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Effect of Climate on Profit Risk in Tea Production: A Study of Nuwara Eliya Tea Estates

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ABSTRACT

Climate change is one of the main global challenges of this century; it is, therefore, imperative to identify its effects on agriculture in developing countries. This study was undertaken to investigate the effect of climate and technology on tea cultivation in Sri Lanka. Tea is one of the major crops grown in the Asian region. Data for this study comes from the Nuwara Eliya District in Sri Lanka, which is one of the largest tea growing districts of the country. Twenty three year production and climatic data were collected from forty-two estates. A profit function was estimated and the variance of error term of the estimated profit function was assumed to be related to 'risk'. We hypothesised that climate influences the risk and therefore related climate variables to the profit variance. As evidenced by previous research, the relationship of climate-related variables takes a non-linear 'U' shape with profit risk. The results also revealed that the optimum annual rainfall for minimum variance in profit in Nuwara-Eliya District was 2000 mm and the optimum annual maximum average temperature was 21 ^{0}C and the optimum annual minimum temperature was 12.25 ^{0}C.

1. Introduction

Tea is grown in many parts of Asia. China, followed by India are the two largest producers in Asia and in the world. A large segment of the population in the Asian region depends directly or indirectly on the tea cultivation and related industries. Therefore, sustainability of this industry is important in terms of reducing poverty in the region.

Historically, Sri Lanka's tea plantations were owned and developed by the British and managed by British private companies [1]. Up to the present tea has gained a large share of foreign earnings. Sri Lanka has been the second largest tea exporter in the world, with a 20 % share of world tea exports [2]. But, in the present scenario, the tea industry shows a decline in growth rate in the last four years [3]. Sri Lanka has dropped down to the fourth position in terms of world tea production following China, India and Kenya[4] establishing a gradually declining trend in the industry.

Sri Lanka grows tea only in five out of the nine provinces in the country, owing to the plant's weather and climatic requirements. This crop is best grown at high altitudes of over 2,100 m (6,890 ft), and requires an annual rainfall of more than 2500 mm.

Total production of estates varies depending on the weather conditions, pest and diseases, labour availability and infrastructure situations. Among these, weather conditions play a major role. Weather is the state of the atmosphere at a particular place and time as regards heat, cloudiness, dryness, sunshine, wind, rain and etc. At the estate level as well as the country level, temperature and the rainfall are the indicators, which are used to monitor the weather condition of a given locality. When in the long term, this is interpreted as climate. Climate is the weather conditions prevailing in an area in general or over a long period. Climate is changing with time and this climate change is one of the most discussed issues in the global scenario today.

No region or a country, including Sri Lanka, is immune to climate change. Therefore, it is exigent that the magnitude of climate change in Sri Lanka and its impacts are identified and quantified. The Intergovernmental Panel on Climate Change (IPCC 2007) [5] defines climate change as "a change in the state of the climate that can be identified by changes in the mean and the variability of its properties and that persists for an extended period, typically decades or longer."

Recent studies have shown that greenhouse gases like Carbon Dioxide lead to changes in climate conditions such as temperature, soil moisture, precipitation and sea level [6]. These climate changes could have adverse effects on agriculture, ecological systems, human health and the economy. Considerable attention has been focused on the effects of climate change on agriculture. Change in climatic conditions from year to year is one of the major determinants of the crop yield fluctuations. Climatic condition and water availability may influence crop and livestock productions. As climatic conditions vary, crop production patterns could change since different crops could react differently to the alterations in climatic conditions [7].

Herath and Rathnayake [8] studying sixty rain gauges oftea estates in the Central Mountains of Sri Lanka over a period of 30 years, observed a decrease in rainfall. It also noticed less rainfall, especially on the leeward side of the Central Hills and adjoining areas of Sri Lanka, due to changes in rainfall pattern during southwest monsoon season [9].

This study considers the tea estate sector and how theseclimate changes affect this sector. Tea yield is sensitive to the climate that it could be considered as an indicator of climate change stress [10]. The tea estates at low and mid-elevations are more susceptible to changes in climate than those at higher elevations. A 100mm reduction in monthly rainfall could reduce the productivity by 30-80 kg of made tea ha^{-1} [11]. Nuwara-Eliya is the largest tea producing district in Sri Lanka and there is a large number of tea estates situated there. Nuwara Eliya tea also has the highest demand in the foreign tea market, because of the unique flavour and the colour [12]. The colour and the flavour primarily depend on the climatic condition in this region. Therefore, the climate changes could have a direct influence on the profitability of these tea estates.

The objective of this research was to study the variability in profits (Risk) among tea estates, and to see weather, climate and technology could have an influence on this risk.

2. Methodology

2.1. Sample Selection

The study population was defined as all tea estates occupied by tea plantations in the Nuwara Eliya District. The primary sampling units were principal tea growing regions while the secondary sampling units were individual tea estates. The sample frame for the primary sample units was a list of all tea growing regions, where tea crop was grown. The sample frame for the secondary sampling units was a list of all tea estates in the selected principal tea growing regions.

A two-stage sampling scheme was employed for sampling, where the cultivated extent of all tea estates in the respective regions and agro-ecological zones were considered as two stages. In the first stage, the whole two principal tea planting regions were selected in Nuwara Eliya District being in line with the objective of the study. In the second stage, tea estates were selected from each principal tea planting region by adopting a stratified random sampling procedure where factors of stratification were cultivated extent of each principal tea growing region and agro-ecological zones. The number of tea estates belongs to each region was determined on probability proportionate to the area under the tea planting region.

The sample size was determined considering margin of error, confidence interval, sample heterogeneity and non-respondents rate, fixed at 0.1, 95 %, 50 - 50 and 1 %, respectively while optimizing the cost and time functions. Production data for the last 23 years were collected from 42 tea estates representing two principal tea growing regions *i.e.* 26 estates from Nuwara-Eliya region, 16 tea estates from Dimbula region, which belong to Nuwara Eliya District. These tea estates were selected based on the extent of the tea cultivation in the region and availability of production data for the last 23 year period.

2.2. Data Collection

The final sample comprised of 42 tea estates and secondary data were collected from relevant plantation companies.

Annual rainfall data and the maximum and minimum temperature data were collected from the Department of Meteorology. Some tea estates also provided us with their proprietary rainfall data.

2.3. Theoretical Framework

In analysing risks involved in farm production operations, considerable research has attempted to provide empirical evidence on how risk influences the nature of decision making in agricultural production. Basically, farm production depends on the amount of input allocation and climatic variations. This study has attempted to investigate the effect of technology and climate change on production risks in the tea estate sector by directly incorporating with the profit function. The profit function can be stated as;

$$\pi=f(X)+e \text{ -------------- } (1)$$

Where: π is profit, X is a vector of controllable inputs (E.g.: labour wage rate, fertilizer price, extent), *e* is the error term.

This error term implies the variance of profit. Consequently, predict the variance and square it. After squaring the predicted variance, it runs with the weather variable and technology changes.

$$e^2=f(T,W) \text{ ------------- } (2)$$

Where: T is technology and W is weather variables.

Technology changes can't be measured by using a variable. Therefore, assuming that with time, technology was changing in proportion to the amount of money they invested in the latest technology. By using that assumption, use the year variable to analyse the change of technology effect on production risks. Normally weather variables are not known at planting time and haven't a linear relationship.

2.4. Empirical Framework

In the present analysis, the Cobb Douglas profit function was estimated by using the input price variables as follows:

$$\ln \pi_{it}=\beta_0+\beta_1 \ln realavgfet_{it}+\beta_2 \ln realW_{it}$$

$$+\beta_3 \ln realNSA_{it}+\beta_4 \ln ext_{it}+e_{it} \text{ --------------- } (3)$$

Where: π is profit, β_0 is intercept, β_{1-4} are the vector of regression coefficients. The other variables can be described as follows:

$realavgfet_{it}$	- Real average fertilizer prices
$realW_{it}$	- Real wage rate
$realNSA_{it}$	- Real net sale average
ext_{it}	- Extent of the estate
e_{it}	- Error term
i	- Estate
t	- Time
ln	- Natural logarithm

The profit risk can be assumed as the variance of the estimated profit function. Because the true variance is unknown, the variance was predicted as the square of the error term of the regression. Then inspected, how the square of error varies with climatic variables, which were past annual rainfall, annual maximum average temperature and the annual minimum average temperature of the Nuwara Eliya District by using the following equation:

$$e_{it}^2=\alpha_0+\alpha_1 Y+\alpha_2 R+\alpha_3 r^2+\alpha_4 T+\alpha_5 T^2+\alpha_6 t+\alpha_7 t^2$$

$$\text{-- } (5)$$

Where;

e^2 – Square of error

year – Yearly investment in new technology

R - Annual Total Precipitation of the Estate

r^2 – Square of Annual Total Precipitation of the Estate

T – Annual Maximum Average Temperature

T^2 – Square of Annual Maximum Average Temperature

t – Annual Minimum Average Temperature

t^2 – Square of Annual Minimum Average Temperature

Because climate/weather effects are expected to be non-linear, squares of the climate variables are included in the model. Using the fixed effect model, this panel data set was analysed by using STATA 14 statistical software.

3. Results and Discussion

The regression results of the profit function are presented in Table 1. And the predicted risk function results are shown in Table 2. Results revealed that these functions have a statistical significance with 95% confidence level.

Excluding the real average fertilizer price, the other responses provided the expected coefficient signs. Real NSA, Real wage rate and extent of the estate were found to be affecting the total profit significantly. However, the real average fertilizer price did not reveal to be affecting the profit significantly. When the output price increases total profit also increases with the significance of real NSA value.

The positive value for extent shows that the largest estates obtain more profits than smaller estates. The positive value of the real wage rate denotes that, when labour wage rate increases, profits decrease as expected.

Table 1. Effect of technology, precipitation, maximum and minimum temperatures on production risk

Climate Variables	Coef.	Std. Err.	P>t
Y	0.01	0.01	0.71
R	-0.02	0.01	0.04
r^2	0.00	0.00	0.03
T	-11.43	4.97	0.02
T^2	0.28	0.12	0.02
t	-72.95	14.90	0.00
t^2	2.97	0.61	0.00
cons	556.63	107.88	0.00

Note: Y- Technology changes, R-Annual total rainfall, r^2- Square of annual total rainfall, T-Annual maximum average temperature, T^2-Square of annual maximum average temperature, t-Annual minimum average temperature, t^2-Square of annual minimum average temperature, R^2-0.180

Table 2. Effect on input and output price on profit function

Input Variables	Coef.	Std. Err.	P>t
lnrealavgfet	0.08	0.16	0.61
lnrealW	-1.35	0.08	0.00
lnrealNSA	1.39	0.42	0.01
lnext	1.17	0.39	0.00
cons	9.61	3.72	0.01

Note: lnrealavgfet-Real average fertiliser price, W-Real average wage rate, realNSA-Real net sale average, ext-Extent of the estate, R^2-0.8133

In the variance function (Table 2), all the responses provided the expected coefficient signs. The variable Y (technology changes) was included in the model as a control for the changes in technology over time. The insignificant Y variable hints that the technology changes have not made a real impaction increasing or decreasing risks in the study period.

3.1. Rainfall

Plants get water from the rainfall. Normally, water is an essential component in the function of ant growth. Lack of water damages plant cells, resulting in decreased growth, wilting and leaf scorch, eventual leaf drops and root damage. Heavy rains can also damage plants, compact soil and cause erosion. Too much water reduces the amount of oxygen in the soil, increases moisture in green leaves, causes nutrient leaching, and results in root loss and injury. It can also make the plant more susceptible to many fungal diseases. Apart from these, in heavy rainy days absence of the sunshine results in low productivity in green leaf and additionally, labour productivity of plucking may be impaired.

According to past research findings, there was a quadratic relationship between the rainfall and the tea yield (Wijeratne *et al.*, 2007) [10]. The outcome of this study also shows a similar relationship. The variance of the error of the profit function shows a U shaped relationship with the level of rainfall.

It was noted, that when rainfall increases profit risk diminishes up to a minimum point and increase with further increases in rainfall. It is clear from Figure 1, that optimum rainfall which minimizes the risk of losing profit is about 2000 mm. Any rainfall above this bound to realise highly variable profits in estates.

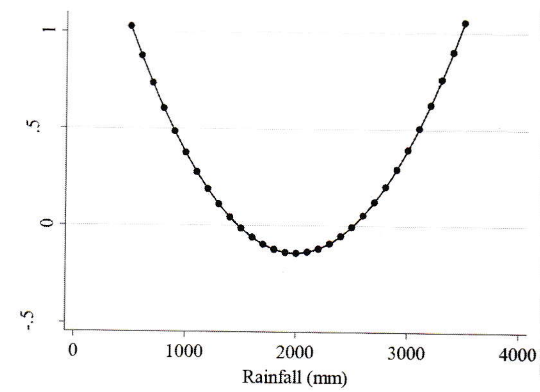

Figure 1. Total annual rainfall with predicted e^2

3.2. Temperature

Generally, plants grow faster with increasing temperature, up to the optimum point. Extreme heat will slow growth with increases in moisture loss too. Very low temperatures also negatively affect plant growth. According to the final result of the analysis, maximum and minimum temperatures too showed quadratic relationships with a "U" shape.

Results also showed that both maximum and minimum temperatures (day temperature-maximum and night temperature-minimum) up to an optimum level, the profit risk becomes minimum. However, the temperature extremes that affect plant growth badly resulted in high variances in profit.

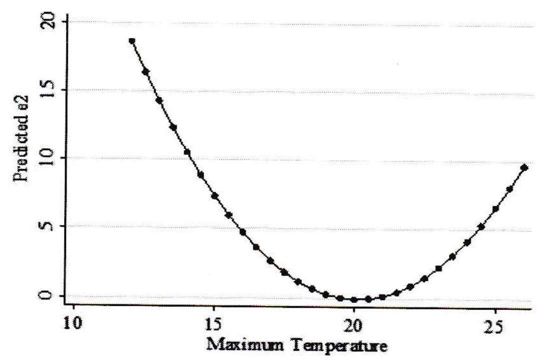

Figure 2. Annual maximum average temperature with predicted e^2

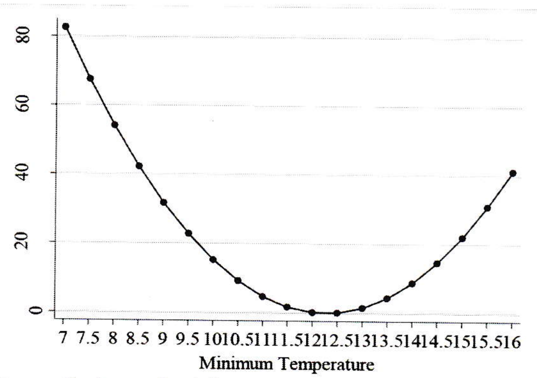

Figure 3. Annual minimum average temperature with predicted e^2

It was clearly shown in Figures 2 and 3 after reaching the minimum points, profit risks increased with the temperature increments. That means the minimum points which shows in the Figures 2 and 3 are the optimum temperature values for tea cultivation.

The temperature response of different species has been evaluated from some studies [13,14]. Extremely high or low temperatures can hamper plant growth. In low temperatures, plants reduce growth and store energy. Without an optimum temperature range during the day, tea plants reduce the leaf bud generating process. And at upper temperature levels, leaves wilt and affect the final production amounts.

Normally, in up country tea productivity is lower than in the low country, because of the temperature variation. But the flavour and the quality of the up country tea depend on the optimum maximum and minimum temperatures of the area. Thus the minimum and maximum temperature changes may affect the flavour of made tea in the up country.

It is clear from the analysis that the profit risk is minimum when the day temperature is about 21 ^{0}C and the night temperature is about 12.25 ^{0}C.

4. Conclusion

This study found that climatic factors play a major role in the variance of profit in the estate sector. The optimum annual total rainfall that minimises risk is 2000 mm, while the optimum maximum annual average temperature is 21 ^{0}C and the optimum minimum annual average temperature is 12.25 ^{0}C. Therefore, the estate sector needs adaptation strategies for weather as well as possible changes in the climate that is bound to happen.

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