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Exploring the Linkage Between Commodity Chain Profile and Performance: A Case Study of Sawn Wood in Uganda

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Abstract: Secure supply of wood remains a challenge partly due to resource conservation efforts that have failed to focus on the sawn wood supply chain as a whole. This study investigated the influence of sawn wood commodity chain profile on its performance. Data were collected from the production and distribution chain of 35 production units selected randomly. Production batches comprising of at least fifteen logs each were used at each unit to collect data on volume recovery factor, value addition and revenue distribution between participants in the unit's distribution chain. One-way multivariate analysis of variance was used to test the hypothesis that there is no difference in performance parameters between the sawn wood commodity chain channels. Results revealed a significant multivariate effect ($p < 0.05$) for channel of operation on performance thus rejecting the null hypothesis. Univariate ANOVA showed significant difference ($p < 0.05$) between the channels on all the three performance parameters. It was recommended that factors influencing the performance parameters be investigated and standards established for benchmarking; the three performance dimensions be integrated into a single index for assessing the overall performance; and the impact of sawn wood commodity chain performance on sawn wood supply sustainability be investigated.

INTRODUCTION

The wood resource base for timber production in Uganda has been declining since the mid 1970s following the collapse of the sawmilling industry and the emergence of artisan timber production [1, 2]. Consequently, the sustainability of sawn wood supply in Uganda is threatened by the prevailing wood resource scarcity as available forests cannot sustain the level of harvesting required to satisfy the steadily increasing sawn wood demand [1-3]. Considerable effort has been put on resource conservation and the improvement of processing efficiency but secure supply of wood remains a challenge. This can be partly attributed to the focus on forest protection and the efficiency of the production stage instead of the sawn wood supply chain in its totality. While it is acknowledged that performance of the sawn wood sector in Sub-Sahara Africa in terms of conversion efficiency is generally poor [4], the strategies adopted in Uganda that focus on selected sections of the timber supply chain and virtually ignoring others may not resolve the resource scarcity challenge.

A supply chain is a network of business entities working together to facilitate the flow of material, information, money and property rights across organizational boundaries [5, 6]. On the other hand, a commodity chain is a series of interlinked exchanges through which a commodity and its constituents pass from extraction to end use; commodity chains serve as conduits through which commercialized natural resources are ushered from the land to their final users [7]. Thus the sawn wood commodity chain can be viewed as a supply chain that facilitates the production and distribution of timber. The timber commodity chain in Uganda consists of three channels (Fig. **1**). In channel 1, sawn wood producers, mainly sawmillers, obtain trees from forest reserves through a public bidding system, produce sawn wood and transport it to urban timber markets. In channel 3, sawn wood producers, mainly pit-sawing contractors, obtain one-year concessions to harvest from designated areas on private land within a district local government. They employ pit-sawyers to produce the sawn wood after which it is transported to markets. Channel 2 is a conduit for illegal timber produced by independent pit-sawyers, operating either on casual license or illegally, and chainsaw millers. The later actors operate illegally. Actors in channel 2 operate extensively on private land and in reserves albeit at a small scale. After conversion, the sawn wood is distributed locally or traded underground in urban areas as it is a target for confiscation by regulatory authorities [8].

Little is known about the performance of the above sawn wood commodity chain. This can be attributed to the current

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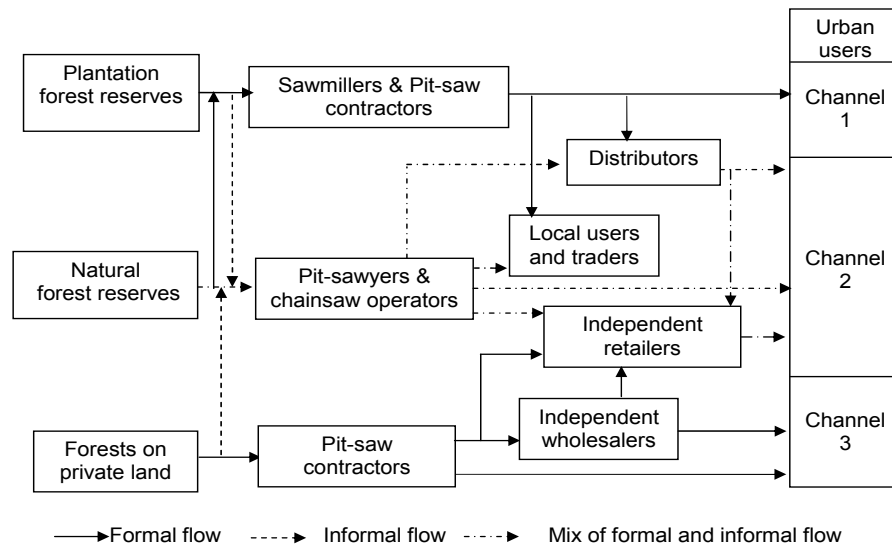
Fig. (1). Sawn wood production and distribution system [8].

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focus on particular segments of the chain, particularly sawn wood production [9]. The measures used are restricted to such segments, with no measurement of overall supply chain performance. It has been noted that effective evaluation of supply chain performance requires the use of integrated measures that are cross-functional and can be applied to the entire process in order to avoid optimization at one point in the chain without considering potential consequences at other points [6]. A wide range of measures for assessing supply chain performance have been developed. However, the traditional performance measures used for supply chain analysis focus on issues relating to logistics such as cost, activity time, inventory level, product quality, customer responsiveness and flexibility [10-13]. These are important characteristics of a supply chain but do not address natural resource commodity chain challenges such as resource shortages and the fair distribution of economic gains among the chain participants. According to [14], the success of a commodity system depends on standardisation of the commodity and its sale at a low price, two aspects that make commodities accessible and dependable but not sustainable because they tend to drive commodity systems towards resource depletion, price instability and inequity. An examination resource sustainability in commodity systems using the sawmill industry as a case study by [15] demonstrated the potential of the industry to overshoot the capacity of the forest resource and showed that commonly advocated policies in response to resource shortages could not solve the challenge.

As wood becomes increasingly scarce, efficiency in its utilization is a primary concern in timber manufacturing and this should be viewed in terms of both increased yields and revenues for the mills [16]. Thus the basic philosophy for the timber production and distribution system should be the optimisation of volume and value yield [17]. Value yield can be calculated as the sum of all revenues generated from one cubic meter of solid wood [18, 19]. On the other hand, volume yield which is expressed as a recovery percentage or a wood consumption factor relates the volume of timber to volume of logs from which the timber is manufactured [18,

20]. These traditional measures of performance in the timber production chain focus on the production stage only. This study investigated the influence of sawn wood commodity chain profile on its performance. The performance of the sawn wood commodity chain was evaluated on the basis of wood conversion capability, value addition potential and distribution of value added between the commodity chain participants. It was hypothesised that there is no difference in the performance of the sawn wood commodity chain channels.

METHODS

Data Collection

Data were collected from the production and distribution chain of 35 production units selected using stratified random sampling with the channel of operation as the strata. A production batch comprising of at least fifteen logs for manual operations and thirty logs for mechanised operations were used at each production unit to collect data on log size (small and large diameter, length), timber size (nominal cross-section and actual length), log cost, and timber price along the distribution chain (ex-mill, wholesale and retail). These data were used to ascertain three performance parameters for the sawn wood commodity chain which included a volume recovery factor (numerically equal to the log volume required to produce a unit volume of timber), a value amplification factor (numerically equal to the number of times the value of a unit volume of logs is amplified by the commodity channel) and a distribution equity index (using timber revenue concentration as a dummy for distribution equity).

Data Analysis

Multivariate analysis of variance was used to test the hypothesis that there is no difference in performance parameters between the sawn wood commodity chain channels. The performance parameters were obtained for each channel of the commodity chain using the formulae

below. Parameters for each production unit were obtained as simple average values for the logs processed and the resulting timber while the parameters for each channel were obtained as simple average values for the units in that channel.

$$VRF = \frac{VL}{VT} \tag{1a}$$

$$VL = \sum_{i=1}^{m}\left[\frac{\pi H_i}{8}\left(dt_i^2 + db_i^2\right)\right] \tag{1b}$$

$$VT = \sum_{j=1}^{n}\left(L_j \times v_j\right) \tag{1c}$$

$$VAF = \frac{PT}{PL} \tag{2a}$$

$$PT = \sum_{j=1}^{n}\left(pt_{j4} \times L_j\right) \tag{2b}$$

$$PL = VL \times pl \tag{2c}$$

$$DEI = \sum_{All\ k} S_k^{\ 2} \tag{3a}$$

$$S_k = \frac{I_k}{PT} \tag{3b}$$

$$I_k = \begin{cases} PL & for\ k = 1 \\ \sum_{j=1}^{n}\left(pt_{jk} - pt_{jk-1}\right) \times L & otherwise \end{cases} \tag{3c}$$

where for each production unit:

VRF = volume recovery factor;

VL = input log volume (m^3) in a log batch;

VT = output timber volume (m^3) from a log batch;

H_i = length (m) of log i;

dt_i and db_i are the small-end and large-end diameters (m) respectively of log i;

L_j is the total timber length (running metres) for timber size j from a log batch;

v_j = volume per running metre (m^3/m) for timber size j;

m = number of logs processed in a log batch;

n = number of timber sizes produced from a log batch;

VAF = value amplification factor;

PT = market value of timber from a log batch;

PL = stumpage value of logs in a log batch;

pt_{jk} = average timber price per running metre for timber size j at stage k;

pl= average stumpage price per m^3 of logs;

DEI = distribution equity index;

S_k = ratio of gross income shared by stage k to the market value of timber;

I_k = gross income shared by stage k of the sawn wood commodity chain;

k = 1 (tree supply), 2 (timber production), 3 (wholesale distribution), 4 (retail distribution).

RESULTS

Analysis shows that the mean volume of wood required to produce a cubic metre of timber was lower in channel 1 compared to channels 2 and 3, with channel 2 requiring the highest volume. Similarly channel 3 exhibited the highest value amplification potential and channel 1 the lowest while in terms of sharing timber revenue, channel 3 exhibited a relatively more even distribution compared to the other channels, with channel 2 having a higher revenue concentration (Table **1**). Taking into account the fact that tree owners barely participate beyond tree supply while producers invariably do the distribution as well, the highest share of revenues captured by a single category of actors ranged between 57-74%, 48-78% and 42-65% in channels 2, 3 and 1 respectively (Fig. **2**). When this is taken into account, the distribution equity index would change to 0.473, 0.602 and 0.608 for channels 1, 2 and 3 respectively indicating higher revenue concentrations for channels 2 and 3 compared to channel 1. A one-way ANOVA for distribution equity index indicates significant difference between the channels ($F_{2, 32}$ = 117.6, p < 0.05) with posthoc tests showing that channels 2 and 3 are not significantly different from each other but both are significantly different from channel 1.

Table 1.   Performance of the Sawn Wood Commodity Chain

Channel	N	Mean Performance*		
		VRF	**VAF**	**DEI**
1	15	3.030 (0.0542)	2.469 (0.0545)	0.365 (0.0075)
2	8	3.251 (0.0675)	5.658 (0.6180)	0.412 (0.0175)
3	12	3.154 (0.1152)	7.788 (0.1152)	0.326 (0.0047)

*Figures in brackets are standard errors.

A one-way MANOVA was conducted to assess the omnibus performance difference between channels of the sawn wood commodity chain (Table **2**). Values in the row for Table **2** labelled 'Channels' indicate whether means of performance parameters differ significantly between channels. The results show a significant (p<0.05) multivariate effect by channel of operation thus rejecting the null hypothesis that there is no difference in performance between channels of the sawn wood commodity chain. Univariate tests were carried out to ascertain the source of the omnibus multivariate effect. Results of these ANOVAs (Table **3**) compare mean performance of the individual performance measures for each channel. According to the values for the row of Table **3** labelled 'Channels', all dependent variables (VRF, VAF & DEI) showed significant (p<0.05) effect of channel of operation on all the three performance parameters. This suggests that channels of the sawn wood commodity chain differ in regard to the amount of raw wood required to produce a unit volume of timber, amplification of the value of wood passing through them and the distribution between participants of the revenue arising from the timber. Post-hoc analysis (Table **4**) revealed significant pair wise differences between channels of the sawn wood commodity
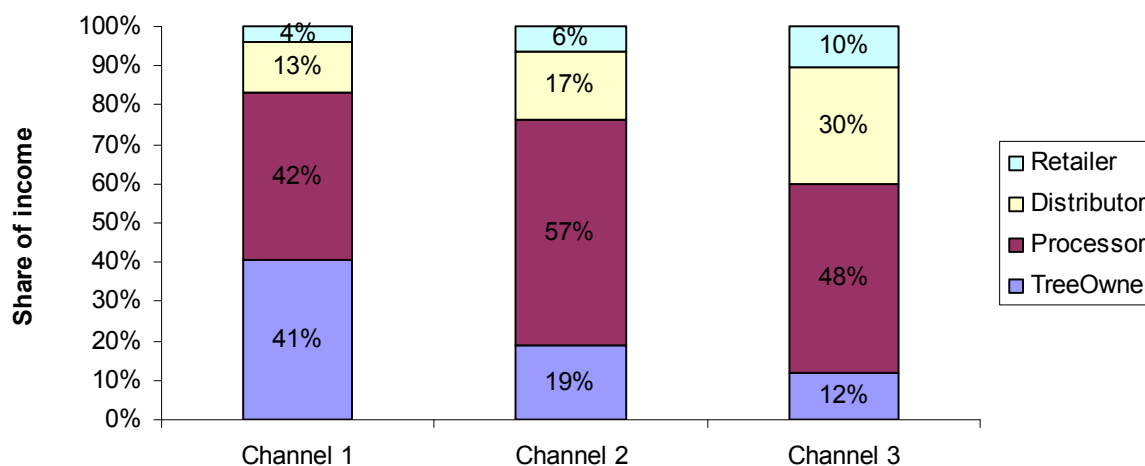
Fig. (2). Share of timber revenue between sawn wood commodity chain participants.

Table 2.   Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.983	613.1	3.000	31.000	.000	.983
	Wilks' Lambda	.017	613.1	3.000	31.000	.000	.983
	Hotelling's Trace	59.335	613.1	3.000	31.000	.000	.983
	Roy's Largest Root	59.335	613.1	3.000	31.000	.000	.983
Channel	Pillai's Trace	.870	68.941	3.000	31.000	.000	.870
	Wilks' Lambda	.130	68.941	3.000	31.000	.000	.870
	Hotelling's Trace	6.672	68.941	3.000	31.000	.000	.870
	Roy's Largest Root	6.672	68.941	3.000	31.000	.000	.870

Table 3.   Univariate ANOVA for Performance Parameters

Source	Dependent Variable	Sum of Squares	Df	Mean Square	F	Sig.	Eta Squared
Intercept	VRF	323.751	1	323.751	10168.846	0.000	0.997
	VAF	921.022	1	921.022	1094.274	0.000	0.972
	DEI	4.427	1	4.427	6981.296	0.000	0.995
Channel	VRF	0.274	2	0.137	4.300	0.022	0.212
	VAF	192.802	2	96.401	114.535	0.000	0.877
	DEI	0.035	2	0.018	27.637	0.000	0.633
Error	VRF	1.019	32	0.039			
	VAF	26.934	32	0.842			
	DEI	0.020	32	0.001			
Total	VRF	342.696	35				
	VAF	1102.272	35				
	DEI	4.656	35				

chain for all the performance parameters except VRF between channels 2 and 3, and channels 1 and 3.

DISCUSSION

Although analysis shows that the volume recovery factor differs significantly between channels of the sawn wood commodity chain, it is evident that a relatively large volume of wood is consumed in producing timber in all the three channels. The high volume of wood required per unit timber volume can be attributed to the inefficient technology used for timber production. These include swivel mobile sawmills in channel 1, pitsaws in channel 3 and mixture of chainsaws, saw benches and pitsaws in channel 2. Owing to the declining wood inventory, only swivel sawmills can be

Table 4.   Pair Wise Comparison Between Channels

Variable	Channel		Mean Difference (I-J)	SE	Sig.
	I	J			
VRF	1	2	-0.222*	0.078	0.008
		3	-0.125	0.069	0.081
	2	3	0.097	0.081	0.243
VAF	1	2	-3.189*	0.402	0.000
		3	-5.139*	0.355	0.000
	2	3	-2.130*	0.419	0.000
DEI	1	2	0.046*	0.011	0.000
		3	0.039*	0.010	0.000
	2	3	0.085*	0.011	0.000

*Significant mean difference at 5% level; SE = standard error.

viably operated due to their small size and these have been noted to be inefficient [9]. Similarly pit-sawing and free-hand chainsaw milling have been noted to be wasteful [2]. The variation in volume of raw wood required can be attributed to differences in the nature of wood processed. Channel 1 actors deal with plantation-grown softwood resource in reserves which have trees that are of relatively good quality compared to trees growing in natural forests and on-farm, which actors in channel 3 handle. Channel 2 is a mixture of trees from all sources and would have had favourable volume recovery as timber producers in this channel are relatively selective in regard to the trees they process. However some of the actors in this channel use inefficient equipment such as free-hand operated chainsaws that result in high levels of waste.

The value amplification factor is a comparison of the value of timber to the value of logs from which it was processed. It is a value-free parameter that can be used to assess the value addition potential of the channel through which the timber is produced and distributed. Analysis has shown a significant difference in value amplification potential of the sawn wood commodity chain channels. This can be attributed to the differences in nature of wood processed which, for channels 1 and 3 attracts different prices while in channel 2 the actors have access to relatively low cost (and sometimes free) wood as a result of their informal operations. Channel 3 has the highest value amplification factor followed by channel 2 while channel 1 had the least (Table **1**). This however doesn't necessarily arise out of superb operations that lead to value creation in channels 1 and 2 but rather to the low value of logs in these channels. Examination of Fig. (**2**) indicates that in channels 3 and 2, the value of logs constitutes only 12 % and 19% respectively of the value of timber extracted from the logs while in channel 1 it is 41%. Thus logs through channels 2 and 3 have low inherent value and this can partly explain the high volume recovery factor because actors in these channels can still breakeven even with low timber recovery. However this is not good for sustaining sawn wood production because low log values lead to low inherent value for forest land which leads to its clearance for alternative enterprises such as agriculture. This may explain the high rate of deforestation particularly on private land from where channel 2 and 3 operators source their wood.

The distribution equity index, an indicator of how the timber revenues are distributed between participants was significantly different between the channels indicating that the revenue is shared differently in the three channels. Channel 2 had the highest value indicating a relatively higher revenue concentration while channel 3 had the lowest value indicating a more uniform distribution relative to the other channels. While further research would be required to ascertain what would constitute an equitable distribution of the timber revenues among participants in the commodity chain, it is evident (Fig. **2**) that tree suppliers in channels 2 and 3 get a disproportionately low share of the timber revenue compared to their counterparts in channel 1. In all the three channels, timber producers take the largest portion of the revenues. According to [9], timber producers barely participate in tree supply/planting but in most cases integrate wholesale distribution in their timber production business. When this is taken into account, it would imply that their share of timber revenues can range between 55% in channel 1 to 78% in channel 2. A high proportion of revenues shared by this link of the sawn wood commodity chain could be attracting more actors to participate in the link and encourages illegal harvesting when such actors fail to get operating licenses. The high share of revenues by the tree supply link in channel 1 can be attributed to the near monopoly supply in this channel since, at the moment, mature plantations are only found in government reserves. On the other hand, tree suppliers in channels 2 and 3 are small scale forest, woodlot or farm owners each selling their trees individually to the timber producers and as such have limited bargaining power. Moreover, according to [1], such forest owners are often ignorant of market prices and frequently sell their trees at low prices. While the timber producers may take advantage of this to make gains, low wood prices for tree suppliers may not be sustainable as already noted above. This also has implications for the current timber woodlots and plantations being widely established on private land in that unless these tree growers come together to have a collective voice and share information, they stand to gain little from their efforts.

CONCLUSION AND RECOMMENDATIONS

This study has demonstrated that there is a significant difference in the performance of channels of the sawn wood commodity chain in relation to the volume of wood required to produce a unit volume of timber, value addition potential and the share of revenues arising from the sawn wood commodity chain. In the absence of benchmarks, no particular channel can be recommended as a model for sawn wood production and distribution on all the three parameters. Generally all the three channels need to address the high wood consumption, the low value addition potential and inequitable distribution of timber revenues especially to the tree supply link to foster sustainable tree supply. It is recommended that the factors that influence performance dimensions be investigated and standards established against which performance of the sawn wood commodity chain can be benchmarked; the three performance dimensions be integrated into a single index that can be used to assess the overall performance of the sawn wood commodity channels and the chain as a whole; and the impact of sawn wood commodity chain performance on sawn wood supply sustainability be investigated.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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