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Use of Dynamic Models to Assess Impact of Changing Tea Prices on Family Income of Smallholders in Kenya

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Abstract: This research aimed at understanding the effect of changing tea prices on welfare of smallholders in Kenya. A total of 60 tea farmers were interviewed. After data collection and preliminary analysis, multivariate cluster analysis was done to classify the families into two groups. Based on findings of statistical analysis of resources and living standards of the families, a strategy of changing the tea prices was formulated. Raising the prices of tea was hypothesized to increase family income. Ten year dynamic models were applied to measure the impact of this strategy on family income. Two types of data were used. The first set was averages from statistical analysis of survey data and the second set of data was prices of tea for a period of 12 years obtained from the local tea factory. Analysis of these prices indicated fluctuation and since the main objective was to test the impact of fluctuation on family income, future random prices were created using the 12 years prices. Optimal family income was first calculated using tea prices obtained from the survey and later recalculated using random prices. Results indicated that fluctuation in tea prices has low effect on stability of family income among the tea smallholders in the survey region.

Key words: Declining living standards, cash crop producers, future development strategy

INTRODUCTION

Since independence, tea production in Kenya has increased from 18,000 to 220,000 metric tons with smallholder subsector rising from 1.7 to 59% (Nyangito and Kimura, 1999a). At a macro level, tea has made a substantial impact on Kenya's economy by employing over 3 million individuals (Gesimba *et al*., 2005) and contributing to foreign exchange. In fact, Kenya is the fourth major black tea producer in the world market and also ranks second after Sri Lanka in tea exports. Kenya's tea plays a very important role in blending with others (Nyangito and Kimura, 1999b) to improve their quality. Compared with other export crops, tea has maintained an upward trend. However, the contribution of tea at the micro level has been declining, especially among smallholders. This is despite the fact that small-scale tea production accounts for 65% of the total area under tea production and about 62% of production (Nyangito, 2000). This decline may be attributed to decline in the world market and diminishing demand in most of the main traditional markets. Since, the late 90s to date, earnings from tea production have not been lucrative and farmers are unable to fulfil their family needs as compared to the period following the introduction of the crop in Kenya and the late 1980's to early 1990's when tea farmers earned much higher than other farmers in the neighbouring regions and other parts of the country. Due to earlier attractive tea prices, they planted large parcels of their land with tea and left little for food crop and other activities. They therefore relied on the market purchase of food. With fluctuation of tea prices and increased production costs, tea smallholders are now faced with double tragedy-low income and low food availability. Getting alternative sources of income has been a challenge for these farmers as they have limited land, capital and water resources-all which are required to increase agricultural production and increase their family income. Some have tried to venture into off-farm activities. However, these opportunities are also limited. There are no large scale farms to work in and those farmers who offer casual labour are few and do not pay enough to enable the labourers to adequately support their families.

The study focus is small scale tea producers who are facing declining living standards and economical struggle despite the fact that tea is a major foreign earner for the country. Farmers are no longer able to meet their basic needs and many youths are moving to urban regions to search for better paying jobs. This study aimed at identifying and testing strategies that could be implemented to enhance family income.

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MATERIALS AND METHODS

The analysis presented in this study relate to data collected in the tea growing zones of Murarandia location, Murang'a District in the year 2005, within a larger framework of a Ph.D research. To select families for the family survey, a list of tea buying centres was obtained from Githambo tea processing factory, the only tea factory in the region. All smallholder tea producers in Kenya have accounts in factories through which they sell their produce. After tea is harvested from the farm, it is taken to the buying centre where it is sorted to ensure only quality leaf is delivered to the factory for further processing and also weighed to determine the amount each farmer has. Eight buying centres under the jurisdiction of Githambo tea factory were randomly selected. The names of all families delivering tea through the eight buying centres were listed alphabetically and systematic random sampling was applied to select 60 families. After data collection and preliminary analysis of family resources, the tea families were found not to be homogenous based on their family and land sizes. These two factors determine the class or group a family can be identified with in terms of their living standards or welfare. Like in many agricultural areas in sub Sahara Africa, land size in this region determines the potential or limitation of production in a family while family size determines requirement of food and sometimes, accessibility of other needs such as education and health. Therefore, variables that explained family and/or land size were used to classify the sample into two homogenous groups, namely the resource rich and resource poor, using hierarchical cluster analysis in SPSS. To identify variables for the analysis, a correlation analysis was first done. As März (1990) indicates, those variables which show high correlations, $r>0.5$, with one or more other variables disturbs the classification process. Therefore, the variables selected for the analysis showed a weak correlation. Using SPSS, average linkage procedure in combination with cosine distance measure were selected to carry out the analysis.

Descriptive statistical analysis of resources, crop and livestock production activities, off-farm and consumption activities and other aspects of living standards of the families were then done to provide an understanding of the farming systems and hence formulate a strategy to improve their income. The analysis indicated that fluctuation of tea prices was a major problem in the region. A strategy of changing the tea prices was therefore formulated. The hypothesis was that increasing tea prices may increase family income. Ten year dynamic models were applied to measure the impact of the strategy on family income. Averages calculated from descriptive analysis were used as statistics in the models. Modelling entails allocation of limited family resources to activities which compete for these resources and provide different contributions to the family objectives. Decision making about resource use in a year has an effect on resource use in other years because farm resources change over time thus the need for dynamic models. Every year or every period in the model applied in this study was linked by a single objective. First and foremost, basic models of the two groups created through hierarchical cluster analysis were designed. The basic model of each group describes the farming system of the group through technical coefficients, resource constraints and a set of activities based on the results of the survey and therefore represent reality. Monte Carlo simulation was then used to randomly create future prices that were applied in testing the strategy of changes in tea prices. After implementation of the strategy, that is, replacing the survey tea prices with the future prices, the models were run again. The results of the model were calculated using the XA professional programme. To assess the impact of the strategy, two procedures were followed:

- Application of the dynamic models of each group for a period of 10 years assuming only the current trend for the entire period (without a new strategy)
- Application of the dynamic models with a modified scenario (with strategies) and then the results were compared

The difference between both outcomes may be regarded as the impact of the tested strategy on the living standards of the farmers.

FLUCTUATION AND FUTURE STRATEGY

Smallholders sell their produce through factories located in their regions. The prices of tea from each of these factories vary depending on various factors, the major one being the quality of tea leaves. Tea prices in Kenya have been fluctuating over the years. In all smallholder factories in the country, farmers are paid monthly according to the amount of tea (green leaf) they deliver. They are also paid a second time (commonly known as bonus) which may be once a year or distributed twice a year. In Githambo tea factory, the price of one kilo of tea leaf per month increased from Ksh 6 in 1999/2000 to Ksh 9 in 2003/04. Bonus decreased from Kshs 23.38 to 12.05 during the same period. Therefore, a strategy of changing tea prices would be appropriate in improving family income and living standards of the smallholders.

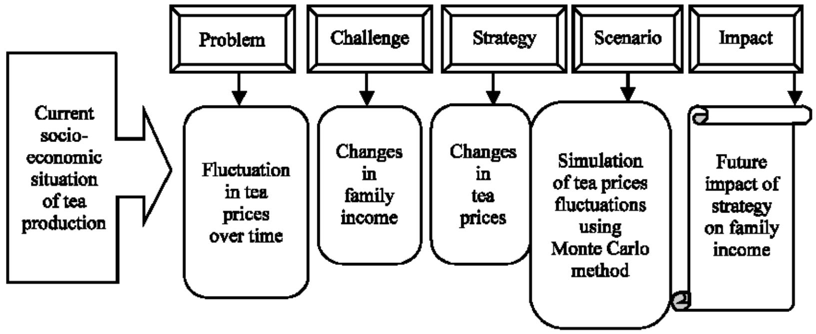

Fig. 1: Strategy and scenario tested for the future impact analysis on family income of smallholder tea producers in Murarandia Location, Murang'a district, Kenya, 2005

This strategy was selected based on farming systems and living standard analysis of the smallholder tea farmers in the region. These analysis identified fluctuation of tea prices as a major problem affecting tea farmers. This is because it leads to variation of family income prompting farmers to continuously adjust their way of life. If a family does not have another source of income, these changes may be more devastating. Children may drop out of school, diseases may go untreated, family may incur debts and food ration may reduce among other problems. The scenario describes how the strategy was tested. This was done by simulating old tea prices to create future prices and then observe the impact of the new prices on family income. When creating the new prices, the trend displayed by the old prices was assumed. Other factors were also assumed to be constant. The problem, scenario and strategy tested are shown in Fig. 1.

Due to the high income contribution of tea to farming families, it was hypothesized that fluctuation of its prices could have a negative effect on the stability of farm income and consequently family income of the families. The fluctuations of tea prices over ten years were simulated using the Monte-Carlo method and the effects on the stability of family income and of the tea production area were estimated using a one-sample t-test. Data to simulate tea prices was for 12 years.

DYNAMIC MODELS

Models provide the link between economic theory and data on one hand and practical appreciation of problems on the other hand (Hazell and Norton, 1986). Limited productive resources have necessitated individual families to make decisions (Hazell and Norton, 1986) on farm, off-farm and household sectors (Grueninger, 2001) which impact on living standards of the farming families. Different actions on this sectors lead to different levels of realization of family objectives. The families are therefore faced with a decision making problem between alternative levels of objective realization (Wallace and Moss, 2001). The modelling of family decisions therefore aims at determining the optimal family resource allocation by determining what is feasible with given knowledge and limited access to resources (Akinsanmi, 2005). This entails allocation of limited family resources to activities which compete for these resources and provide different contributions to the family objectives.

The rationale of modelling is based on the idea that any phenomenon or process can be simplified by leaving out of the picture any aspects or variables that are not of interest to the modeller, while still portraying something meaningful about the real phenomenon or process (Katwijukye, 2005). An attempt is made to investigate the implications for resource management and their use on the sustainable living standard development of the farmers by applying a family model premised on programming techniques.

Decision making about resource use in a year will have an effect on resource use in other years because farm resources change over time. Every year or every period in the model applied in this study was linked by a single objective. The general structure of the dynamic linear programming model has the following mathematical form:

$$\text{Max } Z = \sum_{t=1}^{y}\sum_{j=1}^{n}\left(P_{jt}X_{jt} - C_{jt}X_{jt}\right) \qquad (1)$$

Subject to

$$\sum_{j}^{n} a_{ijtjt} \le b_{it}, \quad \text{all i = 1 to m and all t = 1 to y}$$

$$X_{jt} \ge 0, \quad \text{all j = 1 to n and all t = 1 to y}$$

Where:

- Z = Objective function (family income)
- X_{jt} = Level of activity j in period t
- P_{jt} = Price of per unit of the j output activity in period t
- C_{jt} = Cost per unit of j input activity in period t
- y = No. of periods
- n = No. of possible activities
- m = No. of resources and constraints
- a_{ijt} = Technical coefficient (amount of ith input required to produce one unit of jth activity in period t)
- b_{it} = Amount of ith resource available in period t

The objective function was to maximize the family income subject to family resource availability and other constraints. The family income was maximized through maximization of value of crop and livestock products and off-farm income and minimization of production costs. The components of the objective functions were the variable costs of crop and livestock production per unit of land or livestock unit excluding hired labour costs, the average sales prices of crops and livestock products, household consumption, food purchase, average off-farm wage rate and interest from formal and informal credit. To achieve its objectives, a family must perform activities by using the available resources. These includes farm, family and off-farm activities such as crop production (allocation of each crop), livestock production, selling activities, purchasing of inputs and food, labour used for off-farm activities and hiring of outside labour. The model was subject to resource constraints, the needs of the farm, family and activities that were fixed or have certain minimum or maximum values.

A one-year basic model was used to build the dynamic model for a period of ten years which were linked by a single objective. This is because production plans for one season will have an effect on the following seasons especially in food crop production. The same effect is found in perennial crops whereby effect of one year transcends on the subsequent years. The dynamic model consisted of different periods. For every period, the requirements differ in terms of capital, labour needs and crop yield levels. The technical coefficients in some cases were assumed to be the same in each period but in other cases they were different between periods. The dynamic models were built in such a way that it was possible to transfer surplus cash from period 1 to 2, from period 2 to 3 up to period 10.

Modelling a system requires a certain level of abstraction and simplification of reality, which is expressed in a matrix of main activities and constraints (Katwijukye, 2005). Obtaining model results identical to reality therefore requires complete knowledge and information about farmers' behaviour and decision-making (Pape-Christiansen, 2001). To test how realistic the basic model is and how suitable it will be for future strategy testing, validation is necessary (Praneetvatakul, 1996). A good model should present results, that is, farm, off-farm, family incomes and resource use, that are close to reality (Regassa, 2002) and which behaves in its main components like the real system (März, 1990). Despite the fact that the basic models were designed as close to reality as possible, a gap between the basic model and reality still exists due to the complexity of the real world (Kitchaicharoen, 2003). The mathematical basic model gives results through optimal use and integration of resources in farm and family. It is assumed that the model quality can be accepted if the model results are close to reality. This will not be identical, since reality does not show perfect knowledge and immediate decisions. Validation was done through (1) comparison of farm, off-farm and family income (2) comparison of resource use (land and labour), allocated and enterprise combination.

Table 1 shows that the model predicted higher farm, off-farm and family incomes. The model allocated land used for food crop production to kale, cabbage and potato production. Other food crops which deemed not to contribute significantly to family income were not included. For example, other than kale and cabbage, there were other vegetables such as *solanum* sp. and *amaranthus* sp. grown but only for home consumption and sometimes as wild. Other animals other than cows were found in the farms such as chicken and goats. The farmers however did not keep enough to be considered in the model. As for goats, one could find only one or two which were kept for Christmas or other family gatherings.

The other explanation of the big difference between model results and survey data is that the model allocated the existing land under food crops plus non-cultivated land to food crop production in the model. Therefore, the

Table 1: Comparison of farm, off-farm and family incomes between the basic model and survey among tea smallholders in Murarandia location, Murang'a District, Kenya, 2005

Farm income			Off-farm income			Family income		
Survey	Basic model	Diff. (%)	Survey	Basic model	Diff. (%)	Survey	Basic model	Diff. (%)
76364.9	103244.6	35.2	32240.33	35116.3	8.9	108605.3	138360.8	27.4

Diff. (%): Differences between survey and model results in percentage

Table 2: Comparison of farm, off-farm and family incomes between the basic models and survey among resource rich and resource poor tea smallholders in Murarandia location, Murang'a District, Kenya, 2005

Resource	Farm income			Off-farm income			Family income		
	Survey	Basic model	Diff. (%)	Survey	Basic model	Diff. (%)	Survey	Basic model	Diff. (%)
RR	112606.20	155142.30	37.8	41217.4	44856.40	8.8	153823.6	199998.70	30.0
RP	53836.67	64373.98	19.6	26660.0	31224.71	17.1	80496.7	95598.69	18.8

Diff. (%): Differences between survey and model results in percentage, RR: Resource rich, RP: Resource poor

Table 3: Comparison of enterprise combinations between the basic models and survey incomes, Murarandia location, Murang'a District, Kenya, 2005

Item	All farmers			Resource rich			Resource poor		
	Survey	Model	Diff. (%)	Survey	Model	Diff. (%)	Survey	Model	Diff. (%)
Kales (ha)	0.027	0.030	11.11	0.035	NA	-100.0	0.025	0.03	20.0
Cabbages (ha)	0.027	0.680	2419.00	0.035	1.05	2900.0	0.025	0.37	1380.0
Potatoes (ha)	0.020	0.002	-90.00	0.030	0.02	-33.3	0.020	0.07	250.0
Cash crop (ha)	0.450	0.450	0.00	0.700	0.70	0.0	0.290	0.24	-17.2
Cow (No.)	2.000	2.000	0.00	2.000	2.00	0.0	2.000	2.00	0.0

NA: Not applicable, Diff. (%): Differences between survey and model results in percentage

land under food crop production in the model was higher than the land under food crop production in reality. All the land that do not have cash crop was considered as land that a farmer could grow food. For example, some tea farmers have not cultivated close to the river but there is a possibility that in the future, farmers might grow vegetables in this land. Because of this reason, farm income was higher than reality and this also increases family income.

Analysis between the RR and RP tea smallholders indicate a higher difference between the model and survey incomes (Table 2) among the resource rich. The resource rich also have more uncultivated land which was allocated to food production by the model. The optimal model results indicate variable land sizes were optimized to grow different crops (Table 3).

The model of all farmers has allocated significantly more land to cabbage production as compared to survey results. The model has allocated similar land to tea production because there was no competition of tea land with another crop. The number of dairy cows was the same in both the model and the survey results. There was also no competition of resources with other livestock. Among the resource rich, the model did not allocate any land to kale production but allocated most land to cabbage production. Among the resource poor, results of kale production were not highly significant, similar as what was observed among all farmers. The model also allocates only 0.002 ha of land to potato production as compared to 0.02 ha in survey results. This was due to high production costs of potatoes.

The model allowed for hiring of labour especially during the peak period of tea harvesting and during preparation and planting of food crops. The dual value from the model indicated that increasing land under tea production by 1 ha would increase earnings by Kshs 8,319.21 while increasing land under food crop production by 1 ha would increase earnings by Kshs 50,967.11. This indicates the importance of improving food crop production in the tea zone. The differences in the use of family resources between the model and survey results may be explained by the risk behaviours of the farmers. Farmers may prefer farm plans that provide a satisfactory level of security even if it means sacrificing income on average. The risk behaviours therefore create a gap between the model results and real practices (Sattarasart, 1999). The model assumes a perfect environment but the real practices are met by risks and uncertainties. Based on the results of farm, off-farm and family income, as well as resource use and a combination of farm enterprises, the basic model of all farmers, RR and RP farmers presents enough approximation to the actual farmers' practices. The basic models have therefore been used as a basis of constructing the multi-periodic models.

MONTE CARLO SIMULATION

Simulation is a numerical technique for conducting experiments which involves certain types of mathematical and logical models that describe the behaviour of a system over extended periods of real time (Naylor *et al*., 1966). Monte Carlo is a simulation method which is defined as a stochastic technique that involves using random numbers (Hammersley and Handscomb, 1964; Gujarati, 1995; Wittwer, 2004) and probability statistics to solve or investigate problems. To call something a Monte Carlo experiment, all that is needed is to use random numbers to examine some problem (Pecherska and Merkuryev, 2005). The random variables are defined as stochastic variates which are uniformly distributed (März, 1987). The inputs are randomly generated from probability distributions and so the aim is to choose a distribution for

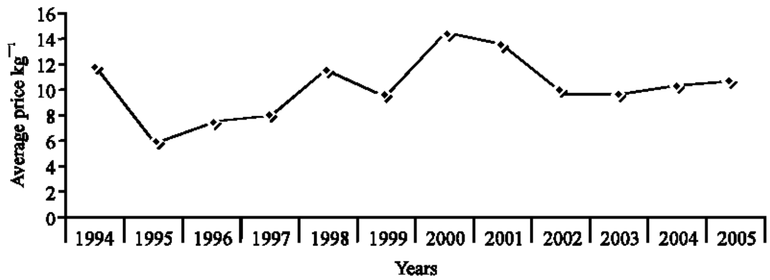

Fig. 2: Fluctuation in average prices of tea in the last 12 year, Murarandia location, Murang'a District

the inputs that most closely matches the existing data, or best represents the current state of knowledge (Wittwer, 2004). A typical Monte Carlo simulation calculates the model hundreds or thousands of times, each time using different randomly-selected values (Wittwer, 2004). The principle behind Monte Carlo therefore, is that the behaviour of a statistic in random samples can be assessed by the empirical process of actually drawing lots of random samples and observing this behaviour (Mooney, 1997). This aims at creating an artificial world which resembles the real world (Kitchaicharoen, 2003).

März (1990) applied Monte Carlo method to simulate a set of correlated crop yield-price data while Kitchaicharoen (2003) simulated a set of lychee prices from historical data of lychee price over 13 years. The same concept was applied in this study. Data obtained from the main tea factory in the study area provided the basis for specifying the parameters (mean and standard deviation) of a normal distribution of tea prices over time. The data includes prices paid to the farmers monthly (first payments) and bonus (second payment) for the year 1994 to 2005. Figure 2 shows fluctuation of tea prices in the past 12 years. Figure 2 used averages of first payments and second payments.

The simplest methods to simulate and test random series are based on the assumption of normal distribution of the data (März, 1987). In this study, price distributions over time are statistically normal. Following Kitchaicharoen, 2003, the procedures (Fig. 3) of the Monte Carlo simulations were as follows:

- Analysis of the distribution of the historical data of tea prices, that is, mean and standard deviation of the distribution of tea prices
- The parameters from the first step were used to generate random tea prices that follow the same distribution as the historical data. For each model run, a new set of random variates of the stochastic variables are generated (März, 1987)
- The simulated tea prices were then entered in the dynamic model

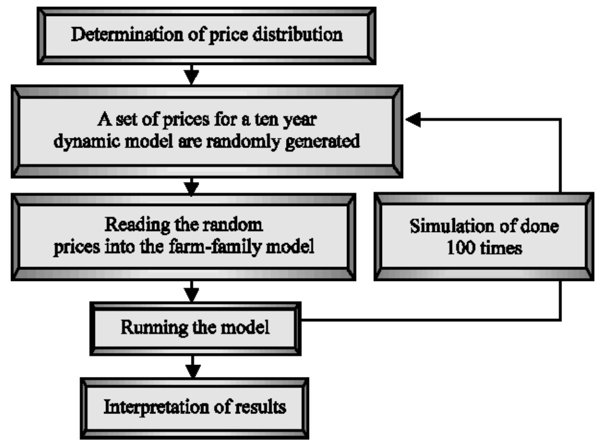

Fig. 3: Procedures of Monte Carlo simulation for tea prices. Source: Kitchaicharoen, 2003

- The dynamic model was run and the results of each run recorded
- The second to fourth steps were repeated 100 times to obtain the probability distribution almost similar to historical data

RANDOM NUMBERS GENERATION AND SIMULATION

As described earlier, historical fluctuation of tea prices in the study area were used as a basis for specifying the mean and standard deviation of a normal distribution of tea prices. The historical tea prices were tested for distribution and were found to be normally distributed and the average of 12 years was 10.3 Kshs kg^{-1}, with a standard deviation of 2.47 Kshs kg^{-1}. These parameters were used to generate random observations which follow the same distribution (März, 1987). The tea prices over time were randomly generated using the random number generation tool in Microsoft Excel 2000. To generate the random number, the number of variables and number of random numbers required were specified. In this study, the variables required were 100 because the model was run 100 times. The number of random numbers required was 10 since the model used was a 10 year dynamic model. Therefore, one random variable was entered for each year, from 1 to 10 year. What were also required to generate the random numbers were the parameters and in this case it was the mean (10.3) and SD (2.47) generated from the historical data. The results generated were saved because the computer clock was used as the random seed and regenerating random numbers a different time would give different results. A random seed is a number used to set the starting point for generating a series of random numbers. It ensures that later rerun of the same analysis at any time produces similar results.

The average price of the simulated tea prices over all ten years and all 100 ten-year iterations was estimated at 10.25 Kshs kg^{-1}, with a standard deviation of 2.44 Kshs kg^{-1}. This average price and standard deviation differ from the average historical prices and the standard deviation by 0.85 and 1%, respectively. A ten-year simulation of the model with the random tea prices for each of the ten years comprises one run of the model. The ten-year simulation run was repeated 100 times to allow estimation of a probability distribution for family income. The average annual family income over all ten years and all 100 runs of all tea farmers and also the two different groups in the tea zone (resource rich and resource poor) was estimated and compared to the average annual family income over ten year under a constant tea price. A statistical t-test was performed to test the significance difference between the average annual family income under simulated prices and the average annual family income under the constant price.

RESULTS OF SIMULATION AND IMPACT OF THE STRATEGY ON FAMILY INCOME

Impact of strategy on family income of all tea farmers: Average annual family income under simulated prices after every 20 years was compared with average annual family income under constant prices. The results indicated that after one run, the difference between the average annual family incomes under constant prices and simulated prices was high (-14.19%) as compared to 60 runs which was only -0.18%. This point out that the more runs that are done, the closer the average annual family income under simulated prices is to the average annual family income under constant prices (Table 4). This indicates that in simulation models generating more random variables to solve a problem gives more effective results and which are close to reality. After the 80 runs, the difference was positive and higher than average

Table 4: Comparison of average annual family income between the constant prices and simulated prices scenarios in the tea zone, Murarandia location, Murang'a District, Kenya, 2005

Runs	Average family income under simulated prices (Kshs)	Difference (%)*
1	117,006.39	-14.19
20	133,775.90	-1.90
40	134,909.60	-1.06
60	136,117.20	-0.18
80	136,593.20	0.17
100	135,741.20	-0.45

Average family income under constant price = Kshs 136, 360.81, *Percentage differences between average family income under simulated prices and average family income under constant prices

Table 5: A t-test to demonstrate the significance difference between the average annual family income under simulated tea prices and average annual family income under constant tea price, Murarandia location, Murang'a District, Kenya, 2005

Parameters	t-value	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference: Lower	Upper
Average annual family income	-0.59	99	0.56	-619.61	-2698.96	1459.74

Test value = 136,360.81

annual family income under constant price. This indicates that the data generated (average annual family income under simulated prices) was following normal distribution trend. If more runs were done above 100 and the data generated was positioned in a graph, it would produce a normal shaped distribution.

Results also show that the average annual family income under the simulated prices (Mean = 135741.20; SD = 10479.44) was less than the average annual family income of Kshs 136,360.81 under determined constant price. This was about 0.45% less than the average annual family income under the constant price of Kshs 10 kg^{-1}. However, a one-sample t-test (Table 5) shows that the difference between the two incomes was not significant: t (99) = -0.59; p = 0.56 (two-tailed). The 95% confidence interval of the difference was (-2,698.96; 1,459.74). The fact that p-value was high indicate that fluctuation in the tea prices has low effect on the stability of family income of the whole sample of tea farmers. The low standard deviation in percentage of the average annual family income under the simulated prices (7.72 %) also indicates stability of family income among the tea farmers.

The histogram (Fig. 4) shows the distribution of the average annual family income over the 10 year simulation and after rerunning the model 100 times. N represents 100 different average annual family incomes, each representing an average of the family incomes calculated from running a 10 year dynamic model. The frequency represents the number of runs or how many average annual family income lie within a particular point. If added

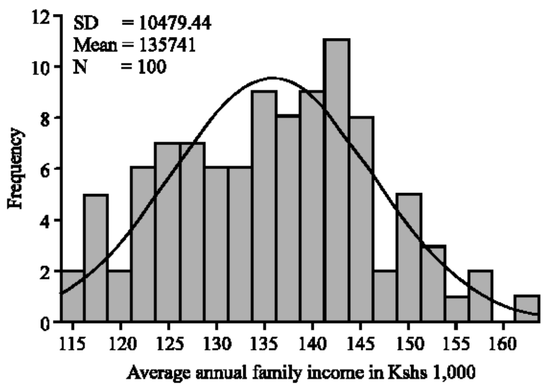

Fig. 4: Distribution of the average annual family incomes of tea farmers under the simulated tea prices, in Murarandia location, Murang'a District

up together, they will total to N = 100. The histogram indicates as mentioned above that the data generated lies along a normal distribution. This is because the data used to generate the random variables was also normally distributed. Since this also follows a normal trend, it is unlikely that errors were made during the calculation of the average annual family income under simulated prices. The histogram also indicates that the probability that the expected average annual family income under simulated prices is equal or above 136,360.81 (average annual family income under constant price) was 47.6% among the tea farmers in the study area. This was calculated using the following equation of z-scores.

$$Z = \frac{X - \bar{X}}{s} \quad (2)$$

Where:

- X = Average family income under constant price
- $\bar{X}$ = Average family income under simulated prices
- s = Standard deviation of family income under simulated prices

X = 136,360.81; $\bar{X}$ = 135,741.20; s = 10,479.44. Z score was calculated as 0.06.

This value in the table of standard normal distribution was 0.47608. One may therefore expect the average of all first years in 100 runs to reflect the average annual family income for the year 2006 (information from the factory in the study area confirmed that the average price paid to the farmer in the year 2006 was 12.44% higher than average price paid in the year 2005), the average of all second years to reflect the average family income for the year 2007 and so on. Figure 5 shows the average annual family incomes for the ten years in the dynamic model after 100 runs.

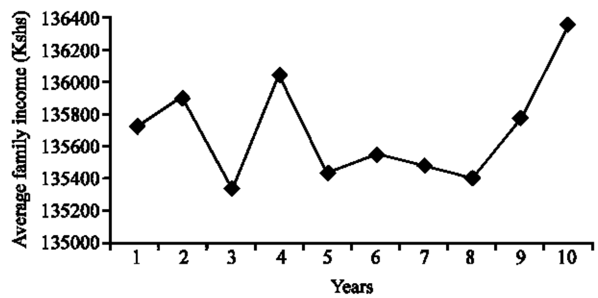

Fig. 5: Distribution of the average annual family incomes under simulated tea prices for 10 years after 100 runs in Murarandia location, Murang'a District

Table 6: Comparison of average family income between the constant prices and simulated prices scenarios among the resource rich in the tea zone, Murarandia location, Murang'a District, Kenya, 2005

Runs	Average family income under simulated prices (Kshs)	Difference (%)*
1	171,086.02	-14.46
20	197,204.30	-1.40
40	198,999.10	-0.50
60	200,930.80	0.47
80	201,725.50	0.86
100	200,375.50	0.19

NB: Average family income under constant price = Kshs 199,998.70, *Percentage differences between average family income under simulated prices and average family income under constant prices

The average for the first years of the 100 runs was calculated and this was repeated for the second to the tenth year. The graph indicates that the average annual family income may increase for the years 2006 and 2007 and then reduce drastically in the year 2008 and then shoot up again in 2009. This may probably be due changes in market forces that affect the prices. The other reason would be climatic changes that may reduce the yields of green leaf harvested thus lowering the average annual family income.

Impact of strategy on family income of resource rich tea farmers: Similar to all farmers situation, the average family income under simulated prices after every 20 years was compared with average family income under constant prices. The results indicate that after one run, the difference between the average family incomes under constant prices and simulated prices was high (-14.46%) as compared to 50 runs which was only -0.50% (Table 6). The direction of the difference changed at 60 runs to positive and was at peak at 80 runs. Similar to the whole zone analysis, the trend of a normal distribution was also observed among the Resource Rich tea farmers.

Results show that the average annual family income under the simulated prices (Mean = 200,375.45; SD = 16,428.51) was greater than the average annual

Table 7: A t-test to demonstrate the significance difference between the average annual family income under simulated tea prices and average annual family income under constant tea price, among the resource rich tea farmers, Murarandia location, Murang'a District, Kenya, 2005

Parameters	t-value	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference Lower	Upper
Average annual family income	0.23	99	0.819	376.77	-2883.00	3636.55

Test value = 199,998.70

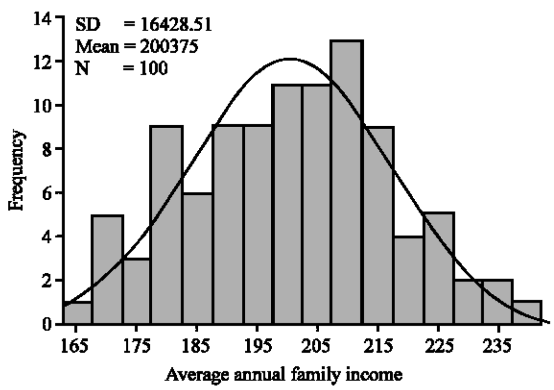

Fig. 6: Distribution of the average annual family income of resource rich tea farmers under the simulated tea prices, in Murarandia location, Murang'a District, Kenya, 2005

family income of Kshs 199,998.70 under determined constant price. This was about 0.19% higher than the average annual family income under the constant price of Kshs 10 kg^{-1}. However, a one-sample t-test (Table 7) shows that the difference between the two incomes was not significant: t (99) = 0.23; p = 0.819 (two-tailed). The 95% confidence interval of the difference was (-2,883.00; 3,636.55). The fact that p-value was high indicate that fluctuation in the tea prices has low effect on the stability of family income of the resource rich tea farmers. The low standard deviation in percentage of the average annual family income under the simulated prices (8.20%) also indicates stability of family income in this group.

The histogram (Fig. 6) shows the distribution of the average annual family income over the 10 year simulation and after rerunning the model 100 times. The frequency represents the number of runs or how many average annual family income lie within a particular point. Similar to the observation among all tea farmers, the histogram indicates that the data generated lies along a normal distribution. The probability that the farm families will get an average annual income in the range from Kshs 200,375.45 to 216,803.96, that is, between the mean and a value one Standard Deviation above the Mean, was approximately 38%.

Table 8: Comparison of average family income between the constant prices and simulated prices scenarios among the resource poor in the tea zone, Murarandia location, Murang'a District, Kenya, 2005

Runs	Average family income under simulated prices (Kshs)	Difference (%)*
1	83,966.76	-12.17
20	94,736.12	-0.90
40	95,503.39	-0.10
60	96,264.85	0.70
80	96,568.92	1.01
100	96,032.62	0.45

NB: Average family income under constant price = Kshs 95,598.69, *Percentage differences between average family income under simulated prices and average family income under constant prices

Table 9: A t-test to demonstrate the significance difference between the average annual family income under simulated tea prices and average annual family income under constant tea price, among the Resource Poor, Murarandia location, Murang'a District, Kenya, 2005

Parameters	t-value	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference Lower	Upper
Average annual family income	0.67	99	0.50	433.93	-843.83	1711.69

Test value = 95,598.69

Impact of strategy on family income of resource poor tea farmers: Average family income under simulated prices after every 20 years was also compared with average family income under constant prices. The results indicate that after one run, the difference between the average family incomes under constant prices and simulated prices was high (-12.17%) as compared to 40 runs which was only -0.10% (Table 8). The direction also changes as observed in earlier analysis but after 60 runs. The peak was after 80 runs which then start to reduce at 100 runs. The trend of a normal distribution was also valid and one can expect a normal curve after more runs above 100.

Results show that the average annual family income under the simulated prices (Mean = 96,032.62; SD = 6,439.62) was greater than the average annual family income of Kshs 95,598.69 under determined constant price. This was about 0.45% higher than the average annual family income under the constant price of Kshs 10 per kilogram. However, a one-sample t-test (Table 9) shows that the difference between the two incomes was not significant: t (99) = 0.67; p = 0.50 (two-tailed). The 95% confidence interval of the difference was (-843.83; 1,711.69). The fact that p-value was high indicate that fluctuation in the tea prices has low effect on the stability of family income of resource poor tea farmers. The low standard deviation in percentage of the average annual family income under the simulated prices (6.71%) also indicates stability of family income among the resource poor tea farmers.

The histogram (Fig. 7) shows the distribution of the average annual family income over the 10 year simulation and after rerunning the model 100 times. The probability

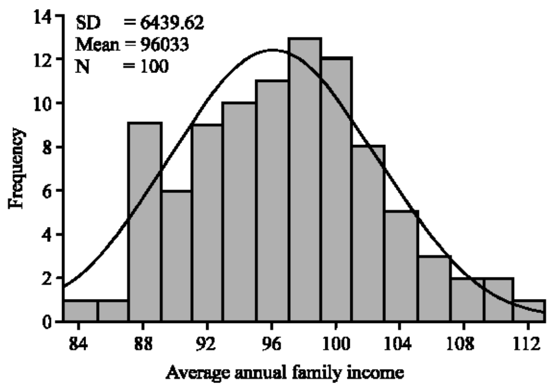

Fig. 7: Distribution of the average annual family income of Resource Poor tea farmers under the simulated tea prices, in Murarandia location, Murang'a District, Kenya, 2005

that the expected average annual family income under simulated prices is equal or above 95,598.69 (the average annual family income under the constant price) was 47% among the resource poor tea farmers. At the same time, the probability that the farm families will get an average annual income in the range from Kshs 96,032.62 to 102,472.25, that is, between the mean and a value one standard deviation above the mean, was approximately 38%. The results indicate that among the whole sample of tea farmers and also among the resource rich and the resource poor, fluctuation of tea prices has low effect on average family income. However, variation was higher among the resource rich as compared to the resource poor. This was because they had more land under tea production and were less diversified with other crops.

CONCLUSION

Results indicated that the difference in average annual family income with simulated prices and with constant prices was not large. This indicates that prices of tea in the study area were fairly stable and the effect of prices changes to average annual family income and resource use was not significant. Other factors which may or may not be related to tea production may affect the average annual family income and resources. This may include lack of good husbandry-poor plucking styles, not utilising the recommended fertilizer, intense sorting of harvested green leaf in the buying centres etc.

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