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Exploring the Dynamics Between Tea Yield and Wages in Sivasagar District, Assam: The Toda-Yamamoto Approach

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ABSTRACT

Background: Assam has always upheld a leading position in terms of India's total tea production, but continues to face challenges such as declining businesses, closure of tea factories, low wages, periodic job cuts and increasing migration among the workers. Therefore, to understand the relationship between productivity and wages is crucial for both industrial profitability and welfare of the workers.

Methods: The present article explores the dynamic relationship between tea yield and wages by employing an advanced time series approach, namely Toda-Yamamoto non-causality test. The analysis is based on annual observations within this time frame from 1989 to 2022.

Result: The findings of the test reveal a feedback causal association between tea yield and wages, indicating both variables contain some information that can be used to predict each other. By doing so, the study provides empirical evidence to the government to adopt a balanced approach between industrial profitability and welfare of the workers.

Key words: Phillips-Perron test, Tea yield, Toda-Yamamoto test, Wages.

INTRODUCTION

Tea is regarded as the world's cheapest and famous non-alcoholic drink, only next to water. It is the second most consumed beverage, with two-third of the world's population drinking it (Nhi *et al.*, 2025). Globally, over three million cups of tea are consumed daily across diverse age groups and all sections of the society (Hicks, 2009). China, India and Sri Lanka are the major tea producing nations in Asia, while Kenya, Malawi, Rwanda, Tanzania and Uganda command tea production in Africa (Gunathilaka and Tularam, 2016). In addition to these major tea producers, there are some smaller nations like Peru, Nepal and Zimbabwe that also contribute to worldwide tea production. Altogether, there are 34 tea producing nations worldwide (Gunathilaka and Tularam, 2016). Amongst these, China, India, Sri Lanka, Kenya and Indonesia are the top five producers, contributing 77% of total world production and 80% of global exports (Basu *et al.*, 2010). India alone contributes about 25% of world's total production of tea, making it one of the biggest exporters in the international tea market (Kumar *et al.*, 2008).

India is the second largest producer of tea, after China and is also a major consumer, with more than one million domestic tea drinkers consuming 80% of the total output (Ghosh, 2021). The tea industry apart from producing traditional, premium, organic and environment-friendly tea products has also contributed to the development of tea tourism, with numerous farms providing tours and other tourism activities (Babitha *et al.,* 2023). In India, tea is mainly cultivated in four major states namely Assam, West Bengal, Tamil Nadu and Kerala, which together contribute to 97.36% of the country's total tea production. Assam leads the chart with the highest share of 52.95% followed by West Bengal (26.73%), Tamil Nadu (13.09%) and Kerala (4.59%), while remaining 2.62% comes from Arunachal Pradesh, Bihar, Himachal Pradesh, Manipur, Mizoram, Nagaland, Sikkim, Tripura and Uttarakhand (Laskar and Thappa, 2018).

Tea is an important cash crop of Assam and is world-famous for its liquor quality, rich savoury aroma and malty flavour, which make it popular among black tea lovers worldwide (Gogoi *et al.*, 2016). Assam has more than 800 tea estates that solely contributes about half of India's total tea output with approximately 3.22 lakh hectares of land under tea cultivation spread across the Brahmaputra and Barak valleys, representing two prominent tea producing belts of the state and having over 50% India's tea cultivation regions. The favourable climatic conditions of the state suited by high rainfall, humid climate and fertile alluvial soil, make it ideal for tea cultivation in the region (Sen *et al*., 1966). Apart from the agricultural importance, the tea

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industry paved the way for the development of hardship infrastructures like railways, highways and utilisation of hilly terrains for tea cultivation in Assam (Borah and Das, 2015). The industry in 1837 during the British colonial rule also led to the migration of diverse ethnic group of cheap, hard pressed and illiterate workers from Orissa, Jharkhand, Bihar, West Bengal, Uttar Pradesh, Madras and Chhattisgarh who latter evolved into 'Tea Tribes' or Adivasi population (Magar and Kar, 2016). This population today constitutes about 20% of the total population of Assam and their long-term socio-cultural association with the greater Assamese society has added new aspect not only to growth of the tea industry but also to the rich culture of Assam (Magar and Kar, 2016). The integration is reflected in their way of life, language, music, work culture, food habits and many other socio-cultural practices observed in many of the big tea estates. Fig 1 shows the trend of tea yield in Sivasagar district from 1989-2022.

The tea sector holds a significant position in Assam's economy, contributing to state's revenue by earning foreign currency. The tea industry of Assam provides significant employment opportunities to both unskilled and semi-skilled labourers (Phukan and Chakraborty, 2025). As the largest private sector employer in the state, it provides employment to over 6.86 lakh workers, which is about 50% of the total average daily wage earner in India (Narzary, 2016). Since tea being a labour-intensive crop, the growth of its industry is closely associated with the welfare of the workers. Among the factors that influence the well-being of the workers, wages form the most critical determinant impacting their standard of living. Fig 2 shows the trend of wages of tea garden workers in Sivasagar district from 1989-2022.

Despite Assam contributing over 50% country's total tea production, the socio-economic condition of the tea garden workers remains hazardous (Sinha *et al.*, 2023; Devi, 2022). They are perhaps the most exploited class in the organised sector of the economy (Sharma and Bhuyan, 2016). Studies show that the current minimum wage levels for tea garden workers are not adequate to live a basic life, manage the rising costs and support their joint families (Spires *et al.*, 2022). The inequality related to gender differences between male and female prevails almost in every sphere of life, in unequal labour mobility, wage pay, occupational and social status (Das and Roy, 2019). This biased gender preferences causes social inequity among the workers and has got direct implications for labour motivation, efficiency and eventually on tea yield outcomes.

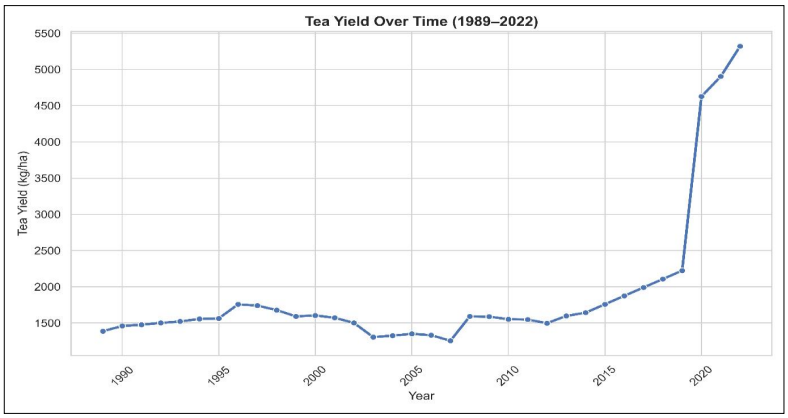


Fig 1: Trend of tea yield (kg/ha) over time.



Fig 2: Trend of wage of tea garden workers over time.

Women, who constitute more than 50% of the workforce are socially exploited based on low wages for equal hours of work as compared to their male counterpart (Ekka and Joseph, 2022). They earn a monthly income ranging from Rs. 5001 to Rs 7000, deemed insufficient to meet monthly expenditure leading to financial instability (Gogoi and Radha, 2023; Datta, 2017). Low income and unstable employment during the off season, demotivate the seasonal or temporary workers to leave the tea sector in search of better paying jobs, resulting in an increase in the number of absentees among the tea estates (Sharma and Bhuyan, 2016). Workers are not only tensed about their poor financial conditions but are also stressed due to challenges like closed and partially opened tea gardens, wage thefts, irregular payments and poor labour administration (Sen, 2015; Saha *et al.*, 2024).

Labour productivity, reflected by tea yield is very important for the sustainability and profitability of the tea industry. Higher tea productivity places the tea estates in a better profitable position, enabling them to extend improved welfare measures and sustainable wage structure for the workers (Kakoty and Kaurinta, 2022). However, the relationship between tea yield and wages is not straight-forward.

Despite the crucial impact of wages in influencing the welfare of the workers and the role of productivity for the growth of the industry, there lies hardly any evidence on whether improvements in tea productivity results into higher wages for workers, or whether rising wages enhances tea productivity.

While there are earlier researches that have assessed the socio-economic conditions and structural challenges of the sector, the dynamics between tea yield productivity and wages of workers still remains untouched and unexplored. To overcome this research gap, the present study employs the Toda and Yamamoto (1995) causality test procedure to investigate the association between tea yield and wages in Sivasagar, Assam. The study provides better and deeper understanding about how the dynamics of labour-productivity is associated with tea plantation sector and offers valuable insights that are important for policy makers to design schemes to balance the industrial profitability with the well-being of the labourers.

MATERIALS AND METHODS

The research was conducted at the Department of Statistics, Cotton University, Assam, India. The paper focuses on Sivasagar district of Assam, a prominent teaproducing region in Brahmaputra valley of Assam, using derived information collected from Open Government Data (OGD) Platform of India, Statistical Handbooks and Tea Board of India reports published in the journals. The dataset consists of annual tea yield (Kg/ha) and average daily wage (in `) of tea plantation workers in Sivasagar, Assam over the period of 1989 to 2022. The two variables were selected as they represent the labour productivity and welfare of the workers as per the requirement of the study. The Toda and Yamamoto (1995) Granger causality test procedure has been used as the methodology of the study.

The Toda-Yamamoto causality (1995) approach test is basically more suitable in case of small samples and is specially more favorable for time series whose order of integration is unknown or may be different, or the order of integration may be greater than two. The test further becomes more advantageous because it ignores the pre-testing of cointegration properties of the variables, provided the integration order must not exceed the actual model lag length. The methodology proposed by Toda and Yamamoto (1995) approach to the Granger causality test directly performs the causality analysis on the test coefficients of the Vector Autoregressive (VAR) levels, which in turn minimize the potential risk connected with the incorrect identification of integration order of the series or the existence of cointegration between the series (Giles, 1997; Mavrotas and Kelly, 2001).

The concept behind the Toda and Yamamoto (1995) procedure is to artificially augment the true VAR of order k with d additional lags, where d represents the highest integration order of the variables in the system. Thus, the foremost step of this procedure is to find the highest integrating order of the series, say, d_{max}. In the second step, the information criterion like Alkaline Information Criteria (AIC) and Final Prediction Error (FPE) were used to identify the ideal lag length k of the VAR model. Next, the artificially augmented VAR order ($p= k + d_{max}$) was analyzed using Seemingly Unrelated Regression (SUR). Finally in the concluding step, the hypothesis of no causality was evaluated using standard Wald test only on first k lags, excluding the extra lags, with the resulting test statistic following an asymptotic chi-square (χ^2) distribution. The application of the above test procedure requires a bi-variate system that links the dynamic relationship between the variables in the study, expressed as:

$$Y_t = \Psi_0 + \Psi_1 Y_{t-1} + \Psi_2 Y_{t-2} + ... + \Psi_k Y_{t-k} + \varepsilon_t$$

Where,

$$Y_t = \begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} TY_t \\ W_t \end{bmatrix},$$

W= The wage of the labourers.

TY= Tea yield.

Ψ_i= 2×2 coefficient matrices.

ε_t= Independently and identically distributed N (0, Σ).

The following augmented level VAR model of order p (= k + d) is estimated to test the null hypothesis of no Granger causality:

$$Y_t = \alpha + \Psi_1 Y_{t-1} + \Psi_2 Y_{t-2} + ... + \Psi_k Y_{t-k} + \Psi_{k+1} Y_{t-k-1} + ... + \Psi_p Y_{t-p} + \varepsilon_t$$

This augmented VAR(p) is estimated by applying the SUR technique.

The no difference hypotheses to be tested were:

H_{01}: Tea yield does not Granger - cause wage, *i.e.*

$$\Psi_{21}^{1} = \Psi_{21}^{2} = ... = \Psi_{21}^{p} = 0$$

H_{02}: Wage does not Granger - cause tea yield, *i.e.*

$$\Psi_{21}^{1} = \Psi_{21}^{2} = \ldots = \Psi_{21}^{p} = 0$$

Both the hypotheses were tested using Wald test statistic (W), expressed as:

$$W = T\,[(a_i' \otimes B')\,\mathrm{vec}\,(\hat{\Psi})]\,[a_i \otimes B')\,\hat{\Sigma}\,(a_i' \otimes B')']^{-1}\,(a_i' \otimes B')\,\mathrm{vec}\,(\hat{\Psi}) \sim \chi^2_k$$

Where,

T= The total number of observations, $a_1 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$, $a_2 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ and $B = I_k \otimes a_j$,

with j = 1,2 and I_k= Identity matrix of order k × k. Let vec (Ψ) denotes the vector form of the estimated coefficient matrix, where all the rows of matrix Ψ are arranged sequentially into a column vector and $\hat{\Sigma}$ is a consistent estimator of the asymptotic variance-covariance matrix $\sqrt{T}\mathrm{vec}\,(\hat{\Psi} - \Psi)$.

The main rationale behind involving the extra lags in the estimation process, while leaving it in the Granger causality hypothesis testing is to avoid issues of non-standard asymptotic distributions connected with the integrated variables. Furthermore, the application of SUR technique in the estimation process enhances the efficiency of Wald test (Zellner, 1962).

RESULTS AND DISCUSSION

To begin with, the Phillips-Perron (PP) test has been applied to identify the integrating order of the two variables included in the study. The PP procedure uses a non-augmented version of the Dickey-Fuller (DF) test, expressed as-

$$\Delta Y_t = \alpha\, Y_{t-1} + x_t'\delta + \varepsilon_t$$

where $\alpha = \rho - 1$.

Here in this equation, Y_t denotes the time series variable under consideration, x_t' represents a set of regressors such as a constant term, or a combination of a constant and a trend, ρ and δ are the parameters to be estimated and ε_t denotes the error term. The null and alternate hypotheses are given by-

$$H_0: \alpha = 0 \text{ and } H_1: \alpha < 0$$

The null hypothesis of non-stationarity is rejected when the calculated PP test statistic is lower than the corresponding critical value at all the chosen levels of significance. The PP test results are summarized in the Table 1 below:

The results summarized in Table 1 demonstrate that both tea yield and wage series are non-stationary at levels under both categories namely with intercept and with intercept and trend. However, after first differencing the calculated value of PP test statistic for both the variables becomes statistically significant, as they are lower than their corresponding critical value at the 1%, 5% and 10% chosen significance levels. Hence, their null hypothesis of non-stationary is rejected at first difference, implying both variables are integrated to order I (1). Therefore, the highest integrating order that needs to be considered for the variables under study is, d_{max} = 1 Consequently, in the Toda-Yamamoto procedure, one additional lag of each variable is to consider in the model to control the potential co-integration among the variables. Thereafter, VAR model's optimal lag length is determined to perform the causality test. The selection of the optimal lag length in case of small samples studies (n<60), AIC and FPE are superior than other information criterion (Lutkepohl, 1991; Liew, 2004). Depending on the lag selection results summarized in Table 2, the appropriate lag length for the VAR model has been identified as k = 2.

Subsequently, a VAR model of order 3 ($p = k + d_{max}$) is estimated using SUR technique and the Wald test is performed using χ^2 distribution. The results of the Toda-Yamamoto Granger non-causality test are presented in Table 3.

The result presented in Table 3 reveals that the first null hypothesis 'Tea yield does not Granger-cause wage' is rejected, as the Wald test statistic value has been found to be 8.343, which is greater than 5% critical value 7.815, with a probability-value of 0.039. This shows that the past values of tea yield significantly influences the wages of the workers. The result supports the economic perception that higher productivity enhances the profitability of the tea-estates, enabling the management to provide sustainable wage structure for the workers.

The second null hypothesis 'Wage does not Granger-cause tea yield' is also rejected, as the Wald test statistic value has been found to be 28.150, which is greater than the 5% critical value 7.815, with a probability-value of 0.000. This implies there exist a strong feedback loop, implying wages too significantly impact tea yield. One possible reason for this is that better wages may improve workers motivation, nutritional intake, financial status and overall well-being, which in turn positively impact labour productivity.

Table 1: PP test for tea yield and wage series.

Variables	Level (Intercept)		Level (Intercept and trend)		First difference (Intercept)		Order of integration
Tea yield	2.095	1%: -3.65	1.188	1%: -4.26	-4.999	1%: -3.65	I (1)
		5%: -2.95		5%: -3.55		5%: -2.96	
		10%: -2.62		10%: -3.21		10%: -2.62	
Wage	5.646	1%: -3.65	2.364	1%: -4.26	-3.932	1%: -3.65	I (1)
		5%: -2.95		5%: -3.55		5%: -2.96	
		10%: -2.62		10%: -3.21		10%: -2.62	

Table 2: Lag order selection based on AIC and FPE.

Lag	AIC	FPE
0	21.27	1.725e+09
1	15.75	6.89e+06
2	15.47*	5.233e+06*

Note. The lag order corresponding to the minimum AIC and FPE values is selected as optimal.

Table 3: Toda-Yamamoto Granger non-causality test results.

Null hypothesis	Chi-Square statistic (d.f)	Critical value	Probability (p) value
Tea yield does not granger-cause wage	8.343 (3)	7.815	0.039
Wage does not granger-cause tea yield	28.150 (3)	7.815	0.000

Thus, both the variables influence one another i.e. there exists a bi-directional feedback loop between tea yield and wages of workers in Sivasagar, Assam, over the sample period. This bi-directional relationship reveals the interdependence between economic sustainability and worker's welfare in the tea industry. The result underlines the importance of adopting a balanced policy approach that simultaneously promotes productivity growth and ensures proper compensation is paid to the workers.

From the view point of policymaking, the policymakers should focus on improving hazardous working conditions such as long working hours, lack of safety equipment and exposure to pesticides, along with ensuring timely wage payments of the workers. These measures can help improve workers livelihoods while supporting sustainable growth of the tea industry. Therefore, the study provides valuable insights for policymakers in designing policies that benefit tea garden wage earners and boost long-term development of the tea sector.

CONCLUSION

Tea cultivation, as a cash crop has always played a very crucial part in uplifting the economy of Assam. The tea industry being the largest private sector employer of the state provides employment to lakhs of workers, particularly women engaged in plucking and packaging of tea leaves. Despite the workers significant contribution towards the growth of the state, the tea garden communities are exploited to face poor socio-economic conditions including low wages and income disparity. Consequently, the study examined the dynamic association between tea yield and wages in Sivasagar, Assam, using annual tea yield and daily wage data of workers over the period of 1989 to 2022. Next the Phillips-Perron test has been conducted which identified that both the variables are integrated to order one. This led the way to the implementation of Toda and Yamamoto Granger causality test procedure.

The results of the test revealed the existence of a bi-directional feedback causal relationship between tea yield and wages in Sivasagar, Assam, indicating both variables contain some valuable information that can be used to predict one another. Higher productivity enhances the earnings of the tea estates which make them in better profitable position to provide sustainable wages to the workers. Improved wages may financially benefit the workers to support joint families, motivate them to work and also enhance their nutritional intake capabilities. The loop further highlights the mutuality between labour welfare and development of the industry.

The study therefore recommends that policies should encourage both productivity and fair wage distribution to the workers for long-term sustainability of the sector. Thus, based on this inter-relationship, the government, management and NGOs can work together towards building a stronger and integrated path for the tea plantations of Assam.

Conflict of interest

The authors declare that they have no conflict of interest.

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