	2.00%	0.46%
29.12.1995	5.34%	6.02%	2.17%	4.48%	-1.72%	1.09%	2.68%	4.10%	9.71%	0.52%
29.3.1996	2.14%	5.37%	5.10%	4.23%	5.77%	2.40%	0.36%	-0.87%	-5.94%	1.04%
28.6.1996	0.12%	4.49%	5.00%	3.11%	3.35%	2.29%	1.03%	0.44%	-0.02%	0.77%
30.9.1996	1.99%	3.09%	0.34%	1.05%	-4.08%	2.63%	1.58%	1.38%	1.39%	0.64%
31.12.1996	6.17%	8.34%	5.20%	4.24%	-0.90%	2.61%	1.89%	2.44%	4.51%	0.89%
31.3.1997	2.89%	2.68%	-5.17%	1.00%	8.04%	2.34%	0.64%	-0.25%	-3.12%	0.44%
30.6.1997	3.12%	17.46%	16.21%	14.97%	7.68%	2.82%	2.20%	2.87%	5.42%	0.25%
30.9.1997	2.35%	7.49%	14.88%	2.37%	-9.40%	3.38%	1.98%	2.89%	5.73%	0.62%
31.12.1997	9.50%	2.87%	-3.35%	-3.26%	-17.84%	4.71%	1.66%	2.29%	6.21%	0.37%
31.3.1998	2.24%	13.95%	10.06%	13.85%	5.71%	4.14%	1.50%	1.66%	1.79%	0.12%
30.6.1998	0.94%	3.30%	-4.66%	0.81%	-24.20%	4.19%	1.50%	1.81%	4.50%	0.49%
30.9.1998	0.70%	-9.95%	-20.15%	-12.27%	-22.89%	3.46%	3.13%	5.43%	8.03%	0.43%
31.12.1998	1.88%	21.30%	16.31%	21.13%	17.30%	3.55%	0.74%	-0.01%	-1.09%	0.55%
31.3.1999	1.44%	4.98%	-5.42%	3.96%	11.97%	2.59%	0.60%	-0.52%	-4.30%	0.24%
30.6.1999	0.06%	7.05%	15.55%	5.78%	23.62%	2.62%	0.59%	-0.30%	-2.17%	0.73%
30.9.1999	2.46%	-6.24%	-6.32%	-1.62%	-5.50%	2.81%	1.26%	1.12%	-0.51%	1.08%
31.12.1999	6.66%	14.88%	18.44%	17.24%	25.15%	2.89%	0.50%	-0.41%	-2.16%	0.60%
31.3.2000	1.64%	2.29%	7.08%	1.16%	2.04%	2.40%	1.25%	1.74%	8.13%	1.30%
30.6.2000	0.70%	-2.66%	-3.78%	-3.72%	-10.79%	3.05%	1.72%	1.85%	1.05%	0.70%
29.9.2000	2.47%	-0.97%	1.11%	-5.44%	-13.35%	2.94%	2.20%	2.49%	2.56%	0.81%
29.12.2000	-0.45%	-7.82%	-6.91%	-6.58%	-13.53%	3.33%	2.73%	4.19%	7.31%	0.58%
30.3.2001	0.49%	-11.86%	-6.51%	-12.42%	-6.19%	2.36%	2.78%	3.17%	1.55%	0.86%
29.6.2001	0.05%	5.85%	14.29%	2.84%	3.11%	2.47%	1.12%	0.11%	-2.37%	0.91%
28.9.2001	0.84%	-14.68%	-20.79%	-14.68%	-22.14%	1.60%	3.42%	5.42%	6.90%	0.23%
31.12.2001	-6.54%	10.69%	21.09%	9.42%	26.25%	0.67%	0.80%	-0.28%	-1.73%	-0.39%
29.3.2002	0.54%	0.27%	3.98%	0.91%	10.72%	1.51%	-0.09%	-0.51%	-1.76%	0.62%
28.6.2002	0.13%	-13.40%	-8.35%	-8.95%	-9.01%	1.61%	2.45%	4.35%	6.11%	0.62%
30.9.2002	0.50%	-17.28%	-21.40%	-18.22%	-16.78%	1.79%	2.45%	6.26%	11.97%	0.67%
31.12.2002	0.70%	8.44%	6.16%	7.84%	9.76%	1.67%	0.89%	0.71%	0.13%	0.55%
31.3.2003	0.61%	-3.15%	-4.49%	-4.98%	-6.79%	1.88%	0.69%	1.06%	1.53%	1.16%
30.6.2003	1.67%	15.39%	23.42%	17.48%	22.19%	2.09%	0.80%	1.82%	4.94%	-0.44%
30.9.2003	1.45%	2.65%	9.08%	5.31%	13.51%	1.97%	0.42%	-0.13%	-2.75%	1.09%
31.12.2003	3.75%	12.18%	14.52%	14.52%	17.25%	2.76%	0.14%	-0.36%	-1.09%	0.22%
31.3.2004	2.04%	1.69%	6.26%	3.04%	8.87%	2.56%	1.00%	2.63%	5.29%	0.86%
30.6.2004	0.86%	1.72%	0.47%	0.52%	-10.34%	3.13%	-1.05%	-2.77%	-4.93%	0.96%
30.9.2004	1.97%	-1.87%	-2.86%	-0.49%	7.39%	3.42%	0.90%	2.35%	6.01%	0.48%

31.12.2004	5.96%	9.23%	14.09%	12.31%	16.81%	4.66%	0.03%	-0.05%	1.42%	1.00%
31.3.2005	1.81%	-2.15%	-5.34%	-0.85%	1.20%	3.51%	-0.27%	-1.21%	0.56%	0.63%
30.6.2005	3.70%	1.37%	4.32%	0.81%	3.00%	5.34%	1.14%	2.45%	7.91%	0.36%
30.9.2005	0.95%	3.60%	4.69%	7.74%	17.01%	4.44%	0.05%	-0.86%	-3.18%	2.69%
30.12.2005	11.98%	2.09%	1.13%	3.43%	6.83%	5.43%	0.66%	0.37%	1.15%	-0.30%
31.3.2006	2.31%	4.21%	13.94%	7.08%	11.51%	3.62%	0.38%	-0.50%	-3.62%	0.71%
30.6.2006	3.49%	-1.44%	-5.02%	-0.61%	-5.11%	4.01%	0.64%	0.25%	-1.23%	1.15%
29.9.2006	0.85%	5.67%	0.44%	4.60%	4.10%	3.51%	1.97%	3.03%	6.49%	0.50%
29.12.2006	6.46%	6.70%	8.90%	9.16%	17.28%	4.51%	0.90%	0.74%	0.47%	0.20%
30.3.2007	1.86%	0.64%	1.95%	2.58%	1.79%	3.62%	1.41%	1.72%	1.13%	0.88%
29.6.2007	2.31%	6.28%	4.42%	7.42%	14.06%	4.59%	0.72%	-0.17%	-1.93%	1.05%
28.9.2007	3.90%	2.03%	-3.09%	3.57%	13.70%	3.56%	2.58%	3.82%	4.81%	0.61%
31.12.2007	9.38%	-3.33%	-4.58%	-1.70%	3.38%	3.21%	2.48%	4.22%	5.92%	1.52%
31.3.2008	4.50%	-9.44%	-9.90%	-9.18%	-11.32%	1.60%	3.08%	5.08%	4.16%	0.77%
30.6.2008	1.01%	-2.73%	0.58%	-1.36%	-1.58%	0.56%	-0.99%	-2.67%	-2.36%	1.92%

A2.4 Mean Returns and Standard Deviations

The mean return and standard deviation, both on a quarterly basis and an annualized basis, for all assets included in the study, are provided below. The annualized figures were used to construct the return VS volatility chart, figure 4.3, and to calculate the coefficient of variation (CV) in table 4.2. The annualized figures are determined from the quarterly figures.

Mean Return on Quarterly Basis

The mean return on a quarterly basis is the simple arithmetic mean of the quarterly returns in A2.3. Results are as follows:

RETURNS ON QUARTERLY BASIS

Asset class	Mean quarterly return
Timber	3.14%
Large cap US stocks	2.57%
Small cap US stocks	2.78%
Global stocks	2.11%
Emerging market stocks	3.06%
US Real estate	2.11%
Short-term govt bonds	1.26%
Medium-term govt bonds	1.50%
Long term govt bonds	2.12%
Inflation	0.74%

Mean Return on Annualized Basis

The average annualized return for each asset class from 1990 – 1998 is calculated from the average quarterly return here above by compounding. Results are as follows:

RETURNS ON ANNUALIZED BASIS

Asset class	Mean annualized return
Timber	13.15%
Large cap US stocks	10.67%
Small cap US stocks	11.61%
Global stocks	8.71%
Emerging market stocks	12.80%
US Real estate	8.71%
Short-term govt bonds	5.13%
Medium-term govt bonds	6.13%
Long term govt bonds	8.77%
Inflation	2.98%

Standard Deviation of Quarterly Returns

The standard deviation of quarterly returns for each asset class is obtained from the variance-covariance matrix of quarterly returns. The variance-covariance matrix was calculated using Microsoft Excel.⁵⁷ The matrix is as follows:

⁵⁷ The “Covariance” tool under “Data Analysis” was used to determine the variance-covariance matrix.

VARIANCE-COVARIANCE MATRIX OF QUARTERLY RETURNS

	<i>Timber</i>	<i>Large cap US stocks</i>	<i>Small cap US stocks</i>	<i>Global stocks</i>	<i>Emerging market stocks</i>	<i>US Real estate</i>	<i>Short-term govt bonds</i>	<i>Medium- term govt bonds</i>	<i>Long term govt bonds</i>
Timber	0,154%								
Large cap US stocks	0,028%	0,545%							
Small cap US stocks	0,019%	0,626%	0,983%						
Global stocks	0,025%	0,528%	0,623%	0,600%					
Emerging market stocks	0,001%	0,590%	0,931%	0,689%	1,703%				
US Real estate	-0,017%	0,002%	-0,010%	0,011%	-0,022%	0,033%			
Short-term govt bonds	-0,001%	-0,017%	-0,032%	-0,024%	-0,054%	-0,001%	0,010%		
Medium- term govt bonds	0,001%	-0,043%	-0,073%	-0,052%	-0,110%	-0,001%	0,020%	0,042%	
Long term govt bonds	0,019%	-0,061%	-0,094%	-0,085%	-0,181%	-0,002%	0,030%	0,070%	0,157%

The diagonal elements in the matrix are the variances of quarterly returns for each asset class. The off-diagonal elements are the covariances between quarterly returns of different assets. Thus, in order to find the standard deviation of quarterly returns, it suffices to take the square root of the diagonal elements. Results are as follows:

STANDARD DEVIATION OF QUARTERLY RETURNS

Asset class	Standard Deviation of Quarterly Returns
Timber	3.93%
Large cap US stocks	7.38%
Small cap US stocks	9.92%
Global stocks	7.75%
Emerging market stocks	13.05%
US Real estate	1.81%
Short-term govt bonds	1.02%
Medium-term govt bonds	2.05%
Long term govt bonds	3.96%
Inflation	0.48%

Standard Deviation of Annualized Returns

The standard deviation of annualized returns is obtained from the variance-covariance matrix of annualized returns. This is found by multiplying the elements in the variance-covariance matrix of quarterly returns by a factor of four, as there are four quarters in one year. The matrix is as follows:

VARIANCE-COVARIANCE MATRIX OF ANNUALIZED RETURNS

	<i>Timber</i>	<i>Large cap US stocks</i>	<i>Small cap US stocks</i>	<i>Global stocks</i>	<i>Emerging market stocks</i>	<i>US Real estate</i>	<i>Short-term govt bonds</i>	<i>Medium- term govt bonds</i>	<i>Long term govt bonds</i>
Timber	0,617%								
Large cap US stocks	0,111%	2,181%							
Small cap US stocks	0,074%	2,505%	3,934%						
Global stocks	0,101%	2,112%	2,493%	2,401%					
Emerging market stocks	0,003%	2,358%	3,726%	2,756%	6,812%				
US Real estate	-0,066%	0,009%	-0,041%	0,045%	-0,088%	0,132%			
Short-term govt bonds	-0,004%	-0,068%	-0,130%	-0,097%	-0,217%	-0,003%	0,041%		
Medium- term govt bonds	0,003%	-0,173%	-0,292%	-0,209%	-0,441%	-0,005%	0,079%	0,168%	
Long term govt bonds	0,078%	-0,245%	-0,377%	-0,339%	-0,724%	-0,006%	0,120%	0,281%	0,628%

As before, the diagonal elements in the matrix are the variances of returns of each asset class, this time on an annualized basis. The standard deviation of annual returns may therefore be found by taking the square root of the diagonal elements. The results are as follows:

STANDARD DEVIATION OF ANNULIZED RETURNS

Asset class	Standard Deviation of Annualized Returns
Timber	7.86%
Large cap US stocks	14.77%
Small cap US stocks	19.83%
Global stocks	15.50%
Emerging market stocks	26.10%
US Real estate	3.63%
Short-term govt bonds	2.03%
Medium-term govt bonds	4.10%
Long term govt bonds	7.93%
Inflation	0.96%

A2.5 Sharpe Ratio

The Sharpe ratios in figure 4.4 were calculated on the basis of the annualized mean returns and standard deviation (A2.4) as well as the risk-free rate, 4.5%, which is the average LIBOR USD 3 Month from 1990-2008. The results of these calculations are provided below.

SHARPE RATIOS

Asset class	Return	Standard deviation	Risk-free rate	Sharpe ratio
Global stocks	8.71%	15.50%	4.50%	0.27
Short-term govt bonds	5.13%	2.03%	4.50%	0.31
Emerging market stocks	12.80%	26.10%	4.50%	0.32
Small cap US stocks	11.61%	19.83%	4.50%	0.36
Medium-term govt bonds	6.13%	4.10%	4.50%	0.40
Large cap US stocks	10.67%	14.77%	4.50%	0.42
Long term govt bonds	8.77%	7.93%	4.50%	0.54
Timber	13.15%	7.86%	4.50%	1.10
US Real estate	8.71%	3.63%	4.50%	1.16

A2.6 Portfolio Frontiers

The data points used to construct the portfolio frontiers in section 4.2 (figures 4.6, 4.7, 4.8 and 4.9) are provided in this section. Inflation and the risk-free rate are not included in the set of available assets when the frontiers are constructed.

As discussed in sections 4.1 and 4.2, the first step of the selection model is to find estimates for the expected returns of each asset class as well the variance-covariance matrix, both on an annualized basis. These estimates are provided in A2.4 here above. The next step of the selection model is to construct the portfolio frontier by mathematically minimizing variance for various fixed return targets by changing the weights of each asset class, w_i .

For a given return target, the portfolio variance is a function of the vector of expected returns of the individual assets, the variance-covariance matrix and the vector of weights. For each return target, the variance – and thus the standard deviation – is minimized by changing the weights. This minimization procedure was carried out in Microsoft Excel.⁵⁸

For all different scenarios, the constraint that the weights sum to one is imposed; this implies that all funds are invested. When short sales are not permitted, the additional constraint that all weights must be greater than or equal to zero is imposed. Finally, when maximum exposure to timber assets is capped at 20%, the additional constraint that the weight allocated to timber may be no greater than 20% is imposed.

Readers who require further instructions on how to construct the portfolio frontier may want to consider additional literature.⁵⁹

⁵⁸ The “Solver” tool was used..

⁵⁹ See for example Bodie, Kane & Marcus (2005) or Hirschey & Nofsinger (2008). Both works provide instructions on how to construct portfolio frontiers using spreadsheet software.

Frontier incl. timber, no short sales and no limit on timber allocations:

Return	Risk	Return	Risk
5,140%	2,019%	9,200%	2,341%
5,150%	2,001%	9,250%	2,366%
5,200%	1,925%	9,300%	2,391%
5,250%	1,864%	9,400%	2,443%
5,300%	1,819%	9,500%	2,496%
5,400%	1,760%	9,600%	2,551%
5,500%	1,709%	9,700%	2,608%
5,600%	1,664%	9,800%	2,666%
5,700%	1,626%	9,900%	2,725%
5,800%	1,595%	10,000%	2,786%
5,900%	1,567%	10,100%	2,849%
6,000%	1,541%	10,200%	2,923%
6,100%	1,519%	10,300%	3,009%
6,200%	1,500%	10,400%	3,104%
6,300%	1,484%	10,500%	3,210%
6,400%	1,472%	10,600%	3,324%
6,500%	1,464%	10,700%	3,445%
6,600%	1,459%	10,800%	3,574%
6,700%	1,459%	10,900%	3,708%
6,800%	1,462%	11,000%	3,848%
6,900%	1,469%	11,100%	3,994%
7,000%	1,480%	11,200%	4,143%
7,100%	1,495%	11,300%	4,297%
7,200%	1,513%	11,400%	4,454%
7,300%	1,534%	11,500%	4,615%
7,400%	1,559%	11,600%	4,778%
7,500%	1,587%	11,700%	4,944%
7,600%	1,619%	11,800%	5,114%
7,700%	1,653%	11,900%	5,286%
7,800%	1,689%	12,000%	5,461%
7,900%	1,728%	12,100%	5,637%
8,000%	1,770%	12,200%	5,816%
8,100%	1,813%	12,300%	5,997%
8,200%	1,859%	12,400%	6,179%
8,300%	1,905%	12,500%	6,363%
8,400%	1,952%	12,600%	6,548%
8,500%	2,000%	12,700%	6,735%
8,600%	2,048%	12,800%	6,922%
8,700%	2,096%	12,900%	7,111%
8,800%	2,144%	13,000%	7,301%
8,900%	2,193%	13,050%	7,396%
9,000%	2,242%	13,100%	7,491%
9,100%	2,292%	13,140%	7,751%

Frontier excl. timber, no short sales and no limit on timber allocations:

Return	Risk	Return	Risk
5,140%	2,019%	9,000%	3,076%
5,150%	2,001%	9,100%	3,227%
5,200%	1,924%	9,200%	3,480%
5,250%	1,864%	9,300%	3,815%
5,300%	1,819%	9,400%	4,211%
5,400%	1,760%	9,500%	4,654%
5,500%	1,709%	9,600%	5,132%
5,600%	1,664%	9,700%	5,635%
5,700%	1,626%	9,800%	6,157%
5,800%	1,595%	9,900%	6,694%
5,900%	1,571%	10,000%	7,243%
6,000%	1,554%	10,100%	7,800%
6,100%	1,545%	10,200%	8,365%
6,200%	1,544%	10,300%	8,936%
6,300%	1,552%	10,400%	9,512%
6,400%	1,569%	10,500%	10,092%
6,500%	1,593%	10,600%	10,677%
6,600%	1,626%	10,700%	11,278%
6,700%	1,665%	10,800%	11,891%
6,800%	1,711%	10,900%	12,517%
6,900%	1,760%	11,000%	13,152%
7,000%	1,811%	11,100%	13,796%
7,100%	1,863%	11,200%	14,447%
7,200%	1,918%	11,300%	15,104%
7,300%	1,974%	11,400%	15,768%
7,400%	2,031%	11,500%	16,436%
7,500%	2,090%	11,600%	17,109%
7,600%	2,150%	11,700%	17,786%
7,700%	2,211%	11,800%	18,468%
7,800%	2,273%	11,900%	19,152%
7,900%	2,336%	12,000%	19,840%
8,000%	2,399%	12,100%	20,531%
8,100%	2,464%	12,200%	21,224%
8,200%	2,529%	12,300%	21,919%
8,300%	2,595%	12,400%	22,627%
8,400%	2,662%	12,500%	23,404%
8,500%	2,729%	12,600%	24,253%
8,600%	2,796%	12,600%	24,253%
8,700%	2,863%	12,700%	25,165%
8,800%	2,932%	12,750%	25,643%
8,900%	3,002%	12,790%	26,036%

Frontier incl. timber, short sales permitted and no limit on timber allocations:

Return	Risk	Return	Risk
0,000%	2,541%	13,000%	3,924%
0,500%	2,318%	13,500%	4,157%
1,000%	2,100%	14,000%	4,390%
1,500%	1,887%	14,500%	4,624%
2,000%	1,680%	15,000%	4,858%
2,500%	1,483%	15,500%	5,093%
3,000%	1,299%	16,000%	5,328%
3,500%	1,137%	16,500%	5,563%
4,000%	1,005%	17,000%	5,799%
4,500%	0,918%	17,500%	6,035%
5,000%	0,887%	18,000%	6,271%
5,500%	0,920%	18,500%	6,507%
6,000%	1,010%	19,000%	6,744%
6,500%	1,143%	19,500%	6,980%
7,000%	1,307%	20,000%	7,217%
7,500%	1,491%	20,500%	7,454%
8,000%	1,689%	21,000%	7,691%
8,500%	1,896%	21,500%	7,928%
9,000%	2,109%	22,000%	8,165%
9,500%	2,328%	22,500%	8,402%
10,000%	2,550%	23,000%	8,639%
10,500%	2,775%	23,500%	8,877%
11,000%	3,002%	24,000%	9,114%
11,500%	3,231%	24,500%	9,351%
12,000%	3,461%	25,000%	9,589%
12,500%	3,692%		

Frontier excl. timber, short sales permitted and no limit on timber allocations:

Return	Risk	Return	Risk
0,000%	3,090%	13,000%	5,295%
0,500%	2,791%	13,500%	5,605%
1,000%	2,497%	14,000%	5,915%
1,500%	2,207%	14,500%	6,225%
2,000%	1,926%	15,000%	6,536%
2,500%	1,656%	15,500%	6,848%
3,000%	1,404%	16,000%	7,159%
3,500%	1,183%	16,500%	7,471%
4,000%	1,013%	17,000%	7,783%
4,500%	0,921%	17,500%	8,095%
5,000%	0,932%	18,000%	8,407%
5,500%	1,042%	18,500%	8,719%
6,000%	1,225%	19,000%	9,032%
6,500%	1,454%	19,500%	9,344%
7,000%	1,710%	20,000%	9,657%
7,500%	1,983%	20,500%	9,970%
8,000%	2,266%	21,000%	10,283%
8,500%	2,557%	21,500%	10,596%
9,000%	2,852%	22,000%	10,909%
9,500%	3,152%	22,500%	11,222%
10,000%	3,454%	23,000%	11,535%
10,500%	3,757%	23,500%	11,848%
11,000%	4,063%	24,000%	12,161%
11,500%	4,370%	24,500%	12,475%
12,000%	4,677%	25,000%	12,788%
12,500%	4,986%		

Frontier incl. timber, no short sales and 20% limit on timber allocations:

Return	Risk	Return	Risk
5,140%	2,019%	9,000%	2,243%
5,150%	2,001%	9,100%	2,294%
5,200%	1,924%	9,200%	2,347%
5,300%	1,819%	9,300%	2,401%
5,400%	1,760%	9,400%	2,459%
5,500%	1,709%	9,500%	2,519%
5,600%	1,664%	9,600%	2,582%
5,700%	1,626%	9,700%	2,647%
5,800%	1,595%	9,800%	2,716%
5,900%	1,567%	9,900%	2,866%
6,000%	1,541%	10,000%	3,129%
6,100%	1,519%	10,100%	3,482%
6,200%	1,500%	10,200%	3,898%
6,300%	1,484%	10,300%	4,359%
6,400%	1,472%	10,400%	4,854%
6,500%	1,464%	10,500%	5,373%
6,600%	1,459%	10,600%	5,909%
6,700%	1,459%	10,700%	6,458%
6,800%	1,462%	10,800%	7,017%
6,900%	1,469%	10,900%	7,583%
7,000%	1,480%	11,000%	8,157%
7,100%	1,495%	11,100%	8,734%
7,200%	1,513%	11,200%	9,318%
7,300%	1,534%	11,300%	9,917%
7,400%	1,559%	11,400%	10,532%
7,500%	1,587%	11,500%	11,159%
7,600%	1,619%	11,600%	11,797%
7,700%	1,653%	11,700%	12,445%
7,800%	1,689%	11,800%	13,100%
7,900%	1,728%	11,900%	13,763%
8,000%	1,770%	12,000%	14,432%
8,100%	1,813%	12,100%	15,106%
8,200%	1,859%	12,200%	15,786%
8,300%	1,905%	12,300%	16,469%
8,400%	1,952%	12,400%	17,156%
8,500%	2,000%	12,500%	17,847%
8,600%	2,048%	12,600%	18,577%
8,700%	2,096%	12,700%	19,399%
8,800%	2,144%	12,800%	20,303%
8,900%	2,193%		

Frontier excl. timber, no short sales and 20% limit on timber allocations:

Return	Risk	Return	Risk
5,140%	2,019%	9,000%	3,076%
5,150%	2,001%	9,100%	3,227%
5,200%	1,924%	9,200%	3,480%
5,250%	1,864%	9,300%	3,815%
5,300%	1,819%	9,400%	4,211%
5,400%	1,760%	9,500%	4,654%
5,500%	1,709%	9,600%	5,132%
5,600%	1,664%	9,700%	5,635%
5,700%	1,626%	9,800%	6,157%
5,800%	1,595%	9,900%	6,694%
5,900%	1,571%	10,000%	7,243%
6,000%	1,554%	10,100%	7,800%
6,100%	1,545%	10,200%	8,365%
6,200%	1,544%	10,300%	8,936%
6,300%	1,552%	10,400%	9,512%
6,400%	1,569%	10,500%	10,092%
6,500%	1,593%	10,600%	10,677%
6,600%	1,626%	10,700%	11,278%
6,700%	1,665%	10,800%	11,891%
6,800%	1,711%	10,900%	12,517%
6,900%	1,760%	11,000%	13,152%
7,000%	1,811%	11,100%	13,796%
7,100%	1,863%	11,200%	14,447%
7,200%	1,918%	11,300%	15,104%
7,300%	1,974%	11,400%	15,768%
7,400%	2,031%	11,500%	16,436%
7,500%	2,090%	11,600%	17,109%
7,600%	2,150%	11,700%	17,786%
7,700%	2,211%	11,800%	18,468%
7,800%	2,273%	11,900%	19,152%
7,900%	2,336%	12,000%	19,840%
8,000%	2,399%	12,100%	20,531%
8,100%	2,464%	12,200%	21,224%
8,200%	2,529%	12,300%	21,919%
8,300%	2,595%	12,400%	22,627%
8,400%	2,662%	12,500%	23,404%
8,500%	2,729%	12,600%	24,253%
8,600%	2,796%	12,600%	24,253%
8,700%	2,863%	12,700%	25,165%
8,800%	2,932%	12,750%	25,643%
8,900%	3,002%	12,790%	26,036%

Frontier incl. timber, short sales permitted and 20% limit on timber allocations:

Return	Risk	Return	Risk
0,000%	2,541%	13,000%	4,234%
0,500%	2,318%	13,500%	4,527%
1,000%	2,100%	14,000%	4,823%
1,500%	1,887%	14,500%	5,122%
2,000%	1,680%	15,000%	5,422%
2,500%	1,483%	15,500%	5,723%
3,000%	1,299%	16,000%	6,026%
3,500%	1,137%	16,500%	6,330%
4,000%	1,005%	17,000%	6,635%
4,500%	0,918%	17,500%	6,941%
5,000%	0,887%	18,000%	7,247%
5,500%	0,920%	18,500%	7,555%
6,000%	1,010%	19,000%	7,862%
6,500%	1,143%	19,500%	8,170%
7,000%	1,307%	20,000%	8,479%
7,500%	1,491%	20,500%	8,788%
8,000%	1,689%	21,000%	9,097%
8,500%	1,896%	21,500%	9,407%
9,000%	2,109%	22,000%	9,717%
9,500%	2,333%	22,500%	10,027%
10,000%	2,576%	23,000%	10,338%
10,500%	2,833%	23,500%	10,648%
11,000%	3,100%	24,000%	10,959%
11,500%	3,375%	24,500%	11,270%
12,000%	3,657%	25,000%	11,581%
12,500%	3,943%		

Frontier excl. timber, short sales permitted and 20% limit on timber allocations:

Return	Risk	Return	Risk
0,000%	3,090%	13,000%	5,295%
0,500%	2,791%	13,500%	5,605%
1,000%	2,497%	14,000%	5,915%
1,500%	2,207%	14,500%	6,225%
2,000%	1,926%	15,000%	6,536%
2,500%	1,656%	15,500%	6,848%
3,000%	1,404%	16,000%	7,159%
3,500%	1,183%	16,500%	7,471%
4,000%	1,013%	17,000%	7,783%
4,500%	0,921%	17,500%	8,095%
5,000%	0,932%	18,000%	8,407%
5,500%	1,042%	18,500%	8,719%
6,000%	1,225%	19,000%	9,032%
6,500%	1,454%	19,500%	9,344%
7,000%	1,710%	20,000%	9,657%
7,500%	1,983%	20,500%	9,970%
8,000%	2,266%	21,000%	10,283%
8,500%	2,557%	21,500%	10,596%
9,000%	2,852%	22,000%	10,909%
9,500%	3,152%	22,500%	11,222%
10,000%	3,454%	23,000%	11,535%
10,500%	3,757%	23,500%	11,848%
11,000%	4,063%	24,000%	12,161%
11,500%	4,370%	24,500%	12,475%
12,000%	4,677%	25,000%	12,788%
12,500%	4,986%		

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