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Quantile regression analysis of the effect of production of natural rubber by Asian countries on world rubber price

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Abstract

In this paper we used conditional quantile regression analysis to investigate the influence of production of natural rubber (NR) of some Asian countries on world prices by modelling at various quantiles (tau= 0.1, 0.25, 0.50, 0.75, 0.95). Rubber consumption is about 18 million tonnes per year, of which natural rubber (NR) make up 48%, solid SBR is 20%, latex SB is 14%, polybutadiene 12%, EPDM 5% Nitrile 2% polychloropreneis 2%, and other Synthetics forming the remaining 7%. Asian countries namely China, India, Indonesia, Malaysia, Sri Lanka and Thailand are among the highest produces of world's NR. In the study we observed that,the average production of rubber for all these countries between 1961-2012was about 4,592,389.8 tonnes per year with Thailand being the highest producer withan average of about 1,334,381 tonnes per year. We also observed that increasing production by most of these countries has negative effect on the word prices at various quantiles which can possibly result in reduction in world rubber price. We further observed that R-square increases across the quantiles with the 95thpercentile having R-square of 93% and with AIC =63 being the lowest. We observed that in this study quantile regression gives a more comprehensive picture of the effects of production of NR by Asian countries on world prices of NR. There was significant difference between the tau values at 5% significant level for all the slopes.

Keywords: Rubber production, Regression analysis, Quantile, Tau, Percentiles

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1. Introduction

Natural rubber (NR) also known as India rubber or Cautchouc, is made up of polymers of the organic compound isoprene, water and minor impurities of other organic compounds. Currently, 80% of rubber is produced by smallholders. Consequently, it has become a social commodity where more than 30 million small farmers are at stake worldwide (Yogaratnam, 2012). It has been used for producing various products such as cooking utensils, medicine, chairs, export items such as tyres, tyre cases, tubs, crates and pallets, sheets and strips, surgical and other gloves, floor coverings and mats, among others. The rubber plant has a life span of 30 years (Baulkwill, 1989).

The British, Dutch and French entrepreneurs, developed rubber production in Sri Lanka Malaysia and the adjoining territories of Indochina, in the countries that are now Thailand, Vietnam and Cambodia and in Indonesia (Figart, 1925). Factors which favoured the rubber plantation industry included favourable climate, plentiful availability of land and stable governments. Transportation problems were not insuperable and adequate labour was either available on the spot or could be brought in as cheap indentured labour from nearby, usually from India or China.

Today, Asia is the main source of natural rubber, accounting for about 93% of output in 2005. Three largest producing countries, Thailand, Indonesia (2.4m tons) and Malaysia, together account for around 72% of all natural rubber production (Rubber Statistical Bulletin, 2003). Natural rubber is now produced almost exclusively in developing countries and South-east Asia region being the largest producing area with an annual production of about 10.27 million MT (93% of the world's NR production) in 2011 (ANRPC, 2011), followed by African region at about 0.47million MT (4.3%) and Latin American countries at about 0.27million MT (2.4%) (ANRPC, 2010).

Several factors affect the prices of natural rubber such as prices of synthetic rubber prices, crude oil prices gold price, and production, etc. A lot of studies have been conducted in this area using different methods. (Hartley et al., 1984) studied the Supply Response of Rubber in Sri Lanka (Etherington, 1977) studied the effect of pricing on rubber replanting using stochastic models (Vogelvang and Smith, 1997), studied the leads and lag prices for synthetic rubber and natural rubber using ordinary least square regression. Edirisinghe (2005) similarly studied the role of price on replanting decisions of rubber with the application of Almon Lag model. Wickramasinghe (2013) also studied the effect of exogenous factors on world rubber natural rubber prices using vector error correction model (VCEM) and concluded there was an influence of exogenous factors on the pricing of natural rubber. Khin et al. (2012) studied the impact of the changes of the world crude oil prices on the natural rubber industry in Malaysia using econometric systems of equations.

We believe that the use of the conditional mean does not explain fully the variations in the data and the quantile regression model parameters may vary within the quantiles[0,1] (Koenker, 2005). We therefore, in this paper propose the use of quantile regression for the estimation, prediction and analysis of the effects of production of natural rubber on world prices. Since South-east Asia region is the largest producing area of rubber, there is the need to study the effects of rubber production from this region on the world prices of rubber. Objectives of this study are to investigate the effects of production of natural rubber by China, India, Indonesia, Malaysia, Sri Lanka and Thailand on the world prices of rubber, by using quantile analysis at various quantiles with tau=(0.1, 0.25, 0.50, 0.75, 0.95).

2. Materials and methods

2.1. Data source

A secondary data comprising of the annual prices and production of Rubber, from FAOSTATAnnual Data (1961-2013), was used and also from the World Bank data base pink sheet (updated August, 2014).

2.2. Statistical software

The R software with the package "Quantreg" was used in analysing and fitting thequantile regression models.

2.3. Behaviour of the data

Figures 1, 2, and 3are the time series plot showing the behaviour of the production of rubber between 1961-2011.

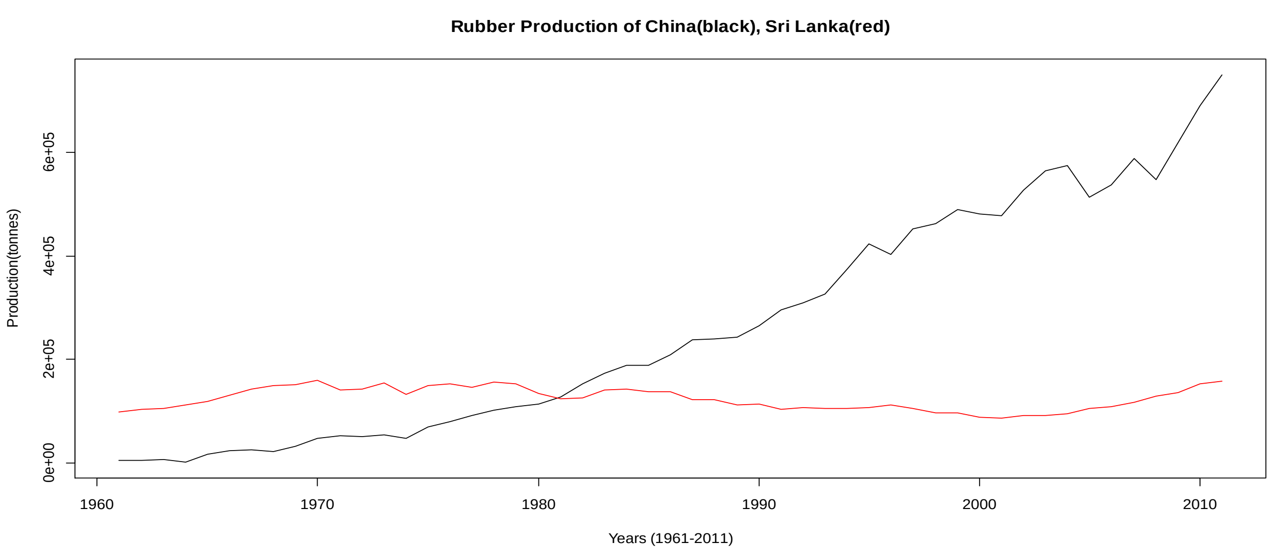

Figure 1. Time series plot of production of China (black) and Sri Lanka (red)

We observed from Figure 1, a gradual increase in production by China from 1961 to 1990 and a high increase from 1991 to 2011. Unlike China, there was a slight increase in production from 1961 to1979, and then a gradual decrease up to 2000 and then slightly increases again till 2011.

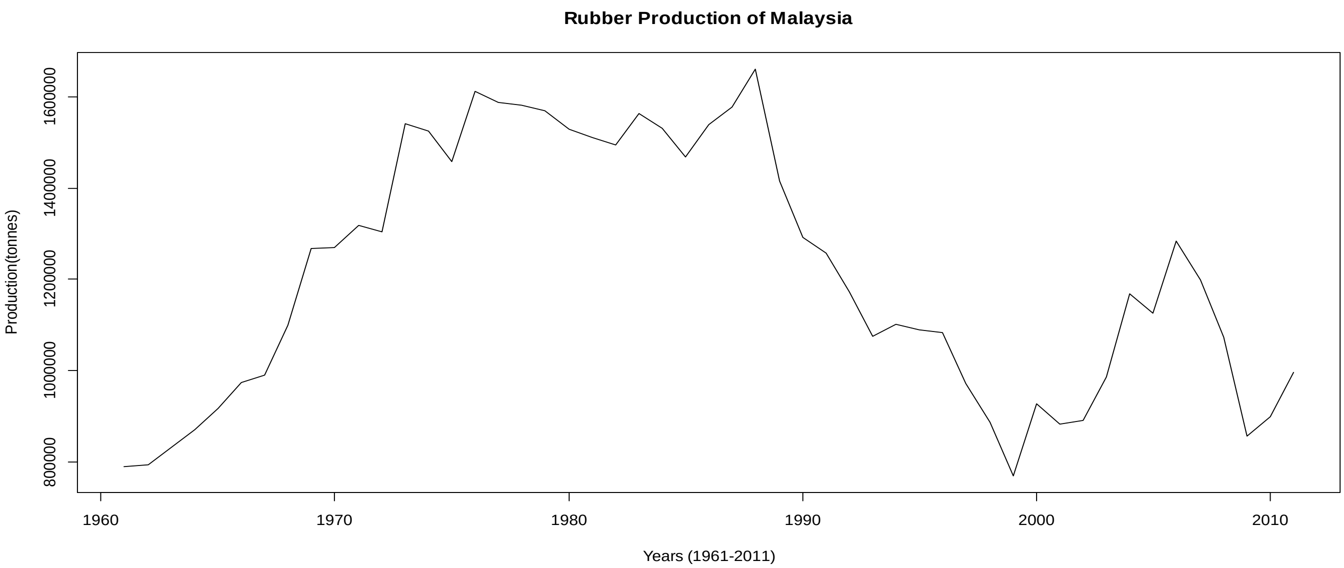

Figure 2. Time series plot of rubber production of Malaysia

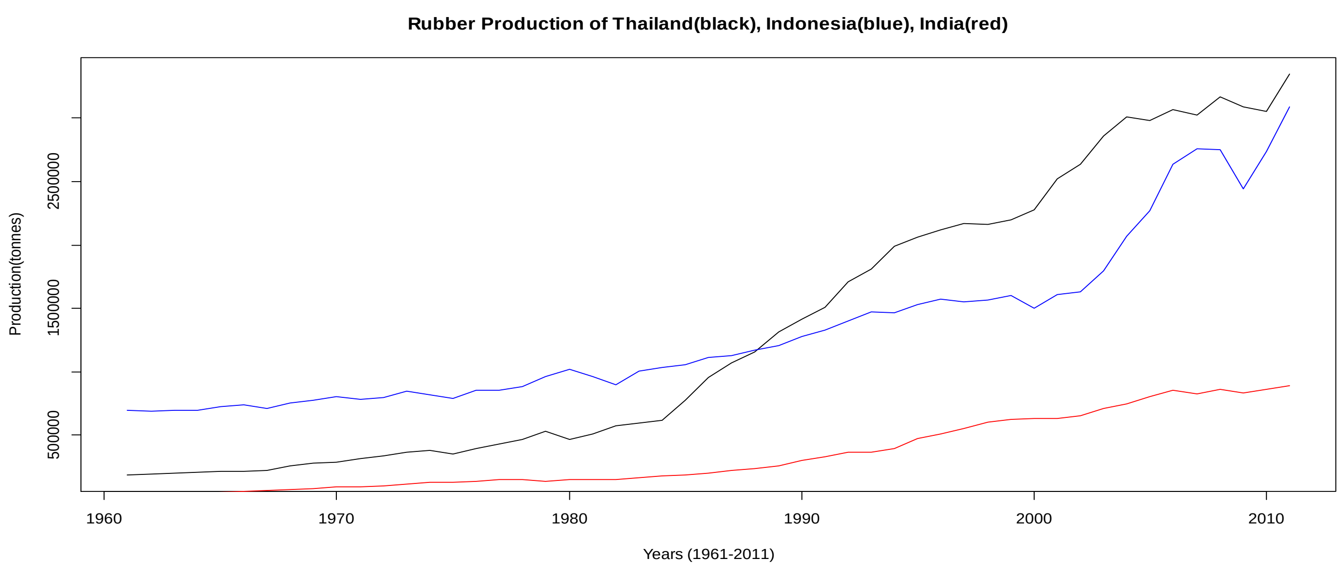

Figure 3. Time series plot of production of Thailand (black), Indonesia(blue)and India (red)

Malaysian rubber production has experienced very high volatility over the years. From Figure 2 we observed a high increase in production by Malaysia from 1961 to 1987 and a high decrease from 1988 until 1999. It picks up again up to 2006 and drops sharply till 2009 and then increase slightly again in 2010 until 2011. We observed from Figure 3, a similar pattern of gradual increase in production by both Thailand and Indonesia from 1961 to 2011. Whilst there is gradual increase in production for India, it is not as high as Thailand and Indonesia between 1961 to 2011.

2.4. Methodology

Given the multiple regression

$$Y_t = \beta_0 + \beta_1 X_1 + - - - + \beta_n X_n + \varepsilon_t \qquad (1)$$

withε_t innovations identically distributed with mean zero and variance one. Given a real valued random variable Y with a distribution function $F_Y(y) = P(Y \leq y)$ by Koenker and Bassett (1982) and Zhao et al. (2008) the τ^{th} quantile of Y is given by

$$Q_Y(\tau) = F_Y^{-1}(\tau) = \inf\{y =: F_Y(y) \geq \tau\} \quad \text{where } \tau\epsilon[0,1]$$

Thus the conditional quantile$Q(\tau|X)$ are the inverse of the conditional distribution function of the response variables. Then the quantilefunction of Equation 1 can be defined as;

$$Y_t = \beta_0(\tau) + \beta_1(\tau)X_1 + - - - + \beta_n(\tau)X_n + \varepsilon_t \qquad (2)$$

The conditional quantile function is given by:

$$Q(\tau|X) = \beta_0(\tau) + \beta_1(\tau)X_1 + - - - + \beta_n(\tau)X_n + \varphi_t \qquad (3)$$

where $\varphi_t = Q(\tau)(\varepsilon_t)$ is identically distributed with mean zero and variance one. This can simply be written as

$$Q_{y_i}(\tau|\xi) = X_i^T \beta_i(\tau)$$

where

$$X_i^T = (1, X_0, - - - , X_n)^T$$

The conditional cumulative probabilities of (Y_i). This is given by

$$Pr(Y_i \leq q(X_i)|X_i = x) = \tau.$$

We solve the minimization problem

$$E(|Y_i - q(X_i)|_\tau|X_i = x) = \min_{f \in L'(u)} E(|Y_i - f(X_i)|_\tau|X_i = x)$$

The τ^{th} – quantile regression estimator $\hat{\beta}_\tau$minimizes over β_τ the objective function

$$Q(\beta_\tau) = \sum_{y_i > x_i\beta_\tau}^{n} (\tau)|Y_i - X^T{}_i\beta_\tau| + \sum_{y_i < x_i\beta_\tau}^{n} (1-\tau)\,|Y_i - X^T{}_i\beta_\tau|$$

where$\tau|e_i|$ and $(1-\tau)|e_i|$ are called the asymmetric penalties for underprediction and overprediction and $0 < \tau < 1$. Using linear programing we estimate the quantile regression coefficients.

3. Results and discussion

3.1. Rubber production

The summary statistics of rubber production (in tonne) and price of rubber between 1961–2012are given in Table 1.

Table 1. Summary statistics for rubber production (in tonne) and price of rubber (USD)

Variable	Observations	Mean	Std. Dev	Min	Max
China Production	51	262396.5	220285.2	1100	750852
India Production	51	340851.8	286258.6	26992	891344
Indonesia Production	51	1323808	645356.7	286258.6	3088400
Malaysia Production	51	1207457	276060.1	768900	1661600
Sri Lanka Production	51	123495.5	21767.68	86230	159158
Thailand Production	51	1334381	1087169	186100	3348897
World Price	51	1771.176	736.6944	705	4430

From Table 1, we observe that the average price of rubber between 1961-2012 was USD 1771.76per year with a minimum price of USD 705.0 and maximum of USD 4430.0 respectively. Also it was observed that the average production of rubber for all the countries between 1961-2012was 4,592,389.8 tonnes, with Sri Lanka having the lowest average production of 123459.5 tonnes and Thailand having the highest average production of 1334381 tonnes per year.

The quantile regression parameter estimates, standard errors and confidence intervals for China, India, Indonesia, Malaysia, Sri Lanka and Thailand are given in Tables 2, 3, 4, 5 and 6 for tau= 0.10, 0.25, 0.50, 0.75 and 0.95 respectively.

Table 2. Quantile regression parameter estimates, standard errors and confidence intervals for production and price of rubber for tau=0.10

Price	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
China	-.0032851	.0011312	-2.90	0.006	-.0055649	-.0010052
India	.0014209	.0023706	0.60	0.552	-.0033568	.0061985
Indonesia	.0018724	.0003378	5.54	0.000	.0011915	.0025532
Malaysia	.000044	.000146	0.30	0.764	-.0002502	.0003382
Sri Lanka	.0017481	.0036215	0.48	0.632	-.0055506	.0090468
Thailand	-.0007098	.0006045	-1.17	0.247	-.0019281	.0005084
Constant	-140.2521	287.3675	-0.49	0.628	-719.4033	438.8991

Pseudo R^2=0.52, RMAD = 108.32, Obs = 51, Prob> F = 0.001,AIC=63.35917

Table 3. Quantile regression parameter estimates, standard errors and confidence intervals for production and price of rubber for tau=0.25

World Price	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
China	-.0027118	.0014364	-1.89	0.036	-.0056068	.0001832
India	.0030689	.0018083	1.70	0.027	-.0005756	.0067133
Indonesia	.0020735	.0004228	4.90	0.000	.0012215	.0029255
Malaysia	-.0005188	.0001959	-2.65	0.011	-.0009137	-.0001239
Sri Lanka	-.0002845	.0048377	-0.06	0.053	-.0100342	.0094652
Thailand	-.0015477	.000605	-2.56	0.014	-.0027669	-.0003285
Constant	1132.323	484.8624	2.34	0.024	155.1469	2109.499

Pseudo R^2=0.599, RMAD = 108.32, Obs = 51, Prob> F = 0.000, AIC=66.17287, From Table 2, we observed that, parameter estimates at the 10th percentile only China and Indonesia are significant. An increase in production of China and Indonesia has a negative effect on the world price of natural rubber. The rest of the estimates are not significant. The R-squared value is 0.52, that is 52% of the dependant variable can be explained by the independent variables with an AIC=63.53. From Table 3, we observed that, all the parameter estimates at the 25th percentile are significant. An increase in production of China, Indonesia, Malaysia, Sri Lanka and Thailand has negative effect on the world price of natural rubber. The R-squared value is 0.60, that is 60% of the dependant variable can be explained by the independent variables with an AIC=66.17. From Table 4, we observed that, all the parameter estimates at the 50thpercentile are significant except for India. With the exception of Sri Lanka, an increase in production of China, India, Indonesia, Malaysia and Thailand has negative effect on the world price of natural rubber. The R-squared value is 0.63, that is 63% of the dependant variable can be explained by the independent variables with an AIC=68.61.

Table 4. Quantile regression parameter estimates, standard errors and confidence intervals for production and price of rubber for tau=0.50

World Price	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
China	-.0019478	.0033754	-0.58	0.056	-.0087504	.0048549
India	-.000644	.0033301	-0.19	0.848	-.0073554	.0060673
Indonesia	.0026156	.0008857	2.95	0.005	.0008307	.0044006
Malaysia	-.0011074	.0005525	-2.00	0.051	-.0022209	6.03e-06
Sri Lanka	.0017344	.0106244	0.16	0.051	-.0196777	.0231466
Thailand	-.001125	.0012265	-0.92	0.036	-.0035969	.0013468
Constant	1695.819	1097.962	1.54	0.013	-516.9783	3908.616

Pseudo R^2=0.6283, RMAD = 126.59, Obs = 51, Prob> F = 0.001,AIC=68.61365

Table 5. Quantile regression parameter estimates, standard errors and confidence intervals for production and price of rubber for tau=0.75

World Price	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
China	.0009502	.0027517	0.35	0.032	-.0045955	.0064959
India	-.0037047	.0026278	-1.41	0.056	-.0090006	.0015912
Indonesia	.0028978	.0008222	3.52	0.001	.0012404	.0045552
Malaysia	-.0015072	.0004621	-3.26	0.002	-.0024385	-.0005759
Sri Lanka	.0079238	.0081873	0.97	0.038	-.0085766	.0244242
Thailand	-.0009791	.0008045	-1.22	0.000	-.0026005	.0009422
Constant	1392.777	1069.367	1.30	0.020	-762.3904	3547.945

Pseudo R^2=0.7365, RMAD = 107.7, Obs = 51, Prob> F = 0.000,AIC=65.04181,

Table 6. Quantile regression parameter estimates, standard errors and confidence intervals for production and price of rubber for tau=0.95

World Price	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
China	-.0061393	.0033754	-63.69	0.000	-.0063336	-.005945
India	-.0025917	.0033301	-29.05	0.000	-.0027715	-.0024119
Indonesia	.0032314	.0008857	149.65	0.000	.0031879	.0032749
Malaysia	-.0016558	.0005525	-116.77	0.000	-.0016844	-.0016273
Sri Lanka	.0067998	.0002737	24.84	0.000	.0062481	.0073514
Thailand	.0001159	.0000327	3.54	0.001	.00005	.0001819
Constant	1556.326	27.28821	57.03	0.000	1501.33	1611.322

Pseudo R^2=0.9266, RMAD = 53.62, Obs = 51, Prob> F = 0.001,AIC=62.75709

From Table 5, we observed that, all the parameter estimates at the 75th percentile are significant. An increase in production of India, Malaysia and Thailand has negative effect on the world price of natural rubber. The R-squared value is 0.74, that is 74% of the dependant variable can be explained by the independent variables with an AIC=65.05. From Table 6, we observed that, all the parameter estimates at the 95th percentile are significant. An increase in production of China, India and Malaysia has negative effect on the world price of natural rubber. The R-squared value is 0.93, that is 60% of the dependant variable can be explained by the independent variables with an AIC=62.76. The 95th percentile also has the small AIC value.

3.2. Graphical interpretation

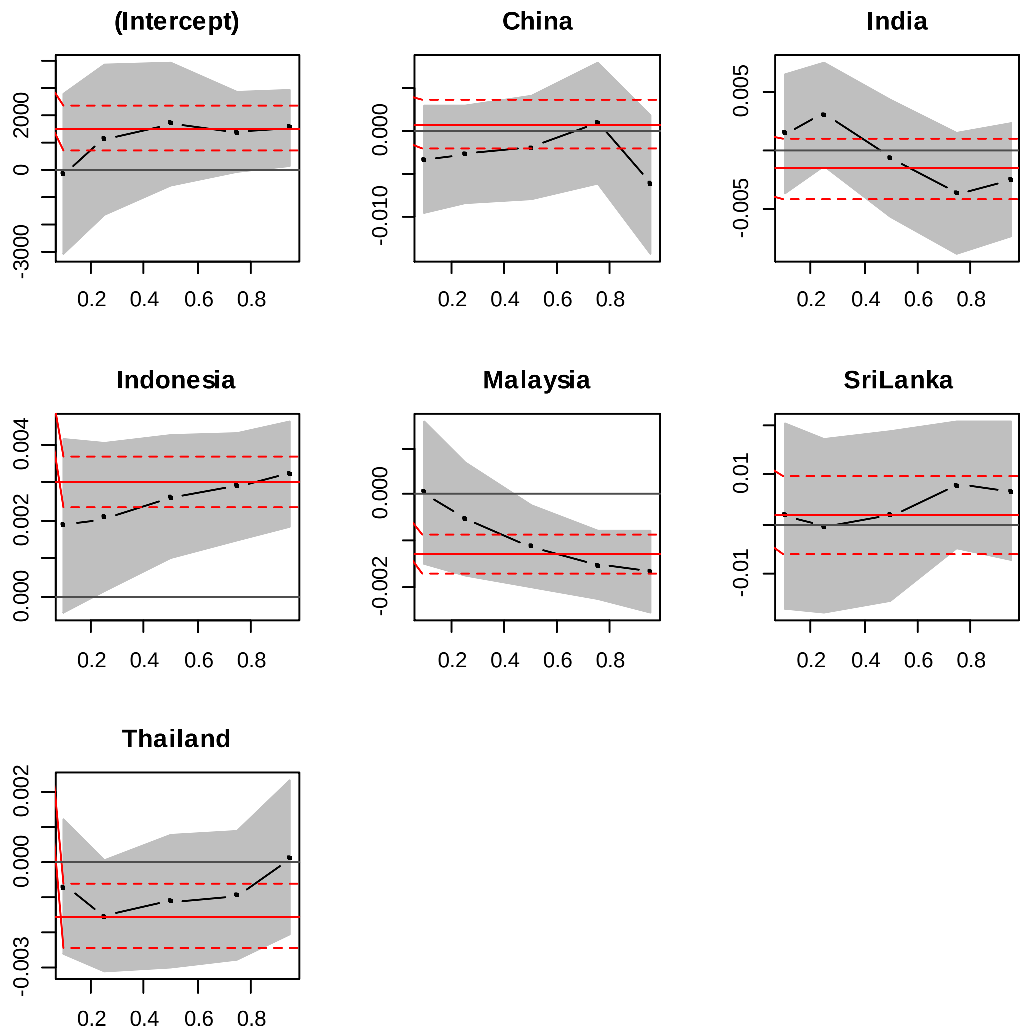

Figure 4. The quantile regression parameter estimates of rubber production

Figure 4.0 gives the quantile regression parameter estimates of rubber production which enables us to compare and make inference, on the fitted model in the coefficient plots (Koenker and Zhijie, 2002). The solid black line in these plots is the point estimate of the respective quantile regression fits, and the lighter blue region indicates a 95% confidence region (CI). The solid (horizontal) black line in some of the plots indicates a null effect. The red line in each of the plots indicates the estimated OLS effects with a red dashed lines around it representing its 95% confidence intervals.

From the intercept we could observe that quantile estimates differ significantly from the OLS and lies below the OLS line at 10^{th} percentile. From the figure of China production, the parameter estimates lie below zero at tau=0.1 which differs significantly from the OLS and also lies far below at tau=0.95, which is below the 95% confidence interval at both lower and higher quantiles. From the figure of India production, the estimates lies above the 95% confidence interval of the OLS at tau=0.1 and increase to tau=0.25 hence differs significantly from the OLS. It decreases at higher quantiles along the CI of the OLS. From Indonesia production figure, at tau= 0.1 and 0.25 the parameter estimates lie below the 95% CI of the OLS, hence differs significantly from the OLS. The parameter estimates increases across the CI of the OLS at higher quantiles. From the figure of Malaysia, the parameter estimates at both the 10^{th} and 25^{th} lie below the 95% CI of the OLS and there differs significantly different from the OLS. The estimates decrease across at higher quantiles. From Sri Lankan figure, there is an increase across the quantiles from 10^{th} percentile to the 95^{th} percentile within the OLS CI of the parameter estimates, and hence does not differ significantly from the OLS. Thailand parameter estimates across at tau=0.1 to 0.8 and lies within the CI of the OLS, but differs significantly at tau=0.95 since it lies above the OLS estimates.

Figure 4.0 Conditional Quantile Regression Coefficient plotted as a function of tau(α) for the production and price of rubber. The solid black line indicates the quantile regression point estimates; the lighter blue region is a pointwise 95% confidence band.

3.3. Analysis of variance

3.3.1. Quantile Regression Analysis of variance Table

Model: worldprice ~ China + India + Indonesia + Malaysia + SriLanka + Thailand

Joint Test of Equality of Slopes: tau in {0.1 0.25 0.5 0.75}, is summarised in Table 7.

Table 7. Quantile Regression Analysis of Variance Table

Df	ResidDf	F value	Pr(>F)
18	186	3.4503	9.523e-06

From the analysis of variance (Qu, 2008), we reject that there is no differences between the slopes of all the tau values at 5% Significance level.

4. Conclusions

The hypothesis that there are no differences between the estimated slopes of all the tau values at 5% Significance level was rejected. Thus, there is a significant difference between all the slopes. We also observed that increasing production by most of these countries has negative effect on the word prices at various quantiles which can possibly result in reduction in world rubber price. We further observed that R-square increases across the quantiles with the 95th percentile having R-square of 93% and with AIC =63 being the lowest. We also observed that quantile regression gives a more comprehensive picture of the effects of production of NR by Asian countries on world prices of NR. With the exception of the Sri Lankan production parameter estimates, all the other parameter estimates were significantly from the OLS. All the fitted models were adequate.

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