Growth of Natural Rubber Production: Implications for Farmers from Global Experience

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ABSTRACT-*Production of natural rubber has substantially increased in all major natural rubber producing countries. Increased farming of natural rubber and increased manufacturing of synthetic rubber have created excess supply of rubber which gave the manaufacturers of rubber products an opportunity to exploit the buyers' market. This has tempted manufacturers of rubber products to make use of price fixing which gave rise to glut in the rubber market. Consequently, price of natural rubber has fallen below the average variable cost which has resulted in unprofitable subsistence farming for many thousands of small farmers in many countries. This has forced many farmers to exit from the rubber farming. The present paper is concerned with the study of the nature of growth and variance of natural rubber production in major natural rubber producing countries during the period 1961 to 2013 and its implications for farmers.*

Keywords:Growth, variance, production, yield, area, elasticity

1. INTRODUCTION

Agricultural production particularly in developing countries is generally a risk process, a considerable evidence exists to suggest that farmers behave in risk-averse ways(Hazell and Norton, 1986). Very wide fluctuations in crop output causes imbalance between the supply and demand and consequently affect the prices of crop and in turn affect income and employment, standard of living of farmers and indirectly affect all other sectors. The current glut of natural rubber have created recession in a number of countries where thousands of small farmers depend only on cultivation of natural rubber for livelihood. Since the majority of natural rubber is grown by the small farmers, a big cut in price of natural rubber would adversely impact the small farmers and the economy. The price of natural rubber per kilogram reached US $4 a year ago and this has fallen to US $2 now. Many small and marginal farmers have no alternative income and employment. When the price of natural rubber has fallen below the average variable cost, the farmers have refused to tap and many of them have cut the rubber plants and started farming of different crops. It must also be recognized that subsistance agriculture is an uncertain activity and therefore risky, particularly, when survival is at stake and this is another factor that breed conservatism and makes change difficult even in the face of opportunities (Galbraith,1979).

In 1961-63, the major natural rubber producing countries in the world were Malaysia (38.64%), followed by Indonesia (33.33%) and Thailand (9.28%). This picture has substantially changed in 2011-13. Not only more countries have emerged in the field of natural rubber production but also the existing top natural rubber producers expanded cropped area substantially to increase production. Brazil, China, Ecuador, Gabon, Guatemala and Mexico have started the production of natural rubber. The top producers of natural rubber in 2011-13 are Thailand(31.53% of production with 22.72% of area), Indonesia(26.51% of production with 35.74% of area), Malaysia (7.99% of production with 10.64% of area), Vietnam(7.61% of production with 5.15% of area), India(7.57% of production with 4.51% of area) and China(7.04% of production with 6.59% of area) (Table 1).

The production of natural rubber increased from 6811 thousand tonnes in 2000 to 11809 thousand tonnes in 2014. The production of synthetic rubber increased from 10870 thousand tonnes in 2000 to 16715 thousand tonnes in 2014 (Figure 1). Substantial growth of synthetic rubber has affected the prices of natural rubber. Manufacturers are capable to substitute synthetic rubber for natural rubber and vice-versa and this plays an important role in holding the prices of one down.

The impact of economic conditions of surplus and deficits of natural rubber production on its prices, income of farmers and general employment and development of different sectors is different for countries. The present paper aims to study the nature and sources of growth and variance of natural rubber production in major natural rubber

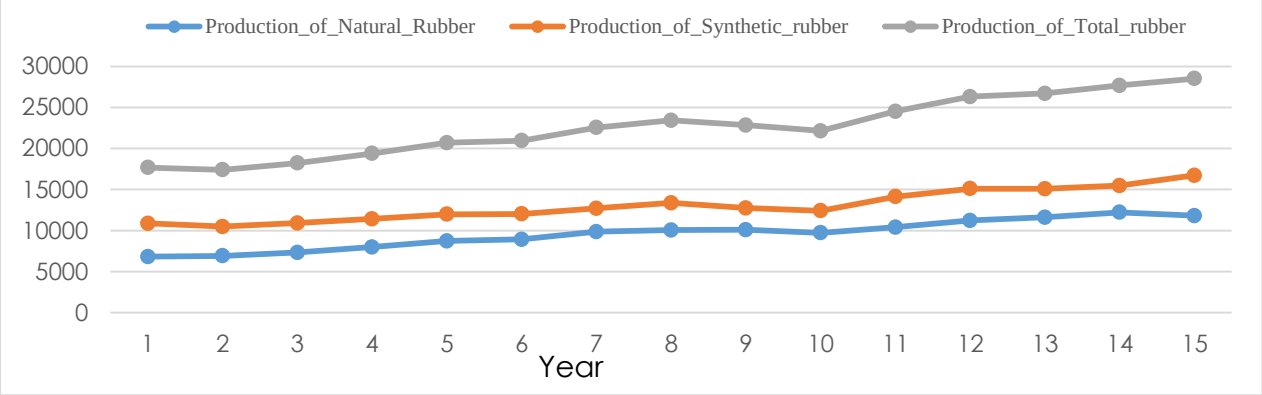
producing countries during the period 1961 to 2013. The study also explores the factors responsible for the expansion of acreage under natural rubber cultivation. An attempt has also been made to find the reason for the yield growth of natural rubber. The relevance of this study is very important in the context of emerging glut in natural rubber production market and consequent falling prices. We have included countries like Brazil, Cambodia, Cameroon, China, Cote d'lvoire, Ecuador, Gabon, Ghana, Guatemala, India, Indonesia, Liberia, Malaysia, Mexico, Myanmar, Nigeria, Philippines, Srilanka, Thailand and Vietnam.

Table 1:Percentage Share of countries in Area and Production of Natural Rubber

	1961-63		2011-13			1961-63		2011-13	
Country	Area	Produ-ction	Area	Produ-ction	Country	Area	Produ-ction	Area	Produ-ction
Brazil	0.00	0.00	1.41	1.53	Indonesia	34.55	33.33	35.74	26.51
Cambodia	1.15	1.96	0.37	0.38	Liberia	1.91	2.05	0.78	0.55
Cameroon	0.34	0.54	0.56	0.49	Malaysia	33.93	38.64	10.64	7.99
China	0.00	0.00	6.59	7.04	Mexico	0.00	0.00	0.15	0.18
Cote d'lvoire	0.02	0.01	1.38	2.28	Myanmar	1.51	0.68	2.05	1.30
Ecuador	0.00	0.00	0.12	0.18	Nigeria	3.31	2.98	3.52	1.25
Gabon	0.00	0.00	0.15	0.18	Philippines	0.36	0.21	1.78	1.05
Ghana	0.02	0.02	0.27	0.18	Srilanka	5.72	4.90	1.33	1.28
Guatemala	0.00	0.00	0.78	0.91	Thailand	12.69	9.28	22.72	31.53
India	1.33	1.53	4.51	7.57	Vietnam	3.16	3.88	5.15	7.61
					Total	100.00	100.00	100.00	100.00

Source:Calculated from FAOSTAT

Figure 1: Global Production ('000 tonnes) of Rubber during 2000-2014



Source:International Rubber Study Group (IRSG)

2.Materials and methods

Annual time series data on cropped area, yield, and production of natural rubber for selected countries like Cambodia, Cameroon, Cote d'lvoire, Ghana, India, Indonesia, Liberia, Malaysia, Myanmar, Nigeria, Philippines, Srilanka, Thailand and Vietnam from 1961 to 2013 are obtained from FAOSTAT (2015). Annual time series data on cropped area, yield, and production of natural rubber for Brazil, China, Ecuador, Gabon, Guatemala and Mexico are available from 1989 to 2013. Price data are not available consistently for all the years for all the selected countries. Price data for Myamar, Cameroon, Indonesia, Philippines, Thailand and Srilanka are available from 1961 to 2013. Price data for Mexico is available from 1988-2013. Price data for India and Nigeria are available from 1961 to 2002. Price data for Cambodia and Ghana are available from 1962 to 1991 whereas for Vietnam, it is available from 1999 to 2012. Consistent price data for Brazil, Cambodia, China,Ecuador, Gabon,Guatemala, Liberia and Malaysia are not available in FAOSTAT.

Meaningful inferences from time series data can be drawn only if that series used in regressions are stationary either in levels or differences. The seasonality and the integration order of the variables were tested using the Augmented Dicky Fuller test. According to this test, it was found that the variables are not stationary and are an integration order one. All we have to do is transform each variable by subtracting from its current value its previous value and run the regression. Transformation in A (cropped area), Y (Yield), P(production) and PC(Price) are calculated using the following formulas. $\Delta \ln P_t = \ln P_t - \ln P_{t-1}$ for production, $\Delta \ln Y_t = \ln Y_t - \ln Y_{t-1}$ for yield, $\Delta \ln A_t = \ln A_t - \ln A_{t-1}$ for area and $\Delta \ln PC_t = \ln PC_t - \ln PC_{t-1}$ for price. ADF tests have been used on the transformed variables and found no unit roots and thus they are conintegrated.

Three year moving average had been computed to eliminate the short term fluctuations. The moving averages provide the trend values or the long term behaviour of the series. The least-squares growth rate (r) for cropped area, yield and production, is estimated by fitting a log-linear regression trend line to the logarithmic moving average annual values of the variable in the relevant period. The regression equation takes the forms: $\ln P_t = a + bt$ for production, $\ln A_t = a + bt$ for cropped area and $\ln Y_t = a + bt$ for yield. Since the presence of autocorrelation observed in the results estimated from the above equations caused inference of no meaningful results, the growth rate for area, yield and production has been estimated again with the modified random walk model, i.e the logged and differenced first order AR model, $\Delta(\ln At) = bt + ut$ for cropped area, $\Delta(\ln Yt) = bt + ut$ for yield and $\Delta(\ln Pt) = bt + ut$ for production. Growth rates have been calculated for 1961-2013 and decadenal sub-periods 1961-70, 1971-80,1981-90,1991-2000 and 2001-2013. Finally, using these time series growth rates, regression **of** growth rates of production on the growth rates of area and yield across countries have been estimated using OLS.

An attempt has also been made to explore the factors responsible for the expansion of cropped area and yield of natural rubber. Production variance has been calculated using coefficient of variation and area-yield covariance. Variance in production has been decomposed into variance contributed by cropped area and yield using area-yield covariance matrix. Time series area-yield covariance has been calculated for cross-section counties. Similarly, cross-section area-yield covariance matrix has been calculated for time series.

2.1 Area Model

Nerlove (1956) developed a model of distributed lags where production, cropped area or yield may be related to the same referred lagged variable, to the lagged crop price and to the lagged input price. This model has obtained the most satisfactory response estimating farmer responses and price expectations (Fisher and Tanner, 1978). In order to estimate a functional form for producer supply, the estimations of the period mentioned were made using a Cobb-Douglas model, based on Morales and Foster (2002). The model is based on the maximization of the net incomes, but due to the difficulty to determine this variable directly, approximations are made using gross production and crop prices. The model assumes a Cobb-Douglas functional form, which is presented below.

$$\ln(A)_t = \alpha + \delta ln(A)_{t-1} + \sum_{i=1}^{n} \beta_i \ln(P)_{t-1} + \sum_{i=n+1}^{m} \gamma_i \ln(PR)_{t-1} \quad (1)$$

Since the estimated equation 1 showed the presence of autocorrelation, following model has been estimated.

$$\Delta\ln(A)_t = \alpha + \delta\, \Delta ln(A)_{t-1} + \sum_{i=1}^{n} \beta_i \Delta\ln(P)_{t-1} + \sum_{i=n+1}^{m} \gamma_i \Delta\ln(PR)_{t-1} \quad (1a)$$

$$\Delta\Delta\ln(A)_t = \alpha + \delta\, \Delta\Delta ln(A)_{t-1} + \sum_{i=1}^{n} \beta_i \Delta\Delta\ln(P)_{t-1} + \sum_{i=n+1}^{m} \gamma_i \Delta\Delta\ln(PR)_{t-1} \quad (1b)$$

Where A stands for natural rubber area sowed in period t, P for gross production of natural rubber and PR for price of natural rubber in period t-1. The estimated equation 1a showed the presence of autocorrelation for couple of countries, **so** equation 1b has been estimated.

2.2 Yield Model

In order to estimate the price-yield elasticities, slightly modified version of the model based on González (2010) was also used, excluding the use of yield prediction models due to their limited range of application, and the requirement of specific for local varieties and climate conditions. The natural rubber yield model relates to yields with prices from previous periods, tendency impacts in technological improvements, and the possible inertia in productive practices, not captured by the changes in the prices observed.

$$\ln(Y)_t = \alpha + \delta_i\, ln(Y)_{t-1} + \sum_{i=1}^{n} \beta_i \ln(P)_{t-1} + \sum_{i=n+1}^{m} \gamma_i \ln(PR)_{t-1+\varphi(T)_t} \quad (2)$$

Since the estimation of equation 2 showed the presence of autocorrelation, following model has been estimated.

$$\Delta \ln(Y)_t = \alpha + \delta_i \, \Delta ln(Y)_{t-1} + \sum_{i=1}^{n} \beta_i \Delta \ln(P)_{t-1} + \sum_{i=n+1}^{m} \gamma_i \Delta \ln(PR)_{t-1+\varphi(T)_t} \qquad (2a)$$

Where Y stands for Yield of Natural Rubber in the period t, PR - price of natural rubber and T time. In this model, the tendency (T) is used to capture the technological progress, such as the use of new machinery and techniques, incorporation of new varieties and other technological improvements. The lagged yield constitutes a proxy variable to take into account and control unobservable costs, i.e. it captures the costs of changing productive practices.

3.Empirical Results

3.1 Graphical Analysis

Production of natural rubber reported in this paper is in tonnes, cropped area in hectares and yield in hectograms per hectare. Graphical presentation of yield per hectare is shown in one graph and the cropped area and production of natural rubber in another graph. Yield has been rising fast in India, Thailand, Vietnam and China while this has shown a slow rise in Indonesia and Malaysia(Fig 1.1).

Figure 1.1: Yield of Natural Rubber during 1961-2013

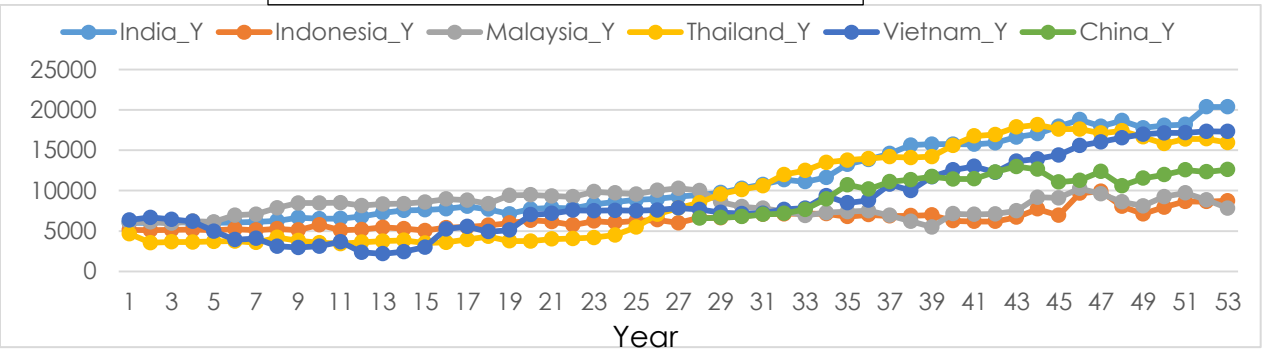


Figure 1.2 shows that yield grew significantly in Myanmar, but growth rate was negligible, though the fluctuation in yield is very high in Srilanka, Cambodia and Philippines during 1961-2013.

Figure 1.2: Yield of Natural Rubber during 1961-2013

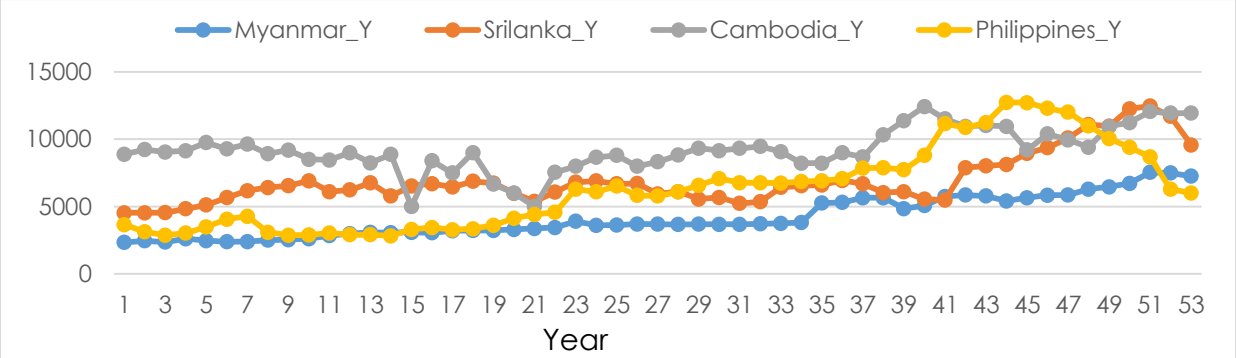


Figure 1.3 shows that yield growth in Cameroon, Ghana, Liberia and Nigeria were negligible and that of Cote d'Ivoire was high during 1961-2013.Figure 1.4 shows that Brazil, Ecuador, Gabon and Mexico had comparatively higher growth rates in yield during 1988-2013.

Graphical plots for cropped area and production for natural rubber for the period 1961-2013 are shown below. Generally, all countries have shown a rising trend in cropped area and production except Malaysia, Srilanka, Cambodia and Liberia. Malaysia and Srilanka have clearly shown a falling trend while Cambodia and Liberia have not shown any clear trend in cropped area and production of natural rubber. In Indonesia, area growth always

exceeded the production growth (Figure 3). Cropped area growth exceeded in Thailand also until early 90's but because of the growth of yield, growth of production exceeded growth of area since 1994(Figure 2) and similar tendency can also be observed for Vietnam (Figure 5), Nigeria (Figure 12), Guatemala(Figure 14) and Ghana (Figure 19). India had similar growth in area and production until 1996, but since then production growth exceeded area growth due to yield growth (Figure 6). Since 2000, Vietnam had yield based production growth (Figure 5). Production growth slightly exceeded the area growth for Brazil (Figure 9) and Cote d'Ivoire (Figure 8). Mexico (Figure 18) always had production exceeding the cropped area and this tendency can also be observed for Ecuador (Figure 20) and Gabon(Figure 21). In rest of the countries, production and cropped area are moving more or less in the same direction implying that there is large scope of yield based growth rather than increasing the production only on the basis of expansion of acreage when the world is facing the problem of limited supply of land for the growing population.

Figure 1.3: Yield of Natural Rubber during 1961-2013

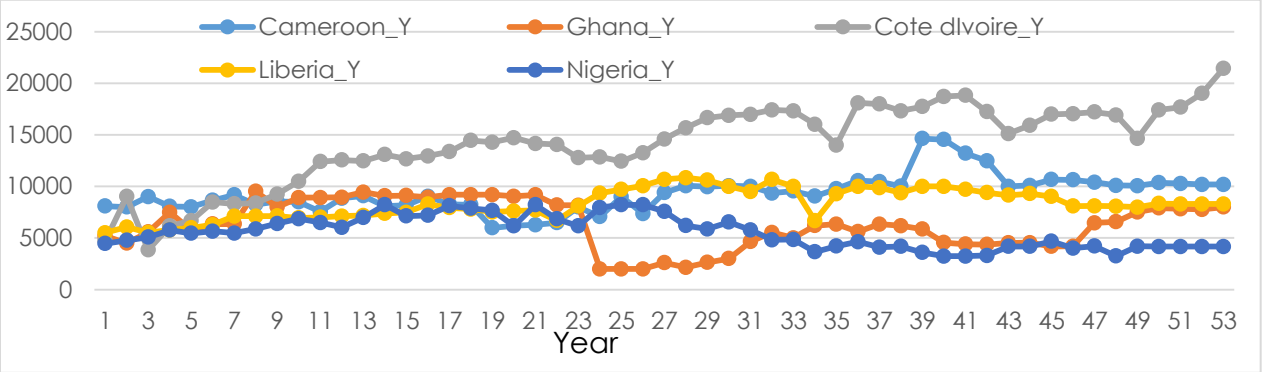


Figure 1.4: Yield of Natural Rubber during 1989-2013

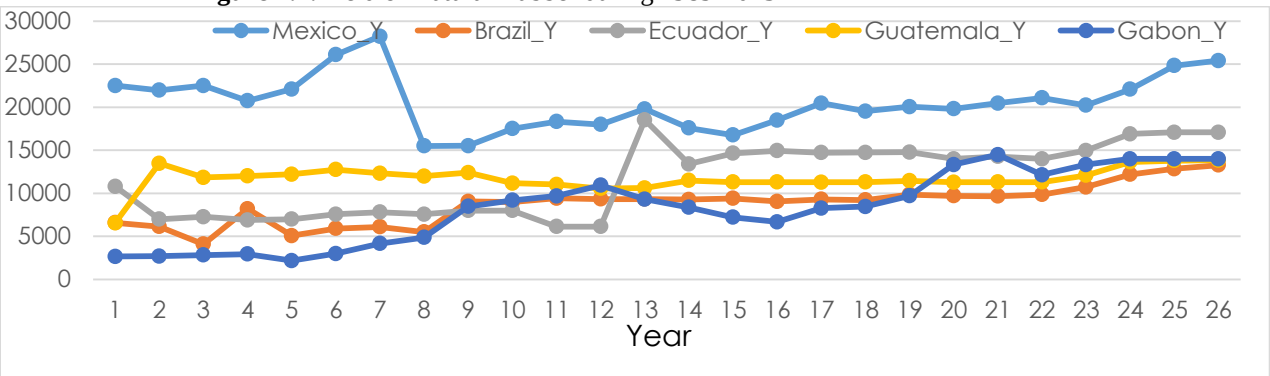


Figure 2: Production and Area of Natural Rubber in Thailand duing 1961-2013

Figure 3: Production and Area of Natural Rubber in Indonesia duing 1961-2013

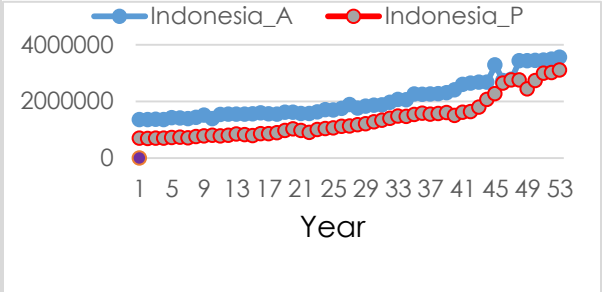


Figure 4: Production and Area of Natural Rubber in Malaysia duing 1961-2013

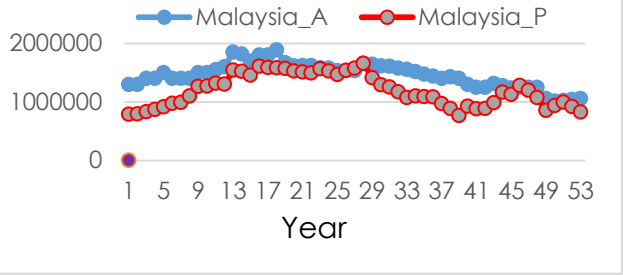


Figure 5: Production and Area of Natural Rubber in Vietnam duing 1961-2013

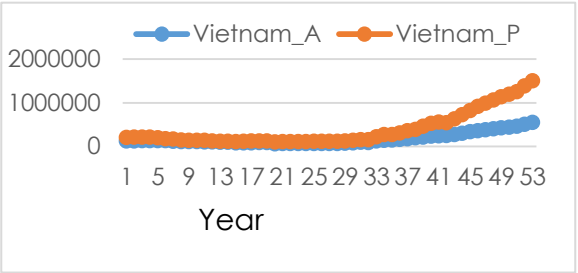


Figure 6: Production and Area of Natural Rubber in India duing 1961-2013

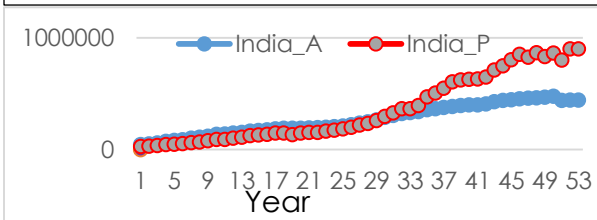


Figure 7: Production and Area of Natural Rubber in China duing 1988-2013

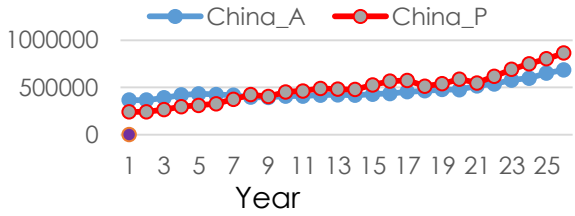


Figure 8: Production and Area of Natural Rubber in Cote d'Ivoire duing 1961-2013

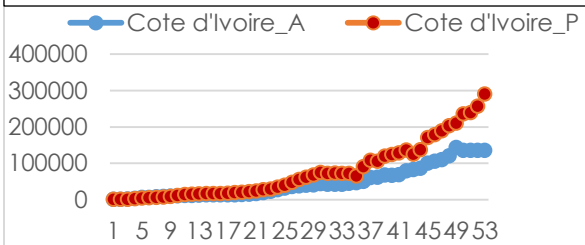


Figure 9: Production and Area of Natural Rubber in Brazil duing 1988-2013

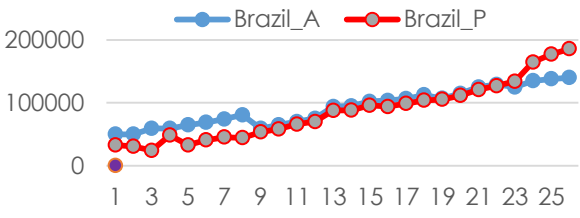


Figure 10: Production and Area of Natural Rubber in Myanmar duing 1961-2013

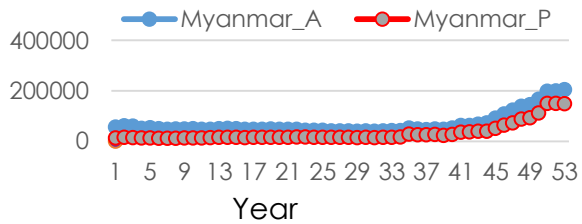


Figure 11: Production and Area of Natural Rubber in Srilanka duing 1961-2013

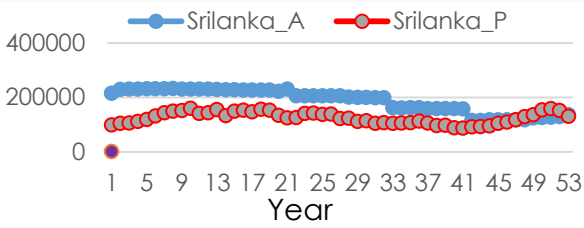


Figure 12: Production and Area of Natural Rubber in Nigeria duing 1961-2013

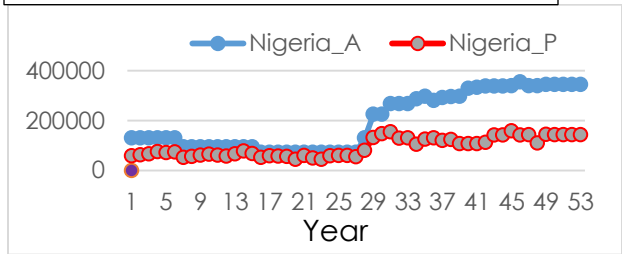


Figure 13: Production and Area of Natural Rubber in Philippines duing 1961-2013

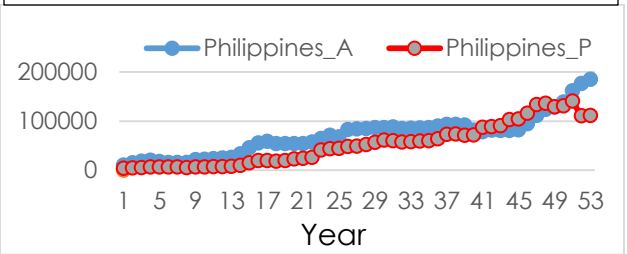


Figure 14: Production and Area of Natural Rubber in Guatemala during 1988-2013

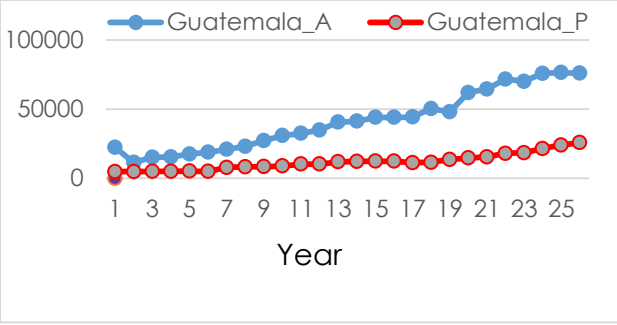


Figure 15: Production and Area of Natural Rubber in Cameroon during 1961-2013

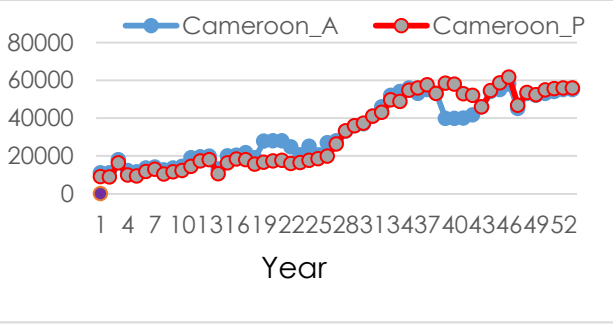


Figure 16: Production and Area of Natural Rubber in Liberia during 1961-2013

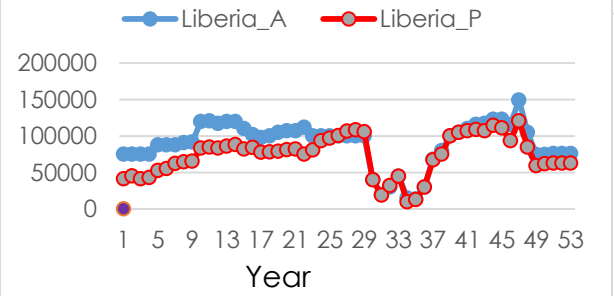


Figure 17: Production and Area of Natural Rubber in Cambodia

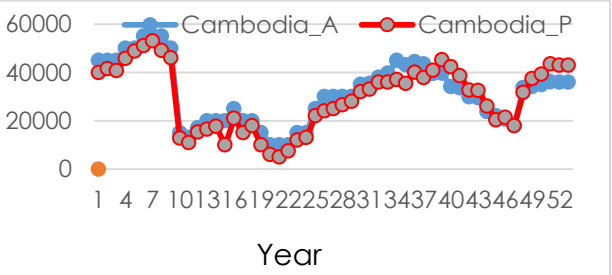


Figure 18: Production and Area of Natural Rubber in Mexico during 1988-2013

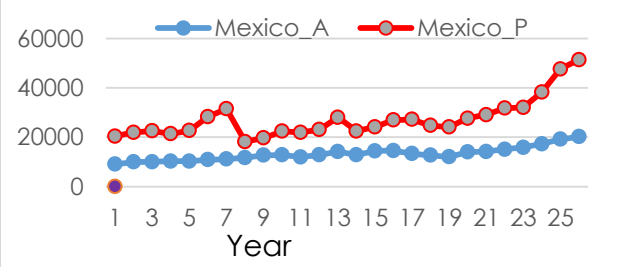


Figure 19: Production and Area of Natural Rubber in Ghana during 1961-2013

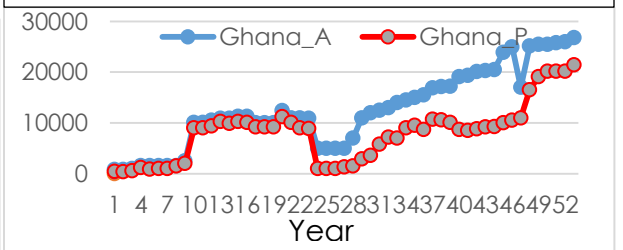


Figure 20: Production and Area of Natural Rubber in Ecuador during 1988-2013

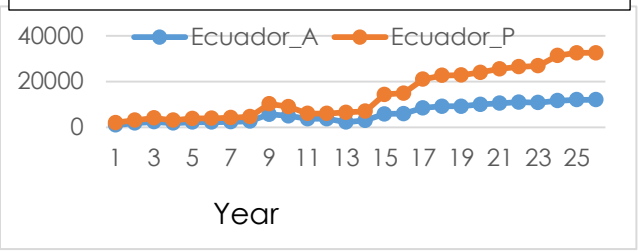
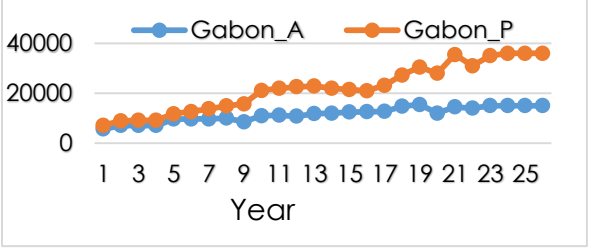


Figure 21: Production and Area of Natural Rubber in Gabon during 1988-2013



3.2 Growth Rates

Table 2: Annual Growth Rate of Area, Yield and Production of Natural Rubber

	1961-2013[1]			2001-2013			1991-2000		
	Area	Yield	Produ-ction	Area	Yield	Produ-ction	Area	Yield	Produ-ction
Brazil	0.22	0.22*	0.46***	0.37***	0.51***	0.87***	0.63	0.58	1.18
Cambodia	0.02	0.03	0.06	0.33	0.19	0.50	-0.46	0.54	0.33**
Cameroon	0.07	0.01	0.08	0.18	-0.10	0.07	-0.90	0.83	0.22
China	0.20***	0.09	0.29**	0.54***	0.10	0.64***	0.06	0.24	0.22
Cote d'lvoire	0.17	0.04	0.22	0.10	0.33	0.73	0.68*	0.21	0.93*
Ecuador	0.42	0.23	0.67*	0.50	0.25	0.84	-0.02	0.95	1.05
Gabon	0.14	0.24	0.28	0.19	0.48	0.66	0.39	0.20	-0.27
Guatemala	0.38**	0.09	0.43***	0.57*	0.34**	0.99***	1.12***	-0.14	0.87**
Ghana	0.11	0.03	0.15	0.31*	0.50	0.61	0.50**	-0.67	-0.33
India	0.02	0.08***	0.10	-0.23	0.25	0.18	0.18	-0.03	-0.15
Indonesia	0.07***	0.04	0.10***	0.31*	0.26	0.43	0.39**	-0.21**	0.13
Liberia	-0.01	0.00	-0.01	-0.48	-0.05	-0.58	2.49	0.10	2.57
Malaysia	-0.03	0.00	-0.04	-0.18	-0.07	-0.24	-0.37***	-0.13	-0.50*
Mexico	0.22**	0.11	0.32**	0.56	0.40**	0.96**	0.30**	-0.19	0.12**
Myanmar	0.14**	0.07**	0.21***	0.69	0.38***	1.39**	0.60	0.26	0.95
Nigeria	0.07	-0.03	0.05	0.02	0.12	0.13	0.36**	-0.80	-0.43
Philippines	0.14*	-0.03	0.11	0.95***	-1.14	-0.40	-0.47	0.69***	0.51**
Srilanka	-0.03	0.03	0.00	0.13	-0.28	-0.39	-0.13	-0.32	-0.37*
Thailand	0.08**	0.08	0.16**	0.55***	-0.06	0.47**	-0.03	0.51	0.49
Vietnam	0.15**	0.09	0.24**	0.60*	0	0.54	0.94	0.89***	1.80***

Source:Calculated from FAOSTAT
Note: 1.Growth rates for Brazil, China, Ecuador, Gabon, Guatemala and Mexico are computed over the years 1988-2013. ***,**,* Statistically significant at 1, 5 and 10 percent respectively.

1961-2013:During 1961-2013, the growth rate of natural rubber production was positive in all countries except

Liberia and Malaysia. Growth rate of production was statistically significant in Brazil, China, Ecuador, Indonesia, Guatemala, Myanmar, Mexico,Thailand and Vietnam. Growth rate of yield was positive for all except Nigeria and Philippines. Growth rate of yield was statistically significant in Brazil, India and Myanmar. Growth rate of cropped area was positive in all countries except Liberia, Malaysia and Srilanka. Growth rate of area was statistically significant in Indonesia,China, Guatemala, Myanmar,Mexico, Philippines, Thailand and Vietnam (Table 2). During this period, the contribution of area growth to production growth was greater than the contribution of yield growth in Cameroon, China, Cote d'Ivoire, Ecuador, Guatemala, Ghana, Indonesia, Mexico, Myanmar, Nigeria, Philippines and Vietnam. The contribution of cropped area and yield to the growth of production was equal in Brazil and Thailand (Table 2).

Yield grew at 0.08% each in India and Thailand (significant for India), 0.09% each in Vietnam and China during 1961-2013. Yield growth rate was negligible in Indonesia and Malaysia. Yield grew significantly in Myanmar at 0.07%, but growth rate was negligible, though the fluctuation in yield is very high in Srilanka, Cambodia and Philippines. Yield growth in Cameroon, Ghana, Liberia and Nigeria were negligible and that of Cote d'Ivoire was 0.04% during 1961-2013 (Table 2).

2001-2013:During this period, production grew positively in all countriues except Liberia, Philippines and Srilanka**.** Growth rate of production was significant in Brazil, China,Guatemala, Myanmar, Mexico and Thailand. Significant growth rate of yield recordered in Brazil, Guatemala, Myanmar and Mexico. Area grew significantly in Brazil, China, Thailand, Philippines, Indonesia, China, Guatemala and Vietnam (Table 2). During this period,growth rate of cropped area was the main contributer to production growth in most of the countries except Brazil, Cote d'Ivoire, Gabon, Ghana, India and Nigeria where yield growth dominated in driving production growth

Table 2(Continued): Annual Growth Rate of Area, Yield and Production of Natural Rubber

Country	1961-70			1971-80			1981-90		
	Area	Yield	Produ-ction	Area	Yield	Produ-ction	Area	Yield	Produ-ction
Cambodia	-4.77	-0.17	-4.73	-2.31*	-0.69	-2.12	0.92	0.36	0.88
Cameroon	0.42	-0.11	0.26	0.91***	-0.77**	0.19	0.90*	0.65 **	1.21*
Cote d'lvoire	2.74	1.28**	4.33	0.63**	0.27*	0.80***	0.01	0.04	-0.01
Ghana	5.23**	0.98*	6.21**	0.14	0.01	0.16	1.42	0.37	1.44
India	1.21*	0.20**	1.44**	-0.18	0.07	0.13	0.72***	0.44***	1.16***
Indonesia	0.18***	0.13***	0.30	0.08	0.32**	0.40***	0.23*	0.25***	0.48***
Liberia	0.90***	0.20	1.21***	0.08	0.02	-0.02	-3.48*	-0.35	-4.10
Malaysia	0.26	0.69***	0.93***	-0.24	0.24***	-0.01	0.01	-0.77*	-0.71
Myanmar	-0.17	0.28	0.23	-0.02	0.20	0.17	-0.11	0.06	-0.16
Nigeria	-0.52	0.59*	-0.01	-0.30	0.07	-0.32	2.52**	-0.38	2.16***
Philippines	1.00	-0.34	0.71	0.13	0.67***	1.22	0.32	0.47	0.77
Srilanka	0.01	-0.16	-0.32				-0.01	-0.38	-0.46
Thailand	1.13***	-0.15	0.93***	0.65***	0.04	0.66*	0.08	0.93	0.97
Vietnam	-0.37	0.04	-0.37	-0.77*	1.46	0.61	0.89**	-0.14	0.56**

Source:Calculated from FAOSTAT; Note:***,**,* Statistically significant at 1, 5 and 10 percent respectively

1991-2000:Production grew positively in all countries except Gabon, Ghana, India, Malaysia,Nigeria and Srilanka and the positive growth rate was statistically significant in Vietnam, Philippines, Mexico, Cambodia,Guatemala and Cote d'Ivoire. Yield grew significantly in Philliphines and Vietnam. Cropped area grew significantly in Nigeria, Mexico, Indonesia, Ghana, Guatemala and Cote d'Ivoire. Area expansion recorded positive growth in all countries except Liberia, Malaysia and Srilanka. Area growth exceeded yield growth in Brazil, Cote d'Ivoire, Gabon,

Guatemala, Ghana, India, Indonesia, Liberia, Mexico, Myanamr, Nigeria and Vietnam and in rest of the countries, yield growth exceeded area growth (Table 2).

1981-90:Production grew significantly in India, Indonesia, Nigeria, Vietnam and Cameroon. Yield growth was significant in India, Indonesia and Cameroon. Vietnam, Nigeria, Indonesia,India and Cameroon had significant growth in cropped area. Infact, area growth was the significant factor in production growth across the countries. Growth of cropped area exceeded the growth of yield in Cambodia, Cameroon, Ghana, India, Nigeria and Vietnam (Table 2).

1971-80:Production grew significantly in Indonesia, Thailand and Cote d'Ivoire. Cropped area grew significantly in Cameroon, Cote d'Ivoire and Thailand. Yield grew significantly in Indonesia, Philippines, Malaysia and Cote d'Ivoire. Area grew significantly in Thailand, Cote d'Ivoire and Cameroon. Cropped area growth was the major contributer to the production growth in Cameroon, Cote d'Ivoire, Ghana, Liberia and Thailand. (Table 2).

1961-70:During this period, production grew significantly in Thailand , Malaysia,Liberia, India and Ghana. Yield growth was statistically significant in Ghana, India, Indonesia, Malaysia, Nigeria and Cote d'Ivoire. Area growth was significant in Thailand, Liberia, Indonesia, Ghana and India. Cropped area growth exceeded the growth of yield in Cameroon, Cotd'Ivore, Ghana, India, Indonesia, Liberia, Philippines and Thailand (Table 2).

Table 3: Regression of time series growth rates of production on the growth rates of area and yield across countries.

Period	Constant	Coefficient of Growth rate Of area	Coefficient of Growth rate of yield	R^2
1961-70	0.0035	0.9772***	1.1519***	0.99
1971-80	0.0801	0.7613***	0.8303***	0.95
1981-90	-0.1347	1.0225***	0.8630***	0.99
1991-00	-0.0164	0.9143***	1.1183***	0.92
2001-13	0.0248	1.0068***	1.1805***	0.94
1961-2013	0.0002	1.0481***	0.8465***	0.98

Note: *** Statistically significant at 1 % level

A cross section regression of time series growth rates of production on the growth rates of area and yield across countries for different time periods are shown above. It clearly shows that the positive coefficients of growth rates of cropped area and yield are significant across countries during 1961-2013 and all sub periods. It is notable that the positive coefficient of growth rate of cropped area is greater than the coefficient of growth rate of yield during 1961-2013 and during 1981-90.

3.3 Variance in Production

Table 4: Coefficient of Variation in Area, Yield and Production of Natural Rubber

Country	Area	Yield	Produ-ction	Country	Area	Yield	Produc ction	Country	Area	Yield	Produc-ction
Brazil	31.67	26.22	53.48	Ghana	61.46	36.35	69.50	Myanmar	64.96	36.09	111.07
Cambodia	40.59	17.25	45.13	Guatemala	51.22	12.01	50.02	Nigeria	57.82	28.02	40.02
Cameroon	48.55	19.06	58.50	India	50.55	42.26	82.66	Philippines	58.81	48.15	81.32
China	18.36	20.47	33.74	Indonesia	33.26	18.63	51.26	Srilanka	23.25	27.94	17.47
Cote d'lvoire	92.26	27.61	101.38	Liberia	33.17	17.60	100.00	Thailand	34.63	61.13	81.58
Ecuador	64.37	35.68	84.75	Malaysia	14.78	15.53	23.21	Vietnam	76.20	52.89	126.21
Gabon	25.15	49.94	64.12	Mexico	20.78	15.28	29.24	Average	45.09	30.40	65.23

Source:Calculated from FAOSTAT

Time series coefficient of variation in cropped area, yield and production are shown in table 4 and its graphical plot is presented in Figure 22. It is notable that coefficient of variation in cropped area exceeded the variation in yield across all countries except China, Gabon, Malaysia, Srilanka and Thailand.

Figure 22: Cross Section Coefficient of Variation over 1961-2013

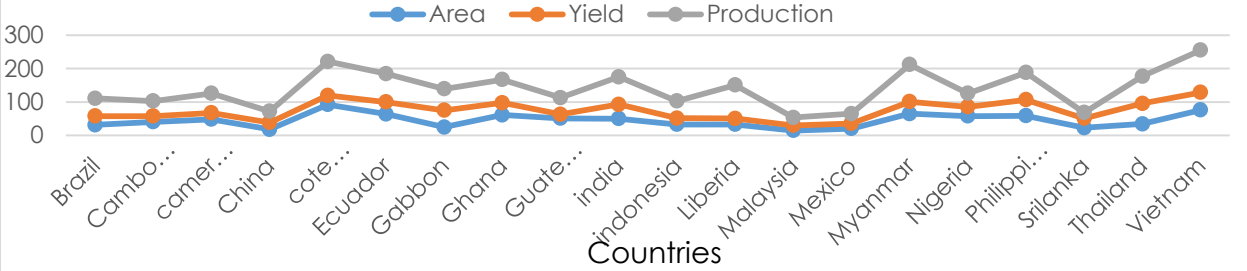
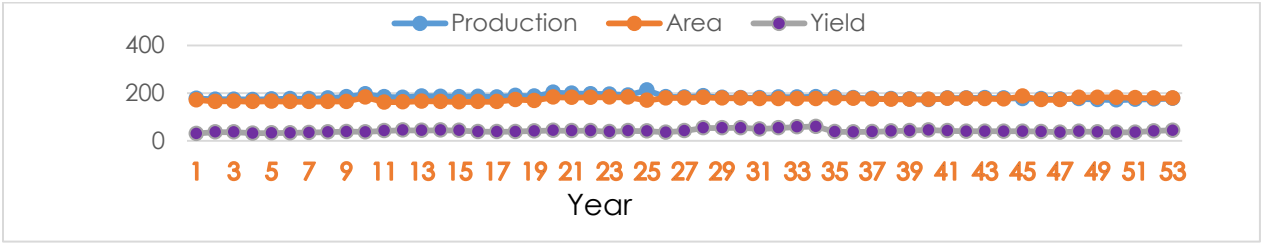


Table 5: Coefficient of Variation in Area, Yield and Production of Natural Rubber

Year	Area	Yield	Produ-ction	Year	Area	Yield	Produ-ction	Year	Area	Yield	Produ-ction
1961	171.34	30.91	177.33	1979	168.96	41.27	187.01	1997	175.24	38.36	177.24
1962	165.02	36.71	173.84	1980	182.90	43.19	202.87	1998	174.08	40.66	176.30
1963	166.01	36.63	174.30	1981	181.53	42.17	199.21	1999	173.20	42.61	175.37
1964	164.33	31.93	173.06	1982	182.37	42.85	197.19	2000	173.16	45.38	172.76
1965	166.02	32.60	174.64	1983	182.63	37.98	195.61	2001	177.38	42.18	178.68
1966	163.86	33.80	176.46	1984	182.81	42.19	191.53	2002	177.77	40.12	179.44
1967	164.25	34.73	176.31	1985	169.40	41.05	212.37	2003	176.79	40.40	179.81
1968	164.75	37.12	179.63	1986	179.34	36.29	184.11	2004	175.06	40.24	178.74
1969	164.67	38.50	184.40	1987	179.50	41.94	183.48	2005	187.07	40.29	176.69
1970	182.55	37.33	195.89	1988	181.85	54.34	188.38	2006	171.78	38.92	176.33
1971	162.31	41.98	183.99	1989	178.89	54.42	181.26	2007	172.03	36.03	175.71
1972	162.80	45.01	182.18	1990	178.71	55.19	180.84	2008	181.43	39.42	176.25
1973	165.90	43.80	187.74	1991	176.73	49.27	179.93	2009	182.37	37.35	173.05
1974	164.91	44.65	186.45	1992	176.45	54.02	183.19	2010	181.95	35.58	170.82
1975	162.88	43.46	184.86	1993	176.92	57.98	183.05	2011	180.23	36.02	173.55
1976	164.38	38.62	186.24	1994	176.01	60.04	184.99	2012	178.59	41.59	174.86
1977	164.06	38.35	183.49	1995	178.72	38.06	183.07	2013	178.63	44.24	177.60
1978	172.95	39.06	189.21	1996	178.03	37.21	181.10				

Source:Calculated from FAOSTAT

Figure 23:Time Series Coefficient of Variation of Production, Area and Yield across Countries during 1961-13



Cross section coefficient of variation across countries for time series cropped area, yield and production has been presented in Table 5 and graphically plotted in Figure 23. Variation in cropped area is much higher than the variation in yield. Plot clearly shows that the variation in production is mainly caused by the variance in cropped area . Variance in cropped area was an important factor in production variance.

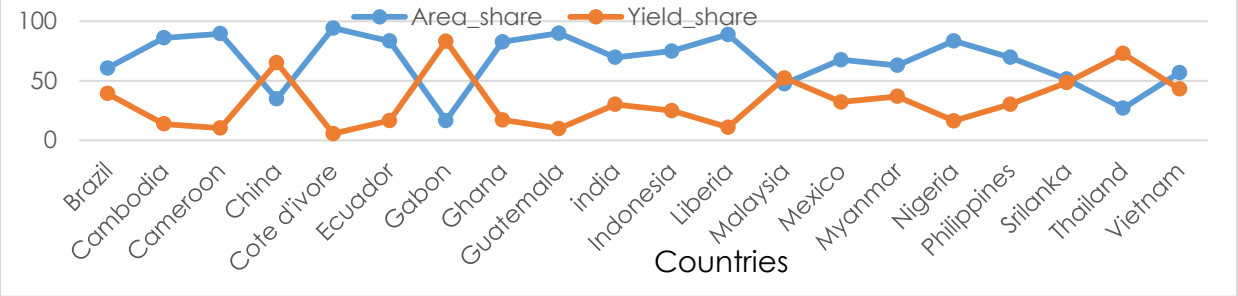
Time series area-yield covariance matix across countries is presented in Table 6. Graphical plot for the share of cropped area and yield in production variance is shown Figure 24. Variance in cropped area accounted for more than 90% in Cote d'Ivoire, more than 80% in Cambodia, Cameroon, Ecuador, Ghana, Liberia and Nigeria, more than 70% in Indonesia, more than 60% in Brazil, India, Mexico, Myanmar and Philippines, around 50% in Srilanka, Vietnam and Malaysia. On the other hand, variance in yield accounted for the major part of production variance in Thailand, China, Malaysia and Gabon.

Table 6: Cropped Area-Yield Covariance Matrix for Natural Rubber
(Percentage Share of Cropped Area and Yield in Production Variance)

Country	Area	Yield	Country	Area	Yield	Country	Area	Yield	Country	Area	Yield
Brazil	60.69	39.31	Ecuador	83.39	16.61	Indonesia	74.95	25.05	Nigeria	83.56	16.44
Cambodia	86.17	13.83	Gabon	16.72	83.28	Liberia	88.93	11.07	Philippines	69.69	30.31
Cameroon	89.66	10.34	Ghana	82.74	17.26	Malaysia	47.54	52.46	Srilanka	51.48	48.52
China	34.76	65.24	Guatemala	90.05	9.95	Mexico	67.76	32.24	Thailand	27.06	72.94
Cote d'lvoire	94.29	5.71	India	69.76	30.24	Myanmar	63.06	36.94	Vietnam	56.92	43.08

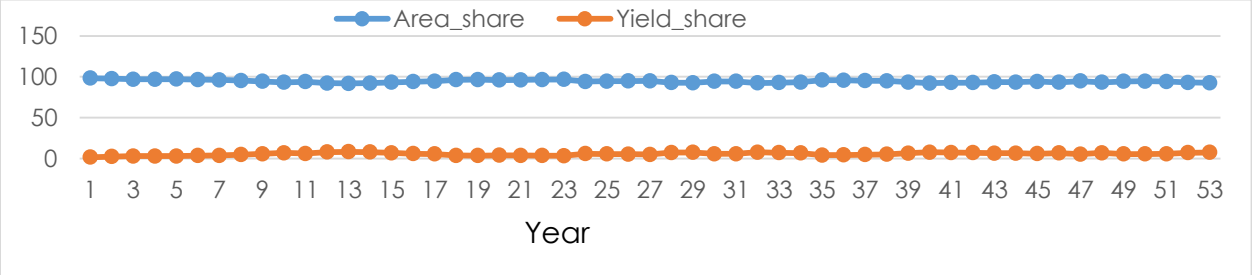
Source:Calculated from FAOSTAT

Figure 24: Share of Area and Yield in production Variance



Cross-section area-yield covariance for time series is presented in Table 7 and it is graphically presented in Figure 25. Area variance across the countries accounted **for the** substantial part of production variance over all the years.

Figure 25: Share of Area and Yield in production Variance during 1961-2013



An unrestricted vector auto regression of the change in cropped area on lag of cropped area and lags of change in production, lags of change in price **is** presented in Table 8. Estimation of equation 1 had shown the presence of

autocorrelation which has been resolved by estimating equation 1a for all except Nigeria and Philippines and for these two countries, issue of autocorrelation had been resolved by estimating equation 1b.

Table 7: Cropped Area-Yield Covariance Matrix for Natural Rubber(Percent share of area and yield)

Year	Area	Yield	Year	Area	Yield	Year	Area	Yield	Year	Area	Yield	Year	Area	Yield
1961	98.37	1.63	1973	91.86	8.14	1985	94.51	5.49	1997	95.23	4.77	2009	94.44	5.56
1962	97.65	2.35	1974	92.23	7.77	1986	94.66	5.34	1998	94.87	5.13	2010	94.53	5.47
1963	96.98	3.02	1975	93.17	6.83	1987	95.00	5.00	1999	93.44	6.56	2011	94.24	5.76
1964	96.97	3.03	1976	94.04	5.96	1988	92.81	7.19	2000	92.27	7.73	2012	93.01	6.99
1965	97.09	2.91	1977	94.50	5.50	1989	92.59	7.41	2001	92.81	7.19	2013	92.52	7.48
1966	96.51	3.49	1978	96.23	3.77	1990	94.27	5.73	2002	92.86	7.14			
1967	96.22	3.78	1979	96.46	3.54	1991	94.26	5.73	2003	93.56	6.44			
1968	95.28	4.72	1980	96.01	3.99	1992	92.35	7.65	2004	93.43	6.57			
1969	94.36	5.64	1981	96.20	3.80	1993	92.88	7.12	2005	94.12	5.88			
1970	93.11	6.89	1982	96.43	3.57	1994	93.38	6.62	2006	93.27	6.73			
1971	93.93	6.07	1983	96.72	3.28	1995	95.89	4.11	2007	94.69	5.31			
1972	92.19	7.81	1984	94.14	5.86	1996	95.77	4.23	2008	93.11	6.89			

Source:Calculated from FAOSTAT

Table 8: Regression Estimates of Cropped Area on Lags of Cropped Area, Production and Price

	Myan-mar	India	Indon-esia	Philip-pines	Thai-land	Sri-lanka	Camb-odia	Came-roon	Nige-ria	Cote d'-Ivoire	Ghana	Viet-nam	Mexi-co
CONST	0.01	0.00	0.01	0.02	0.01	-0.02	0.02	0.02	-0.00	0.02	0.15	0.02	0.01
ΔA(-1)	1.20***	0.93***	0.34**	0.43**	0.68***	0.47***	0.83	0.59***	0 .57**	0.89***	0.25	1.57***	0.14
ΔP(-1)	-0.22	0.21*	0.24**	-0.04	0.13	-0.06	-0.08	-0.15	-0.41**	0.08	0.20	0.67**	-0.08
ΔP(-2)	-0.17	-0.12		-0.16	-0.20	0.31*	-0.32*	-0.01		-0.30*	0.12		0.11
ΔP(-3)	-0.04	-0.12					-0.01	-0.18		0.08	-0.27**		0.25*
ΔP(-4)	0.24**	0.13						0.46**					
ΔP(-5)	-0.08	-0.15*						-0.29*					
ΔPC(-1)	0.01	0.02	-0.06***	-0.01	0.05	0.04	-1.18**	-0.10	-0.16**	0.01	-0.13	0.05	-0.08
ΔPC(-2)	0.03	0.02	-0.00	-0.02	0.00	-0.05	0.96**			-0.01	-0.21		0.09
ΔPC(-3)	-0.04	-0.12**	0.02				0.08			0.02			0.10
ΔPC(-4)	0.07**	0.12***											
ΔPC(-5)	-0.03	-0.09**											
ΔPC(-6)	0.01	0.05											
DW	1.94	2.13	2.13	1.90	2.34	1.78	1.98	2.05	1.81	1.71	2.01	1.52	2.26
R^2	0.90	0.94	0.26	0.19	0.51	0.57	0.56	0.38	0.24	0.80	0.57	0.71	0.38
$\bar{R}^2$	0.87	0.90	0.17	0.09	0.45	0.49	0.45	0.26	0.17	0.76	0.43	0.60	0.02
F	24.39***	27.18***	2.86**	1.96	8.76***	7.34***	5.29**	3.23**	3.54**	22.33***	4.19***	6.39***	1.07
σ	0.021	0.007	0.083	0.043	0.022	0.023	0.15	0.063	0.065	0.026	0.181	0.012	0.070

Note: ***,,**,* Statistically significant at 1, 5 and 10 percent respectively
Nigeria and Philippines in second difference

Table 8 shows the results of vector auto regression estimates of equation 1a and 1b. Change in price is positively correlated with the change in cropped area for Myanmar, India and Cambodia as the coefficient associated with the change is significant for those three countries. Expectation of future income is important for change in cropped area in Myanmar, India, Indonesia, Srilanka, Cameroon and Mexico. Change in cropped area of previous year in the expectation of stable future income is very important for change in cropped area and this coefficient is significant for all countries except Ghana, Mexico and Cambodia(Table 8). Vector auto regression coefficient of change in cropped area of previous year is statistically significant for all except Cambodia, Ghana and Mexico. Area elasticity

of change in previous year's cropped area is very high for Vietnam (1.57), Myanmar(1.20), India(0.93), Cote d'Ivoire(0.89), Thailand (0.68) and around 0.58 in Cameroon and Nigeria and around 0.45 in Srilanka and Philippines. The estimated model is not significant for Mexico and Philippines.

The area elasticity of production is 0.24 for Myanmar, 0.21 for India, 0.24 for Indonesia, 0.31 for Srilanka, 0.46 for Cameroon, 0.25 for Mexico and these regression coefficients are significant. Significant negative area-production elasticity is observed for India (-0.15), Cambodia(-0.32), Cameroon (-0.29), Nigeria (-0.41), Cote d'Ivoire(0.30) and Ghana (-0.27). Significant positive area-price elasticity are observed for Myanmar(0.07), India (0.12) and Cambodia (0.96). It is also notable that significant negative area-price elasticity is also observed for India (-0.12), Cambodia(-1.18) and Nigeria.

Table 9: Regression Estimates of Yield on Lags of Yield, Production and Price

	Myan-mar	India	Indon-esia	Philip-pines	Thai-land	Sri-lanka	Camb-odia	Came-roon	Nige-ria	Cote d'-Ivoire	Ghana	Viet-nam	Mexi-co
CONST	0.02	0.01	-0.02	0.03	0.02	0.01	-0.03	-0.00	0.02	-0.01	0.03	0.01	-0.07
ΔY(-1)	0.35*	0.47*	-0.00	0.90***	0.87***	0.62**	0.20	0.43***	0.39	0.59***	0.85**	-0.19	0.14
ΔP(-1)	0.18	0.38*	0.92**	0.01	0.06	0.34	-0.06	0.07	-0.07	0.25	-0.15	0.39*	-0.47
ΔP(-2)	0.02	-0.45*	-0.65***	0.08	-0.30	-0.19	0.06		0.04	0.11		0.07	-0.75**
ΔP(-3)	-0.22*	0.11		-0.50***	0.04	-0.37	-0.22*		-0.10	-0.47*			-0.45
ΔP(-4)	0.09			0.50***	0.44*		0.08		0.03	0.23**			
ΔP(-5)	-0.08			-0.18	-0.42**				-0.06				
ΔPC(-1)	-0.04	-0.01	0.07**	-0.06	-0.07	-0.06	0.27	-0.15*	-0.05	0.01	-0.18	0.00	-0.04
ΔPC(-2)	0.03	-0.02	-0.02	0.03	-0.07	0.04	-0.86*	0.05	-0.07	0.04			-0.23
ΔPC(-3)	-0.03	-0.03		-0.00	-0.02	-0.05	0.27		0.04	-0.05			-0.09
ΔPC(-4)	0.08**						-0.86		0.13				
ΔPC(-5)	0.01						0.48		-0.10				
T	-0.00		-0.00	-0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	-0.00*	0.01
DW	2.00	1.84	2.24	1.92	1.59	1.72	1.63	2.00	1.54	1.66	2.18	2.65	2.05
R^2	0.69	0.63	0.55	0.72	0.77	0.58	0.37	0.32	0.51	0.56	0.30	0.86	0.42
$\bar{R}^2$	0.57	0.52	0.48	0.64	0.71	0.50	-0.00	0.25	0.24	0.45	0.17	0.73	-0.01
F	5.83***	5.87***	8.23***	8.67***	11.57***	6.67***	0.99	4.07**	1.88	5.04***	2.43*	6.39**	0.97
σ	0.022	0.014	0.027	0.043	0.028	0.036	0.082	0.049	0.053	0.033	0.175	0.008	0.160

Note: ***,,**,* Statistically significant at 1, 5 and 10 percent respectively

Table 9 shows the results of vector auto regression (equation 2a) results of change in yield on lags of yield, production and prices. Estimated yield models were significant for all except Cambodia, Nigeria and Mexico. Significant positive yield-production elasticity is observed for India (0.38), Indonesia(0.92), Phillippines (0.50), Thailand (0.44), Cote d'Ivoire(0.23) and Vietnam(0.39). Similarly, significant negative yield-production elasticity is observed for Myanmar(-0.22), India(-0.45), Indonesia(-0.65), Philippines(-0.50), Thailand(-0.42), Cambodia(-0.22), Cote d'Ivoire(-0.47) and Mexico(-0.75). Significant positive yield-price elasticity is observed for Myanmar(0.08) and Indonesia(0.07). Signifiant negative yield-price elasticity is found for Cambodia and Cameroon. The effect of techonological progress on yield is positive for Thailand, Srilanka, Cameroon, Cote d'Ivoire, Ghana and Mexico. The sign of yield elasticity of change in yield of previous year is expected for all except Indonesia and Vietnam. Yield elasticity of change in yield of previous year is found to be high for Philippines(0.90) followed by Thailand(0.87), Ghana(0.85), around in 0.60 for Srilanka and Cote d'Ivoire and around 0.40 for India, Cameroon and Myanmar. Expectation of future income is important for change in yield in Myanmar, Indonesia and Vietnam. Change in yield of previous years in the expectation of stable future income is very important in Myanmar, Cameroon, Philippines, Thailand, Srilanka, Cote d'Ivoire, Ghana and India.

Final model for equations 1a, 1b and 2a for each country is selected on the basis of lowest standard error of the model. Final model passes a series of diagnostic tests for serial correlation, lagged dependent variables, multicollinearity and heteroscedasticity.

4.CONCLUSION

This paper presented evidence on the nature of growth of natural rubber production in major countries. During the period 1961-2013, the contribution of area growth to the production growth was greater than the contribution of yield growth in Cameroon, China, Cote d'Ivoire, Ecuador, Guatemala, Ghana, Indonesia, Mexico, Myanmar, Nigeria, Philippines and Vietnam. The contribution of cropped area and yield to the growth of production was equal in Brazil and Thailand. The contribution of yield growth to the production growth exceeded the area growth in India and Gabon. Generally, main source of production growth was the growth of cropped area during 1961-2013 across the countries.

The coefficient of variation in cropped area exceeded the variation in yield across all countries except China, Gabon, Malaysia, Srilanka and Thailand. Time series area-yield covariance across countries showed that the variance in cropped area was an important source of production variance. Cross-section area-yield covariance matrix for time series also showed that variance in cropped area accounted for major part of production variance for all countries except Thailand, China, Malaysia and Gabon where yield accounted for the major part of production variance.

Estimated area models show that change in price is positively correlated with the change in cropped area for Myanmar, India and Cambodia. Expectation of future income is important for change in cropped area in Myanmar, India, Indonesia, Srilanka, Cameroon and Mexico. Change in cropped area of previous year in the expectation of stable future income is very important for change in cropped area for all countries except Ghana, Mexico and Cambodia. We have observed significant positive as well as negative area-production elasticity and area-price elasticity. Even if the current price is low, farmers expand the acreage under rubber cultivation because they expect the price will go up in the future.

Estimated yield models were significant for all except Cambodia, Nigeria and Mexico. Significant positive yield-production elasticity is observed for India, Indonesia, Philippines, Thailand, Cote d'Ivoire and Vietnam. Similarly, significant negative yield-production elasticity is observed for Myanmar, India, Indonesia, Philippines, Thailand, Cambodia, Cote d'Ivoire and Mexico. Significant positive yield-price elasticity is observed for Myanmar and Indonesia. Significant negative yield-price elasticity is found for Cambodia and Cameroon. The sign of yield elasticity of change in yield of previous year is expected for all except Indonesia and Vietnam. Negative yield-price elasticity implies that farmers increase the yield in spite of low price because they expect the price will go up in the future.

A substantial growth of production can be attributed to the area expansion across the countries over the years. Evidence suggests that major part of production variance is caused by the variance in cropped area than in yield. Increase in the cropped area under cultivation was the main source of production growth during 1961-2013. However, along with area growth, yield became the secondary source of growth in certain countries, especially, Thailand, Vietnam, India, China, Cote d'Ivoire, Brazil, Mexico, Ecuador and Gabon. It is the introduction of new high yielding varieties that is primarily responsible for increase in yield. The coefficient of variation in cropped area increased in all countries over the years. It is important to note that the variation in cropped area was the main source of variability in production of natural rubber across the countries over the years. Since variance in production is introduced because of the year-to-year adjustment in crop area sown, steps have to be taken that reduce the fluctuations in sown area. Measures need to be taken to increase the yield per hectare using the high yielding varieties, especially, for countries like Indonesia, Malaysia, Myanmar, Srilanka, Nigeria, Philippines, Guatemala, Cameroon, Liberia, Cambodia and Ghana. While taking the steps to raise the growth of production it is necessary to see that variance is not increasing. So the steps to be taken not only to induce the factors which promote growth but those that reduce variance in production.

Natural rubber cultivation is undertaken mainly for a stable income. Fluctuation in the prices of natural rubber causes fluctuations in the income of the farmers. In order to reduce the risk of fluctuation in natural rubber production,especially, farmers can take some precautions. Focus on increasing the productivity of natural rubber using high yielding varieties. Don't expand the acreage under rubber cultivation without a limit. Practice mixed cropping suitable to the weather and soil of the regions instead of cultivation of a single crop. Increase the efficiency of the farming and production of natural rubber so that the cost of rubber farming can be reduced. Uneconomic small farmers can practice joint cultivation so that better technical innovation can be applied to the small farms as

well while keeping the cost of production low. Investigate and adopt new technology and innovation in rubber cultivation and production so that the cost of production is economic for thousands of small farmers. Government policies on tariffs is another measure that can be applied wherever possible to protect the interests of producers and consumers. If the cost of production of rubber is very high in India, consumers of natural rubber import the rubber from countries where the price plus the tariffs is less than the domestic price. In certain circumstances, Government aid to farmers to boost the production may help in the short term. But this can't be a long term policy in the interests of producers and consumers.

Recent evidences from some countries show that Government of the respective countries are protecting the interests of few oligopolists at the expense of thousands of small farmers. If the rubber product manufacturers create an artificial glut in the rubber market to jeopardize the reasonable price accruing to the farmers, Government or other organization has to make use of the tariff and aid policies to protect the interests of farmers because the welfare effect of protecting the interests of many thousands of small farmers is greater than protecting the interests of few oligopolists.

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6.REFERENCES

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