Properties of Timberland Returns

Fabian Leinfelder
fabian.leinfelder@gmail.com

Zacharias Sjöberg
zacharias.sjoberg@gmail.com

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"For some people, money does grow on trees."

— Jeff D. Opdyke, *WSJ*

Abstract

Assumptions and proxies underlying the return composition of timberland investments have created a divergence of findings in academics' and practitioners' research alike. This paper removes the necessity for these assumptions by including price estimates from timberland property brokers in a complete Swedish dataset (1951-2011) and suggests that the previous proxies bare little resemblance of actual timberland returns. An alternative proxy is proposed. The obtained timberland returns provide evidence of low market exposure and poor inflation hedge characteristics independent of market regimes. Furthermore, timberland returns increase when sell side liquidity deteriorates suggesting the existence of a liquidity premium. Focusing on the direct returns, predictability is identified but deemed too weak to provide fruitful forecasts. Finally, a regional Swedish dataset (1991-2011) suggests that there is market segmentation within Swedish timberland and portfolio improvements to be made by including regional timberland in a broader investment portfolio comprised of stocks and real estate.

Acknowledgements

We are grateful to our supervisor Paolo Sodini, Professor of Finance at the Stockholm School of Economics, for supporting us throughout the work, and to Jonas Jacobsson, Partner at Greengold, for providing essential practical insights into the field of timberland investments. Furthermore, we would like to thank Sveriges Statistiska Centralbyrå, the Swedish Forestry Agency and Gunnar Rutegård, Forest Economist at Lantmäteriet, for providing us with rich data and fruitful recommendations. We sincerely hope that the paper can be of academic and practical use for all of you.

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1 Introduction

The markets for institutional timberland investments have matured remarkably throughout the past years mainly due to its several favorable portfolio characteristics. While North America, Australia, and New Zealand remain the most significant regions for forestry investments constituting up to 90% of the timberland investment activity, the asset class is expected to expand largely in the semi-mature forestry markets of Latin America, Asia, Africa and Europe (Brand (2011)). With an annual net felling of approximately 70 million m^3 in 2015 (9.6% of total net felling in Europe), Sweden is the second largest producer of timber in Europe after Russia. While globalization is shifting the pulp and paper industry (including both production and consumption) from Europe to tropical regions and emerging economies, e.g. China, India and Brazil, the growing demand for woody biomass from the bioenergy sector in Europe is expected to offset this shift. Due to increasing orientation towards value-added products instead of timber as a commodity, the outlook for the sawmill industry is forecasted to remain stable (UNECE (2011)).

Despite the industry's popularity and stable outlook, timberland investments lack extensive research from investors' perspective - scarcity of statistical data is the main explanation. The papers covering financial performance and characteristics of timberland investments are mainly conducted in North America, leaving Europe and Sweden with large potential for new findings. North American studies primarily focus on the diversification benefits of timberland and its property as an inflation hedge. Hence, this paper examines and expands these topics for the Swedish market of timberland. An updated method and a dataset free of assumptions are employed. The composition of the return series is based on the general formula for composition of financial return (Ibbotson & Sinquefield (1976)) decomposing the total return into the dividend component and the capital gain component, i.e. direct return and capital return (see Section 2.2). The formula is expanded by splitting the two components into variables representing biological growth, harvest, profit per harvested volume and price development of the underlying property. Previous research estimates capital returns using proxies, which requires strong assumptions and potentially creates divergence from the actual capital returns of timberland. Instead, this paper employs timberland broker estimates to efficiently capture the price development of timberland properties, thus providing a realistic capital return series for the Swedish market. This new return series, subsequently referred to as *broker*, is initially compared to the return series obtained using previously established methods, subsequently referred to as *traditional*, to evaluate the validity of the underlying assumptions. Following the comparison of the different return composition methods, the properties of the broker return series are examined in detail. Since the performed analyses in this second part of the paper solely employ broker direct-, capital- and total returns, the term *broker* is omitted to avoid excessive labeling. Seven hypotheses are developed.

Hypothesis 1 *To what extent is the broker return series statistically different from the traditional return series?*

> **Hypothesis 1a** *How do the expected returns and variances vary among the different composition methods?*
>
> **Hypothesis 1b** *To what degree do the different returns series correlate with each other?*
>
> **Hypothesis 1c** *How much variation in the broker return series can be explained by the traditional return series, i.e.* R^2 *and* β*?*
>
> **Hypothesis 1d** *Can the capital return component of traditional return series be improved?*
>
> **Hypothesis 1e** *Does the broker return composition mitigate the return smoothening due to data persistence identified in previous literature?*

Previous research suggests that timberland investments have low market exposure, thus providing additional diversification benefits when added to an investment portfolio. This is examined both in an unconditional setting as well as under different market regimes. An analysis of conditional correlation examines if the correlation structure changes in the event of negative or positive tail realizations. This is identified for other asset classes by e.g. Campbell et al. (2002) and Longin & Solnik (2001).

Hypothesis 2 *Timberland investments have low market betas and are exempted from increased correlation in bear markets.*

Building upon Hypothesis 2, the paper further investigates the properties of the return series. Like most real assets, timberland investments are illiquid due to the usually extensive process of finding and matching buyers and sellers. To compensate for that liquidity risk, investors in timberland should require higher returns.

Hypothesis 3 *Timberland investments contain a liquidity premium in excess of the market risk exposure.*

Investments in timberland are widely perceived as inflation protection as return from the sale of harvested timber (used for construction, furnishing, paper, biomass fuel) and the value change of the property in previous research is assumed to track timber prices and thus also the Consumer Price Index. However, with price changes of timberland properties (capital returns) being a main driver of total returns, the asset class' quality as an inflation hedge is questionable.

Hypothesis 4 *Timberland is a poor inflation hedge.*

Forecasting direct returns potentially provides relevant information for developing optimized harvesting policies.

Hypothesis 5 *There is predictability in timberland direct returns.*

Regional timberland returns of the three regions Norrland, Svealand and Götaland are analyzed to determine if there is segmentation in the market of Swedish timberland.

Hypothesis 6 *The market of timberland is geographically segmented as regions provide different risk-adjusted returns.*

Ultimately, a mean-variance optimized portfolio of the three regions (included in a broader investment universe) is compared to that of the national series in order to evaluate potential improvements in risk-adjusted returns.

Hypothesis 7 *A mean-variance optimizing investor allocates more capital to timberland when regional investments are considered.*

2 Related Literature

2.1 Alternative Investments

Alternative investments have gradually increased during the past decades as private and institutional investors expand their investment universe to improve risk-adjusted returns. In theory, adding an asset with low correlation to traditional asset classes reduces dependence on traditional marketable securities providing a positive effect on the risk return trade-off (Getmansky et al. (2004)). Alternative asset classes include real assets, private equity and absolute return, commonly referred to as the hedge fund approach (Swensen (2009)). In contrast to traditional asset classes, which depend on market-generated returns, alternatives require active management. Furthermore, the alternative assets partly lack pricing efficiency and easily accessible markets (Swensen (2009)). These two characteristics are accompanied by additional caveats increasing the uncertainty of the assets; (1) Alternative investments usually provide short historical time series impeding quantitative analysis even for the simplest quantitative measures. The issue is further augmented in cases of low liquidity. (2) Alternative investments include features not captured in the traditional mean-variance analysis. These features, for instance, include event risk, illiquidity and seasonality. The caveats often lead to smoothened and/or phased return series, neglecting possible volatility between available data points. Getmansky et al. (2004) illustrates this issue by examining how illiquidity in the hedge fund market results in return smoothening. He finds that the return smoothening erroneously lowers the volatility of illiquid funds thus overestimating their Sharpe Ratios. The paper further illustrates spurious serial correlation within the examined return series, resulting in biased market beta estimates as well as correlation structures. Adjusting for the serial correlation, the most illiquid funds, e.g. within emerging market debt and fixed income arbitrage, tend to have less attractive characteristics.

2.2 Timberland Investments

Timberland is categorized as a real asset within the alternative asset spectrum (Swensen (2009)). In this paper, a timberland investment is defined as the ownership of forestry land property and the trees standing on it (Binkley & de Bever (2005)). The asset is held directly in the form of real estate or via a special purpose vehicle, which is more common in North America. Several studies investigate timberland investments, mainly in North America, and detect numerous beneficial characteristics. In his book, Zinkhan et al. (1992) states that investments in timberland reduce volatility of an institutional investment portfolio. Furthermore, he suggests that timberland investments are particularly attractive to investors with long-term investment horizons and illustrates that timberland yields remarkably high returns in relation to its relatively low risk. Aside from that, Graham (1985) describes timberland investments as an inflation-hedge closely tracking the Consumer Price Indices, whereas Mills & Hoover (1982) promotes timberland as a way of portfolio diversification. A potential reason for the observed low or negative correlation to traditional asset classes is due to timberland's biological growth. This growth is unique for the asset class (Zinkhan et al. (1992)) and allows for delay of harvest when timber prices are disadvantageous. Instead of causing elevated storage costs, trees grow naturally and increase in volume and value. As two downsides, Swensen (2009) names required active management and illiquidity. However, these can be mitigated through partnerships among timberland owners and the employment of asset managers specialized in timberland investments (Zinkhan et al. (1992)). As the majority of timberland-related research is conducted in North America, the Swedish market bears ample potential for new country-specific and general findings.

2.2.1 Traditional Compositions of Timberland Returns

The return composition, based on the underlying valuation of timberland, is critical for reliable conclusions. Due to the long-term investment horizon, illiquidity and lack of transparency in timberland investments, methods and associated assumptions regarding the compilation of data varies among research studies. Most methods for composing the return series, however, are built upon the general formula for composition of returns from financial securities (Ibbotson & Sinquefield (1976)).

General composition of financial return:

$$r_t = \frac{D_t + A_t}{A_{t-1}} - 1 = \frac{D_t}{A_{t-1}} + \frac{A_t}{A_{t-1}} - 1 = d_t + c_t$$

Where:

D_t = Dividend

A_t = Price of Underlying Asset

r_t = Total Return (%)

d_t = Dividend or Direct Return (%)

c_t = Capital Gain or Capital Return (%)

The direct return and capital return components are split as to incorporate available data points. Thomson (1987) introduces a method to estimate timberland returns using stumpage prices (assuming constant forest growth), subsequently referred to as the *Stumpage Price Method*. Stumpage price is the price of the right to harvest a standing volume of timber. The method decomposes total returns into the dividend return component $P_tH - C$ and the capital gain component P_tG as follows:

$$r_t = \frac{P_tG + P_tH - C}{P_{t-1}G} - 1$$

Where:

r = Timberland Return

H = Volume Harvested

P = Stumpage Price

C = Annual Cost of Managing Forest

G = Annual Growth

Redmond & Cubbage (1988) and Thomson & Baumgartner (1988) also employ stumpage prices as a proxy for capital returns. Researchers further develop this simple method by multiplying the standing volume with current stumpage prices to estimate the capital return component (Washburn & Binkley (1989)). This method, however, assumes that the bare land value moves in line with the growing stock, which eventually is driven by stumpage price development. Sun & Zhang (2001) concludes that solely stumpage prices are a poor proxy for timberland performance since they are neglecting a major source of return, i.e. actual price changes of timberland property. Furthermore, Penttinen & Lausti (2004) question the role of stumpage prices as proxy by referring to Klemperer et al. (1996) who shows that forest properties often trade below total felling values. Despite mentioned flaws, this method is commonly used due to data availability.

Another method built upon the traditional return composition assumes that capital return is driven by both the value of bare farmland and the value of standing timber (valued using stumpage prices) Mills & Hoover (1982). This method is subsequently referred to as *Farmland Property Method*. The authors use a framework suitable for investments in multiple timberland species:

$$r_t = \sum X_s \frac{P_{t+1,s}((1 - M_{ts})\nu_{ts} + G_{ts}(1 - I_{ts})(1 - M_{ts})) - P_{ts}\nu_{ts} + \Delta L_{t+1} - C_t}{P_t\nu_t + L_t}$$

Where:

r = Total Return

X = Proportional Amount of Each Species per Acre

P = Stumpage Price

M = Mortality of Species

I = Growth Loss of Species

G = Expected Growth of Species

ν = Volume of Growing Stock

L = Land Value Based on Average Value for Farmland Real Estate

C = Expenses

However, when examining timberland consisting of only one species and redefining growth as $G_n = G - M - I$, the complex formula is simplified:

$$\begin{aligned} r_t &= \frac{P_{t+1}(\nu_t + G_{nt}) - P_t\nu_t + \Delta L_{t+1} - C_t}{P_t\nu_t + L_t} \\ &= \frac{\Delta P_{t+1}\nu_t + P_{t+1}G_{nt} + \Delta L_{t+1} - C_t}{P_t\nu_t + L_t} \end{aligned}$$

The simplified formula shows that the returns are in fact constructed from three individual components:

1. Changes in stumpage prices multiplied by standing volume at the start of the year (subtracting maintenance costs)

2. Value of this year's growth

3. Changes in prices of farmland property

The model does not assume any dividend return from harvesting. However, it is implicitly included in the standing volume, or expected growth, and could easily be separated out if necessary. The approach thus explicitly assumes that the capital return of timberland is directly linked to the development in farmland property adjusted for changes in value of standing timber volume.

The two presented methods both depend on implicit or explicit assumptions regarding the price development of timberland property (capital returns). The assumptions are caused by scarce data availability and/or low quality of data. Washburn & Binkley (1989) show that the two different approaches lead to substantially different mean returns and standard deviations impeding significant conclusions. The authors further discuss the fact that forestry data is measured in averages throughout time periods, e.g. 1-5 years. This applies to annual growth volume of timber since the annual development is difficult to estimate accurately. The data distortion induces serial dependencies in the composed timberland returns ultimately affecting statistical assumptions and the corresponding conclusions. The effects are in line with the findings of Getmansky et al. (2004), although the described distortion in this case is caused by difficulties of measurement rather than illiquidity.

2.2.2 Previous Findings

The first analysis of timberland in a portfolio optimized setting was published by Mills & Hoover (1982). Following their work, researchers examined the diversification effect both in North America as well as in other markets (Thomson (1987), Thomson & Baumgartner (1988), Redmond & Cubbage (1988)). Researchers further apply the regular CAPM and Sharpe's (1963) single-index market model to evaluate forestry performance. Two conclusions are apparent; (1) Returns of timberland display low correlation with many traditional asset classes and thus provide diversification benefits when added to an investment portfolio. (2) Timberland investments feature relatively low levels of financial risk suggesting that investors should require relatively low returns. However, differing return composition methods lead to alternating conclusions (Washburn & Binkley (1989)).

Caulfield (1998) provides evidence of illiquidity effects in institutional timberland funds but does not evaluate this further. To the best of our knowledge, the effect of illiquidity on timberland investments is so far not examined.

Penttinen & Lausti (2004) find that forest ownership in Finland produces a nominal return of 8.4% between 1972-2003, comprised of price change (4.6%), felling (3.1%) and change in standing volume (1.0%). Correlation is only significant with private housing. It is concluded that financial investments outperform investments in real assets during low inflation from 1987 to 2003 and that, unlike most American studies, forestry does not reduce portfolio risk. This is supported by their derived price change, which is 1.2% below inflation, suggesting that timberland is an inferior inflation hedge compared to nominal government bonds.

3 Data and Empirical Methodology

3.1 Data

3.1.1 Composition of Timberland Returns

This paper employs a return composition method built upon the classic formula for composition of financial return. Due to the availability of reliable sample data on Swedish timberland, strong assumptions necessary in the traditional methods can be abandoned.[1]

Recall the general composition of financial return:

$$r_t = \frac{D_t + A_t}{A_{t-1}} - 1 = \frac{D_t}{A_{t-1}} + \frac{A_t}{A_{t-1}} - 1 = d_t + c_t$$

The direct return component is constructed by multiplying harvested timber volume with the realized profit per volume unit of timber sold. The product is set in relation to the value of the underlying timberland, yielding the direct return from a timberland investment. In line with previous research, other sources of return, e.g. hunting leaseholds and renting space to telecom operators, are neglected throughout the analyses.

$$d_t = \frac{H_t}{\nu_{t-1}} * \frac{\pi_t}{V_{t-1}}$$

Where:

$H =$ Harvested Timber $[m^3]$

$\nu =$ Standing Volume $[m^3]$

$\pi =$ Profit $[SEK/m^3]$

$V =$ Value of Timberland Property $[SEK/m^3]$

The capital return consists of the residual growth of timber (not harvested)

[1] The return composition of timberland used in this paper is strongly inspired by a framework developed by practitioner Jonas Jacobsson, Partner at GreenGold

added to the standing volume, i.e. net standing growth, and the price changes of timberland property in nominal terms obtained from timberland broker estimates.

$$c_t = (1 + \frac{G_t - H_t}{\nu_{t-1}}) * (1 + \frac{\Delta V_t}{V_{t-1}}) - 1$$

Where:

G = Annual Growth $[m^3]$

As stated in Section 2.2, traditional methods apply a methodically similar composition but require implicit and explicit assumptions regarding the price development of timberland property. Thomson (1987) implicitly assumes that capital gains track changes in stumpage prices while Mills & Hoover (1982) assumes that capital returns track price changes of farmland property adjusted for standing timber value (see Table 1 for overview).

Table 1: Overview of Capital Return Assumptions

Paper	Method Denotation	Proxy for Capital Return
Thomson (1987)	Stumpage Price	Stumpage prices
Mills & Hoover (1982)	Farmland Property	Farmland property and stumpage prices
Leinfelder & Sjöberg (2016)	Broker	None (timberland broker estimates)

By introducing this simple but efficient return composition method and including timberland broker estimates (i.e. not estimated capital returns using proxies), this paper intends to mitigate methodological weaknesses as identified in Section 2.2 and shed light on more realistic properties of timberland investments.

3.1.2 Data Description

Sweden offers an outstanding degree of transparency within timberland investments by statistically tracking conditions and activities on an annual basis. The compiled dataset allows for analyses of several topics and mitigates ambiguities regarding data consistency and data compilation as discussed in Section 2.2. In accordance with the new return composition method, data of employed variables are sourced from the Swedish Forestry Agency ('SFA') and the Sveriges Statistiska Centralbyrå ('SCB'). The two governmental institutions publish an annual *Statistisk Årsbok* (engl. Statistical Yearbook) containing a specific sub-category on timberland and the forest industry. The data is compiled using all types of productive timberland and is representative for investments in timberland as defined in Section 2.2. The publication includes statistics of both timberland property and trees - unlike separate investments in trees only, e.g. timber deed or forestry right, or land only, e.g. timber lease. The SFA provides national as well regional data, i.e. Norrland, Svealand and Götaland, of annual forestry growth rates, gross felling and standing volume, denominated in m^3. Annual profits, denominated in SEK per m^3, are defined as net felling less logging costs, silvicultural costs including cleaning, scarification, planting and sowing, pre-commercial thinning, fertilization and investments in drainage and roads. Series of national profit is employed for both the national and regional return composition as the industry measures profits for timber at roadside, thus excluding transportation costs (Jacobsson (2016)). Annual prices of timberland property are sourced from Gunnar Rutegård, Forest Economist at *Lantmäteriet* (engl. Land Surveying Office). The data is based on semi-annual *Minienkäten* (engl. Short Surveys) estimations by timberland brokers on current price development of national and regional timberland. The obtained data stands in contrast to data used in previous academic research (see Section 2.2) and is perceived to represent price changes of timberland property more reliably among practitioners, e.g. financial institutions, investors and consultants within the industry. Inflation rates are based on the non-forestry related Swedish Consumer Price Index ('CIP') sourced from SCB. The time series of entire Sweden ranges from 1951 to 2011, whereas the regional data covers the time frame 1991–2011 due to the lack of reliable statistics.

Variable	Unit	Sweden | Regions	Source
Annual Growth	m^3	Yes | Yes	SFA
Annual Gross Felling	m^3	Yes | Yes	SFA
Standing Volume	m^3	Yes | Yes	SFA
Profit	SEK/m^3	Yes | -	SFA
Consumer Price Index	Index	Yes | -	SCB
Timberland Property Prices	SEK/m^3	Yes | Yes	Lantmäteriet

In order to compare the broker return series above with return series obtained using the two traditional methods, annual stumpage prices of timber, annual tax values of farmland property and annual price-to-taxation coefficients of forestry property are sourced from SFA and SCB (the latter two are sourced from merely physical documents). Stumpage prices are employed as a proxy to simulate comparable capital return series using the Stumpage Price Method. The Farmland Property Method (see Section 2.2.1) is composed of the derived performance of forestry property (using tax values and price-to-taxation coefficients) as well as the area of productive timberland, annual timber growth, gross felling and standing volume.

Variable	Unit	Sweden | Regions	Source
Stumpage Prices	SEK/m^3	Yes | -	SFA
Tax Values Farmland Property	SEK/ha	Yes | -	SCB
Tax Coefficients Forestry Property	%	Yes | -	SCB
Area	ha	Yes | -	SCB

Additional statistics on Swedish timberland and other asset classes are sourced from the subsequent sources. Transaction volumes of Swedish timberland property used for investigating illiquidity characteristics are derived from SCB data. An index of the Swedish stock market (1951-2011) is obtained from the OMX Affärsvärldens Generalindex, AFGX [2]. Annual traded volumes on the stock market, annual market capitalization and yields of Swedish government bonds are sourced from Waldenström (2014). Sveriges Riksbank provides annual price development of Swedish real estate overall, as well as of houses and apartments separately (Edvinsson et al. (2014)).

[2] http://bors.affarsvarlden.se/afvbors.sv/site/download/afv/AFGX.xls 2016-02-29

Variable	Unit	Sweden | Regions	Source
Transaction Vol. Forestry Property	SEK	Yes | -	SCB
Share Price Index	Index	Yes | -	OMX
Market Capitalization	SEK	Yes | -	Waldenström (2014)
Traded Share Volume	SEK	Yes | -	Waldenström (2014)
Yields of Government Bonds	%	Yes | -	Waldenström (2014)
Real Estate Prices	Index	Yes | -	Edvinsson et al. (2014)

Initial insight of characteristics and quality of the broker return series itself is provided by descriptive statistics. All national data points (see Table 2) show significant positive skewness and excess kurtosis whereas the same significance cannot be seen in the shorter regional series (see Table 3). Norrland displays the lowest raw standard deviation of total return among the regions (10.1%) while delivering the second highest raw mean (9.7%) suggesting attractive risk-adjusted returns. Interestingly, excess direct returns in both the national and regional data feature a negative mean suggesting that the annual cash return is lower than for a risk-free investment.

Table 2: Descriptive Statistics: National Return Series

This table presents summary statistics of annual broker direct returns ('DR'), broker capital returns ('CR') and broker total returns ('TR') for Sweden (national) - in both raw as well as excess returns. The sample period is 1951 - 2011.

	Raw Returns			Excess Returns		
	DR	**CR**	**TR**	**DR**	**CR**	**TR**
Mean (%)	3.42	8.79	12.21	-3.60	1.78	5.20
Standard Deviation (%)	2.29	11.53	12.26	4.46	11.71	12.50
Skewness	2.61	1.33	1.27	0.59	1.06	1.01
p-value	0.00	0.00	0.00	0.06	0.00	0.00
Excess kurtosis	8.00	3.98	3.62	0.72	3.27	2.81
p-value	0.00	0.00	0.00	0.25	0.00	0.00
Max (%)	14.38	58.37	64.03	11.08	50.20	55.86
Min (%)	1.05	-13.44	-11.39	-10.88	-23.35	-21.30

Table 3: Descriptive Statistics: Regional Return Series

This table presents summary statistics of annual broker direct returns ('DR'), broker capital returns ('CR') and broker total returns ('TR') for three regions in Sweden (regional) - in both raw as well as excess returns. The sample period is 1991 - 2011

Panel 1: Norrland

	Raw Returns			Excess Returns		
	DR	**CR**	**TR**	**DR**	**CR**	**TR**
Mean (%)	2.36	7.33	9.69	-2.90	2.07	4.43
Standard Deviation (%)	0.78	10.02	10.05	1.97	10.92	10.82
Skewness	0.85	0.09	0.05	-1.37	-0.14	-0.20
p-value	0.12	0.87	0.92	0.01	0.80	0.72
Excess kurtosis	-0.37	-0.25	-0.33	1.27	0.33	0.36
p-value	0.73	0.82	0.77	0.25	0.76	0.74
Max (%)	3.97	26.50	28.59	0.11	22.15	24.24
Min (%)	1.27	-14.48	-12.21	-7.71	-24.39	-22.12

Panel 2: Svealand

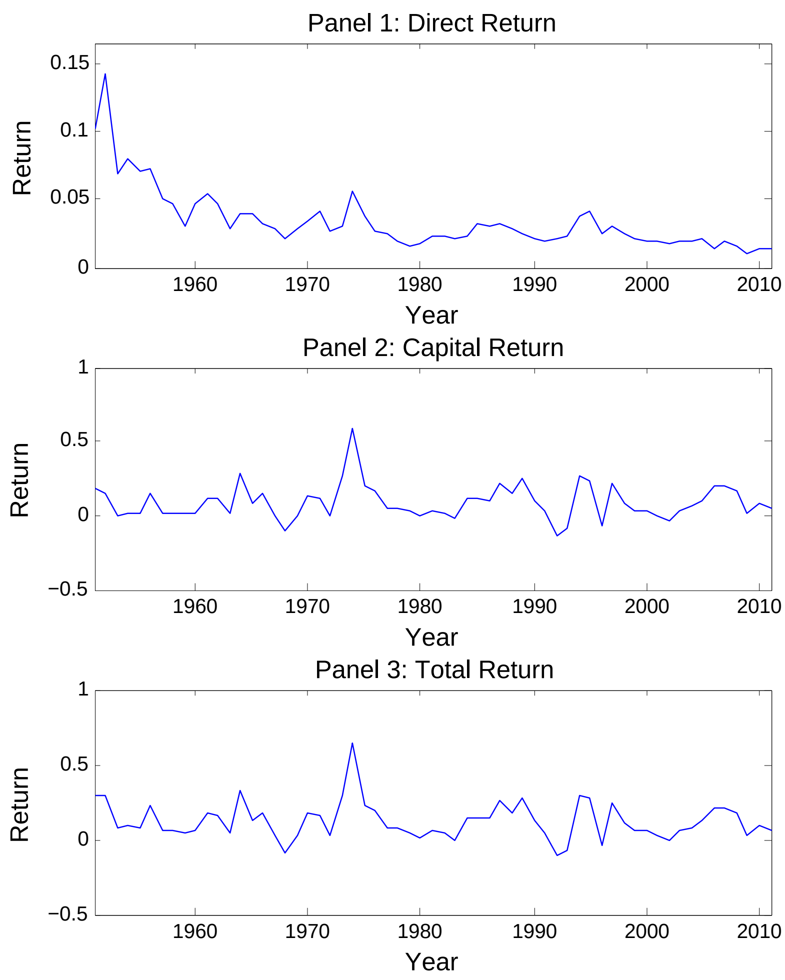
	Raw Returns			Excess Returns		
	DR	**CR**	**TR**	**DR**	**CR**	**TR**
Mean (%)	1.82	8.24	10.06	-3.44	2.97	4.80
Standard Deviation (%)	0.63	12.61	12.75	2.02	12.97	13.02
Skewness	0.75	0.15	0.22	-1.23	-0.25	-0.20
p-value	0.17	0.79	0.68	0.02	0.65	0.71
Excess kurtosis	-0.72	-0.65	-0.63	1.03	-0.29	-0.32
p-value	0.51	0.55	0.56	0.35	0.79	0.77
Max (%)	3.02	31.44	34.41	-0.30	26.43	27.86
Min (%)	0.94	-13.84	-12.41	-8.48	-23.75	-22.32

Panel 3: Götaland

	Raw Returns			Excess Returns		
	DR	**CR**	**TR**	**DR**	**CR**	**TR**
Mean (%)	2.02	7.43	9.45	-3.25	2.17	4.19
Standard Deviation (%)	0.58	11.14	11.37	2.04	11.33	11.47
Skewness	1.15	0.02	0.15	-0.88	-0.81	-0.69
p-value	0.04	0.98	0.79	0.11	0.14	0.21
Excess kurtosis	0.61	0.40	0.42	0.11	0.86	0.78
p-value	0.58	0.71	0.70	0.92	0.43	0.48
Max (%)	3.37	31.07	34.41	-0.25	20.32	23.52
Min (%)	1.34	-17.98	-15.92	-7.84	-27.89	25.83

Table 4: National Direct-, Capital- and Total Returns (1951-2011)

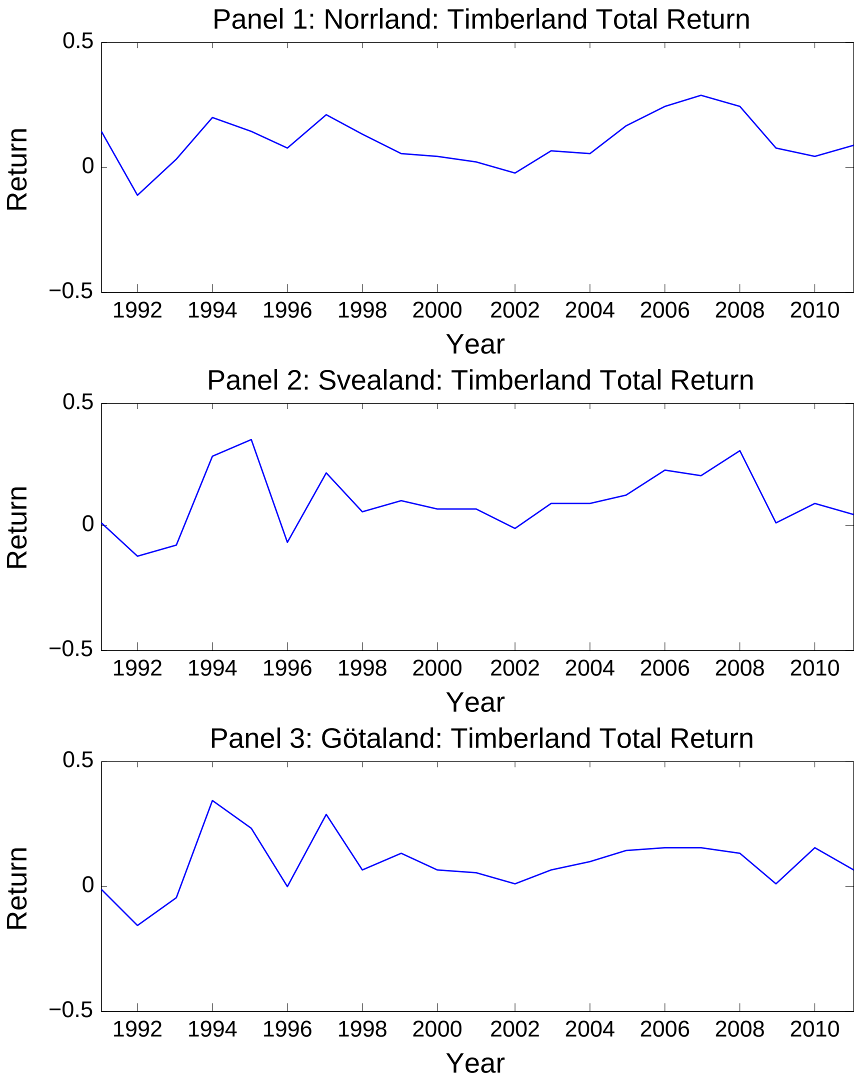
In the panels below, the broker direct return, broker capital return and broker total return are plotted. The sample uses the complete time series 1951 - 2011. All three series are plotted in annual returns.



As seen in Table 4, the total returns are mainly comprised of capital returns driven by price development of timberland property. This is also applies to the regional return series seen in Table 5. However, direct returns differ significantly between the three regions due to different levels of required initial investment to acquire the forest property.

Table 5: Regional Total Returns (1991-2011)

In the panels below, the regional broker total returns for Norrland, Svealand and Götaland are plotted. The shorter time series (1991-2011) are due to data availability. All three series are plotted in annual returns.



3.2 Empirical Methodology

3.2.1 Evaluation of Traditional Methods

Differences between the broker return series (see Section 3.1.1) and the series obtained using the traditional methods allow for an evaluation of the subsequent hypothesis and its sub-hypotheses:

Hypothesis 1 *To what extent is the broker return series statistically different from the traditional return series?*

The different proxies for capital returns (Stumpage Price and Farmland Property) are compared to broker capital returns.

Hypothesis 1a *How do the expected returns and variances vary among the different composition methods?*

Descriptive statistics of the three differently composed return series are prepared.

Hypothesis 1b *To what degree do the different returns series correlate with each other?*

Plain correlations between the three return series are evaluated.

Hypothesis 1c *How much variation in the broker return series can be explained by the traditional return series, i.e.* R^2 *and* β*?*

OLS linear regressions are employed as described below.

Regress:

$$\text{CR}_t = \alpha_i + \beta_i X_{it} + \varepsilon_{it}$$

Where:

CR = Broker Capital Return

X_1 = Capital Return Using Stumpage Price Method

X_2 = Capital Return Using Farmland Property Method

Hypothesis 1d *Can the capital return component of traditional return series be improved?*

An improved proxy for broker capital returns is developed by constructing a fixed-weight linear portfolio of tradable assets, subsequently referred to as *Clone Portfolio*. Broker capital returns *CR* are regressed on returns of the six factors: stumpage prices, Swedish apartments, Swedish houses, Swedish farmland properties, stocks and bonds. The intercept is omitted as the model aims to fully mimic the characteristics of the broker capital return series. Insignificant factors are then gradually removed from the regression until all remaining factors display significance.

Regress:

$$\begin{aligned}\text{CR}_t &= \beta_1 \text{Stumpage}_t + \beta_2 \text{Apartments}_t \\ &+ \beta_3 \text{Houses}_t + \beta_4 \text{Farmland}_t + \beta_5 \text{Stocks}_t \\ &+ \beta_6 \text{Bonds}_t + \varepsilon_t\end{aligned}$$

The significant factors are used as factors in a regression model fitted using the first half of the sample (1958-1980). The resulting $\hat{\beta}_i$s are then employed as weights in the Clone Portfolio and the obtained capital return series is scaled by a volatility factor γ_s defined as follows:

$$\gamma_s = \frac{\hat{\sigma}_{CR}}{\hat{\sigma}_{Clone}}$$

To determine the degree of the proxy's suitability, the resulting out-of-sample return series of the Clone Portfolio (i.e. 1981-2003) as well as capital returns of the Stumpage Price Method are separately set in relation to broker capital returns. A sum of squared residuals ('SSR') comparison is employed. The shorter time frame is due to limited data availability of the six factors.

Hypothesis 1e *Does the broker return composition mitigate the return smoothening due to data persistence identified in previous literature?*

To examine if the broker return series mitigates the caveat of return smoothening due to data persistence (see Section 2.2), the three broker return components, i.e. broker direct return, broker capital return and broker total return, are tested for stationarity. An Augmented Dickey-Fuller ('ADF') test is conducted to investigate the null hypothesis of a unit root. All three series are tested against a non-trending alternative. Stock prices are assumed to be an $I(1)$ process according to stylized facts. The three return series are subsequently controlled for autocorrelation using the Ljung-Box (1978) test. Lags are set to four in order to maximize the power of the test [ln(t) with t = 61]. Specifications for the ADF and Ljung-Box (1978) tests are seen in Appendix B.

3.2.2 Three-Factor Model

The following three hypotheses are evaluated using a three-factor model.

Hypothesis 2 *Timberland investments have low market betas and are exempted from increased correlation in bear markets.*

Hypothesis 3 *Timberland investments contain a liquidity premium in excess of the market risk exposure.*

Hypothesis 4 *Timberland is a poor inflation hedge.*

The constructed multi-factor model regresses the excess total returns of timberland, i.e. difference between annual total returns of timberland and risk

-free rate, on incrementally added explanatory variables including market excess returns, i.e. difference between annual stock market returns and risk-free rate, changes in traded volume of timberland transactions in relation to the entire monetary volume of timberland, i.e. timberland market capitalization, and inflation.

Regress:

(1) $r_t - r_{ft} = \alpha_t + \beta(r_{mt} - r_{ft}) + \epsilon_t$

(2) $r_t - r_{ft} = \alpha_t + \beta_1(r_{mt} - r_{ft}) + \beta_2(\Delta\text{Liq}_t) + \epsilon_t$

(3) $r_t - r_{ft} = \alpha_t + \beta_1(r_{mt} - r_{ft}) + \beta_2(\Delta\text{Liq}_t) + \beta_3(I_t) + \epsilon_t$

Where:

r_t = Total Return of Timberland (%)

r_{mt} = Annual Return of Stock Market (%)

r_{ft} = Risk Free Rate (%)

Liq_t = Traded Timberland Volume over Timberland Market Capitalization

I_t = Inflation (%)

ϵ_t = Error term $\sim$ i.i.d., $E(\epsilon_t) = 0$ and $Cov(\epsilon_t, \epsilon_{t-s}) = 0 \; \forall \; t$

The paper then analyzes **Hypothesis 2 and 4** by looking at the correlation structure between total returns of timberland and stock returns as well as total timberland returns and inflation.

Conditional Correlation:

$$\text{Conditional Correlation} = \begin{cases} \text{Corr}(r_t, y_t \,|\, y_t > Q_{50\%,60\%,70\%,80\%,90\%}) \\ \\ \text{Corr}(r_t, y_t \,|\, y_t < Q_{50\%,40\%,30\%,20\%,10\%}) \end{cases}$$

Estimated for the following two pairs:

$$r_t = \text{Total Timberland Return} \qquad y_t = \text{Stock Return}$$

$$r_t = \text{Total Timberland Return} \qquad y_t = \text{Inflation}$$

3.2.3 Serial Correlation in Direct Returns

Hypothesis 5 *There is predictability in timberland direct returns.*

To evaluate if forest managers successfully allocate harvest to periods of high profits per m^3, an OLS linear regression of the harvest ratio on profit from sold timber is applied.

Regress:

$$\frac{H_t}{S_{t-1} + G_t} = \alpha + \beta \pi_t + \varepsilon_t$$

Where:

H = Harvested Timber $[m^3]$

S = Standing Volume $[m^3]$

G = Annual Growth $[m^3]$

π = Profit [thousand SEK/m^3]

The profit/investment component of the direct return series (defined as $\frac{\pi_t}{V_{t-1}}$ in Section 3.1.1) is controlled for autocorrelation using the Ljung-Box (1978) test with lags set to four. Consequently, an Auto Regressive Moving Average ('ARMA') model is annually fitted using a rolling twenty-year fitting period of $t-1$ to $t-20$. The specified ARMA-model is then used for one-period forecasts of the component. The most parsimonious ARMA-model specification valid for the entire forecast period is employed.

ARMA(p,q):

$$X_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

Where:

$p =$ Number of Autoregressive Terms

$q =$ Number of Moving Average Terms

The one-period out-of-sample forecasts of the ARMA-model are estimated for 31 years and compared to the naive estimator $E(\frac{\pi_{t+1}}{V_t}) = \frac{\pi_t}{V_{t-1}}$ in order to examine the degree of viability.

3.2.4 Market Segmentation and Portfolio Allocation

Hypothesis 6 *The market of timberland is geographically segmented as regions provide different risk-adjusted returns.*

Hypothesis 7 *A mean-variance optimizing investor allocates more capital to timberland when regional investments are considered.*

In order to investigate the different statistical properties of the regional return series, total returns of timberland in the regions Norrland, Svealand and Götaland, are regressed on the national total return series. The results of the regressions enable initial conclusions on segmentation within the Swedish market of timberland and pave the way for further analyses of market efficiency and the potential skew in capital allocation among regions.

Regress:

$$TR_{i,t} = \alpha_i + \beta_i TR_{Sweden,t} + \varepsilon_{i,t}$$

Where:

$TR_1 = $ Norrland

$TR_2 = $ Svealand

$TR_3 = $ Götaland

Consequently, three mean-variance optimization problems are addressed; (1) Portfolio consisting of stocks and real estate in Sweden, (2) Portfolio consisting of the national timberland, stocks and real estate in Sweden and (3) Portfolio consisting of regional timberland, stocks and real estate in Sweden.

Mean-Variance Portfolio Optimization:

$$\text{Mean-Variance Frontier} = \min_{w}(w^T \sum w)$$

Where:

$$w = \text{Portfolio Weights s.t.} \sum_{i=1}^{n} w_i = 1 \text{ and } w_i \geq 0 \; \forall \; i$$

The three mean-variance optimized portfolios reveal if timberland investments are included in the mean-variance optimized portfolio and which of the two tangency portfolios including timberland investments that generate the higher Sharpe Ratio. The weights of the individual assets in the three tangency portfolios are compared.

Sharpe Ratio:

$$\hat{\zeta}_i = \frac{\hat{\mu}_i}{\hat{\sigma}_i}$$

Where:

$\hat{\zeta}_i$ = Sample Sharpe Ratio

$\hat{\mu}_i$ = Mean Sample Excess Return

$\hat{\sigma}_i$ = Sample Standard Deviation

In his paper, Lo (2002) finds that the Sharpe Ratio follows an asymptotic normal distribution with standard deviation and confidence interval defined as below. This is especially convenient when examining timberland investments with its finite sample sizes. As the asymptotically normal assumption holds only for independent and identically distributed [IID] returns, this is controlled for using a Ljung-Box (1978) test. The Jarque-Bera test for normality is performed on the timberland return series to further justify the asymptotical normality assumption (test statistics are seen in Appendix D).

Standard error of Sharpe Ratio:

$$se \approx \sqrt{\frac{1 + \frac{\hat{\zeta}_i^2}{2}}{n}}$$

A $1 - \alpha$ confidence interval is thus approximated by (note the alteration in the denominator as $n - 1$ is proved to result in better small sample coverage for normal returns):

$$\hat{\zeta}_i \pm z_{\alpha/2} \sqrt{\frac{1 + \frac{\hat{\zeta}_i^2}{2}}{n - 1}}$$

Where $z_{\alpha/2}$ is the $\alpha/2$ quantile of the normal distribution. Results indicate if there is inefficient capital allocation in the Swedish market of timberland when timberland is included in a broader investment universe. The analysis of

Hypothesis 6 and 7 could also identify alternative preferences of non-institutional investors other than risk-adjusted returns, i.e. using forestland as hunting grounds or recreational areas.

4 Empirical Findings and Discussion

4.1 Properties of Timberland Returns

4.1.1 Statistical Comparison of Methods

Capital returns are identified as the main driver of total timberland returns (see Table 4), however, their composition varies between different methods. This renders the capital return composition fundamental for a reliable return series. For initial comparison, Table 6 depicts descriptive statistics of the different capital return methods. The broker capital returns show a expected return of 8.8% and a standard deviation of 11.5%. While the Stumpage Price Method understates the expected return (6.1%) and overstates standard deviation (15.3%), the Farmland Property Method understates both expected returns (7.2%) and standard deviation (9.5%).

Table 6: Descriptive Statistics: Capital Returns of Different Methods

This table presents descriptive statistics of broker capital returns ('B'), capital returns of the Stumpage Price Method ('SP') and the capital returns of the Farmland Property Method ('FP') - of raw as well as excess returns. Data ranges from 1951-2011.

	Raw Returns			Excess Returns		
	B	**SP**	**FP**	**B**	**SP**	**FP**
Mean (%)	8.79	6.14	7.15	1.78	-2.04	-1.03
Standard Deviation (%)	11.53	15.34	9.52	11.71	14.80	9.45
Skewness	1.33	0.95	0.83	1.06	0.95	0.70
p-value	0.00	0.01	0.02	0.00	0.01	0.05
Excess Kurtosis	3.98	1.02	0.96	3.27	1.38	0.49
p-value	0.00	0.16	0.18	0.00	0.06	0.50
Max (%)	58.37	55.80	34.23	50.20	47.63	25.08
Min (%)	-13.44	-17.78	-10.07	-23.35	-27.45	-17.31

Table 7 shows the correlation of the broker capital returns and the two traditional methods Stumpage Price and Farmland Property. A suitable (unsuitable) proxy for capital return should display high (low) correlation to the broker capital returns.

Table 7: Correlations: Capital Returns of Different Methods

The table contains correlations between the three capital return series; Broker, Stumpage Price and Farmland Property - of raw as well as excess returns.

	Raw Returns			Excess Returns		
	(1)	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
Broker (1)	1.00	-	-	1.00	-	-
Stumpage Price (2)	0.66	1.00	-	0.64	1.00	-
Farmland Property (3)	0.09	0.16	1.00	0.08	0.11	1.00

The low correlations between the broker capital returns and the two traditional capital returns suggest that neither stumpage prices nor farmland property are viable proxies for capital returns of timberland investments. As to further determine to what extent the two traditional methods explain the broker capital returns, results of the linear OLS regression of the broker capital returns on the capital returns using the Stumpage Price Method and the Farmland Property Method are summarized in Table 8.

Table 8: Regressions: Broker Capital Returns on Alternative Capital Returns

Linear regression of broker capital returns on capital returns of the Stumpage Price Method and the Farmland Property Method.

	Stumpage Price	**Farmland Property**
α	0.055	0.080
95% conf. int.	0.024 - 0.086	0.031 - 0.128
β_i	0.548	0.112
95% conf. int.	0.359 - 0.736	-0.294 - 0.518
R^2	0.445	0.007
F - stat	34.423	0.312
P - value	0.000	0.580
σ_ϵ^2	0.009	0.016

The capital returns obtained from the Stumpage Price Method explain 54.8% of the variations in the broker capital returns. The R^2-value of 44.5% depicts a relatively high goodness of fit. Thus, the Stumpage Price Model explains the variation of the broker capital returns to a higher degree outperforming the explanatory power of capital returns of Farmland Property (explaining 11.2% of the variations with an insignificant β and a low R^2 of 0.7%). Regression results in Table 8 support the results of the correlations in Table 7. However, neither of the two capital return proxies are deemed viable for estimating broker capital returns of timberland.

The regression of broker capital returns on the six factors, i.e. stumpage prices, Swedish apartments, Swedish houses, Swedish farmland properties, stocks and bonds, yields significant βs for stumpage prices and Swedish apartments. Similar dependence of timberland on private housing is identified in the Finnish timberland market by Penttinen & Lausti (2004). The βs used as constant weights in the Clone Portfolio are presented in Table 9.

Table 9: Regression: Broker Capital Returns on Factors of Clone Portfolio

The table shows the resulting significant βs from the linear regression of broker capital returns on returns of stumpage prices and Swedish apartments. The regression is fitted using the first 23 years (1958-1980) of the sample. The obtained β estimates are employed as weights in the Clone Portfolio. Hence, the remaining 23 years (1981-2003) are used for an evaluation of the weights in the Clone Portfolio out-of-sample.

	Estimates
$\beta_{Stumpage}$	0.596
$\beta_{Apartment}$	0.582

The volatility factor γ_s employed to scale the capital return series obtained from the portfolio of stumpage prices and apartments is calculated as follows:

$$\gamma_s = \frac{0.141}{0.111} = 1.268$$

The obtained γ_s is only observable in the Swedish market and considered a constant in case the methodology is applied to different geographic markets. Descriptive statistics for the period 1981-2003 of the broker capital returns, capital returns of the Stumpage Price Method and the Clone Portfolio (out-of-sample) are presented in Table 10. A visualization of the compete three capital return series is presented in Table 21 in Appendix A.

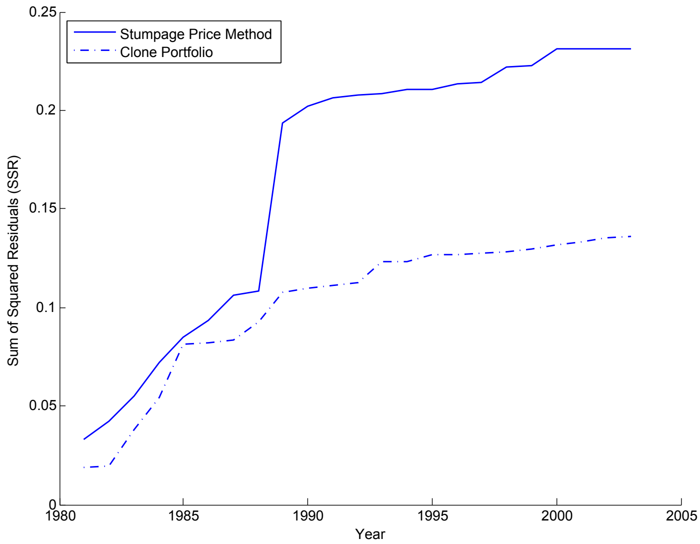
Table 10: Descriptive Statistics: Capital Returns of Broker, Stumpage Price and Clone Portfolio

	Broker	Stumpage Price	Clone Portfolio
Mean (%)	7.33	4.90	8.99
Standard Deviation (%)	11.21	12.36	12.89
Corr. w/ Broker	1.00	0.65	0.80
Sharpe Ratio	0.65	0.40	0.70
Skewness	0.14	0.37	-0.53
Excess Kurtosis	0.19	-0.15	0.76
Min (%)	-13.44	-12.38	-19.67
Max (%)	26.17	25.17	28.33

The Clone Portfolio displays a mean, correlation and Sharpe Ratio more in line with the broker capital returns than the capital returns obtained from the Stumpage Price Method. SSR performed to evaluate the two proxies is visualized in Table 11.

Table 11: Sum of Squared Residuals: Stumpage Price and Clone Portfolio

The graph shows cumulative SSR for the capital returns of the Stumpage Price Model and the Clone Portfolio. Squared residuals are defined as $(\hat{r}_{Proxy} - r_{Broker})^2$, where the r_{Proxy} is the capital return using Stumpage Prices Model or the capital returns of the Clone Portfolio (with weights fitted from 1958-1980) and r_{Broker} is the broker capital returns. Data ranges from 1981 - 2003.



The Clone Portfolio lowers the SSR by 41.3% compared to the Stumpage

Price Method. The improvement in the SSR suggests that the Clone Portfolio is a more suitable proxy for estimating timberland capital returns.

The low dependence between the analyzed capital return series examined in Hypothesis 1a - 1c justifies analysis of further statistical properties of the broker returns of timberland. Subsequently, it is examined whether the broker return series is exempted from return smoothening which is applicable to the two traditional methods (see Section 2.2). As broker return series are the only return series of timberland employed from here on, the denotation *broker* return series becomes redundant.

4.1.2 Stationarity

Direct return, capital return and total return are controlled for stationarity using an ADF test, with results shown in Table 12. All three series display stationarity, an important characteristic for evaluating serial dependencies within the data. The finding is in line with stylized facts as financial price series are assumed to be integrated at order one [I(1)].

Table 12: ADF Test of Direct-, Capital- and Total Returns

This table presents the key results of ADF-tests on direct return, capital return and total return for Sweden. The alternative hypothesis in all three cases does not include a time trend

Series	Test Statistic	P-value
Direct Return	-3.46	0.02
Capital Return	-5.46	0.00
Total Return	-5.50	0.00

4.1.3 Autocorrelation

Autocorrelation within the three return series is controlled for using a Ljung-Box (1978) test and the results are shown in Table 13.

Table 13: Ljung-Box Test of Direct-, Capital- and Total Returns

This table presents the key results of Ljung-Box (1978) test for autocorrelation in the three return series of Swedish timberland investments. The test follows the finite-sample correction of Box and Pierce (1970) which yields a better fit to the $\chi^2(m)$ for small sample sizes. Lags are set to four to maximize the power of the test (ln(t) = 4 for t = 61)

Series	H	P-value
Direct Return	1	0.00
Capital Return	0	0.08
Total Return	0	0.08

Table 13 depicts serial correlation within the direct return series, which is in line with the findings of Washburn & Binkley (1989). However, the capital return series as well as the total return series do not display any serial correlation. This conclusion suggests that the broker total return series has more suitable statistical properties than the return series compiled using the two traditional methods (caveats pointed out in Washburn & Binkley (1989) and discussed in Section 2.2). In turn, it allows for more robust statistical conclusions compared to previous literature.

4.1.4 Serial Correlation in Direct Returns

In Table 14, the results of the regression of the harvest ratio on profit reveal a small and insignificant β suggesting that forest managers unsuccessfully allocate harvest to periods of high profits.

Table 14: Regression: Harvest Ratio on Profit

The table shows the results of the linear regression of the harvest ratio on profit: $\frac{H_t}{S_{t-1}+G_t} = \alpha + \beta\pi_t + \varepsilon_t$, where H = Harvested timber, S = Standing volume of timber, G = Growth of timber and π = Profit per timber sold

	Profit
α	0.025
95% conf. int.	0.023 - 0.028
β_i	-0.005
95% conf. int.	-0.015 - 0.005
R^2	0.015
F - stat	0.882
P - value	0.351
σ^2_ϵ	0.000

However, serial correlation is identified within direct returns in Table 13 making the conclusion in Table 14 worthwhile. Looking closer into the direct return composition, there is apparent serial correlation in both harvest and in the profit/investments component, providing evidence of predictability. An ADF test using up to 20 lags and the Bayesian Information Criteria rejects a unit root on all reasonable significance levels. A parsimonious Auto Regressive Moving Average model ARMA(1,1) is fitted to the profit/investment component. The simple model is used as it allows for unbiased estimates of all the 31 one-period forecasts without requiring a change of model specifications. Each period, a new ARMA(1,1) model is estimated using a rolling historical time frame of 20 years. The complete out-of-sample forecast is seen in Table 15.

Table 15: ARMA (1,1) Model: Forecasts of Profit/Investment

The graph shows out-of-sample forecasts and actual realizations of the profit/investment component. The one-period forecasts are obtained from a rolling ARMA(1,1) fitted using past 20 annual realizations. Out-of-sample forecasts are estimated for half of the sample period, thus ranging from 1982-2012 (31 years)

To evaluate the performance of the fitted model, it is compared to the naive model of using today's level as indicator of future realizations in the next year, i.e. $E(\frac{\pi_{t+1}}{V_t}) = \frac{\pi_t}{V_{t-1}}$. The mean errors and mean squared errors are seen in Table 16.

Table 16: Mean Errors and Mean Squared Errors of ARMA(1,1) Forecasts

The table shows the mean errors and mean squared errors for the one-period ARMA(1,1) forecasts of the Profit/Investment component and the naive model $E(\frac{\pi_{t+1}}{V_t}) = \frac{\pi_t}{V_{t-1}}$.

	ARMA(1,1)	**Naive model**
$E(\hat{\epsilon})$	0.058	0.018
$E(\hat{\epsilon}^2)$	0.042	0.034

Table 16 shows that, despite the identified predictability within the profit/ investment component, the naive model $E(\frac{\pi_{t+1}}{V_t}) = \frac{\pi_t}{V_{t-1}}$ still yields lower $E(\hat{\epsilon})$

and $E(\hat{\epsilon}^2)$ compared to the ARMA(1,1) model. The predictability is thus not strong enough to provide fruitful forecasts. This poses as a potential explanation for why forest managers fail to allocate harvest to periods when profits per m^3 are exceptionally high. A straightforward out-of-sample six-period forecast obtained from an ARMA(2,2) fitted using the complete history, together with the model specifications, is seen in Table 22 and Table 23 in Appendix C. The conclusions are unaltered.

4.2 Three-Factor Model

The results from the three-factor model incorporating market risk, liquidity and inflation are summarized in Table 17.

Table 17: Regressions: Three-Factor Model

This table shows regression results of excess total returns of timberland on a three-factor model (market risk, liquidity and inflation) from 1951 to 2011. The full model is specified as follows: $r_t - r_{ft} = \alpha_t + \beta_1(r_{mt} - r_{ft}) + \beta_2(\Delta Liq_t) + \beta_3(I_t) + \epsilon_t$

	Model (1)	**Model (2)**	**Model (3)**
α	0.0580	0.0549	0.0551
95% conf. int.	0.03 - 0.09	0.02 - 0.09	0.00 - 0.11
β_m	-0.1180	-0.1255	-0.1256
95% conf. int.	-0.25 - 0.01	-0.25 - 0.00	-0.26 - 0.01
β_{liq}		-9.8630	-9.8700
95% conf. int.		-18.33 - -1.40	-18.54 - -1.20
β_I			-0.0040
95% conf. int.			-0.84 - 0.83
R^2	0.05	0.13	0.13
F - stat	3.19	4.44	2.91
P - value	0.08	0.02	0.04
σ^2_ϵ	0.02	0.01	0.01

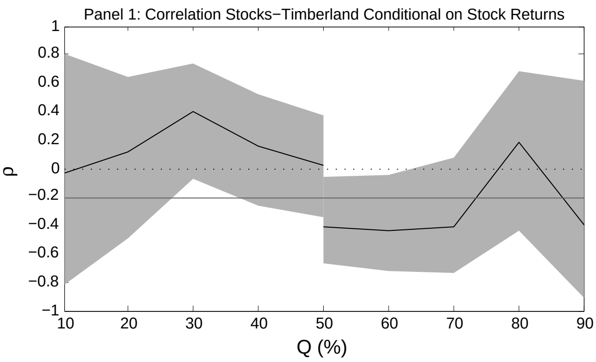
The insignificant market beta in all three regressions is in line with previous findings and suggests that timberland returns are not explained by exposure to systematic market risk. Changes in liquidity in the forestry market depict a significantly negative effect on timberland returns in both regressions 2 and 3. The results propose a limited demand for forestry properties as returns are lower in years when the number of transactions increase. This impedes investors to quickly divest large holdings and supports the existence of a liquidity premium. The inflation beta in regression 3 is insignificantly different from zero which suggests that the Swedish market of timberland offers poor protection against inflation. This finding adds to the discussion about timberland investments as inflation protection in Section 2.2. In all three models, there are significant αs implying that timberland investments generate abnormal returns not explained by either systematic risk, illiquidity or inflation in an unconditional setting.

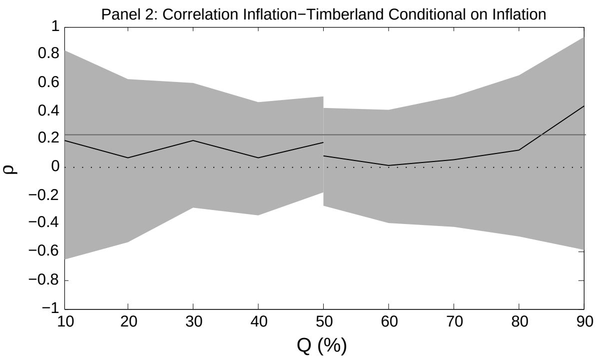
4.3 Conditional Correlation

Building upon the findings in Table 17, Table 18 shows the correlation structure of timberland returns using conditional correlation, with contemporaneous stock returns and inflation as conditional variables.

Table 18: Conditional Correlation Depending on Market Regime

The graphs show correlation between two assets depending on contemporaneous realizations of a given asset (with 95% confidence bounds). The first five values from the left show $\text{Corr}(r_t, y_t | y_t < Q_{50\%,40\%,30\%,20\%,10\%})$ and the next five values show $\text{Corr}(r_t, y_t | y_t > Q_{50\%,60\%,70\%,80\%,90\%})$. r and y are given in the panel titles.





Panel 1 in Table 18 shows a significant negative correlation between timberland and stock returns when stock returns realize above the 50% quantile. This attribute of the series is perceived as unfavorable since rational portfolio investors would prefer the opposite, i.e. positive correlations in bull markets and negative in bear markets. No significant correlation is observed when stocks realize below the 50% quantile. This is of particular interest as correlation structures of other assets tend to show higher positive correlation in extreme negative tail realizations. This downside protection, together with the positive skewness of the return series identified in Table 2, supports the attractive characteristics identified in the multi-factor regressions in Table 17.

Panel 2 in Table 18 shows that correlation between timberland return and inflation is insignificantly different from zero throughout all quantiles of inflation realizations. This does not allow for additional conclusions related to the property as inflation hedge other than identified in Table 17. It supports the observation that returns from timberland investments are driven by real price changes of timberland property and thus emphasizes the importance of the capital return composition.

4.4 Market Segmentation and Portfolio Allocation

Results of the linear regressions of the three regional return series on national series are shown in Table 19.

Table 19: Regressions: Regional Returns on National Returns

The table contains the results of linear regressions of the regional total timberland returns on the national total return series: $TR_{i,t} = \alpha_i + \beta_i TR_{Sweden,t} + \varepsilon_{it}$ where $TR_1 =$ Norrland, $TR_2 =$ Svealand, $TR_3 =$ Götaland

	Norrland	**Svealand**	**Götaland**
α	0.032	-0.001	0.003
90% conf. int.	0.005 - 0.060	-0.020 - 0.019	-0.018 - 0.024
β_i	0.729	1.065	0.941
90% conf. int.	0.536 - 0.921	0.929 - 1.202	0.792 - 1.089
R^2	0.693	0.905	0.863
F - stat	42.866	181.780	119.855
P - value	0.000	0.000	0.000
σ^2_ϵ	0.003	0.002	0.002

Table 19 shows that Norrland generates an α that is significantly different from zero, whereas the αs of both Svealand and Götaland are not. Higher βs and R^2-values of Svealand and Götaland support higher explanatory power and goodness of fit with the national return series than Norrland. Despite differing statistical characteristics among the three return series, Norrland is the region most segmented to the rest. The finding suggests inefficiencies in the market of Swedish timberland.

Market segmentation is further supported by the mean-variance portfolio optimization which shows large differences in allocations between the regions in the Swedish timberland market (see Table 20). The mean-variance efficiency frontiers and the three respective tangency portfolios (together with the complete investment universe) are seen in Table 24 in Appendix D.

Table 20: Mean-Variance Portfolio Optimization: Weights in Tangency Portfolios

Weights obtained from a mean-variance portfolio optimization of the national and regional return series together with stock and real estate investments. In the No Timberland Tangency Portfolio ('No Timberland TP'), only investments in stocks and real estate are allowed. In the national tangency portfolio ('National TP'), investments in national timberland, stocks and real estate are allowed and in the regional tangency portfolio ('Regional TP'), investments in regional timberland, stocks and real estate are allowed. The risk-free rate is set to 3.28%, representing the last value of the sample period. Due to difficulties in short-selling timberland, a constraint of no negative weights is added.

	No Timberland TP	**National TP**	**Regional TP**
National	-	0.57	-
$\sum_{i=1}^{3} w_{Regions}$	-	-	0.77
Norrland	-	-	0.61
Svealand	-	-	0.17
Götaland	-	-	0
Stocks	0.22	0.21	0.19
Real Estate	0.78	0.23	0.04

Timberland receives positive allocation within the mean-variance optimized portfolio providing evidence of the diversification benefits of adding timberland to an investment portfolio. The total allocation to timberland subsequently increases from 57% to 77% when a mean-variance optimizing investor invests in the three regions separately. In the regional tangency portfolio, Norrland and Svealand receive positive allocations while Götaland receives an allocation of zero. The zero allocation to Götaland in the mean-variance optimized portfolio further depicts inefficiencies within the Swedish timberland market. Götaland's risk-adjusted return and variance-covariance structure are disadvantageous compared to the other assets. The weight in stock investments are relatively constant when both national and regional timberland are introduced into the investment universe. However, the weights of timberland investments gradually increase at the expense of real estate investments. This suggests that the timberland investments feature similar but more advantageous variance-covariance structures than real estate investments. A Jarque-Bera test for normality does not reject the normality assumption for any of the timberland return series, which suggests that the assumption of asymptotical normality holds. The Ljung-Box (1978) test does not reject the null hypothesis of no serial autocorrelation in any of the series, promoting IID returns (test statistics seen in Appendix D). These statistical properties of the timberland return series allow for a comparison of the Sharpe Ratios of the tangency portfolios for no timberland, national timberland and regional timberland, including their 95% confidence intervals (details of tests specified in Section 3.2.4).

$$\hat{\zeta}_{NoTimberland} = 0.52 \pm 1.96 * 0.24 = 0.52 \pm 0.48$$
$$\hat{\zeta}_{National} = 0.69 \pm 1.96 * 0.26 = 0.69 \pm 0.50$$
$$\hat{\zeta}_{Regional} = 0.79 \pm 1.96 * 0.26 = 0.79 \pm 0.52$$

Sharpe Ratios of 0.79 for the regional tangency portfolio and 0.69 for the national tangency portfolio further depict the inefficiencies in the market of Swedish timberland. The identified return-enhancing characteristics of optimized timberland portfolios could potentially increase the α of the multi-factor model in Table 17. However, valid statistical conclusions are impeded by the broad confidence bounds caused by the short time horizon of regional return series.

5 Conclusion and Further Remarks

Hypothesis 1 *To what extent is the broker return series statistically different from the traditional return series?*

> **Hypothesis 1a** *How do the expected returns and variances vary among the different composition methods?*
>
> **Hypothesis 1b** *To what degree do the different returns series correlate with each other?*
>
> **Hypothesis 1c** *How much variation in the broker return series can be explained by the traditional return series, i.e.* R^2 *and* β*?*
>
> **Hypothesis 1d** *Can the capital return component of traditional return series be improved?*
>
> **Hypothesis 1e** *Does the broker return composition mitigate the return smoothening due to data persistence identified in previous literature?*

The composed and analyzed broker return series features superior statistical properties compared to alternative return series used in previous research. Given that the broker return series is representative for actual timberland returns, stumpage prices and prices of farmland property are poor proxies for capital returns of timberland. A linear clone portfolio consisting of stumpage prices and Swedish apartment prices is a more suitable proxy when actual capital returns are unknown. Furthermore, autocorrelation affecting risk-adjusted returns due to return smoothening is mitigated by using the broker capital and total return series.

Hypothesis 2 *Timberland investments have low market betas and are exempted from increased correlation in bear markets.*

Timberland investments display a market beta insignificantly different from zero. However, there is negative correlation between stock returns and timberland returns when the stock market realizes above its median. Not identified in previous research, this characteristic of timberland returns should be perceived as negative since a rational investor prefers the opposite. Interestingly, correlation remains indifferent from zero in times of strong negative stock market development. This positive attribute, together with positive skewness of the overall series, further emphasizes the attractiveness of timberland investments.

Hypothesis 3 *Timberland investments contain a liquidity premium in excess of the market risk exposure.*

Changes in sell side liquidity have an inverse effect on timberland returns. The finding suggests that there is limited and/or inelastic demand for timberland properties providing support for the existence of a liquidity premium.

Hypothesis 4 *Timberland is a poor inflation hedge.*

Findings support that the inflation hedging properties of timberland investments are overstated in previous literature. It is shown that timberland's inflation hedge attributes are not dependent on inflation regimes.

Hypothesis 5 *There is predictability in timberland direct returns.*

Forest managers do not allocate harvest to periods of exceptional profits even though predictability is identified in the profit/investment component of direct returns. This can be explained by the fact that a fitted ARMA-model does not provide more accurate forecasts than a naive model using past realizations as predictors.

Hypothesis 6 *The market of timberland is geographically segmented as regions provide different risk-adjusted returns.*

There is market segmentation and inefficiencies within the Swedish timberland market. The total return series of Norrland yields a significant alpha when regressed on the national return series whereas the other regions do not. This is further supported by a Sharpe Ratio analysis of two timberland mean-variance optimized portfolios.

Hypothesis 7 *A mean-variance optimizing investor allocates more capital to timberland when regional investments are considered.*

The total allocation to timberland investments increases when it is possible for investors to invest in the three regions instead of the national timberland only. The individual weights of the three regions are highly skewed due to the identified market segmentation within Swedish timberland.

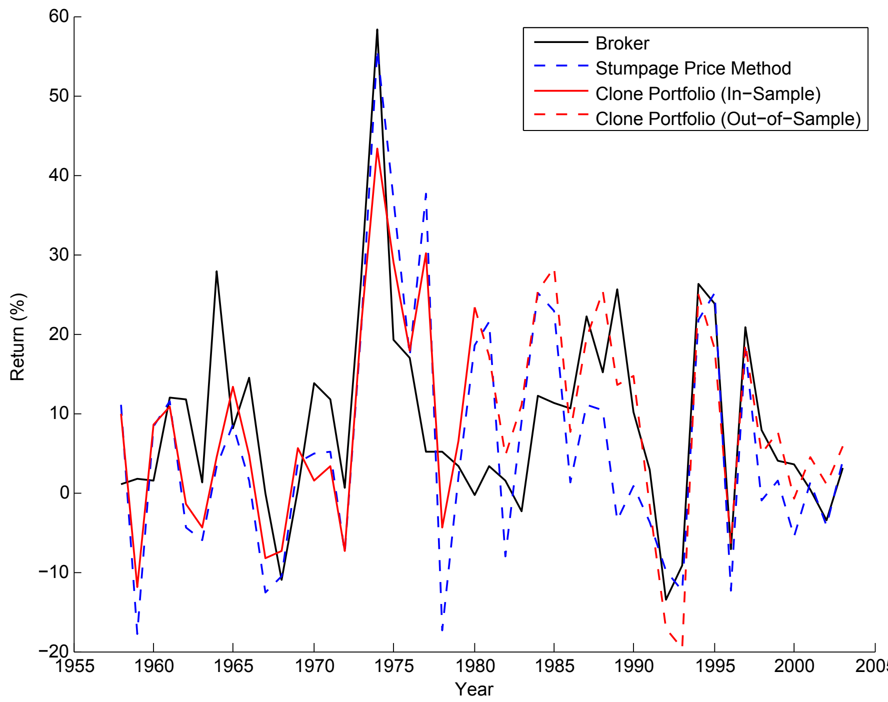
Future research has to be conducted to verify that the findings in this paper are applicable to other geographic markets. The analysis will, however, be contingent on the collection of a representative dataset free of underlying assumptions. Hopefully more countries begin tracking conditions and activities within the forestry industry as thoroughly as Sweden.

6 Appendix

Appendix A: Comparison of Capital Returns: Broker, Stumpage Price Method and Clone Portfolio

Table 21: Capital Returns of Broker, Stumpage Price and Clone Portfolio

The graph shows the broker capital returns and the capital returns obtained using the Stumpage Price Method and the Cloned Portfolio. Data ranges from 1958 - 2003.



Appendix B: Additional Methodology for Evaluating Timberland Returns

Augmented Dickey–Fuller Test

$$\Delta \mathrm{X}_t = a_0 + \gamma \mathrm{X}_{t-1} + \sum_{i=1}^{k} \beta_i \Delta \mathrm{X}_{t-i} + \varepsilon_t$$

$H_0 : \gamma = 0$ (Unit Root Hypothesis)

$H_1 : \gamma < 0$ (Stationary Alternative)

Ljung-Box Test

$$Q_{LB} = T(T+2) * \sum_{t=1}^{s} \frac{r_k^2}{(T-k)} \sim \chi^2(R)$$

$H_0 : \gamma = 0$ (No Serial Autocorrelation)

$H_1 : \gamma < 0$ (Serial Autocorrelation)

Where:

T = Observations

s = Tested Number of Lags

r_k = Sample Autocorrelation

R = Degrees of Freedom

Appendix C: Forecasting Direct Returns Using ARMA Methodology

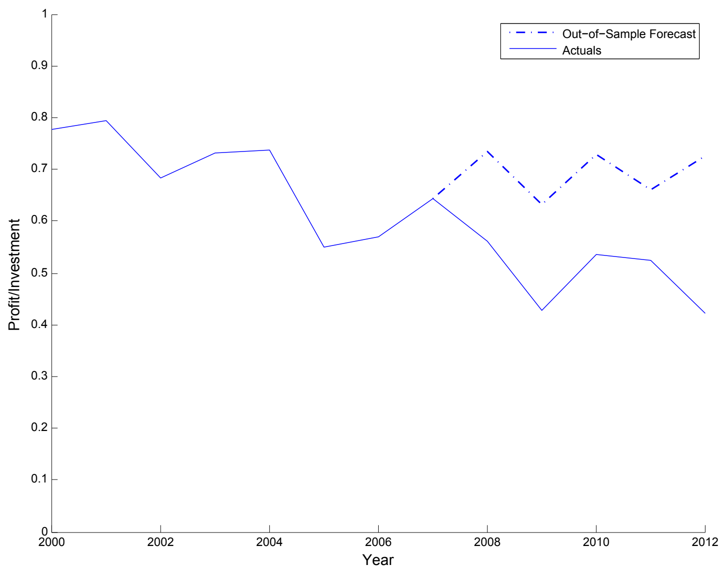
Table 22: ARMA(2,2) Model

ARMA(2,2) model is fitted to the national profit/investment component for 1951 - 2007. ARMA(2,2) is the most parsimonious model still powerful enough to remove all serial correlation from the residual series. The residuals are tested both with partial autocorrelation function and with a Ljung-Box (1978) test using four lags. Neither of the tests show any remaining serial correlation in the residual series.

Parameter	**Value**	**Std. error**	**T-stat**
Constant	0.115	0.080	1.447
AR(1)	0.087	0.035	2.524
AR(2)	0.760	0.042	18.061
MA(1)	0.395	0.105	3.767
MA(2)	-0.605	0.141	-4.283
Variance	0.115	0.029	3.972

Table 23: ARMA (2,2) Model: Six-Period Forecast of Profit/Investment

Plotted six-period out-of-sample forecast and actual realizations of profit/investment using the model specifications in Table 22



The model consistently overstates the level of the profit/investment and since there is no remaining serial correlation in the residual series the model cannot be improved further. The predictability is not strong enough to be used for forecasting.

Appendix D: Regional Timberland Investments

Table 24: Mean-Variance Portfolio Optimization: Efficiency Frontiers

Efficiency frontiers for (1) Stocks and real estate (2) National timberland, stocks and real estate and (3) Three timberland regions, stocks and real estate. Constraints: weights sum to one and no short selling. Risk-free rate is set to 3.28%, representing the last value of the sample. Data ranges from 1991-2011.

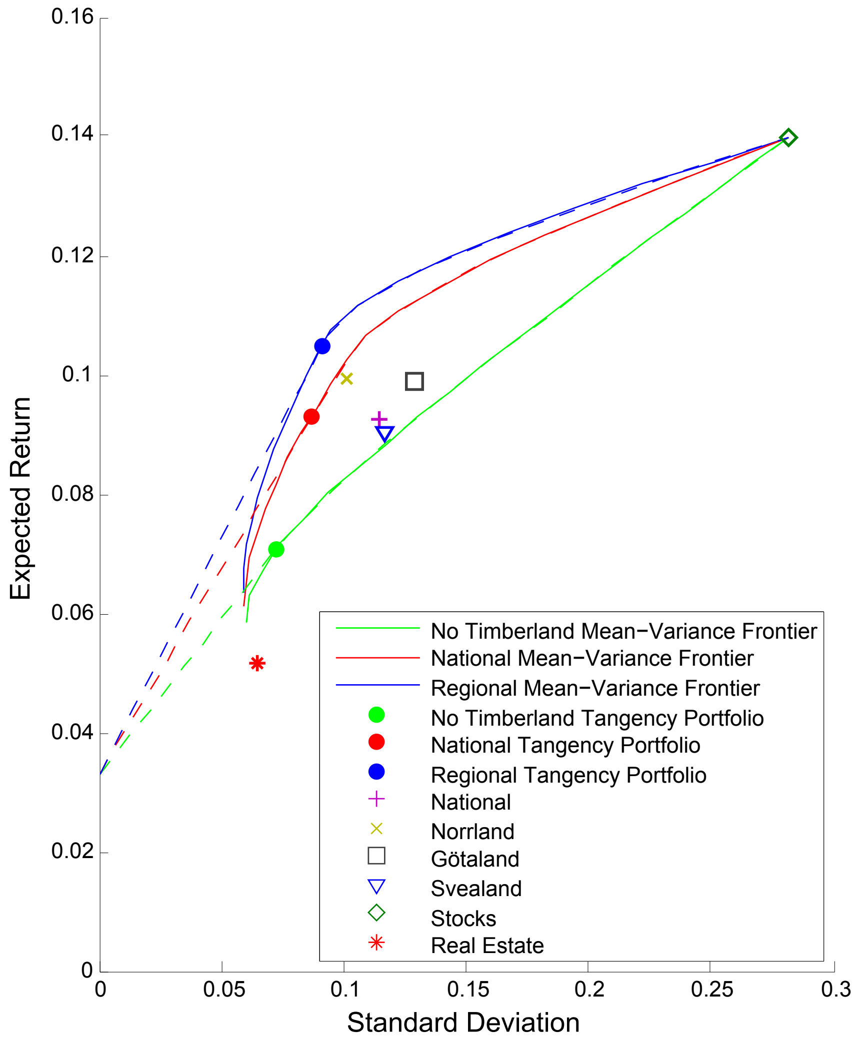


Table 25: Jarque-Bera Test on Regional and National Returns

This table presents the key results of the Jarque-Bera test for normality three regional and the national return series (1991-2011). P-values are greater than the largest tabulated values, thus returning 0.5

Series	H	p-value
Norrland	0	0.50
Svealand	0	0.50
Götaland	0	0.50
National	0	0.50

Table 26: Ljung-Box Test on Regional and National Returns

This table presents the key results of a Ljung-Box (1978) test for serial correlation within the three regional and the national return series using four lags. Data ranges from 1991-2011.

Series	H	p-value
Norrland	0	0.16
Svealand	0	0.78
Götaland	0	0.75
National	0	0.62

References

Binkley, C. S. & de Bever, L. (2005). Timberland: The natural alternative. *The Handbook of Inflation-Hedging Investments, ed. B. Grier. McGraw Hill, New York*, (pp. 231–245).

Brand, D. (2011). New forests' timberland investment outlook 2011–2015. *New Forests Asset Management Pty Limited. www.newforests.com.au/news/pdf/articles/MarketOutlook_NewForests TimberlandInvestmentOutlook. pdf.*

Campbell, R., Koedijk, K., & Kofman, P. (2002). Increased correlation in bear markets. *Financial Analysts Journal*, 58(1), 87–94.

Caulfield, J. P. (1998). Timberland in institutional portfolios and the question of persistence. *Forest products journal*, 48(4), 23.

Edvinsson, R., Jacobson, T., & Waldenström, D. (2014). Historical monetary and financial statistics for sweden, volume ii. house prices, stock returns, national accounts, and the riksbank balance sheet, 1620–2012. *Stockholm: Ekerlids Förlag*.

Getmansky, M., Lo, A. W., & Makarov, I. (2004). An econometric model of serial correlation and illiquidity in hedge fund returns. *Journal of Financial Economics*, 74(3), 529–609.

Graham, D. S. (1985). Timber and the institutional investment pool. *Forest Farmer*, 45(2), 12–13.

Ibbotson, R. G. & Sinquefield, R. A. (1976). Stocks, bonds, bills, and inflation: year-by-year historical returns (1926-1974). *The Journal of Business*, 49(1), 11–47.

Jacobsson, J. (2016). Personal communication, e-mail.

Klemperer, W. D. et al. (1996). *Forest resource economics and finance*. McGraw-Hill Inc.

Lo, A. W. (2002). The statistics of sharpe ratios. *Financial Analysts Journal*, 58(4), 36–52.

Longin, F. & Solnik, B. (2001). Extreme correlation of international equity markets. *The journal of finance*, 56(2), 649–676.

Mills, W. & Hoover, W. L. (1982). Investment in forest land: aspects of risk and diversification. *Land Economics*, 58(1), 33–51.

Penttinen, M. & Lausti, A. (2004). The competitiveness and return components of nipf ownership in finland. *Liiketaloudellinen Aikakauskirja*, (pp. 143–156).

Redmond, C. H. & Cubbage, F. W. (1988). Portfolio risk and returns from timber asset investments. *Land Economics*, 64(4), 325–337.

Sun, C. & Zhang, D. (2001). Assessing the financial performance of forestry-related investment vehicles: Capital asset pricing model vs. arbitrage pricing theory. *American Journal of Agricultural Economics*, 83(3), 617–628.

Swensen, D. F. (2009). *Pioneering portfolio management: An unconventional approach to institutional investment, fully revised and updated.* Simon and Schuster.

Thomson, T. A. (1987). Financial risk and timber portfolios for some southern and midwestern species. In *Proceedings, Joint Annual Meeting of the Southern Forest Economics Workers—Midwestern Forest Economists, Asheville, North Carolina* (pp. 46–55).

Thomson, T. A. & Baumgartner, D. C. (1988). Alternative specifications and solutions of the timber management portfolio problem. *General technical report RM-Rocky Mountain Forest and Range Experiment Station, US Department of Agriculture, Forest Service (USA).*

UNECE, F. (2011). The european forest sector - outlook study ii 2010-2030. *Septiembre, Ginebra.*

Waldenström, D. (2014). Swedish stock and bond returns, 1856–2012.

Washburn, C. L. & Binkley, C. S. (1989). Some problems in estimating the capital asset pricing model for timberland investments. In *Proceedings of* *the 1989 Southern Forest Economics Workshop. Available from www. ifiallc. com/PDFs/capitalasset. pdf* (pp. 45–65).

Zinkhan, F. C., Sizemore, W. R., Mason, G. H., Ebner, T. J., et al. (1992). *Timberland investments: a portfolio perspective.* Timber Press.