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EFFECT OF CLIMATE CHANGE ON TEA PRODUCTION IN BANGLADESH: ECONOMIC IMPLICATIONS FOR DOMESTIC CONSUMPTION, EXPORT EARNINGS AND TRADE DEFICIT

SUDIP DEY[1]

Abstract

This paper explores climate change's effects on Bangladesh's tea production, focusing on the economic consequences for domestic consumption, export earnings, and trade deficits. This study utilizes annual time series data from 1971 to 2022 to analyze the influence of climate variables on tea production. The findings indicate that while both maximum and minimum humidity negatively affect tea production, only maximum humidity has a significant impact, suggesting optimal production at moderate humidity levels. Rainfall plays a crucial role by enhancing root growth, soil moisture, nutrient supply, and pest prevention, significantly boosting tea production. Temperature effects are mixed; minimum temperature supports production, whereas maximum temperature has harmful effects, such as heatwaves, pest outbreaks, and reduced photosynthesis. Additionally, carbon dioxide (CO_2) emissions enhance both tea production and leaf quality by improving photosynthesis and respiration. From 2002 to 2021, domestic tea consumption surged significantly due to population growth, rising incomes, urbanization, changing preferences, and perceived health benefits. Conversely, export earnings declined significantly, driven by high domestic consumption, falling global prices, limited tea varieties, and increased international competition. The study identifies a persistent trade deficit over the past 12 years, linked to high production costs, low productivity, poor quality, and insufficient innovation. To mitigate these challenges, the study recommends strategies including import tariffs, export incentives, infrastructure improvements, higher labor wages, the creation of new tea varieties, improving quality, adopting modern technologies, and fiscal and monetary policy adjustments to boost export earnings and achieve trade balance.

Keywords: Climate change; Tea production; Domestic consumption; Export earnings; Trade deficit.

Introduction

Tea is the most extensively consumed beverage in the world, behind water, and in Bangladeshi culture, it's a popular drink for entertaining guests. The quantity and

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quality of tea are primarily influenced by climate factors, including temperature, precipitation, humidity, greenhouse gases, etc. Bangladesh depends greatly on tea production to meet its domestic consumption demands, generate substantial export revenue, and maintain its trade balance. Climate change has become the biggest threat to the tea industry. Most tea-exporting countries have decided to tackle this challenge with profound attention. Under the current climate conditions, both the quantity and quality of tea are being adversely affected (Biswas, 2018). At one time, tea was Bangladesh's second-most important export commodity, coming after jute. Bangladesh ranks 8th in production area, 10th in production volume, and 12th in tea exports (ITC, 2015). The tea farming sector is recognized for enhancing living standards, generating employment opportunities, ensuring food security, and alleviating poverty in rural areas of producing regions. In Bangladesh, a significant portion of the population relies heavily on the tea industry. Currently, Bangladesh has 167 commercial tea production estates and gardens covering 279,507.88 acres, employing approximately 150,000 workers. Additionally, Bangladesh produces 3 percent of the world's tea. In 2021, the market size of tea industry in Bangladesh was around taka 3,500 crore. It is the country’s second-largest cash crop after jute, contributing roughly 1 percent to Bangladesh's gross domestic product (GDP) (Hossan, 2022).

Numerous studies have examined how tea output responds to climate change. Raza (2019) explored the prospects of the tea industry in Bangladesh, while Nasir and Shamsuddoha (2012) focused on tea production, consumption, and exports from both global and Bangladeshi viewpoints. Arefin and Hossain (2022) provided insights into the current status and future potential of tea production in Bangladesh. Han et al. (2018) analyzed how climate change impacts tea cultivation in China. Islam et al. (2021) examined the climate and environmental challenges affecting tea cultivation in the Sylhet region of Bangladesh. Rahman (2022) discussed how rainfall influences tea production and its socio-economic implications in Bangladesh. While numerous studies have explored climate change and tea production, none, to our knowledge, have thoroughly examined the economic implications related to domestic consumption, foreign export earnings, and trade deficits from a Bangladeshi perspective. Additionally, our research stands out by including both minimum and maximum humidity in the model and employing advanced econometric and statistical methods, setting it apart from previous studies.

This study utilizes statistical and econometric approaches to assess climate-related effects on tea production in Bangladesh, as well as economic data on tea consumption, export earnings, and trade surplus. This analysis provides valuable information to stakeholder policymakers, allowing them to build reactive policies against climate change impacts that will keep tea as a vital economic sector in Bangladesh. This study provides knowledge that is essential for Bangladesh's financial growth because agriculture remains the backbone of the country's economic structure. In order to come up with adaptation strategies, people need to know a lot about how changes in climate affect growing tea, as well as how domestic tea consumption, export volumes, and trade imbalances affect the economy. These measures are vital for protecting the livelihoods of individuals reliant on tea cultivation and the nation's economic stability.

Materials and Methods

Data Collection

This study utilizes annual time series data from 1971 to 2022, gathered from various secondary sources. The average precipitation (in millimeters) and temperature (in degrees Celsius), including both minimum and maximum values, are sourced from the Climate Change Knowledge Portal (2021). Data on carbon dioxide (CO_2) emissions (in million tons) is obtained from the CO_2 country profile for Bangladesh by Hannah Ritchie and Max Roser (Ritchie et al., 2020). Humidity data (both minimum and maximum in percentages) is retrieved from the Climate Information Management System (2024). Data on domestic tea consumption (in million kilograms), production (in million kilograms), export (in million kilograms and million US dollars), and import (in million kilograms) is collected from the Bangladesh Tea Board (2024).

Model Specification

The analysis examines six climate change variables in Bangladesh, including both minimum and maximum humidity and average precipitation levels alongside minimum and maximum temperatures and carbon dioxide emissions. The log-log model analysis requires the application of logarithms to existing variables for both dependent and independent measurements. Logarithmic transformation enhances regression analysis by addressing nonlinearity while controlling heteroscedasticity and simplifying data relationships and data handling as well as stabilizing data variations to enable more interpretable results and percentage change analysis in diverse fields. The study considers the following model:

$$LNTEA_t = \alpha_0 + \alpha_1 LNHUMDYMIN_t + \alpha_2 LNHUMDYMAX_t + \alpha_3 LNPCIPT_t + \alpha_4 LNTEMPRMIN_t + \alpha_5 LNTEMPRMAX_t + \alpha_6 LNCARBDO + U_t \ldots\ldots\ldots\ldots\ldots \quad \text{(i)}$$

Where, LNTEA = Log of tea production, LNHUMDYMIN = Log of minimum humidity, LNHUMDYMAX = Log of maximum humidity, LNPCIPT = Log of average precipitation, LNTEMPRMIN = Log of minimum temperature, LNTEMPRMAX = Log of maximum temperature, and LNCARBDO = Log of carbon dioxide (CO_2) emissions.

Econometric and Statistical Methods

The stationarity of variables was verified through augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests with Eviews software. The Fully Modified OLS

(FMOLS) model is employed to demonstrate the impact of climate change on tea productivity.

The fully modified ordinary least squares (FMOLS) technique, introduced by Phillips and Hansen (1990), assumes the presence of a single co-integration vector. According to their study, the FMOLS estimator exhibits super consistency and asymptotic deviations. The FMOLS technique provides several key advantages. It is particularly effective in generating reliable parameter estimates, even with small sample sizes. It also tackles intricate issues, including measurement errors, endogeneity, serial correlation, and omitted variable bias. This method also allows for variations in long-term parameters, as highlighted by the studies of Kalim and Shahbaz (2009) and Fereidouni et al. (2017). Before employing FMOLS, the variables must exhibit co-integration at the first difference. In our analysis, all variables were confirmed to be co-integrated.

Using SPSS software, the planned comparison method is employed to assess significant differences in domestic tea consumption and export earnings over the past 20 years (both variables are normally distributed). The years from 2002 to 2021 are divided into four different groups (Group 1: 2002–2006, Group 2: 2007–2011, Group 3: 2012–2016, and Group 4: 2017–2021), each spanning five years. The one-way ANOVA (analysis of variance) is then applied to determine whether there are significant differences in domestic consumption, export earnings, and periods across these four groups. Additionally, the trade deficit (based on export and import volumes) over the last 12 years (2010-2021) is analyzed using graphical representations.

Results and Discussion

Descriptive Statistics

Table 1 illustrates the descriptive statistics for the variables from 1971 to 2022, including the mean, median, maximum, and minimum values for each variable.

Table 1. Descriptive statistics

	Lntea	Lnhumdy min	Lnhumdy max	Lnpcipt	Lntempr min	Lntempr max	Lncarb do
Mean	3.9020	4.0069	4.5222	7.6962	3.0382	3.4136	3.0567
Median	3.9405	4.0149	4.5214	7.6975	3.0359	3.4136	3.1043
Max	4.5696	4.2246	4.5408	7.9531	3.0763	3.4528	4.6259
Min	2.5217	1.2556	4.4930	7.4260	2.9997	3.3891	1.2556
Obs.	52	52	52	52	52	52	52

Source: Eviews software based on annual time series data (1971-2022).

Table 2. Augmented Dickey-Fuller (ADF) unit root test

Variables	Level			First Difference		
	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend	None
LNTEA	0.33	0.00***	0.99	0.00***	0.00***	0.00***
LNHUMDYMIN	0.42	0.00***	0.73	0.00***	0.00***	0.00***
LNHUMDYMAX	0.56	0.45	0.54	0.00***	0.00***	0.00***
LNPCIPT	0.63	0.21	0.64	0.00***	0.00***	0.00***
LNTEMPRMIN	0.94	0.45	0.79	0.00***	0.00***	0.00***
LNTEMPRMAX	0.20	0.00***	0.74	0.00***	0.00***	0.00***
LNCARBDO	0.30	0.67	1.00	0.00***	0.00***	0.00***

Source: Eviews software based on annual time series data (1971-2022). Notes: *** P<0.01, **P<0.05, *P<0.10.

Table 3. Phillips-Perron (PP) unit root test

Variables	Level			First Difference		
	Intercept	Intercept and Trend	None	Intercept	Intercept and Trend	None
LNTEA	0.10	0.00***	0.99	0.00***	0.00***	0.00***
LNHUMDYMIN	0.32	0.00***	0.67	0.00***	0.00***	0.00***
LNHUMDYMAX	0.45	0.50	0.45	0.00***	0.00***	0.00***
LNPCIPT	0.72	0.85	0.57	0.00***	0.00***	0.00***
LNTEMPRMIN	0.80	0.90	0.89	0.00***	0.00***	0.00***
LNTEMPRMAX	0.43	0.32	0.81	0.00***	0.00***	0.00***
LNCARBDO	0.12	0.56	1.00	0.00***	0.00***	0.00***

Source: Eviews software based on annual time series data (1971-2022). Notes: *** P<0.01, **P<0.05, *P<0.10.

Unit Root Test

To assess the stationarity of the variables, we applied the augmented Dickey-Fuller (1979) and Phillips-Perron (1988) unit root tests. The results, shown in Tables 2 and 3, indicate that the tests were conducted twice: first on the variables in their original form and then on their first differences. The findings from both tests confirm that all variables are stationary at the first difference, indicating that their order of integration is I (1).

Co-integration test

Selecting the appropriate lag length is essential before conducting co-integration tests, as it dramatically influences the test results. The optimal lag length is determined using the Akaike (1973) Information Criterion (AIC), which recommends using three lags. Consequently, a co-integration test is performed with a lag length of three. The results of the Johansen (1988) co-integration analysis are presented in Table 4, where both the trace and Max-Eigen statistics indicate the presence of two co-integrating equations at the 1 percent and 5 percent significance levels. This reflects the long-term association between tea production and the explanatory variables.

Table 4. Results of co-integration test

No. of CE(S)	Trace statistic value	Prob.	Max-Eigen statistic value	Prob.
None	237.71***	0.00	102.80***	0.00
At most 1	134.91***	0.00	49.71***	0.01
At most 2	85.19	0.08	37.08	0.06
At most 3	48.11	0.50	21.54	0.52
At most 4	26.57	0.70	14.23	0.70
At most 5	12.34	0.79	8.83	0.74
At most 6	3.51	0.81	3.51	0.81

Source: Eviews software based on annual time series data (1971-2022). Notes: *** P<0.01, **P<0.05.

Estimated Results of FMOLS and Discussion

The estimated equation is:

$$LNTEA = 30.27 - 0.27LNHUMDYMIN - 2.89LNHUMDYMAX + 0.03LNPCIPT + 5.71LNTEMPRMIN - 9.03LNTEMPRMAX + 0.33LNCARBDO$$

The study applied an advanced regression method, fully modified OLS (FMOLS), to derive its findings. First of all, the results indicate that lower humidity levels (LNHUMDYMIN) are associated with a decrease in domestic tea production (LNTEA), though this relationship is insignificant (Mallik and Ghosh, 2022). The coefficient for minimum humidity is -0.27, suggesting that a 1 percent rise in minimum humidity corresponds to a 0.27 percent decline in tea production (Table 5). Similarly, maximum humidity (LNHUMDYMAX) negatively affects domestic tea production (LNTEA) in Bangladesh, which is significant at the 10 percent level of significance (Mallik and Ghosh, 2022). A 1 percent increase in maximum humidity leads to a 2.89 percent reduction in tea production. Consequently, both minimum and maximum humidity levels appear to be unfavorable for tea production. Moderate humidity is crucial for tea production. Humidity plays a role in the quality of tea leaves, affecting the aroma and taste. A moderate level of humidity, between 60 percent and 70 percent, is considered ideal for optimal tea cultivation (Barman, 2024). Tea plantations thrive in climates with moderate humidity, where it's crucial to maintain the proper humidity levels for processing freshly harvested leaves into tea. During the oxidation process, often referred to as fermentation in the tea industry, it’s essential to carefully manage both temperature and humidity. This ensures that the polyphenols in the withered leaves develop into the theaflavins, thearubigins, and other compounds that give black teas, pouchong, and oolongs their distinctive flavors and colors. If the leaves dry out, oxidation slows because water is needed for the process. To sustain fermentation, a relative humidity of 95 percent to 98 percent RH (relative humidity) at 20^0C to 26^0C is required, and even a slight drop in humidity can negatively impact the process, leading to lower yields (Barman, 2024).

This study shows that precipitation (LNPCIPT) has a positive and significant impact on tea (LNTEA) production (Farukh et al., 2020; Mallik & Ghosh, 2022; Ali et al., 2014; Rahman, 2022). Table 5 shows that a 1 percent rise in precipitation results in a 0.03 percent increase in tea production. Moderate rainfall is significant for tea production. Tea cultivation requires 1750 to 2500 millimeters of rainfall, which is why tea production is more abundant in countries with monsoons and tropical regions. It helps the tea plants develop new roots and creates moisture in the soil for tea plants, and the rainwater contains nitrogen, which is very beneficial for tea plants and enhances the quality of tea. Furthermore, sufficient rainfall facilitates the dissolution and movement of nutrients in the soil. During the rainy season, crucial nutrients such as nitrogen, phosphorus, and potassium become more accessible to tea plants. When there is insufficient rainfall, nutrient absorption can be restricted, resulting in diminished plant health and lower yields. Rainfall distribution and quantity have a direct effect on the chemical makeup of tea leaves, which in turn influences the tea's flavor, aroma, and general quality. Consistent rainfall can help manage the presence of certain pests and diseases in tea plantations. For example, it can remove pests or fungi that flourish in dry conditions, thereby decreasing the reliance on chemical treatments. The present analysis reveals that minimum temperature (LNTEMPRMIN) has a positive and highly significant effect on tea (LNTEA) production (Mallik and Ghosh, 2022). A 1 percent rise in the minimum temperature results in a 5.71 percent increase in tea production. It depicts that minimum temperatures are favorable for tea production in Bangladesh. Conversely, the analysis shows a negative and highly significant impact of maximum temperature (LNTEMPRMAX) on tea production (LNTEA), with a high coefficient of 9.03 (Gunathilaka et al., 2017; Verma et al., 2016; Mila et al., 2024), which means that maximum temperatures are very detrimental for tea plantations. This indicates that a 1 percent increase in maximum temperature results in a 9.03 percent decrease in tea production. As rising temperatures impact other agricultural products in the country, tea cultivation is also being affected. Several studies suggest that this impact may become even more pronounced in the future. Sudden changes in temperature or abnormal temperature increases can have an immediate negative effect on tea production, leading to a decrease in yield. Moreover, tea produced at higher temperatures is generally bitter. The rises in global temperatures and climate change have become the biggest threats to the tea industry. Intense heat and a lack of heavy rainfall have led to an infestation of red spider mites. According to Brodowicz (2024), as temperatures rise and rainfall decreases, tea plants' ability to photosynthesize will slowly diminish. This reduction in photosynthesis will, in turn, impact the growth and development of the tea plants. According to Saha (2024), the number of heatwaves in the Sylhet region from April to October has increased compared to previous years. Sylhet is known for its cooler climate, but recently, the number of cold days has decreased. Data indicates that since 2005, rainfall during the pre-monsoon season in Sylhet has also declined. The ideal temperature for tea cultivation is between 18^0C to 30^0C. If the temperature goes above or below this range, tea production starts to fall. Due to global warming, temperatures of 34^0C to 35^0C are now common in April, May, and other months. When the temperature exceeds the optimal range by 4^0C, tea production can decrease by up to 20 percent. The impact of temperature has significantly reduced tea production in Bangladesh. The color, brightness, and liquor production of black tea depend on two key components: theaflavins and thearubigins. As temperatures rise, not only does tea production decrease, but the levels of these essential components in tea also decline. Consequently, the quality of the tea is believed to diminish, according to experts.

Finally, we found that carbon dioxide (CO_2) emissions (LNCARBDO) have a positive and significant impact on tea (LNTEA) production (Pokharel et al., 2021) in Bangladesh. A 1 percent increase in carbon dioxide emissions leads to a 0.33 percent increase in tea production. Carbon dioxide (CO_2) is crucial for the vascular plants' growth and development. A rise in atmospheric CO_2 levels is expected to significantly impact photosynthesis, metabolism in plants, and overall growth (Ainsworth and Rogers, 2007; Nowak et al., 2004). When tea plants are exposed to higher levels of CO_2, it notably enhances both photosynthesis and respiration in the leaves (Li et al., 2017). The effects of increased CO_2's impacts on tea plants' respiration and photosynthesis ultimately influenced the biosynthesis of essential secondary metabolites, resulting in the production of a higher quality and greater quantity of green tea. Numerous bioactive substances, such as caffeine, amino acids, and polyphenols, are crucial in determining the functional quality of tea. Higher CO_2 levels significantly affect these compounds in tea leaves, which are vital for maintaining tea quality (Pokharel et al., 2021).

Table 5: Results of Fully Modified Least Squares (FMOLS)

Dependent variable: LNTEA

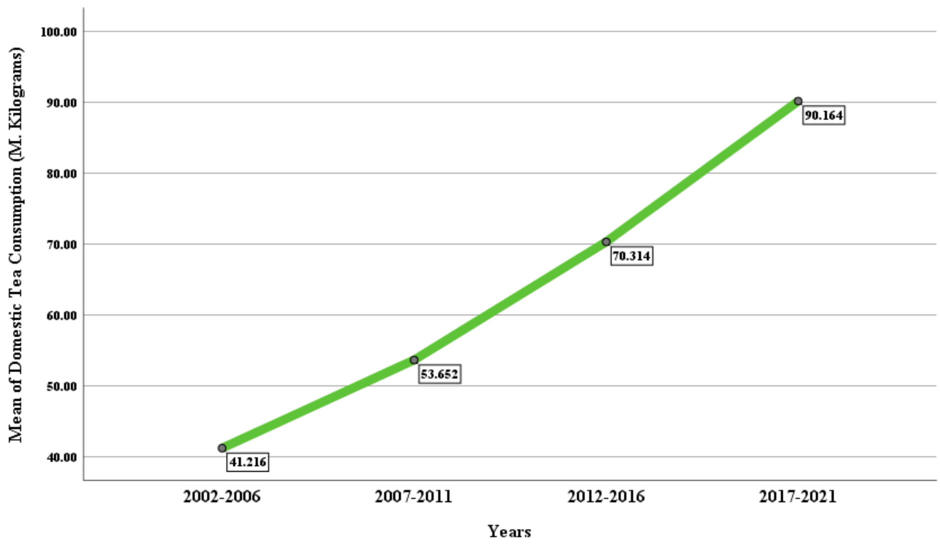
Variables	FMOLS			
	Coefficient	Std. error	t-statistics	Prob.
C	30.27	8.1434	3.72	0.00***
LNHUMDYMIN	-0.27	0.2221	-1.20	0.23
LNHUMDYMAX	-2.89	1.5629	-1.85	0.07*
LNPCIPT	0.03	0.1586	2.04	0.05**
LNTEMPRMIN	5.71	2.0510	2.78	0.00***
LNTEMPRMAX	-9.03	2.6136	-3.45	0.00***
LNCARBDO	0.33	0.0224	14.76	0.00***
R^2	0.92			

Source: Eviews software based on annual time series data (1971-2022). Notes: *** $P<0.01$, **$P<0.05$, *$P<0.10$.

Domestic Consumption

The ANOVA (Analysis of Variance) analysis shows an F-value of 66.58 with a p-value of 0.00 (Appendix A: Table 6), indicating significant differences among the four groups since the p-value is below the 5 percent significance level. The contrast values for the null hypothesis (H_0: Assume equal variances) and the alternative hypothesis (H_a: Does not assume equal variances) are 105.31, with corresponding t-statistics of 11.69 and 12.60 (Appendix B: Table 7). Both p-values are 0.00, below the 5 percent significance level. This suggests significant differences in mean domestic tea consumption between group four (2017-2021) and the other three groups (2002-2006, 2007-2011, and 2012-2016). Therefore, domestic tea consumption increased significantly from 2002 to 2021 (Arefin and Hossain, 2022). The outcomes are shown in Figure 1. For the past 7-8 years, domestic consumption has increased by 6-7 percent. As noted by Shyamol (2023), Bangladesh's economy has seen substantial growth over the past decade, leading to a rise in tea consumption across the country. The average tea consumption per person in Bangladesh has increased to over 580 grams, up from just 100 grams (Hossan, 2022). The sharp increase in domestic tea consumption suggests a growing demand for tea within the country. This could be due to factors like population growth, increasing per capita income, continuous urbanization, the purchasing power of people, better prices in the domestic market compared to the global market, changing consumer preferences, health benefit issues, and effective local marketing strategies (Boonerjee et al., 2024). If tea production hasn't expanded enough to meet both domestic and international demand, the rise in local consumption could be taking up a large portion of the tea supply, leaving less for export. Focusing more on the domestic market might boost the local economy by retaining more value within the country, benefiting local producers and related industries. However, if domestic consumption keeps rising at the expense of exports, there could be long-term risks to Bangladesh's competitiveness in global tea markets. Losing market share can be challenging to recover.

Figure 1: Domestic Tea Consumption (M. Kilograms) from 2002-2021

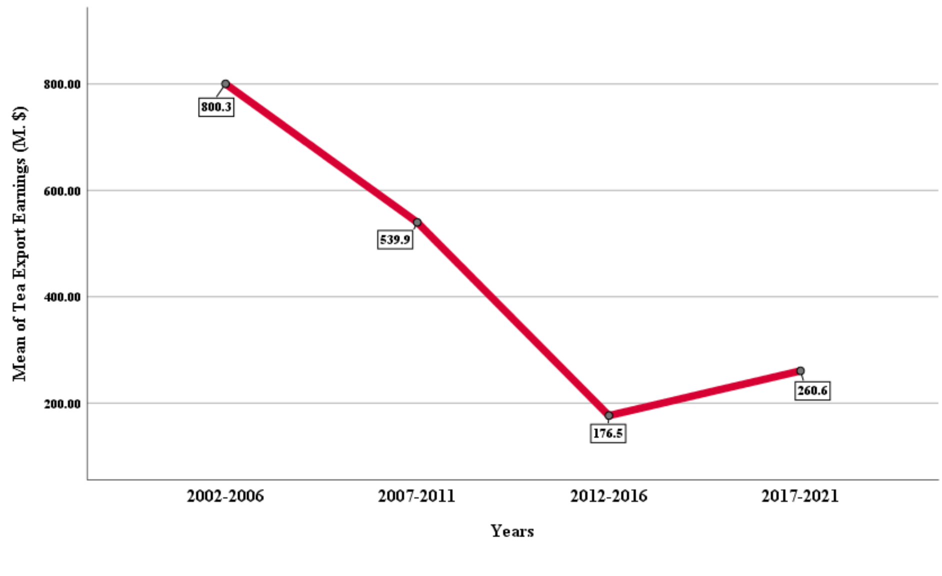


Export Earnings

The ANOVA analysis resulted in an F-value of 8.15 with a p-value of 0.00 (Appendix C: Table 8), indicating significant differences among the four groups since the p-value is less than the 5 percent significance level. The contrast values for the null hypothesis (H_0: Assume equal variances) and the alternative hypothesis (H_a: Does not assume equal variances) are -734.81, with t-statistics of -2.13 and -3.18, respectively (Appendix D: Table 9). Both p-values, 0.04 and 0.01, fall below the 5 percent significance level, indicating significant differences in mean tea export earnings between group four (2017–2021) and the other three groups (2002–2006, 2007–2011, and 2012–2016). As a result, export earnings declined significantly from 2002 to 2021 (Arefin and Hossain, 2022). Figure 2 presents these findings. In today's interconnected world, export earnings are essential for developing countries like Bangladesh to stimulate economic growth and bring prosperity to countries around the world. Exporting allows nations to utilize their unique resources, skills, and knowledge to gain access to global markets and promote development.

Researchers have identified three key factors contributing to the decline in tea exports: increased domestic demand, limited production capacity, and a reduction in the output of premium-quality tea. Although overall production has grown, it has not kept pace with rising demand. A producing country is expected to meet domestic demand while maintaining export capacity, but this has not been fully realized. The tea consumed in the domestic market has seen lower demand internationally (Islam, 2023). The drop in export earnings indicates that the country's tea is facing stronger competition in global markets. Competitors are likely offer better prices, higher quality, or more appealing varieties, affecting the country’s market share (Boonerjee et al., 2024). Additionally, global tea prices may have fallen, reducing earnings despite steady or increased export volumes. The domestic market appears more profitable, prompting producers to prioritize local sales over exports. This decline in export earnings highlights the need to rethink the country's export strategy, including improving the quality of its tea, seeking new markets, and enhancing international marketing efforts.

Figure 2: Tea Export Earnings (M. $) from 2002-2021



Trade Deficit

Over the past twelve years, tea imports consistently exceeded exports, leading to a trade deficit (in volume) from 2010 to 2021 (Figure 3). In 2010, tea imports totaled

4.13 million kilograms, while exports were only 0.91 million kilograms, resulting in a trade deficit of 3.22 million kilograms. By 2015, imports had surged to 10 million kilograms, while exports dropped to 0.54 million kilograms, increasing the trade deficit to 9.46 million kilograms. However, in 2020 and 2021, the trade deficit turned positive, with very small surpluses of 1.50 and 0.06 million kilograms, respectively. As seen in Figure 3, the export trend of tea shows fluctuations. Industry experts point out that the steady increase in domestic consumption, along with variations in production, has contributed to this uneven export pattern. Additionally, the quality of locally produced tea leaves has also played a role (Faruque, 2022).

A negative trade balance could indicate that the country's industries are struggling to compete internationally. This could be due to high production costs, low productivity, or insufficient innovation. Additionally, the economy may be more focused on consumption than production, resulting in a higher level of imports compared to exports. In a developing country like Bangladesh, export earnings hold greater significance than import revenues. Rising imports can deflate the economy, worsen the fiscal deficit, and weaken the local currency as domestic industries shrink and jobs are outsourced. It is possible that the nation would sell its resources and assets to foreign companies in an attempt to attract foreign investment to close the trade imbalance. Over the past 12 years, we have seen a rise in imports, which challenges our economy and affects exchange rates. A persistent trade deficit can weaken the national currency because increased demand for foreign currency is needed to cover the cost of imports. To mitigate this, we should consider implementing import tariffs on tea imports. Additionally, the government could offer incentives to boost export activities, motivating exporters to increase their exports. The government may need to introduce policies to boost exports, such as enhancing infrastructure, increasing labor wages, applying modern technology, and investing in technology for export-focused industries (Razzaque et al., 2024). Additionally, adjustments to fiscal and monetary policies might be required to tackle the root causes of the trade deficit. Since in most cases we import high-quality tea that is not produced locally, we should work on enhancing our tea production and introducing more varieties. Currently, tea quality is high only in Sylhet and Chattogram, while in other regions, tea quality is not so good. Faruque (2022) observes that renowned tea companies continue to import tea leaves from countries like Kenya to uphold the quality of their premium brands. Most of the 167 tea gardens in the country have struggled to produce high-quality leaves as garden owners focus on boosting yields and maximizing profits. Despite the Bangladesh Tea Board's push to increase overall tea production, it has not been very responsible for maintaining quality standards.

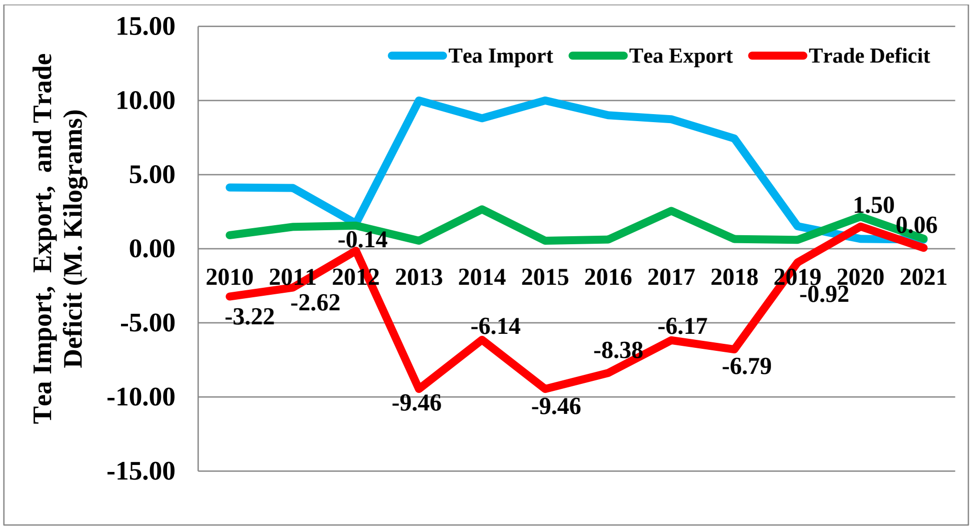


Fig. 3. Tea Import, Export, and Trade Deficit (M. Kilograms) from 2010-2021.

Conclusion

This study provided a comprehensive analysis of the effects of climate change on tea production in Bangladesh, as well as the economic implications related to domestic consumption, export earnings, and the trade deficit. One important contribution of this research is its examination of these economic factors using advanced econometric and statistical methods. The study revealed two opposing climate effects on tea production because maximum humidity with minimum humidity along with maximum temperature creates negative impacts, but rainfall with minimum temperature and carbon dioxide emissions supports its growth. Over the past twenty years the study revealed substantial growth in domestic tea consumption which resulted from population expansion together with increased earning capacity, shifts in consumer taste preferences and surging urbanization rates etc. The market has shown export earnings reduction because domestic demand remains high while prices have fallen globally and competition increased. Over the past 12 years, the trade deficit has continued despite high production costs accompanied by low productivity and insufficient quality innovations. The study demonstrated that strategic measures, including strong import tariffs with enhanced export incentives together with infrastructure improvements, should be used to address these problems. The research advocated for wages that benefit workers as well as a double effort to create new tea plant varieties and better quality while synchronizing national policies with monetary instruments and embracing progressive farming methods. The research acknowledged its limitations and suggested that future studies could benefit from including additional variables like soil fertility, solar radiation, and wind speed to explore new dimensions.

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Appendices

Appendix A: Table 6. ANOVA

Tea Consumption	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6752.53	3	2250.84	66.58	0.00
Within Groups	540.88	16	33.80		
Total	7293.41	19			

Source: SPSS software based on secondary data (2002-2021).

Appendix B: Table 7. Contrast tests

Variable	Hypotheses	Contrast	Value of Contrast	**t**	Sig. (2-tailed)
Tea Consumption	Assume equal variances	1	105.31	11.69	0.00
	Does not assume equal variances	1	105.1	12.60	0.00

Source: SPSS software based on secondary data (2002-2021).

Appendix C: Table 8. ANOVA

Export Earning	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1206347.14	3	402115.71	8.15	0.00
Within Groups	789568.19	16	49348.01		
Total	1995915.32	19			

Source: SPSS software based on secondary data (2002-2021).

Appendix D: Table 9. Contrast tests

Variable	Hypotheses	Contrast	Value of Contrast	**t**	Sig. (2-tailed)
Export Earnings	Assume equal variances	1	-734.81	-2.13	0.04
	Does not assume equal variances	1	-734.81	-3.18	0.01

Source: SPSS software based on secondary data (2002-2021).