Indonesia’s Natural Rubber Productivity and Technically Specified Natural Rubber 20 Export: The Effect of El Nino Southern Oscillation

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ABSTRACT

El Nino Southern Oscillation (ENSO) causes rainfall anomalies, which may disrupt Indonesia’s natural rubber production by interfering with the trees’ growth and affecting the export volume. This study analyzed the effect of ENSO dynamics on the monthly productivity of natural rubber and Technically Specified Natural Rubber (TSNR) 20 export. Monthly data from January 2006 to December 2019 were collected from the Statistics Indonesia, International Trade Centre (ITC), World Bank, Bank Indonesia, and National Ocean and Atmospheric Administration (NOAA). Descriptive statistics unveiled that strong La Nina increased the average of monthly productivity by 3.37% to 9.68%, while strong El Nino tended to decrease productivity by 1.30% to 9.27%. Moreover, the Vector Error Correction Model (VECM) demonstrated the negative effect of ENSO on Indonesia’s natural rubber export, both in the short and long term.

Keywords: El Nino; La Nina; Natural rubber; Productivity; TSNR 20 export

INTRODUCTION

Natural rubber is one of the plantation commodities with a considerable contribution to Indonesia’s economy. The report from Statistics Indonesia (2021) revealed that natural rubber contributed 6.13% to the national income of plantation sub-sector in 2019. It also adds to the national income from international trade since 80% of its production is exported. Most types of natural rubber are exported in the form of technically specified natural rubber (TSNR 20/HS 40012220). To maintain the stability of production, water management is crucial. In this regard, climate factors, including rainfall, affect the growth and productivity of natural rubber plants (Daslin, 2013; Susetyo & Hadi, 2012). The average Indonesia rainfall is modulated by climate variability modes, such as El Nino Southern Oscillation (ENSO) (Amirudin, Salimun, Tangang, Juneng, & Zuhairi, 2020; Lestari et al., 2016; Supari et al., 2018).

Rainfall anomalies induced by ENSO can interfere with growth, productivity, and tapping process of rubber plants. ENSO occurs as two distinct phenomena, El Nino,
associated with lower rainfall than normal, and La Nina, linked to higher rainfall than normal. Both El Nino and La Nina cause extreme rainfall or flooding and drought throughout Indonesia (Kurniadi, Weller, Min, & Seong, 2021), with the most substantial impact seen during dry season and the weaker impact in wet season. It is strongly tied to the growth of rubber plants in Indonesia, hampered during 1994 and 1997 El Nino as well as 2015 El Nino (Saputra, Stevanus, & Cahyo, 2016). In contrast, there was no interference with rubber growth during the La Nina years (Cahyo, Murti, & Putra, 2020).

In terms of agricultural commodities, ENSO also affects the productivity of oil palm (e.g., Azlan et al., 2016; Stiegler et al., 2019; Suresh, 2013), wheat (Gutierrez, 2017), and other crops (e.g., Anderson, Seager, Baethgen, & Cane, 2017; Iizumi et al., 2014; Nóia Júnior & Sentelhas, 2019). On wider scopes, studies uncovered that ENSO impacted the socioeconomic aspects of society, such as that in South America (Cai et al., 2020), civil conflict (Hsiang, Meng, & Cane, 2011), critical sectors in the society, i.e., water, agriculture, and health (Zebiak et al., 2015), as well as transportation system, such as in California, Hawaii, and the US-affiliated Pacific Islands (Kim, Chowdhury, Pant, Yamashita, & Ghimire, 2021). The link between ENSO and the macroeconomic aspects, including economic growth and inflation, has also been examined (e.g., Cashin, Mohaddes, & Raissi, 2015; Generoso, Couharde, Damette, & Mohaddes, 2020; Smith & Ubilava, 2017).

Previous research analyzed the determinant factors of Indonesia’s natural rubber export. Yanita, Yazid, Alamsyah, & Mulyana (2016) discovered that determinant factors of crumb rubber export between 2005 and 2012 consisted of production quantity, exchange rate, and export in previous period. Higher production and lower exchange rate were associated with higher export of natural rubber. In another study on a particular natural rubber importer’s country, Sari, Supriana, & Rahmanta (2021) disclosed that the determinant factors of Indonesia’s natural rubber export to Japan comprised a positive sign of production and price. Nevertheless, there has been no study on the effect of ENSO climate anomaly on Indonesia’s natural rubber export. Therefore, this study assessed the effect of ENSO on the volume of TSNR 20 natural rubber export and computed the monthly productivity differences of natural rubber across the ENSO events.

**RESEARCH METHOD**

This study utilized secondary data, monthly data from January 2006 to December 2019. The variables of interest included the production quantity and land area of natural rubber, collected from the Statistics Indonesia, the export volume of TSNR 20/SIR 20 (HS 40012220) from the International Trade Centre (ITC) trade map, the international price of natural rubber from the World Bank, and the exchange rate of Indonesian Rupiah (IDR) to US Dollar (USD) from Bank Indonesia (i.e., Indonesia’s Central Bank). This study employed the Oceanic Nino Index (ONI) as indicator of El Nino and La Nina occurrence collected by the U.S. National Ocean and Atmospheric Administration (NOAA). The ONI was computed from differences in the sea surface temperature (SST) of the Pacific Ocean Nino region 3.4. El Niño occurs when the ONI is +0.5 or higher, indicating that the corresponding region is
much warmer than normal. Meanwhile, La Nina occurs when ONI is -0.5 or lower, meaning that the region is cooler than normal (National Oceanic and Atmospheric Administration [NOAA], 2021).

This study analyzed the differences in productivity across the ENSO phenomena descriptively. The productivity rate was measured by comparing productivity between the same month in different years to determine the difference between months across years. Then, the average monthly productivity changes were compared with the different annual ENSO intensities classified into weak or strong El Nino, weak or strong La Nina, and normal condition. Index level of +0.5 to +1.5/(-0.5 to -1.5) belongs to weak El Nino/(La Nina), while higher than +1.5/(-1.5) indicates strong El Nino/(La Nina).

The influence of ENSO on the volume of natural rubber export was examined using Vector Error Correction Model (VECM) regression. The stages performed before obtaining the VECM results encompassed (1) test for stationarity with unit root test, (2) determination of optimal lag criteria, (3) stability test, (4) cointegration test, and (5) VECM regression. The estimation of the VECM equations is as follows.

Long-term equation:

\[ ECT_{t,1} = \beta_0 + \beta_1 \log(Exp_{TSNR20,t-1}) + \beta_2 \log(Prodtv_{t,1}) + \beta_3 \log(Exc_{t,1}) + \beta_4 \log(Price_{TSNR20,t-1}) + \beta_5 ONI_{t,1} \]  

Short-term equation:

\[ \Delta \log(Exp_{TSNR20,t}) = \alpha ECT_{t,n} + \beta_0 + \beta_1 \Delta \log(Exp_{TSNR20,t}) + \beta_2 \Delta \log(Prodtv_{t,n}) + \beta_3 \Delta \log(Exc_{t,n}) + \beta_4 \Delta \log(Price_{TSNR20,t}) + \beta_5 \Delta ONI_{t,n} \]

ECT refers to the error correction term or matrix of coefficient cointegration. Exp_{TSNR20} is the export volume of Technically Specified Natural Rubber (ton per hectare). Prodtv represents the productivity of dry natural rubber (ton per hectare). Exc is IDR to the USD exchange rate. Price_{TSNR20} implies the international price of TSNR 20 (USD per ton). Meanwhile, the ONI serves as the ENSO indicator. Data were analyzed in log form, except the ONI data. The symbol of \( \alpha \) indicates the coefficient of ECT, \( \beta_0 \) refers to a constant, \( \beta_1 \beta_5 \) are coefficient of all independent variables, \( t-1 \) implies the period in one previous month, and \( n \) signifies the optimal period on analysis.

RESULTS AND DISCUSSION

ENSO-Monthly Productivity Rate

Rubber trees is an annual plan that begins to produce latex five years after planting. Tapping can be carried out every day until the plants are unproductive. Rubber trees are perennial and sensitive to weather or climatic changes, unlike seasonal crops, of which climatic necessities during cultivation can be easily modified. ENSO consists of normal, La Nina, and El Nino phases of different durations, as described in Table 1.
TABLE 1. LA NINA AND EL NINO EVENTS FROM JANUARY 2006 TO DECEMBER 2019

| La Nina Period      | ONI Average | Duration (Month) | El Nino Period    | ONI Average | Duration (Month) |
|---------------------|-------------|------------------|-------------------|-------------|------------------|
| Jan 2006–Mar 2006   | -0.76       | 3                | Sep 2006–Jan 2007 | 0.76        | 5                |
| Jun 2007–Jun 2008   | -1.09       | 13               | Jul 2009–Mar 2010 | 1.03        | 9                |
| Nov 2008–Mar 2009   | -0.7        | 5                | Oct 2014–Apr 2016 | 1.39        | 19               |
| Jun 2010–May 2011   | -1.18       | 12               | Sep 2018–Jun 2019 | 0.68        | 10               |
| Jul 2011–Apr 2012   | -0.77       | 10               | Nov 2019–Dec 2019 | 0.5         | 2                |
| Feb 2014            | -0.5        | 1                |                   |             |                  |
| Aug 2016–Dec 2016   | -0.62       | 5                |                   |             |                  |
| Oct 2017–Apr 2018   | -0.79       | 7                |                   |             |                  |
| **Total**           | **56**      | **Total**        |                   | **45**      |                  |

SOURCE: NOAA (2021)

From January 2006 to December 2019, El Nino lasted 45 months, and La Nina persisted for 56 months. The most prolonged El Nino occurred for 19 months, from October 2014 to April 2016, with an average ONI of 1.39, considered one of the strongest El Nino recorded since the 1980s. Another El Nino arrived in September 2018 and took place for ten months. The most decisive phase of La Nina happened from June 2010 until May 2011, with a duration of 12 months and an average ONI of -1.18. A month later, La Nina returned, occurring from July 2011 to May 2012, lasting ten months.

ENSO has a seasonal cycle and impacts varied atmospheric circulations (Timmermann et al., 2018). In this case, monthly Indonesia’s natural rubber productivity was graphed against the ONI along the 2006 to 2019 study period to exhibit the fluctuation in its productivity during the El Nino and La Nina events. Some notable high productivity of 110 kg per hectare per month or more was associated with La Nina events, as depicted by negative downward bars in Figure 1. On the other hand, El Nino episodes, indicated by positive upward bars, were associated with lower productivity of 60 to 100 kg per hectare per month.

FIGURE 1. MONTHLY NATURAL RUBBER PRODUCTIVITY IN INDONESIA VERSUS THE OCEANIC NINO INDEX, 2006-2019
SOURCE: NOAA (2021); STATISTICS INDONESIA (2021)

Nevertheless, it should be noted that La Nina could caused also lower productivity, as occurred in 2008 and 2010, with a monthly productivity of 70 to 80 kg per hectare per month. However, the effect of El Nino could be inconsistent and asymmetries (Ubilava & Abdolrahimi, 2019). For instance, the strong 2015 El Nino was linked to the monthly
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(Cahyaningtyas, Utami, and Waluyuti)

productivity of 80 to 90 kg per hectare, higher than those from 2009 to 2010 El Nino with only 60 to 80 kg per hectare. The 2015 El Nino was noted as the extreme one, as it fits the description of environmental disasters (Chen, Li, Behera, & Doi, 2016; Meijide et al., 2018; Santos, Mcphaden, & Cai, 2017). By itself, El Nino is characteristically stronger, if not more extreme, than La Nina (Dommenger, Bayr, & Frauen, 2013; Hsiang & Meng, 2015).

Moreover, Indonesia’s natural rubber productivity amounted to 1,095.17 kg per hectare in 2019, or about 91.26 kg per hectare per month (Statistics Indonesia, 2021). The productivity of natural rubber demonstrated seasonal patterns, as exhibited in Figure 2. Average productivity experienced two peak harvests in June and December, while low average productivity occurred from March to April and August to September. Nonetheless, La Nina and El Nino events classified in weak and strong intensities resulted in differences in annual productivity patterns. Seasonal patterns tended to be more regular from 2013 to 2019. However, in 2015, a strong El Nino caused a decrease in average productivity from January to August compared to two years earlier, despite the different production risks in other regions (Qian, Zhao, Zheng, Cao, & Xue, 2020).

FIGURE 2. MONTHLY PRODUCTIVITY OF NATURAL RUBBER IN INDONESIA (KG PER HECTARE) DIFFERENTIATED BY EL NINO AND LA NINA INTENSITY: (A) IN 2006-2012 AND (B) IN 2013-2019
SOURCE: STATISTICS INDONESIA (2021)
Productivity change analysis described the rate of productivity growth across months. Table 2 displays the analysis results. The average productivity growth rate of natural rubber tended to increase during strong or weak La Niña and decrease following strong or weak El Niño. Strong La Niña raised the average monthly productivity rate by 3.10 to 9.27%, while the strong El Niño event lowered the average monthly productivity by 1.30 to 9.27%. La Niña, causing higher rainfall, could affect the natural rubber supply. Hence, increasing rainfall will enhance the natural rubber supply (Arunwarakorn, Suthiwartnarueput, & Pornchaiwiseskul, 2019).

| Year | Event       | Jan  | Feb  | Mar  | Apr  | May  | June | July | Aug  | Sep  | Oct  | Nov  | Dec  | Average |
|------|-------------|------|------|------|------|------|------|------|------|------|------|------|------|---------|
| 2007 | Strong LN   | 12.90| 2.54 | -1.45| -6.05| -1.01| -6.42| -5.50| 4.42 | 11.79| 24.58| 22.01| -5.83| 3.37    |
| 2008 | Weak LN     | -15.34| -12.85| 8.43 | 15.58| 13.27| 30.95| 9.64 | -19.80| -20.55| 0.34 | -3.86| 0.70 | 0.69    |
| 2009 | Strong EN   | -9.20| -11.04| -11.92| -12.54| -11.36| -12.47| -10.17| -6.52 | -6.21 | -5.53 | -9.80 | -4.46 | -9.27   |
| 2010 | Strong LN   | 9.49 | 9.40 | 9.68 | 9.77 | 9.70 | 10.06| 9.80 | 9.45 | 9.46 | 9.94 | 9.81 | 9.56 | 9.68    |
| 2011 | Weak LN     | 8.38 | 8.38 | 8.32 | 8.28 | 8.29 | 8.23 | 8.39 | 8.39 | 8.39 | 8.28 | 8.30 | 8.38 | 8.33    |
| 2012 | Normal      | 0.00 | 0.07 | 0.12 | 0.24 | 0.33 | 0.55 | 0.41 | 0.09 | 0.18 | 0.48 | 0.36 | 0.03 | 0.24    |
| 2013 | Normal      | 5.67 | 10.08| 12.18| 6.88 | -4.51| -14.97| -6.60| 11.39| 8.43 | -0.35| 2.87 | -7.18| 1.99    |
| 2014 | Weak EN     | -1.87| -1.60| -1.31| -1.42| -2.09| -2.84| -2.39| -1.33| -4.97| -5.13| -4.46| -4.10| -2.79   |
| 2015 | Strong EN   | -7.85| -7.75| -7.14| -7.32| -5.20| -5.19| -7.70| -7.81| 13.84| 9.58 | 6.19 | 10.78| -1.30   |
| 2016 | Weak LN     | 6.55 | 6.54 | 6.46 | 6.53 | 6.61 | 7.01 | 6.93 | 6.54 | 6.46 | 6.45 | 6.36 | 6.29 | 6.56    |
| 2017 | Weak LN     | 5.69 | 5.99 | 7.02 | 6.18 | 7.38 | 7.39 | 5.96 | 5.81 | 15.80| 13.51| 11.98| 15.16| 8.99    |
| 2018 | Weak EN     | -0.31| -0.47| -0.96| -0.22| -1.57| -1.36| -0.09| -0.29| -10.52| -8.23| -6.73| -9.57| -3.36   |
| 2019 | Normal      | -4.07| -4.48| -5.13| -5.75| -2.51| -4.34| -3.80| -4.34| -8.67| -8.46| -7.87| -7.83| -5.61   |

Note: Strong LN = Strong La Niña; Weak LN = Weak La Niña; Strong EN = Strong El Niño; Weak EN = Weak El Niño

In contrast, El Niño, lowering rainfall, could decrease natural rubber productivity, as demonstrated by the 2015 El Niño (Saputra, Stevanus, & Cahyo, 2016). To compare these results to another critical and valuable commodity, lower yield due to El Niño also occurring in palm oil plantations (e.g., Azlan et al., 2016; Khor et al., 2021; Oettli, Behera, & Yamagata, 2018; Stieglar et al., 2019). Khor et al. (2021) computed that the opportunity losses because of El Niño, beginning from 1986 (excluding 2018, 2019), were around USD 9.55 billion, while Oettli et al. (2018) discovered that La Niña was favorable for improving profit. These results are consistent with Selvaraju (2003), examining the impact of ENSO on food grain production, uncovering that total food grain production increased from normal during La Niña.

Vector Error Correction Model (VECM) Estimation

Before running the VECM regression, Augmented-Dickey Fuller (ADF) test was conducted to ensure data stationarity. The VECM required stationary variables in the first difference (l). Table 3 exhibits three insignificant variables at this level. However, all variables of interest were significant in the first difference level (p-value < 0.05).

After all, these variables were stationary, and the subsequent step was determining the optimum lag to be utilized in the regression analysis. Optimal lag testing could take advantage of some information by using Akaike Information Criterion, Schwarz Criterion, and Hannan-
Quin Criterion. The optimum lag length was based on the smallest value among the other lags. The second lag was optimum from AIC, SC, and HQ values marked with asterisks (*) (Table 4).

| Variable                | Level        | First Difference | ADF       | Probs     | ADF       | Probs     |
|-------------------------|--------------|------------------|-----------|-----------|-----------|-----------|
| Log (Exp_TSNR20)        | -3.891322*** | 0.0026           | -21.51016*** | 0.0000    |           |           |
| Log (Prodtv)            | -1.321500m   | 0.6189           | -3.602440*** | 0.0067    |           |           |
| Log (Exc)               | -0.832823m   | 0.8069           | -10.07921*** | 0.0000    |           |           |
| Log (Price_TSNR20)      | -1.857535m   | 0.3518           | -9.095177*** | 0.0000    |           |           |
| ONI                     | -5.223822*** | 0.0000           | -6.043501*** | 0.0000    |           |           |

Notes: * Log (Exp_TSNR20) = Export volume of TSNR 20; Log (Prodtv) = Rubber Productivity; Log (Exc) = Exchange rate; Log (Price_TSNR20) = Price of TSNR 20; ONI = ENSO indicator

**Significant at the 0.01 alpha,** *insignificant

Subsequently, the stability test was run, ensuring the modulus was less than one for the regression model to be stable. Table 5 displays less than one modulus on the model. Thus, the second lag fit and the established VARMA was stable.

| Root | Modulus  |
|------|----------|
| 0.986685 | 0.986685 |
| 0.886536 - 0.251219i | 0.902217 |
| 0.866536 + 0.251219i | 0.902217 |
| 0.884816 | 0.884816 |
| 0.349903 - 0.685643i | 0.769765 |
| 0.349903 + 0.685643i | 0.769765 |
| 0.684584 | 0.684584 |
| 0.423816 | 0.423816 |
| -0.417256 | 0.417256 |
| 0.093150 | 0.093150 |

A cointegration test followed to confirm the short- and long-term equilibrium. Table 6 describes that trace and maximum eigenvalue test indicated three cointegrating equations and might be a long-term equilibrium relationship, confirming the appropriateness of using VECM regression. Table 7 exhibits an ECT coefficient of -0.236381, significant at 0.10 alpha, implying the model's validity. The ECT coefficient determined how quickly the equilibrium
was recovered. An ECT of -0.236381 signifies that its equilibrium and the development of the previous TSNR 20 export volume were corrected for the current period of 23.64%.

### Table 6. Cointegration Test

| $H_0$                | Eigenvalue | Trace Statistic | Critical Value 0.05 | Prob.** |
|----------------------|------------|-----------------|---------------------|---------|
| None***              | 0.570496   | 221.2900        | 76.97277            | 0.0000  |
| At most 1***         | 0.218516   | 80.99939        | 54.07904            | 0.0000  |
| At most 2**          | 0.154764   | 40.07027        | 35.19275            | 0.0138  |
| At most 3*           | 0.056362   | 12.15921        | 20.26184            | 0.4347  |

**UNRESTRICTED COINTEGRATION RANK TEST (MAXIMUM EIGENVALUE)**

| $H_0$                | Eigenvalue | Trace Statistic | Critical Value 0.05 | Prob.** |
|----------------------|------------|-----------------|---------------------|---------|
| None**               | 0.570496   | 140.2906        | 34.80587            | 0.0000  |
| At most 1***         | 0.218516   | 40.92913        | 28.58808            | 0.0008  |
| At most 2**          | 0.154764   | 27.91106        | 22.29962            | 0.0074  |
| At most 3*           | 0.056362   | 9.630022        | 15.89210            | 0.3692  |

Notes: The null hypothesis, $H_0$, was no cointegrating vector.

- "None" = No co-integrating equation; ‘At most (1 to 3)’ = The number of co-integrating equations.
- **), **) Denotes rejection at the 0.01 and 0.05 alpha, *) insignificant
- Prob.** MacKinnon-Haug-Michelis (1999) p-values

### Table 7. Estimation of the Vector Error Correction Model (VECM)

| Variable               | Coefficient | Statistics-t | Prob.  |
|------------------------|-------------|--------------|--------|
| **Long-Term**          |             |              |        |
| LogExp_TSNR20(-1)      | 1.000000    |              |        |
| LogProdtv(-1)          | -1.556677** | -12.7314     | 0.12227|
| LogExc(-1)             | 0.516614**  | 3.53543      | 0.14612|
| LogPrice_TSNR20(-1)    | 0.027125*   | 0.50275      | 0.05395|
| ONI(-1)                | -0.020219** | -1.32340     | 0.01528|
| C                      | 2.388028    |              |        |
| **Short-Term**         |             |              |        |
| D(LogExp_TSNR20(-1))   | -0.487927*  | -5.20763     | 0.09369|
| D(LogExp_TSNR20(-2))   | -0.174404*  | -2.08602     | 0.08361|
| D(LogProdtv(-1))       | -0.286970*  | -3.34544     | 0.08578|
| D(LogProdtv(-2))       | -0.245177** | -2.35612     | 0.10406|
| D(LogExc(-1))          | -0.221982*  | 0.54001      | 0.41107|
| D(LogExc(-2))          | -0.251514*  | -0.61428     | 0.40945|
| D(LogPrice_TSNR20(-1)) | 0.128369*   | 1.10268      | 0.11426|
| D(LogPrice_TSNR20(-2)) | 0.400922*   | 3.48682      | 0.11494|
| D(ONI(-1))             | 0.042009*   | 0.62032      | 0.06772|
| D(ONI(-2))             | -0.065942*  | -0.06645     | 0.06645|
| ECT                    | -0.236381*  | -3.00134     | 0.07876|

Note: LogExp_TSNR20(-1) = TSNR 20 export volume; LogProdtv(-1) = Rubber Productivity; LogExc(-1) = Exchange rate; LogPrice_TSNR20(-1) = Price of TSNR 20; ONI(-1) = ENSO indicator.

All variables were differenced in the short-term equation and lag 2 was the optimal period. D(LogExp_TSNR20(-1)) = TSNR 20 export volume in lag 1; D(LogExp_TSNR20(-2)) = TSNR 20 export volume in lag 2; D(LogProdtv(-1)) = Rubber productivity in lag 1; D(LogProdtv(-2)) = Rubber productivity in lag 2; D(LogExc(-1)) = Exchange rate at lag 1; D(LogExc(-2)) = Exchange rate at lag 2; D(LogPrice_TSNR20(-1)) = Price of TSNR 20 at lag 1; D(LogPrice_TSNR20(-2)) = Price of TSNR 20 at lag 2; D(ONI(-1)) = ENSO indicator at lag 1; D(ONI(-2)) = ENSO indicator at lag 2; ECT = Error Correction Term.

*) Significant at the 0.05 alpha, *) 0.10 alpha, *) insignificant
Table 7 portrays the VECM regression results. Regarding the effect of ENSO on TNSR export volume, an increase of one unit of the ONI, or the tendency of El Nino event, both in the long- and short-term equilibrium, was related to a reduction in the TSNR 20 export volume. A higher ONI indicated the occurrence of El Nino, signifying that El Nino decreased natural rubber export, while La Nina was beneficial for it. It was evidenced by the statistically significant ONI variable in the model, at 5% alpha in the long term and 10% alpha in the short term. One unit increase in the ONI variable (ONI (-1)) in the long term harmed decreasing the TSNR 20 export volume by 100.0201 = 1.05 ton. In the short term, the ONI variable from two previous months (D (ONI (-2))) was associated with declining the TNSR 20 export volume by 1.16 tons.

These results emphasized the effect of non-economic factors, such as El Nino, on natural rubber export. These findings align with Gutierrez (2017), disclosing a negative association between global wheat export and ENSO anomalies. The study, however, discovered that La Nina put a higher burden on wheat export than El Nino. La Nina’s highest impact on wheat export was -2.23% after six months following the event, compared to El Nino’s highest impact of -0.62% after three months of its occurrence.

ENSO can affect a country’s export, especially concerning the national income, including Indonesia. Cashin et al. (2015) uncovered a relative short-term decrease in GDP during El Nino episodes. If traced back to the effect of El Nino on the decline of natural rubber productivity, downstream industries, such as TSNR 20 processing, could be impacted by the availability of natural rubber. It could inhibit export, which consequently lowered the national income. Moreover, excessive heat due to the strong El Nino phase could reduce economic growth (Dell, Jones, & Olken, 2012).

Moreover, the TSNR 20 price variable (LogPrice_TSNR20(-1)) demonstrated a significant and positive value in the long term, meaning that one unit increase in TSNR 20 price, on average, increased the TSNR 20 export volume by 1,064 ton, holding constant other variables. This result is supported by Khin, Bin, Kai, Teng, & Chiun (2019), revealing that when the price dropped by USD 1, the export of natural rubber decreased by up to 30 tons in the ASEAN market. Higher natural rubber price in the world market is an indication of more profit to obtain. It also highlights the importance of natural rubber as one export commodity for the national income (Claudia, Yulianto, & Mawardi, 2016).

Natural rubber export remained steady despite declining the natural rubber price globally (Perdana, 2019). The TSNR 20 price highly affected export since it signaled natural rubber producers of the prospective high profit to earn. Accordingly, it encouraged producers to improve the maintenance of rubber plantations, increasing output and more export (Yanita et al., 2016). On the micro-scale, research by Syarifa, Agustina, Nancy, & Supriadi (2016) revealed that some farmers remained to tap rubber even during falling prices.

Regarding natural rubber productivity, the variable was insignificant in the long-term analysis (LogProdtv (-1)) but negatively significant in the short term on one previous month (D(LogProdtv(-1))). These results contradict Amoro & Shen (2013). The sign on the variable of natural rubber productivity was positive, signifying that an increase in production
stimulated an escalation in export. However, this research had a lag time between productivity and export volume. Farmers sometimes reduced the tapping days and delayed the dry rubber trade to the factory or middlemen because of falling prices (Suwardin, 2015). Indeed, it could cause the buildup of dry rubber products to be sold in the following month.

Concerning the effect of TSNR 20 export, the variable was negatively significant in the short term. In other words, the lower export volume in one (D(LogExp_TSNR20(-1))) and two previous months (D(LogExp_TSNR20(-2))) was responded by the higher TSNR export volume. Crumb rubber processing capacity in South Sumatra was only 76.5% fulfilled (Suwardin, 2015). Hence, to optimize the processing and export capacity of natural rubber, the low quality of rubber material, rubber processing technique, and supply chain should be enhanced (Antoni & Tokuda, 2019).

Exchange rate variable depicted insignificant effect in both long (LogExc(-1)) and short term (D(LogExc(-1)) and D(LogExc(-2))). Empirically, it is in line with Klaassen (2004), revealing that the exchange rate had no significant effect on export. In another study, however, the exchange rate affected export due to the depreciation of the Indonesian Rupiah (IDR) currency in the importing country, causing the product price to be lower to improve trade flows (Arumta, Mulyo, & Irham, 2019). On the other hand, another factor excluded in this model was variation in domestic policies across countries. Some policies in some countries, such as using tires, vehicles, and crude oil, could influence the demand for natural rubber. The crude oil price could be an essential factor in the natural rubber price. The input cost of natural rubber products depends on the crude oil price, which is the raw material for synthetic rubber (Fong, Khin, & Lim, 2018). However, although natural rubber is currently less produced and less consumed than synthetic rubber, natural rubber remains irreplaceable by synthetic rubber. In many ways, the advantages of the quality of natural rubber are difficult to match with synthetic rubber (Wahyudy, Khairizal, & Heriyanto, 2018).

Furthermore, Figure 3 presents the impulse response function (IRF), comparing the effect of variables included in the regression. The IRF demonstrated that the shock of the
natural rubber export volume by one standard deviation in the first month increased natural rubber export by 11.05% and had not responded to the shock from other variables. In the second month, a shock by ENSO was responded positively by natural rubber export by 0.59%. Then, the response fluctuated until the fifth month, when the export volume negatively responded to the ENSO shock in the next period. The response of natural rubber export to the ENSO shock began to reach balance in the 23rd month, where natural rubber export responded negatively to the shock by 0.96%.

Moreover, variance decomposition analysis helped explain the shock contribution from the natural rubber productivity variable, price, exchange rate, and ENSO to fluctuation in the TSNR 20 export volume. The time frame to forecast this variance decomposition was 36 months (three years). Figure 4 displays that the export shock caused export fluctuation in the first month. In the next 12 months, the export volume was affected by TNSR 20 export by 68.23%, TSNR 20 price by 17.55%, productivity by 11.64%, the exchange rate by 1.60%, and the ONI by 0.97%. However, in the next 36 months, the export volume was influenced by TNSR 20 export by 62.24%, TSNR 20 price by 20.54%, productivity by 13.38%, the exchange rate by 1.99%, and the ONI by 1.86%. The smallest proportion of the ENSO shock disclosed that ENSO in the following few periods did not significantly affect the export shock (Bastianin, Lanza, & Manera, 2018). Fluctuation in the volume of natural rubber export in some periods was predominantly influenced by the export volume rather than other variables.

![Figure 4: Variance Decomposition (VD) of the Technically Specified Natural Rubber (TSNR) 20 Export Volume (Shock Contribution from ENSO, Productivity, Exchange Rate, and Price)](image)

**CONCLUSION**

This study assessed the effect of El Nino Southern Oscillation (ENSO) on natural rubber productivity and the TSNR 20 export volume. A descriptive analysis of natural rubber productivity under the La Nina and El Nino conditions unveiled that La Nina was associated with increased productivity, while El Nino decreased natural rubber productivity. As for the effect of ENSO on the TSNR 20 export volume, in-line results were discovered. The Vector
Error Correction Model (VECM) regression revealed that higher ONI, indicating El Nino, led to the lower TSNR 20 export volume, both in the long and short term.

Following the effect of ENSO on natural rubber productivity, several mitigation efforts could be directed toward using drought-resistant clones and improving water management in rubber plantations, especially during El Nino. Meanwhile, to buffer the shock of ENSO on the export volume, the rubber industry could develop inventory management, specifically during high production or when El Nino is predicted to occur. Expectedly, the inventory could provide the TSNR 20 stock to be exported during low production to lessen the shock on export.

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