Statistical Distributions of Timberland Returns

Hancock Timber Research Report

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Executive Summary

The mean-variance portfolio theory has been frequently employed by investors as an aid in the asset allocation process. However, a prudent application of the methodology requires that asset class returns be normally distributed. A growing body of empirical research has shown that the assumption of normally distributed returns is not satisfied by many asset classes, and reliance on the mean-variance methodology in such cases can lead to suboptimal asset allocation decisions. As an asset class, timberland is characterized by infrequent large scale transactions, and timberland returns are not readily observable by existing or prospective market participants. In this report, we analyze returns calculated with two methodologies: the NCREIF Timberland Index and the John Hancock Timber Index. The NCREIF Timberland Index is available in the United States, and calculates timberland returns from manager supplied data on income and capital appreciation. The John Hancock Timber Index is constructed from available data on timber prices and average cash flow rates and can be applied in any region where sufficient data are available. In this report, we analyze the properties of timberland return distributions in Australia, Brazil, Canada, New Zealand, and the United States. Although the regional returns series vary in length, conclusions regarding timberland investments can be drawn from our analysis. Visual observation of the return distributions reveals varying degrees of departures from normality in all of the regions, and the results of several normality tests show these departures to be statistically significant in NCREIF return series from the US South and Pacific Northwest. The series from Brazil is too short to make strong conclusions regarding the distribution of timberland returns in that country. The statistical evidence for non-normality in the NCREIF returns from US South and Pacific Northwest indicates that the mean-variance is not well suited to assist in capital allocation to timberland in those regions.

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Introduction

In this note we review two methodologies used to calculate timberland returns realized by investors holding timberlands in the United States, Canada, New Zealand, Australia, and Brazil. Our results reveal how statistical properties of timberland returns respond to the choice of methodology employed in their calculation, geographical location, and existing regulatory framework.

Timberland Returns Methodology

Returns from timberland are primarily composed of cash income from timber harvests and capital appreciation. A relatively simple task in principle, calculating timberland returns poses a unique challenge because timberland is an illiquid asset that changes hands infrequently, in large-scale, and through irregular transaction. Given the limited amount of transactions data, economists have had to rely on simplifying assumptions and resort to using proxies to calculate returns from timberland.

We analyze timberland returns compiled with two different methodologies. The first methodology was developed at John Hancock Life Insurance Company to construct the John Hancock Timber Index (JHTI). The JHTI approximates timberland returns from available records of timber prices under the assumptions of fully regulated forests and rational expectations. The second methodology was developed by the National Council of Real Estate Investment Fiduciaries (NCREIF) and is published as the NCREIF Timberland Index. The NCREIF Timberland Index combines realized operating income with appraisal-based capital appreciation to proxy market transaction data.

The JHTI was developed by John Wilson, an economist at John Hancock, for the Hancock Timber Resource Group (HTRG) in the late 1980s. The Index was further refined by Clark Binkley and Court Washburn in the early 1990s. The primary motivation behind the JHTI methodology was to approximate returns from timberland when the majority of privately held timberland was owned by vertically integrated forestry firms, and no market data on the performance of timberland itself were available. In a given quarter *t*, the JHTI return from timberland

(1) $$RR_t = [(NI_t + CVal_t)/CVal_{t-1}] - 1 ,$$

where RR_t stands for rate of return at time *t*, net income NI_t is an index of the net revenue produced by the forest during quarter *t*, and capital value $CVal_t$ is an index of the value of forest land and timber growing stock calculated as an eight-quarter linearly weighted average of historical timber prices. That is,

$$CVal_t = \frac{8P_t + 7P_{t-1} + \cdots + 2P_{t-6} + P_{t-7}}{36} \qquad (2)$$

with P_t being the price of timber during quarter *t*. The formulation specified by Equation 2 assumes that values of forest land and timber growing stock are determined by investors' expectations of future timber prices, which, in turn, are formulated from a combination of current and past timber prices.

In a given quarter *t*, the value of the NCREIF Timberland Index consists of the sum of income and capital returns. The income component

$$IR_t = \frac{EBITDDA_t}{MV_{t-1} + 0.5(CI_t - PS_t + PP_t - EBITDDA_t)} \qquad (3)$$

and the capital component

$$CR_t = \frac{MV_t - MV_{t-1} - CI_t + PS_t - PP_t}{MV_{t-1} + 0.5(CI_t - PS_t + PP_t - EBITDDA_t)} . \qquad (4)$$

In Equations 3 and 4, $EBITDDA_t$ represents the net operating revenue obtained from a timberland property (primarily from timber sales) during quarter *t*, CI_t stands for capitalized expenditures on the timberland property (e.g., forest regeneration and road construction) during quarter *t*, PS_t equals net proceeds from sales of land (with or without timber) from the property during quarter *t*, PP_t represents gross costs of adding land (with or without timber) to the property during quarter *t*, and MV_t stands for market value of the property at end of quarter *t*.

Returns Analysis

In this section we present the results of statistical analysis of NCREIF and JHTI returns from timberland in the US South, Northeast, and Pacific Northwest. Investors in US timberland are in the unique position of being able to employ both methodologies to calculate their returns. In Australia, Brazil, British Columbia, and New Zealand, a consistent, NCREIF-like framework for calculating timberland returns has not yet been implemented. Consequently, we are able to only apply the JHTI methodology in these countries with capital appreciation estimates calculated from

Return Analysis

Table 1: US South timberland returns summary statistics, 1987-2010.				
Statistic	Mean (% per year)	Std. Deviation (% per year)	Excess Kurtosis	Skewness
JHTI	6.74	9.63	-0.72	0.26
NCREIF	10.53	7.20	-0.31	-0.54

Table 2: p-Values for normality tests for US South returns, 1987-2010.					
Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
JHTI	0.60	0.52	0.58	0.54	0.73
NCREIF	0.03	0.02	0.04	0.01	0.09

timber prices via Equation 2.

The NCREIF data presented here encompass returns achieved by all participating timberland managers. The JHTI data represent proxy timberland returns constructed from timber prices available through subscription to third party timber price reporting services. We contrast the results obtained from NCREIF with their JHTI derived counterparts in regions where both series are available.

We begin the returns analysis in the Southeastern United States and analyze JHTI and NCREIF annual return series from 1987 to 2010. Basic summary statistics are presented in Table 1. Note that for both return series the values of excess kurtosis (a measure of tail heaviness of the return distribution) and skewness (a measure of asymmetry of the return distribution) differ from the zero value that is expected with normally distributed data.

Figure 1 contains the histograms, Gaussian-kernel density estimates, and corresponding normal distributions whose means and standard deviations were calculated from observed data. Visually, the JHTI and NCREIF methodologies produce different return distributions. Also, the density estimates differ markedly from their normal counterparts, particularly in the NCREIF case. These differences indicate that at least one of the return series is not normally distributed. Figure 2 contains the Quantile-Quantile (QQ) plots of the JHTI and NCREIF return series, which map the quantiles of the observed return distribution to their normal distribution analogs. Because the points in the NCREIF plot fall away from the straight line, the NCREIF plot in Figure 2 indicates departure from normality.

To see whether the signs of non-normality shown in Table 1 and Figures 1 and 2 are statistically significant, we conduct several tests with normally distributed returns in the null hypothesis and non-normality in the alternative. The results are presented in Table 2.

The p-values given in Table 2 show that the null hypothesis of normally distributed returns in the US South can be rejected for the NCREIF data but not for the JHTI data. By rejecting the normality assumption for the NCREIF series, the normality tests confirm the intuition about departures from normality in the US South timberland returns gained from Figures 1 and 2.

We continue our analysis of timberland returns by turning to the US Pacific Northwest. The data available in this region contain the annual returns for both the JHTI and the NCREIF methodologies for the years 1987-2010. Summary statistics are presented in Table 3. As is the case with the US South returns, the values of all summary statistics differ between the JHTI and NCREIF series, and excess kurtosis and skewness are not equal to zero.

Return Analysis

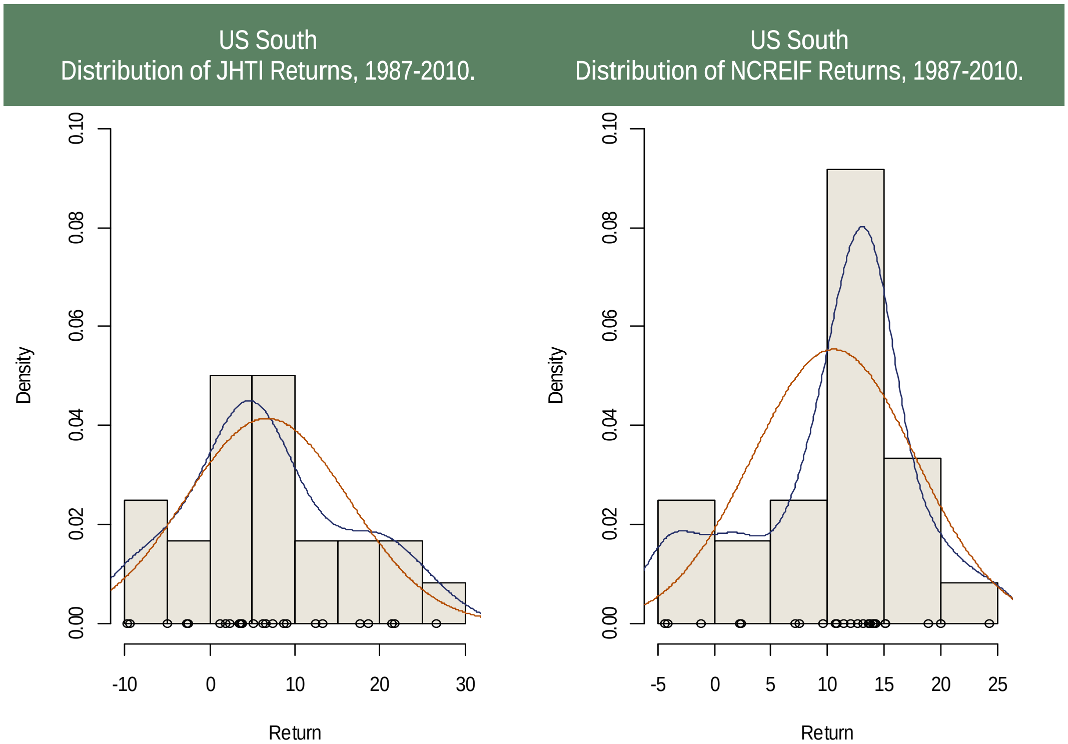

Figure 1: US south timberland returns. Density estimates are plotted in blue. Normal distributions with means and standard deviations calculated from observed data are plotted in red.

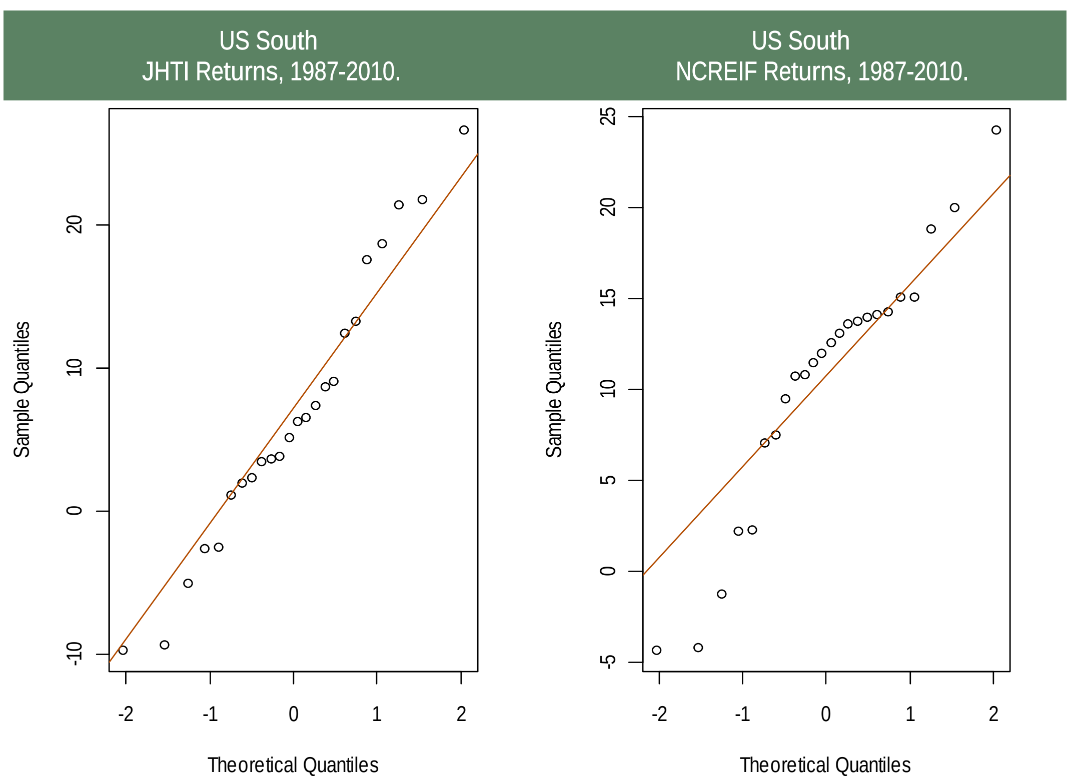

Figure 2: QQ plots of timberland returns in the US South. Points located away from the red line indicate departures from normality.

US Pacific Northwest Distribution of JHTI Returns, 1987-2010.	US Pacific Northwest Distribution of NCREIF Returns, 1987-2010.

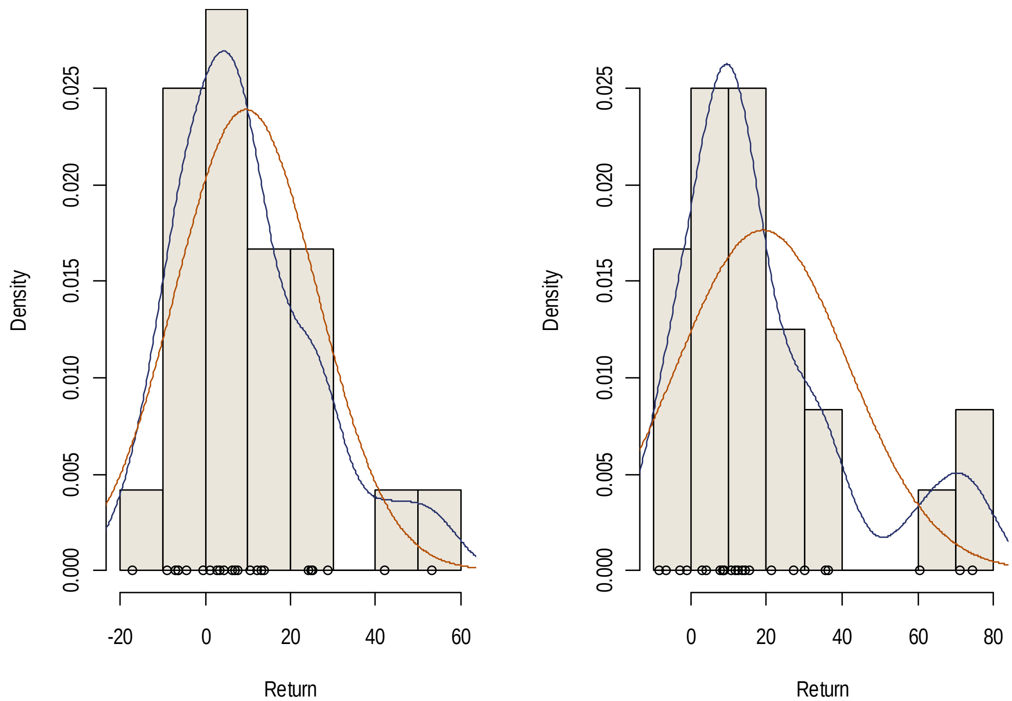

Figure 3: US Pacific Northwest timberland returns. Density estimates are plotted in blue. Normal distributions with means and standard deviations calculated from observed data are plotted in red.

Table 3: US Pacific Northwest timberland returns summary statistics, 1987-2010.				
Statistic	Mean (% per year)	Std. Deviation (% per year)	Excess Kurtosis	Skewness
JHTI	9.62	16.67	0.20	0.83
NCREIF	19.00	22.58	0.45	1.18

Figure 3 contains the histograms, Gaussian-kernel density estimates, and normal distributions with means and variances calculated from sample data. The density estimates, particularly in the case of NCREIF returns, differ markedly from their normal counterparts. This indication of non-normality is further reinforced by the QQ-plots presented in Figure 4. Note the departures from normality in the upper tails of the JHTI and NCREIF return distributions. In order to assess the statistical significance of the departures from normality observed in Figures 3 and 4, we perform several hypothesis tests for normality. The p-values reported in Table 4 indicate that, as in the US South, the null hypothesis of normally distributed returns can be rejected for the NCREIF return series in the US Pacific Northwest.

The Northeast is the final timber producing region in the US where return data from privately held timberland are available through the NCREIF Timberland Index. There are, however, several caveats with regard to the Northeast NCREIF return series.

Return Analysis

US Pacific Northwest JHTI Returns, 1987-2010.	US Pacific Northwest NCREIF Returns, 1987-2010.

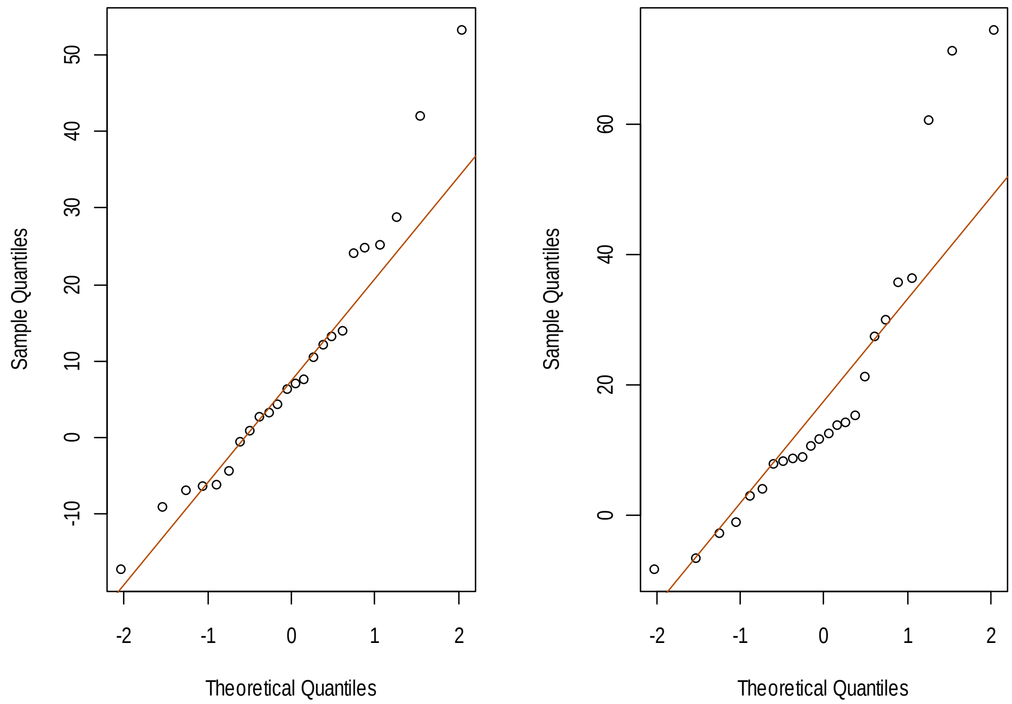

Figure 4: QQ plots of timberland returns in the US Pacific Northwest. Points located away from the red line indicate departures from normality.

Table 4: p-Values for normality tests for US Pacific Northwest returns, 1987-2010.

Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
JHTI	0.16	0.16	0.19	0.54	0.738
NCREIF	0.00	0.00	0.00	0.01	0.09

Relative to the return series from the US South and Pacific Northwest, the NCREIF return series in the Northeast is shorter, and spans the years 1995-2010. In addition, there are fewer timberland managers active in the region, and the number of properties used to construct the return series is lower. Consequently, the conclusions drawn from the smaller, less informative dataset are weaker than the results obtained for the US South and Pacific Northwest.

The summary statistics of timberland returns for the US Northeast are presented in Table 5. Notably, the calculated means and standard deviations for JHTI and NCREIF returns are much closer in the Northeast than the other two US regions. Both excess kurtosis and skewness differ from zero, however, indicating a potential departure from normality.

The histograms, Gaussian-kernel density estimates, and normal distributions with means and standard deviations calculated from historical data are displayed in Figure 5 and show relatively small departures from

Return Analysis

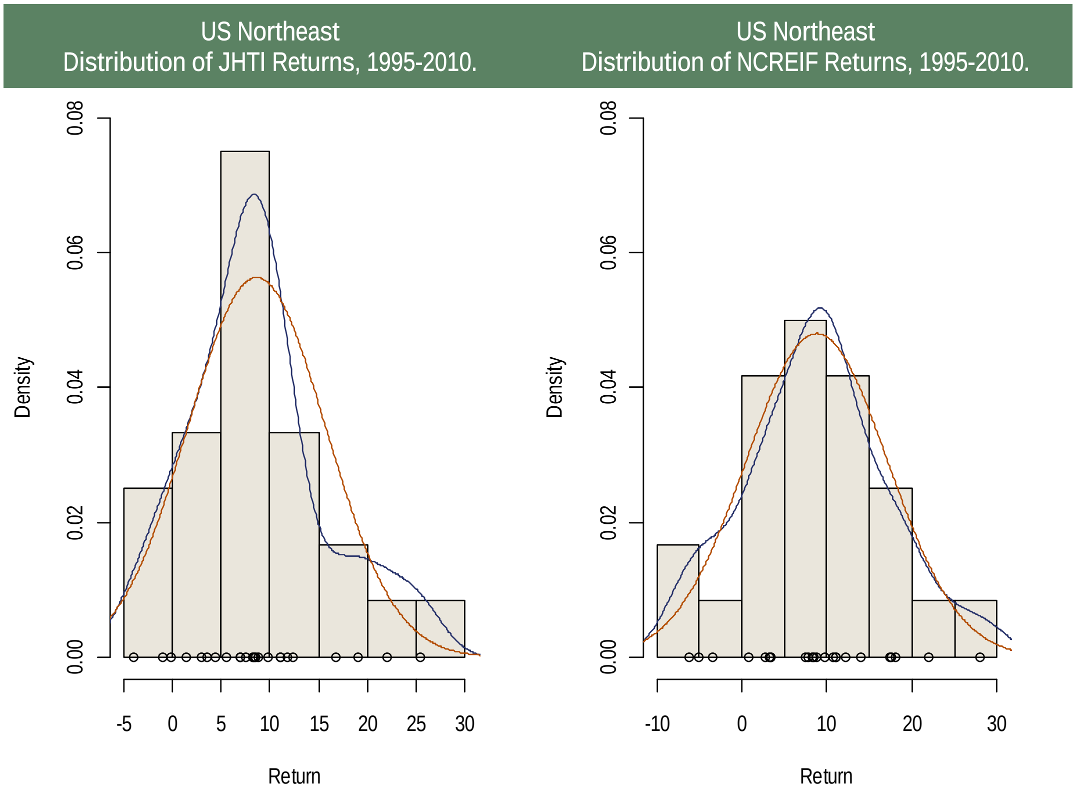

Figure 5: US Northeast timberland returns. Density estimates are plotted in blue. Normal distributions with means and standard deviations calculated from observed data are plotted in red.

Table 5 US Northeast timberland returns summary statistics, 1995-2010.

Statistic	Mean	Std. Deviation	Excess Kurtosis	Skewness
JHTI	7.98%	7.89%	-0.56	0.52
NCREIF	7.86%	9.44%	-0.81	0.30

normality. The QQ-plots in Figure 6 provide further confirmation that departures from normality in the Northeast return series are relatively small. As in the other two US regions, we perform five different hypothesis tests for normality of the Northeast return series. The p-values obtained from the tests are reported in Table 6.

The results presented in Table 6 show that the null hypothesis of normally distributed returns cannot be rejected for either return series with any of the conducted tests. Caution should be exercised when interpreting these results, however, due to the short time period of historical returns used to draw these conclusions.

Coastal British Columbia is the first region we analyze in this report where NCREIF returns cannot be calculated. However, the long record of timber prices in the region and its proximity to US Pacific Northwest allows for an interesting comparison of JHTI returns. Table 7 contains basic statistics of US dollar

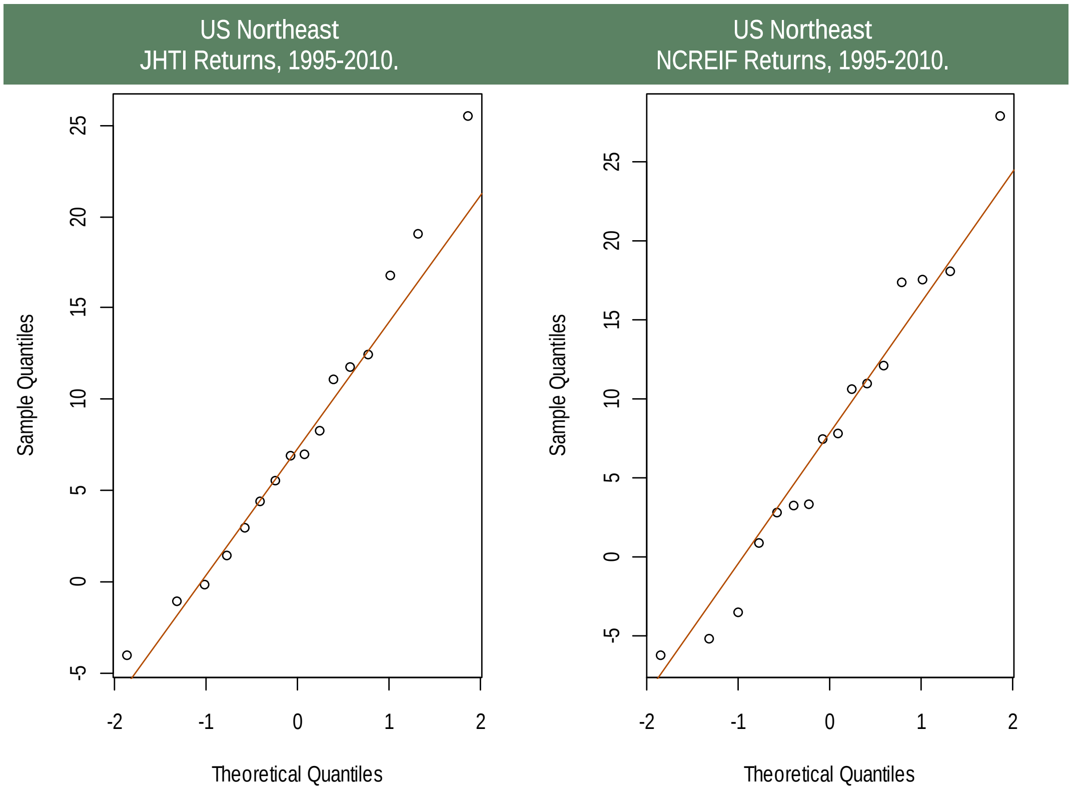

Figure 6: QQ plots of timberland returns in the US Northeast. Points located away from the red line indicate departures from normality.

Table 6: p-Values for normality tests for US Northeast returns, 1995-2010.					
Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
JHTI	0.85	0.83	0.84	0.51	0.74
NCREIF	0.82	0.86	0.76	0.82	0.75

denominated JHTI returns in Coastal British Columbia and the US Pacific Northwest during the years 1960-2010.

The standard deviation of observed returns shown in Table 7 is notably higher in the US Pacific Northwest. The difference is even more remarkable in the case of excess kurtosis and skewness. The values of excess kurtosis and skewness obtained from the Northwest data are much higher than their British Columbia counterparts, which are near zero.

The differences in timberland returns observed in British Columbia and the US Pacific Northwest are illustrated in Figures 7 and 8. Both figures indicate a marked departure from normality in the US Pacific Northwest, while the returns in British Columbia fit the normal distribution relatively well. Table 8 contains the results of several normality tests.

The displayed p-values confirm the intuition from Figures 7 and 8. The British Columbia returns are normal, while normality is soundly rejected for returns

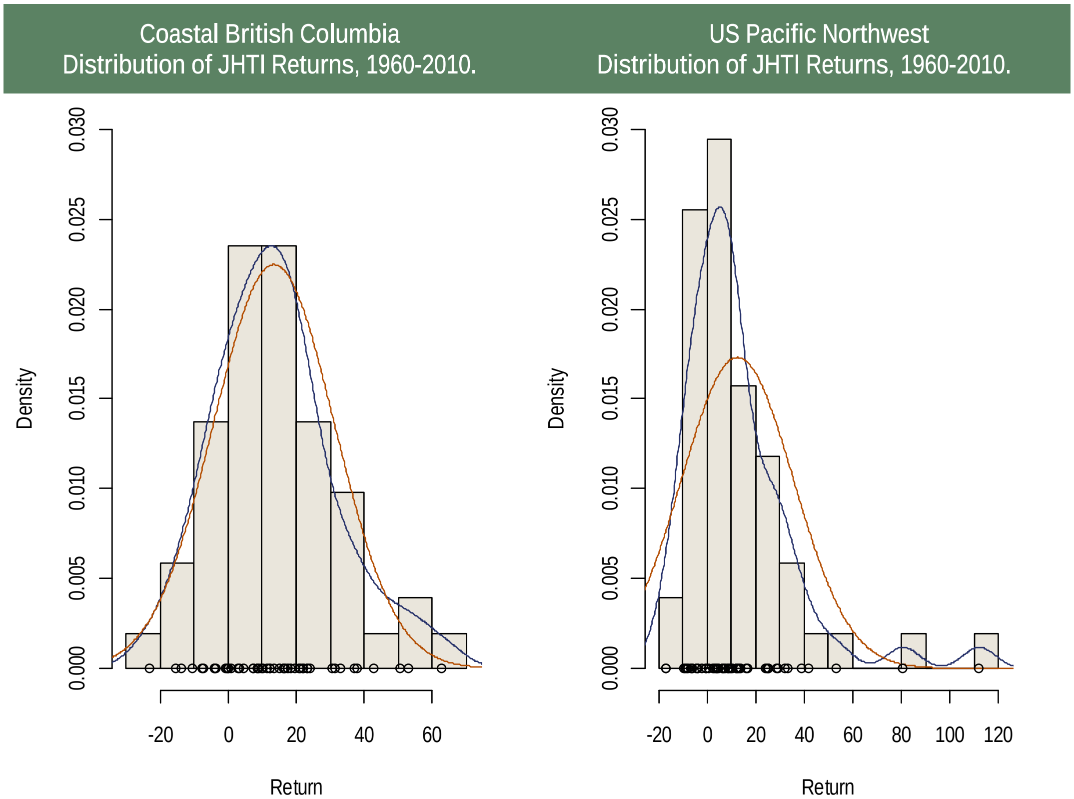

Figure 7: JHTI returns in coastal British Columbia and the US Pacific Northwest. Despite geographical proximity and similarity in products, the return distributions differ considerably.

Table 7: Coastal British Columbia and US Pacific Northwest JHTI timberland returns summary statistics, 1960-2010.

Statistic	Mean (% per year)	Std. Deviation (% per year)	Excess Kurtosis	Skewness
BC Coast	13.48	17.75	0.23	0.54
US PNW	12.57	23.05	5.84	2.09

in the US Pacific Northwest.

This result is noteworthy, because the two regions are adjacent geographically, have similar weather and productivity characteristics, and largely serve the same markets. In a latter section, we show that the significant differences in return distributions can be attributed to changes in environmental regulation and economic policy.

As is the case in British Columbia, New Zealand is a significant timber producing region of the world where NCREIF returns are not available. The compiled timber price data allows for the calculation of JHTI returns from timberland during the years 1975-2010. Table 9 contains basic summary statistics of New Zealand timberland returns.

Although the values of excess kurtosis and skewness are positive, the departures from zero are mild. The empirical and normal distributions shown in Figure 9 show a departure from normality particularly to the left

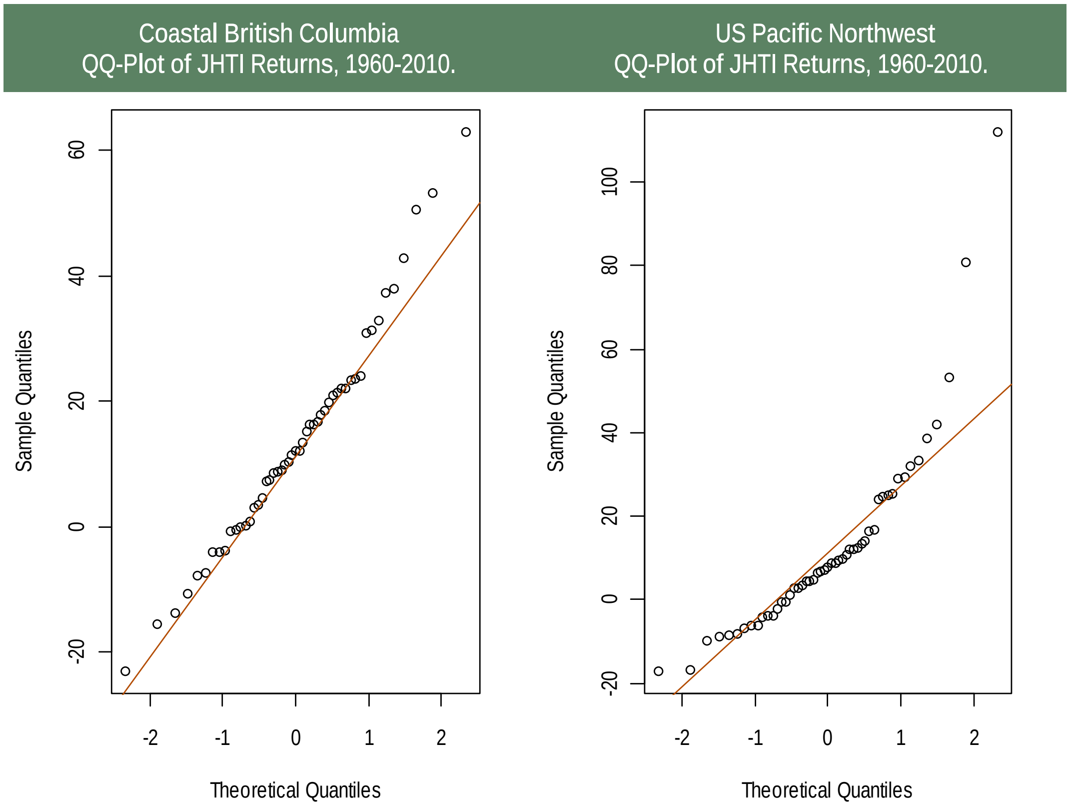

Figure 8: QQ plots of timberland returns in coastal British Columbia and the US Pacific Northwest. The Northwest returns show a more pronounced departure from normality in the right tail of the distribution.

Table 8: p-Values for normality tests of JHTI timberland returns in coastal British Columbia and US Pacific Northwest, 1960-2010.

Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
BC Coast	0.38	0.40	0.20	0.81	0.29
US PNW	6.593e-06	3.905e-05	2184e-04	0.01	4.001e-06

of the mode and in the right tail of the empirical distribution. The QQ-plot in Figure 9 also indicates a moderate departure from normality, particularly in the upper tail of the returns distribution. The results of several hypothesis tests for normality are given in Table 10, and are rather inconclusive.

The p-values of the Anderson-Darling and Shapiro-Francia tests are small, indicating that the null hypothesis of normally distributed returns should be rejected. However, the Lillifors and Pearson tests returned higher p-values, indicating that the null should not be rejected. The p-value obtained from the Cramer-von Mises test is inconclusive. Although the data set is relatively long by forest economics standards, it only contains 35 observations, and detecting evidence of non-normality in small samples has proven to be a difficult task. Because the test results are mixed, some degree of non-normality likely exists in New Zealand returns.

Whether or not this departure from normality is

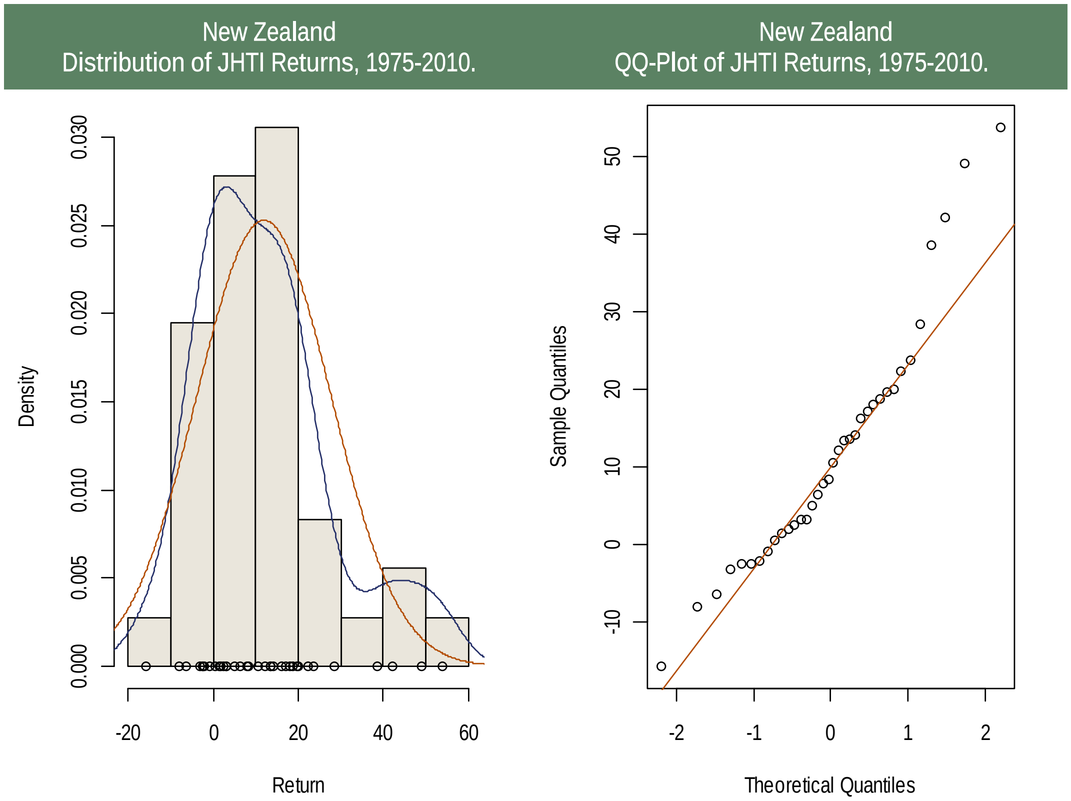

Figure 9: Distribution and QQ-plot of JHTI returns in New Zealand. The Gaussian-kernel empirical density is drawn in blue, a normal distribution with the mean and variance calculated from available data is drawn in red.

Table 9: New Zealand JHTI timberland returns summary statistics, 1975-2010.

Statistic	Mean (% per year)	Std. Deviation (% per year)	Excess Kurtosis	Skewness
Value	11.93	15.79	0.36	0.87

significant remains to be seen, and caution should be exercised when interpreting the results of the normality tests with New Zealand returns data.

The JHTI returns from timberland in Australia span a shorter period and are available for the years 1982-2010. The basic summary statistics for the Australian return series are given in Table 11.

In Table 11, note the small value of the skewness statistic relative to skewness values obtained for JHTI returns in other timber producing regions, for example the US South (pg. 8) or Pacific Northwest (pg. 10). Figure 10 contains plots of the empirical distribution, the normal distribution with mean variance calculated from the data, and the QQ-plot of the Australian timberland returns. The plots indicate that the returns data are reasonably approximated by the normal distribution. This insight is supported by the results of formal hypothesis test given in Table 12.

All p-values in Table 12 are large, close to 1, and

Table 10: p-Values from normality tests of JHTI timberland returns in New Zealand, 1975-2010.					
Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
p-value	0.04	0.07	0.29	0.32	0.03

Table 11: Australian JHTI timberland returns summary statistics, 1982-2010.				
Statistic	Mean (% per year)	Std. Deviation (% per year)	Excess Kurtosis	Skewness
Value	11.48	9.39	-0.38	-0.05

Table 12: p-Values from normality tests of JHTI timberland returns in Australia, 1982-2010.					
Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
p-value	0.93	0.86	0.93	0.82	0.97

therefore indicate a good fit by the normal distribution. However, as is the case with New Zealand returns, the small sample caveat applies to the Australian returns. The Australian data set contains 28 observations, and may be too small to fully reveal the true nature of timberland returns in Australia. Additional return observations are necessary to resolve remaining uncertainty.

Brazil is the final timber producing region that we consider here. JHTI returns from Brazilian timberlands are available for the years 1992-2010. Table 13 contains the values of basic summary statistics, with the values of excess kurtosis and skewness differing from zero – an indicator of non-normality.

The plots of the empirical and normal distributions, and the QQ-plot in Figure 11 illustrate, however, that the departure from normality is presently small. The results of formal hypothesis tests for normality confirm this insight, and show that the null hypothesis of normally distributed returns cannot be rejected.

The dataset of returns from Brazilian timberland contains 18 observations and is too short to be truly informative. Consequently, the results for Brazil should be interpreted with caution as we include them here for the sake of completeness.

Skew-t Distribution Model

The analysis presented above indicates that several of the return series are not normally distributed. Because the normal distribution is not a suitable model for

Skew-t Distribution Model

Australia Distribution of JHTI Returns, 1982-2010.	Australia QQ-Plot of JHTI Returns, 1982-2010.

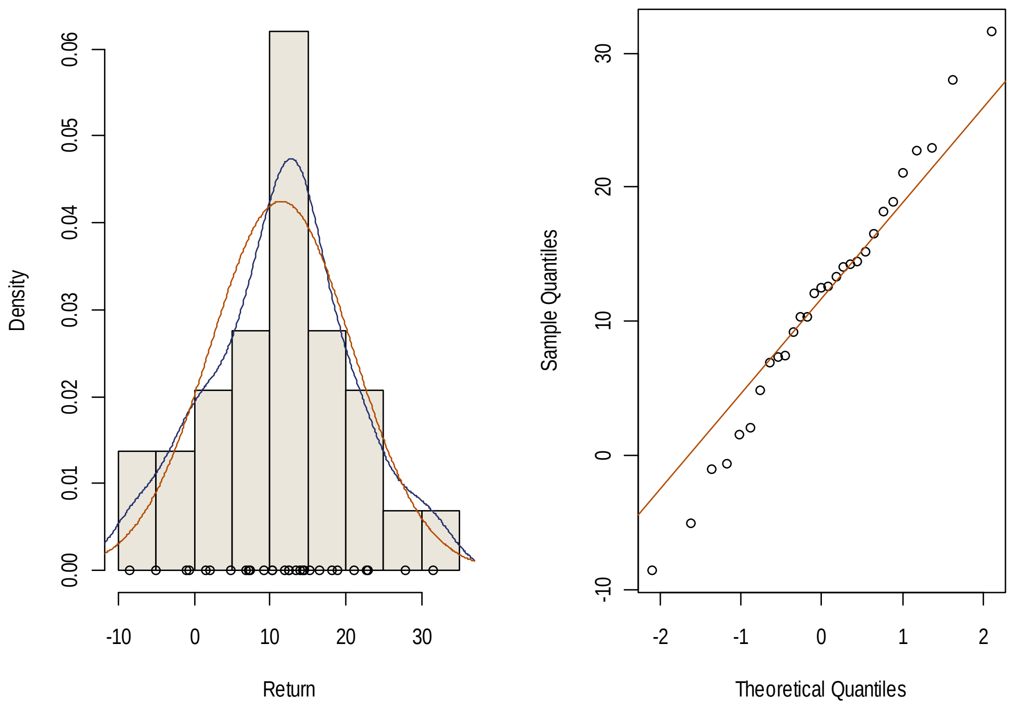

Figure 10: Distribution and QQ-plot of JHTI returns in Australia. The Gaussian-kernel empirical density is drawn in blue, a normal distribution with the mean and variance calculated from available data is drawn in red.

Table 13: Brazilian JHTI timberland returns summary statistics, 1992-2010.

Statistic	Mean (% per year)	Std. Deviation (% per year)	Excess Kurtosis	Skewness
Value	16.66	18.83	-0.92	0.32

Table 14: p-Values from normality tests of JHTI timberland returns in Brazil, 1992-2010.

Test	Anderson-Darling	Cramer-von Mises	Lilliefors (Kolmogorov-Smirnov)	Pearson Chi-square	Shapiro-Francia
p-value	0.62	0.54	0.28	0.60	0.77

Skew-t Distribution Model

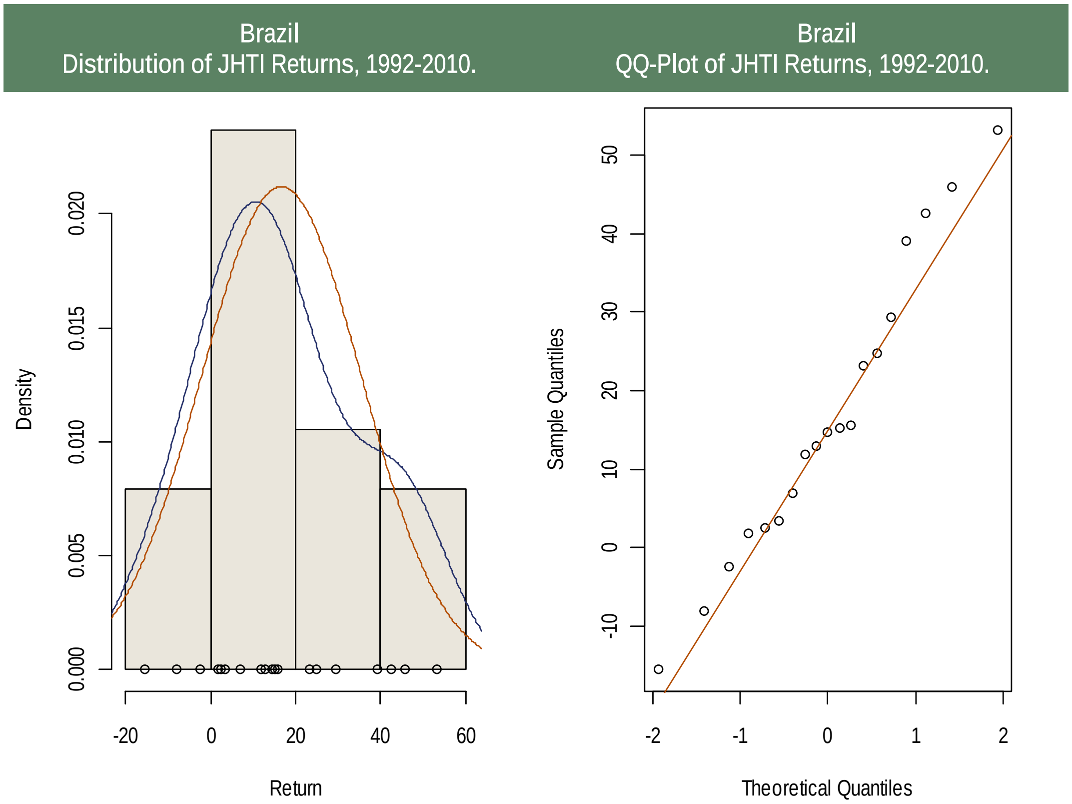

Figure 11: Distribution and QQ-plot of JHTI returns in Brazil. The Gaussian-kernel empirical density is drawn in blue, a normal distribution with the mean and variance calculated from available data is drawn in red.

Table 15: US South timberland returns. A composition of 1960-1986 JHTI returns and 1987-2010 NCREIF returns.

Parameter	Location	Dispersion	Shape	d.f.
Value	13.20	129.81	-0.32	34.26

return data, we identified the skew-t distribution as a suitable alternative, and present the distributions fitted to the timberland returns in this section.

Introduced relatively recently (Azzalini and Capitanio, 2003), the skew-t distribution generalizes the well known Student-t distribution, and is capable of modeling data are characterized by the presence of both heavy tails and skewness. A member of the skew-t family is identified with four parameters: location, dispersion, shape, and degrees of freedom. Setting the shape parameter equal to zero reduces the Skew-t distribution to the usual Student-t distribution. When the degrees of freedom are infinite, the skew-t reduces to the skew-normal distribution. Similarly, a Skew-t distribution with zero shape parameter and infinite degrees of freedom is equivalent to the normal distribution.

We used maximum likelihood to identify the parameter values of the timberland return distributions in the US South, Pacific Northwest, and the Northeast; British

Skew-t Distribution Model

US South Returns, 1960-2010 Skew-t Distribution.	Empirical and Skew-t Cumulative Distribution Functions.

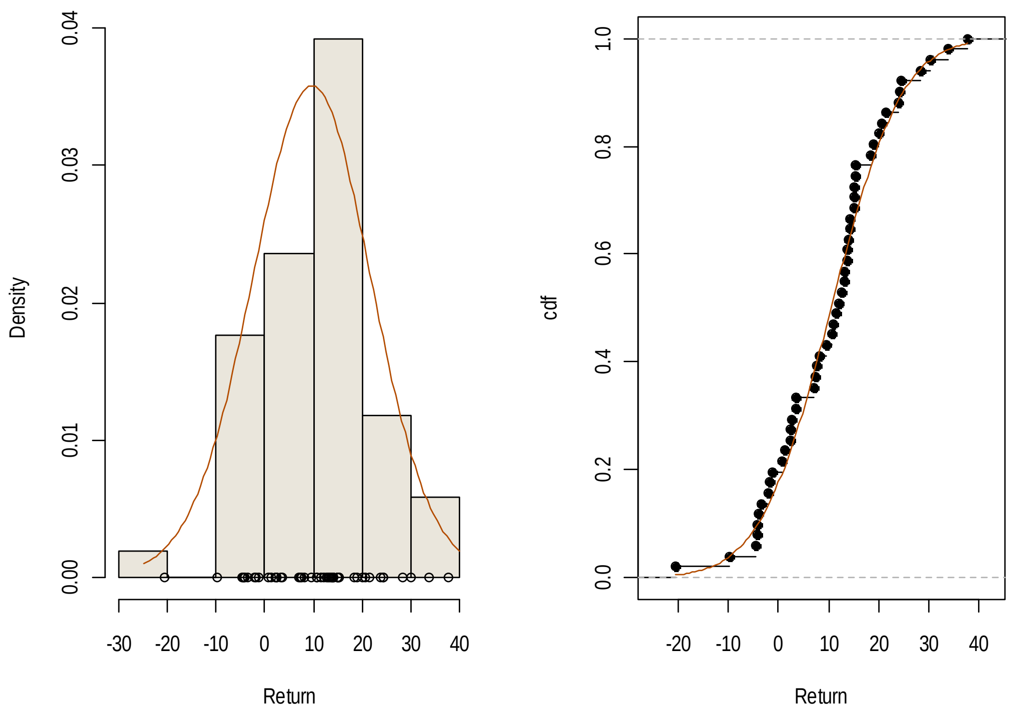

Figure 12: Skew-t distribution of timberland returns in the US South.

Table 16: US Pacific Northwest timberland returns. A composition of 1960-1986 JHTI returns and 1987-2010 NCREIF returns.				
Parameter	Location	Dispersion	Shape	d.f.
Value	-6.76	529.85	3.78	3.28

Columbia; New Zealand and Australia; and Brazil. The results are presented below.

The parameters for the Skew-t distribution of US South timberland returns are given in Table 15. We constructed the return series by forming a composition of the JHTI returns for the years 1960-1986 and the NCREIF returns for the years 1987-2010, with 1987 being the first year when NCREIF returns are available. Note the negative value of the shape parameter, indicating slight left skewness, and degrees of freedom greater than thirty, indicating the absence of heavy tails.

Figure 12 displays the fitted probability density function on the left and an overlay plot of the empirical and fitted cumulative density functions on the right. The fitted cumulative density function does not deviate far from its empirical counterpart, indicating a good fit to the data.

The Skew-t distribution parameters of the US Pacific

Skew-t Distribution Model

US Pacific Northwest Returns, 1960-2010 Skew-t Distribution.	Empirical and Skew-t Cumulative Distribution Functions.

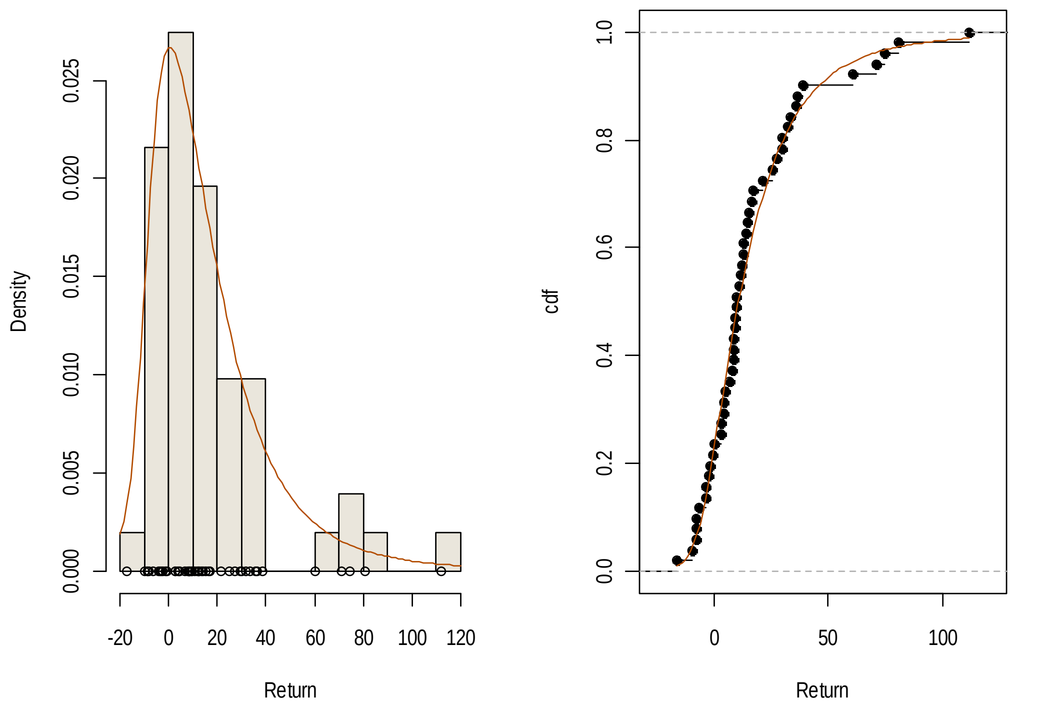

Figure 13: Skew-t distribution of timberland returns in the US Pacific Northwest.

Northwest timberland returns are given in Table 16. As for the US South, the Pacific Northwest return series is a composition of the JHTI returns from years 1960-1986 and the NCREIF returns from years 1987-2010.

Note the large positive value of the shape parameter and low degrees of freedom. This indicates the presence of strong positive skewness and heavy tails. The shape of the fitted Skew-t distribution is illustrated in the left pane of Figure 13. The right pane of Figure 13 shows an overlay of fitted and empirical cumulative density functions. The Skew-t distribution fits the data well particularly in the left tail and around the median. The fit in the right tail of the distribution is less strong due to the presence of outliers in the data.

The presence of outliers in the US Pacific Northwest return series makes the selection of a proper density function difficult. A quick glance at the time series plots of the returns reveals that the US Pacific Northwest experienced two periods of large and highly volatile returns. The occurrence of abnormally high returns occurred in the 1970s, and resulted from when a combination of the monetary policy pursued by the Federal Reserve and timber harvest contract management practiced by the Forest Service.

In this period, the Forest Service, then the dominant supplier of stumpage in the region, continued to auction timber harvest contracts, which gave the winner the right, but not the obligation, to harvest timber from a specified area. Simultaneously, the Federal Reserve, led by Paul Volcker, embarked on a policy designed the stamp out high inflation. The announced inflation fighting goal was initially viewed as lacking credibility by the harvest contract auction participants, who continued to aggressively compete for timber harvest rights and found themselves embroiled in an ever intensifying bidding contest as they struggled to avoid bankruptcy during a period of high interest rates and depressed economic activity (Mattey, 1990).

Skew-t Distribution Model

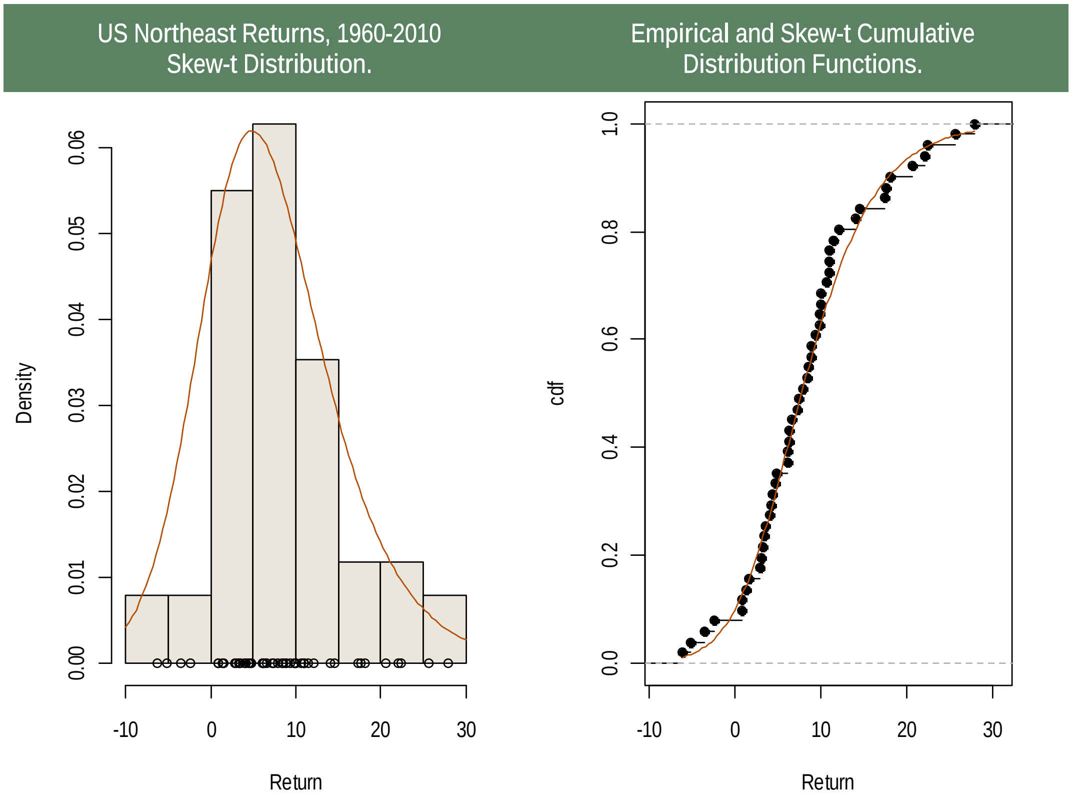

Figure 14: Skew-t distribution of timberland returns in the US Northeast.

Table 17: US Northeast timberland returns. A composition of 1960-1994 JHTI returns and 1995-2010 NCREIF returns.				
Parameter	Location	Dispersion	Shape	d.f.
Value	2.17	73.71	1.57	9.57

The second high-return period began in the late 1980s and lasted until the early 1990s. In this period, returns to private timberland were driven upward by the uncertainty regarding the timber supply from public forests created by years of litigation over the status of the northern spotted owl. A 1990 federal court ruling declared the spotted owl a protected species and barred the Forest Service from harvesting timber from national forests in the US Pacific Northwest. The sudden reduction in timber supply pushed up prices and led to higher returns to private forest owners. (Sohngen and Haynes, 1994; Adams et al., 1996)

Because the outliers in the US Pacific Northwest returns were caused by policy shifts that are unlikely to be repeated in the future, robust statistical methods could be used to decrease the outlier influence within the sample data to improve the fit of the skew-t distribution—a topic for a future publication.

The skew-t parameters for the returns to timberland in the US Northeast are shown in Table 17. The return

Skew-t Distribution Model

Coastal British Columbia Returns, 1960-2010 Skew-t Distribution.	Empirical and Skew-t Cumulative Distribution Functions.

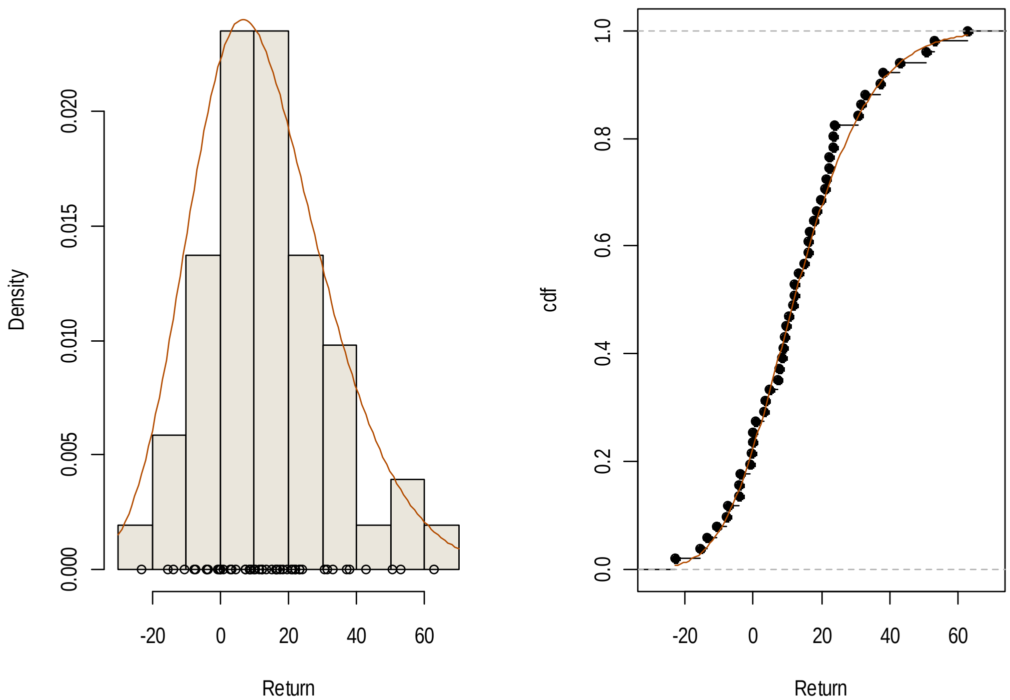

Figure 15: Skew-t distribution of timberland returns in coastal British Columbia.

Table 18: JHTI timberland returns from coastal British Columbia, 1960-2010.				
Parameter	Location	Dispersion	Shape	d.f.
Value	4.44	614.86	2.07	85.47

series is composed from the JHTI returns from years 1960-1994 and NCREIF returns from 1995-2010, with 1995 being the first year when NCREIF returns are available in the region. Note that the shape parameter in Table 17 is positive, indicating moderately right skewed returns, and the degrees of freedom are low, indicating the presence of heavy tails.

The fitted skew-t probability density is illustrated in the left pane of Figure 14. The right pane displays an overlay of the fitted and empirical cumulative density functions. The overlay plot indicates that the Skew-t distribution with parameters given in Table 17 provides a good fit of the US Northeast timberland returns.

The skew-t distribution parameters for timberland returns in coastal British Columbia are shown in Table 18. Recall, no NCREIF returns are available for non-US regions, hence the entire series is composed of JHTI returns.

The shape parameter in Table 18 is positive and

Skew-t Distribution Model

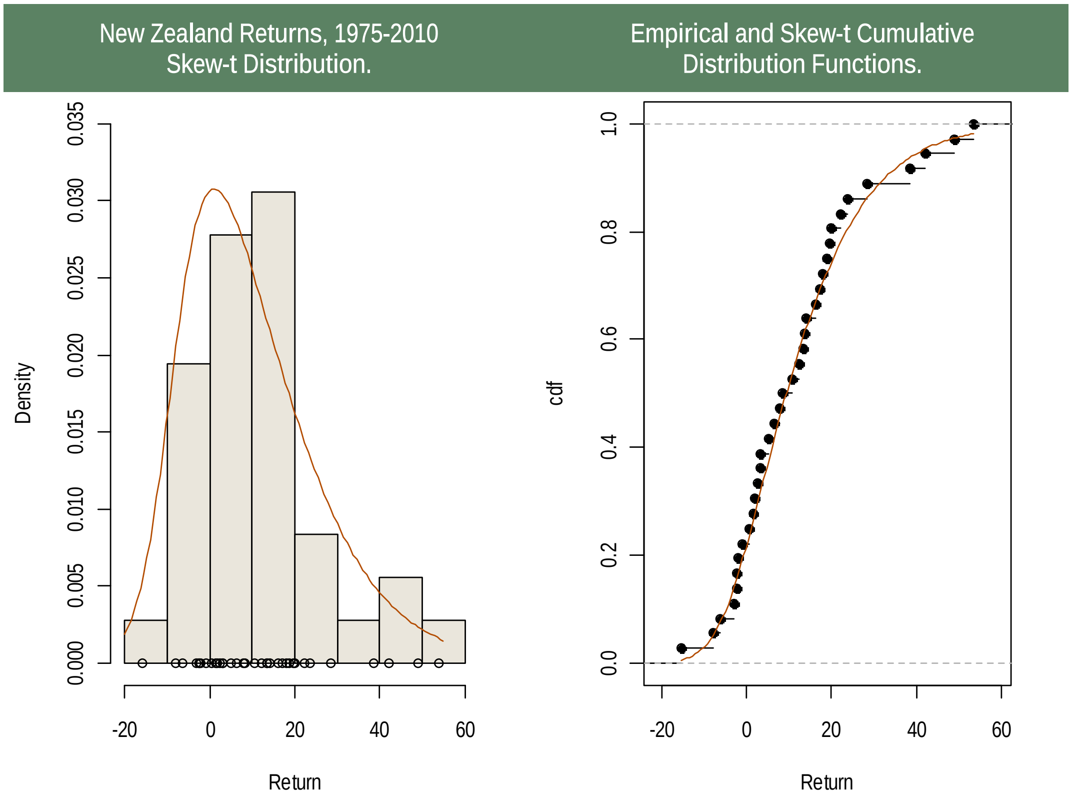

Figure 16: Skew-t distribution of timberland returns in New Zealand.

Table 19: JHTI timberland returns from New Zealand, 1975-2010.				
Parameter	Location	Dispersion	Shape	d.f.
Value	-5.37	444.06	3.36	10.52

indicates moderately right skewed data. Degrees of freedom are high, which shows that the coastal British Columbia returns do not exhibit heavy tails. The left pane of Figure 15 illustrates the shape of the skew-t distribution with parameters given in Table 18. The overlay plot in the right pane of Figure 15 shows that the fitted distribution matches the returns data observed in the region well.

Table 19 holds the skew-t distribution parameters of New Zealand timberland returns. As in the other non-US regions, no NCREIF data are available and the entire dataset is composed of JHTI returns for the years 1975-2010.

The values of the shape parameter and degrees of freedom indicate that the data are positively skewed and exhibit heavy tails. Figure 16 illustrates the shape of the fitted skew-t distribution in the left pane, and provides a visual assessment of the fit quality in the right pane. The skew-t distribution fits the New Zealand data well, particularly in the lower tail and

Skew-t Distribution Model

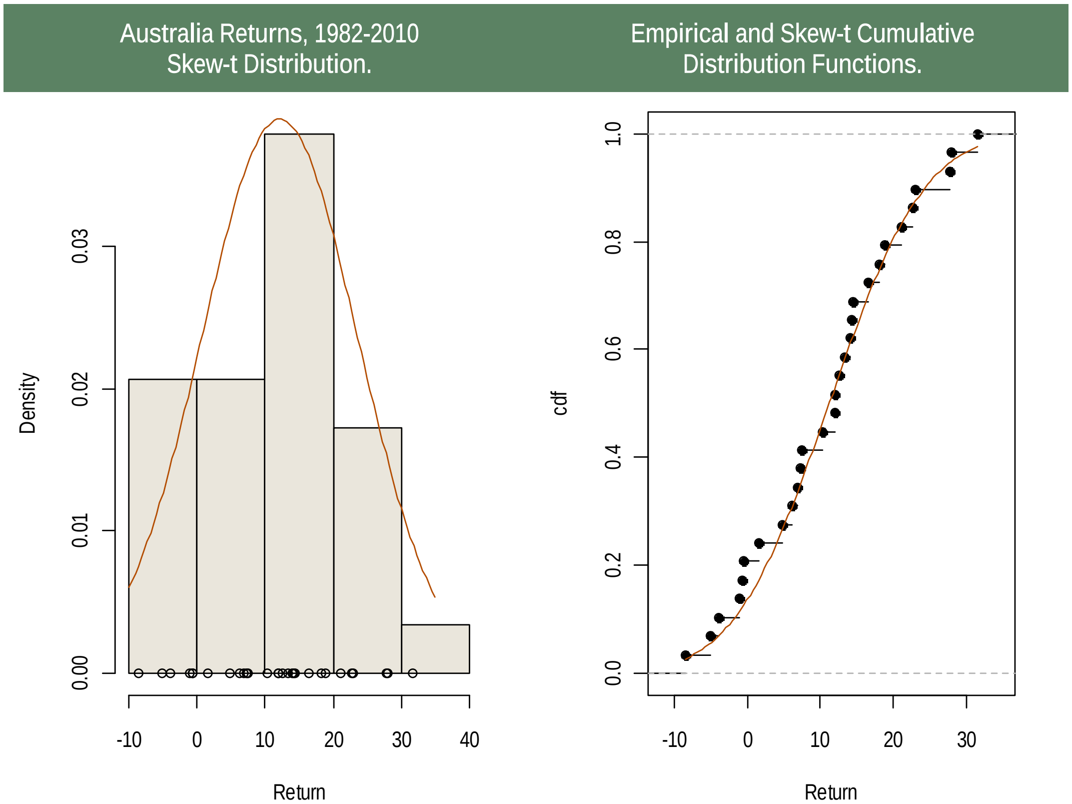

Figure 17: Skew-t distribution of timberland returns in Australia.

Table 20: JHTI timberland returns from Australia, 1982-2010.				
Parameter	Location	Dispersion	Shape	d.f.
Value	11.18	104.85	0.004	15688.79

around the mode of the distribution.

The parameters of the skew-t distribution fitted to timberland returns observed in Australia are presented in Table 20. The dataset consists of historical JHTI returns recorded over the years 1982-2010. Note that the shape parameter is nearly zero and the degrees of freedom are very large. These two results indicate that the return distribution is nearly symmetrical and does not exhibit heavy tails, and confirm earlier findings that the null hypothesis of normality cannot be rejected at a reasonable confidence level.

Figure 17 provides an illustration of the shape of the skew-t distribution fitted to the Australian return data in the left pane, and a visual assessment of the goodness of fit in the right pane. The fitted cumulative distribution function well approximates its empirical counterpart, though caution should be exercised when interpreting the results due to the limited size of the dataset.

Skew-t Distribution Model

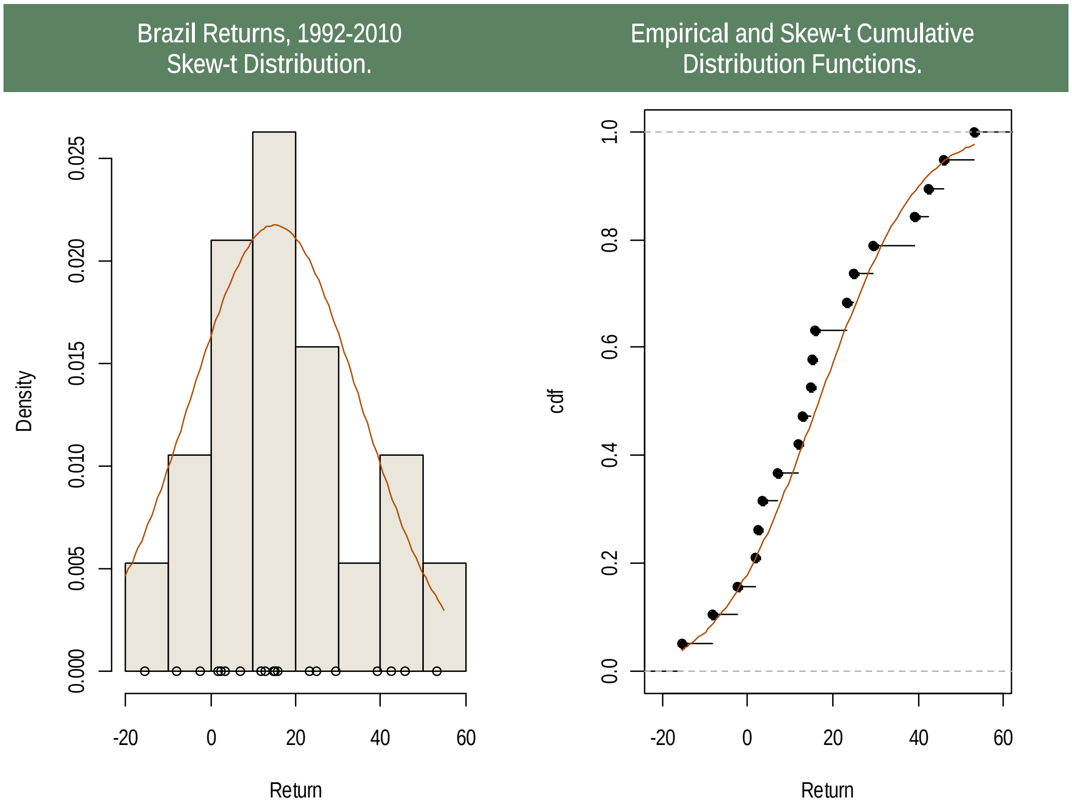

Figure 18: Skew-t distribution of timberland returns in Brazil.

Table 21: JHTI timberland returns in Brazil, 1992-2010.				
Parameter	Location	Dispersion	Shape	d.f.
Value	16.27	336.20	0.03	10196.50

Although the available return series for timberland in Brazil is limited, we fit a skew-t distribution to observed returns and provide the results for the sake of completeness. The parameters of the returns distribution are presented in Table 21. Note the low value of the skewness parameter and the large value of the degrees of freedom. These values indicate that the data are nearly normally distributed and confirm the results discussed in the previous section where the null hypothesis of normally distributed returns could not be rejected at reasonable confidence levels.

A visual of the fitted skew-t distribution is given in the left pane of Figure 18. The right pane shows an overlay of the empirical and skew-t cumulative density functions, and indicates that the skew-t distribution provides a good fit to the observed returns from timberland in Brazil. The results, though, should be interpreted cautiously because the amount of available returns data in Brazil is limited.

Summary

Our analysis of timberland returns reveals some degree of departure from normality in most regions. In particular, the normality assumption can be rejected for the NCREIF, but not the JHTI, returns in the US South and Pacific Northwest. This disparity in test results indicates that the timber price driven JHTI methodology does not fully capture all aspects of timberland returns in the US, where a large part of timberland returns is formed by capital appreciation—a component not employed in the construction of the Index. The NCREIF return series from the US Northeast does not significantly depart from normality, but it is shorter and based on fewer properties than the US South and Northwest data, and the results of normality tests in the Northeast are therefore less robust.

In New Zealand, where NCREIF returns are unavailable, the visual analysis of QQ-plots of returns shows mild non-normality in the data, but the results of several hypothesis tests are inconclusive. Similarly, the JHTI returns in Brazil, coastal British Columbia, and Australia show heavier tails in their QQ-plots than would be expected under the normal distribution, but the departures are not statistically significant. However, unlike the results for coastal British Columbia, the results for Australia and Brazil are obtained from relatively small datasets, and more data are needed to draw more definitive conclusions.

In all regions, the Skew-t distribution fits the data better than the normal distribution, and provides a more flexible model of timberland return distribution. The skew-t distribution is particularly suited to modeling NCREIF returns in the US South and Pacific Northwest, which show the largest departures from normality.

Because the Markowitz mean-variance portfolio optimization methodology, a popular tool for analysis of timberland investments, relies on the assumption of normally distributed returns, its use may not be appropriate in the case of many timberland investments. Methods developed to address non-normality in the context of portfolio optimization need to be employed in such cases.

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Glossary

Alternative Hypothesis – Rival hypothesis of the null hypothesis

Density Estimate – Probability distribution constructed from observed data

EBITDDA – Earnings before interest, taxes, depletion, depreciation, and amortization

Gaussian Kernel – Weighting function based on the normal distribution

JHTI – John Hancock Timberland Index

Kurtosis – Measure of thickness of probability distribution tails with default value of 3

Excess Kurtosis – Kurtosis minus 3

NCREIF – National Council of Real Estate Investment Fiduciaries

Null Hypothesis – Scientific hypothesis capable of being falsified using a test of observed data

p-Value – Probability of observing a test statistic value as extreme or more extreme than the value actually observed under a given null hypothesis

Quantile – Set of points that divide ordered data into essentially equal-sized data subsets

QQ-Plot – Quantile-Quantile plot maps theoretical distribution quantiles to empirical ones

Skewness – Measure of non-symmetry of a probability distribution

Skew-t distribution – Generalized Student t-distribution which allows both heavy tails and skewness