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Thomas Kopp, Bernhard Dalheimer, Zulkifli Alamsyah, Mirawati Yanita, Bernhard Brümmer

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Georg-August-Universität Göttingen
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Keywords: Price Transmission Analysis; VECM; Tripartite Rubber Council; Indonesia; Thailand; Malaysia; Policy Interventions

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Can the Tripartite Rubber Council Manipulate International Rubber Prices?

Thomas Kopp*, Bernhard Dalheimer*, Zulkifli Alamsyah†, Mirawati Yanita†, and Bernhard Brümmer*

Abstract: *In contrast to the trend of a generally increasing liberalization of markets, agriculture remains one of the most protected sectors. In globally distributed production networks the effects of sector specific policies may spill over to other sectors and other countries. While the effects of these policy spill-overs are likely to be substantial, both conceptual and empirical work is surprisingly limited in the literature.*

This paper suggests an extension of the Gardner Model by two policy interventions to theoretically predict effects of exogenous policy shocks in one input market on price relations towards its substitutes. The economic model is then applied to the markets for natural and synthetic rubber which is an insightful example because the natural rubber market has been dominated by three big exporters who have collectively introduced policies to gain price control for decades.

Results of a vector error correction analysis indicate that prices of natural rubber, synthetic rubber and crude oil are cointegrated. Both policies under consideration – an export tax and several measures to restrict supply – partly detached the natural from the synthetic rubber price in international markets. However, one of the policy measures might have produced effects detrimental to the intended targets.

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1 Introduction

International trade in intermediate products has increased largely in the past decades and has become equally important to the trade of final products (Jones, 2000). This development has been fostered by price- and technology driven reductions in transport and transaction costs, as well as political changes, e.g., multi-lateral or regional trade liberalisation, including liberalisation of input markets. Evidence on the trade effects of the role of trade liberalisation in input markets has been analysed in the existing literature for some emerging economies, e.g., Chile (Pavcnik, 2002), China (Khandelwal et al., 2013), India (Topalova and Khandelwal, 2011), and Indonesia (Amiti and Konings, 2007). Bas and Strauss-Kahn (2015) show that manufacturers of final manufactured goods gain from input trade liberalisation, especially when specialising in high-quality products.

In contrast to these general trends in trade liberalisation along supply chains for manufactured goods, the situation for agricultural products in general, and non-food agricultural products that are used in non-agricultural supply chains in particular, remains fundamentally different. Governments continue to intervene heavily in agricultural product markets, given the domestic and international dynamics of supply and demand. Mitra and Josling (2009) observe that especially in times of market turmoil and crises, exporting countries for example often impose export restrictions on agricultural goods before other sectors. Such interventions are also frequent for the case of non-food agricultural commodities.

One of the reasons for governments in developing countries to intervene in such markets is related to the substantial income effects that the prices of these goods have for smallholder producers. One such commodity is natural rubber, the majority of which is produced by small scale farmers in South East Asia and has been subject to policy interventions for decades. The three biggest exporters of natural rubber - Thailand, Indonesia, and Malaysia, have been at the fore front of market intervention. Within the framework of the "Tripartite Rubber Council" (TRC) these countries have introduced a set of policies to increase rubber prices on the world market.

Generally, these interventions, targeting one specific sector, can result in undesired by-effects when spilling over to other sectors – including ones in other regions – due to the global distribution of production networks. Interventions that target prices for agricultural commodities like rubber might not only induce price effects on the targeted market itself but likely induce effects on markets for close substitutes, e.g. synthetic rubber. At the same time, the effectiveness of interventions in agricultural price formation might be affected by price shocks in the substitute markets. The interplay of these closely connected markets will hence be decisive for both the effectiveness of government interventions, and the resulting by-effects. The present study addresses this issue by assessing the effects of exogenous policy shocks in one input market (natural rubber) onto another input market (synthetic rubber and crude oil) and subsequently analysing how different policy instruments differ in their outcomes. To date no study was undertaken to investigate whether the policies introduced by the TRC have created any effect at all, and – if yes – lead to the desired effect or caused adverse effects.

These questions are addressed by modelling policy effects through an extension of the well-established Gardner Model (Gardner, 1975) by two kinds of policy interventions. The first intervention is a long-term reduction of output quantities and the second one is an export quota. Both these interventions share one common characteristic, namely to insulate price developments in natural rubber from price shocks in related markets. Our extended Gardner model allows us to understand the possible effects of policy interventions that try to detach prices on agricultural commodity markets from price trends in other sectors.

The theoretical considerations are subsequently applied to the markets for natural and synthetic rubber, which are an ideal study object for our approach: natural rubber has long been subject to heavy government interventions at the multinational level, starting from the first International Rubber Agreement in 1980 (Gilbert, 1996). It is closely interlinked with the market for synthetic rubber, which in turn is influenced by developments in the notoriously volatile crude oil market. Understanding the consequences of these interventions is crucial not only for economic welfare in rural areas, but also for generating insights on these dynamics' effects on ecological sustainability. For example, Feintrenie et al. (2010) highlight the role of price levels and price volatility in natural rubber for land-use change decisions.

Employing a standard Vector Error Correction Model (VECM), we first analyse the level of integration and cointegration of natural and synthetic rubber markets in order to establish the presence and extent of spillovers between these markets. Second, we analyse the spatial and temporal dynamics of price formation processes in these markets.

Results indicate that the prices of natural and synthetic rubber are cointegrated and that policies directed to natural rubber prices also affect prices of synthetic rubber. Both policies under consideration – an export tax and several measures to restrict supply – partly detached the natural from the synthetic rubber price in international markets. The different measures of output reduction varied in their effects, up to the point of having effects opposite to their intended objectives.

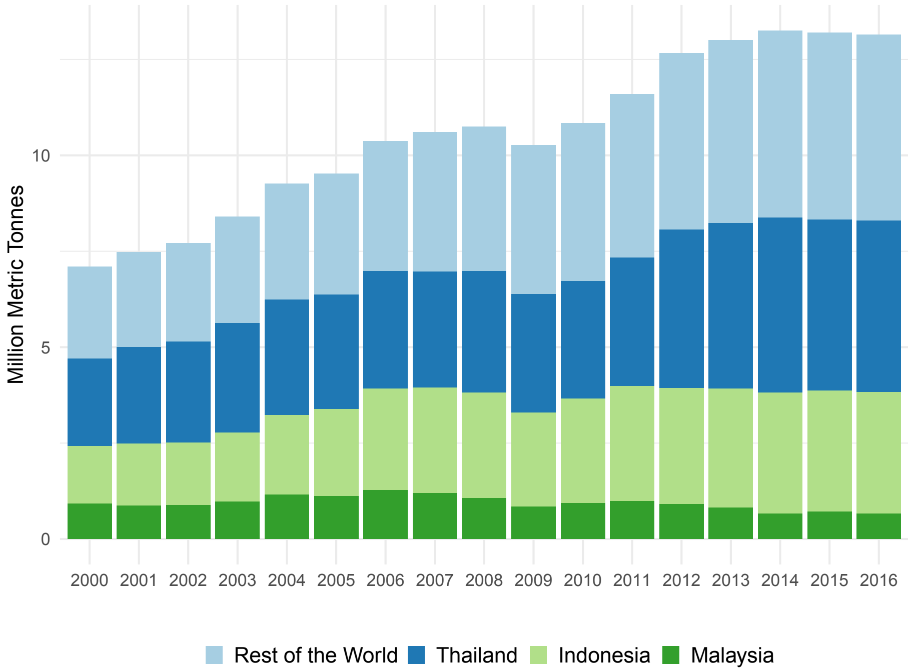
The paper is structured as follows: the following section 2 provides the background of the policies of the Tripartite Rubber Council in Southeast Asia. Subsequent Section 3 is devoted to model development. The empirical application is undertaken in Sections 4 and 5, before Section 6 concludes.

2 The Tripartite Rubber Council

The Tripartite Rubber Council (TRC) was launched in November 2001 through an agreement between Indonesia, Malaysia and Thailand (International Rubber Consortium Limited, 2001). In terms of both production as well as export quantities these countries have been and continue to be the most important suppliers of natural rubber globally. Figure 1 depicts annual global production quantities compared to those of the members of the TRC agreement. Although their share of global output has been declining steadily over the past 15 years and is substantially lower than during the 1960s and 1970s, in 2016 the three producers were still responsible for about 63% of the world's production (FAO, 2017).

Yet, the apparent possibility to exert market power, given that the members of the TRC account for about two thirds of global supply, appears to not have translated into international price dynamics as desired by the member countries (Verico, 2013). In an effort to insulate price developments in natural rubber from price shocks in related markets and to pressure international prices upwards in both long and short term horizons, the member states have established a trio of distinct policy measures (Ministry of Industry and Trade Indonesia, 2002).

Figure 1: Global and TRC natural rubber production by year (FAO, 2017)

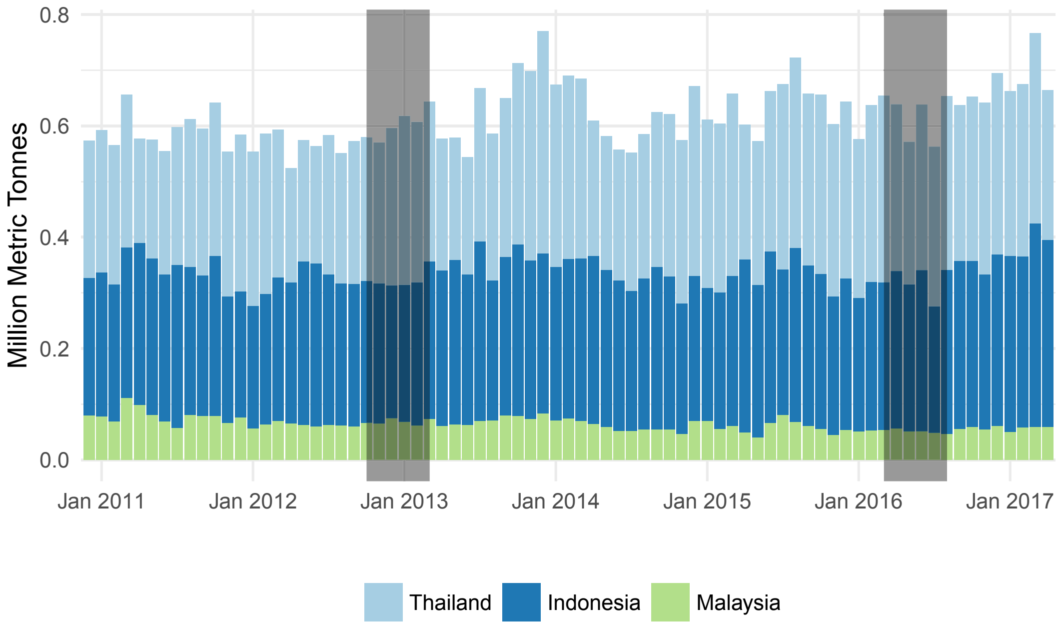


First, the Supply Management Scheme (SMS) is intended as a long term strategy to influence prices via restraining supply. Measures under the SMS include reducing the planted area through crop diversification (International Tripartite Rubber Council, 2014), limiting the establishment of new plantations (ibid.), and an increased frequency of rejuvenation of rubber plantations in times of low prices (Ministry of Agriculture Indonesia, 2008),[1] as well as promoting domestic consumption (Anwar, 2017) by an 'increase in locally manufactured rubber based products' (International Tripartite Rubber Council, 2015). In its first phase from 2002 onwards, the SMS was set to aim at a reduction of aggregate output by 4% per annum (Verico, 2013). The program goals where redefined following the global financial crisis to reduce production quantities by $215,000$ tonnes per annum from 2009 onwards (Ministry of Agriculture Indonesia, 2008).

Second, short term export quotas are applied under the framework of the Agreed Export Tonnage Scheme (AETS). This scheme provides the potential to limit export supplies to international markets for a limited time span of less than one year (Anwar, 2017). In practice, the institutions at the national levels are supposed to implement the AETS by allocating export quotas to each company producing and exporting rubber (Malaysian Rubber Board, 2012). The governing bodies agree upon targeted reductions in export quantities. However, the reference period has not clearly been identified which prevents the derivation of *de facto* quotas. The AETS was applied in 2002, in 2009, over 2012/2013 (October to March), and in 2016 (March to August) (Anwar, 2017). During 2002 the goal of an export reduction of 10% has been set for each country in combination with the aforementioned production reduction of 4% under SMS (Verico, 2013). From 2009 on, the AETS has been defined as export reduction in tonnes. The countries decided to collectively reduce rubber exports by $700,000$ tonnes in

[1] While rejuvenation is likely to increase output per plot in the first years of the next tree generation, it reduces the share of area that is productive at an aggregate level, which might outbalance the productivity gains. The SMS measure is based upon the premise that the aggregate output of a given area of rubber plantation over a period of time greater than the life span of one tree generation is reduced.

Figure 2: TRC monthly exports of natural rubber from 2011 to 2017 and active AETS periods (UNCTAD/WTO, 2017)



this year as a response to low prices. In 2012/2013 the reduction quantity was set to 300,000 tonnes which was shared among the three countries in proportion to production quantities in 2011 (Malaysian Rubber Board, 2012). In 2016 the member countries agreed to a reduction of exports by 615,000 tonnes (Thailand: 324,005 tonnes, Indonesia: 238,736 tonnes, Malaysia: 52,259 tonnes, Ministry of Industry and Trade Indonesia, 2016).

Third, the Strategic Market Operation (SMO) program envisages mostly market information systems to support and evaluate other international agreements and policies, in particular both SMS and AETS. Furthermore, governments agree to purchase excess supplies for public storage, aiming to reach certain price levels through this stock management. However, until 2018, only Thailand has actively intervened in its rubber market by building up domestic stocks. Hence, the SMO is primarily a long term policy with regards to improved information systems and monitoring, and serves in rare case as a short term policy when stocks are bought in times of low prices (International Tripartite Rubber Council, 2016).

All of these policies are implemented under the supervision of the International Tripartite Rubber Consortium Ltd. (ITRC), which has been founded jointly by the three governments (Verico, 2013). Policy interventions are agreed in member state meetings, and then coordinated and implemented by the ITRC. Within each member country, a National Tripartite Rubber Corporation (NTRC) is responsible for the implementation of the agreed policy measures. In Indonesia, this function has been transferred to the Association of Rubber Businesses Indonesia, GAPKINDO (Ministry of Industry and Trade Indonesia, 2002). In Thailand and Malaysia, the Thai Rubber Association and the Malaysian Rubber Board, respectively, are in charge of implementing the policy measures in collaboration with the ITRC.

However, despite the efforts being undertaken to form the ITRC and to agree upon policy measures, the success of the intergovernmental union and their policy framework is unclear, as the body of literature is marginal. Only few scientific studies analysing the efficacy of international rubber policy are available. While the implementing organs of all member states have attributed short term upward price developments towards AETS and SMS implementations (e.g. Malaysian Rubber Board, 2012; Thai Rubber Association, 2016), some literature points out that the policies have been largely ineffective due to lack of compliance as well as coordination. Verico (2013) argues that TRC member states are actually competing instead of collaborating and exploiting their hypothetical oligopolistic power. Figure 2 reveals a point in case. The two periods of active AETS from October 2012 to March 2013 and from March 2016 to August 2016 are represented by the dark shaded area. In the first period, accumulated exports of the partners have increased, although a drop is observable after the policy had expired. The second period featured larger fluctuations of exports and a rather increasing trend in the post implementation period. In both cases no strategic export reduction can be observed.

Nevertheless, commodity markets follow complex mechanisms and available quantities may not solely be responsible for price formation. For instance, the mere announcement of restrictive policy may already have impacts on international price development. Therefore, the assessment of the efficacy of TRC policy calls for a more profound analysis.

3 Model

3.1 The Gardner Model

To evaluate the consequences of policy measures that try to detach one specific price from price dynamics in other sectors it is essential to develop an understanding of which factors affect these consequences and what outcome is within the realm of possibility for policy makers. The policies' success is determined by a) the level of market power that the implementing stakeholders can exercise, b) the level of the cross price elasticity and c) the rigorousness with which the measures are implemented. The same factors are equivalently decisive for the dynamics in the other sector as a result of the policy measures.

We base our analysis on the model introduced by Bruce Gardner (1975) which has served as the workhorse model for many decades. It includes three markets, one for an agricultural input a, one for a non-agricultural (*industrial*) input b, and one for the composite output Q. The model accounts for external effects on production such as factors influencing production like weather, as well as factors influencing demand, such as the global macroeconomic environment.

The objective of our extensions to the basic Gardner model is to allow for an assessment of b), the cross price elasticity, and how this is affected by measures implemented by stakeholders who allegedly can exercise market power. The solution of the model allows for a prediction of the highest plausible level that the policy can achieve.

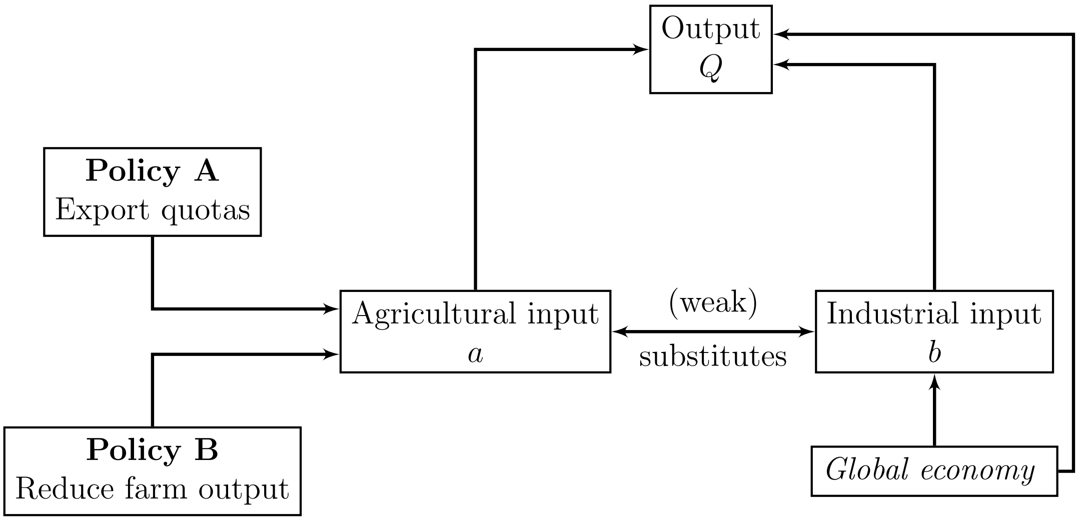
This general intuition stands in the tradition of authors who have applied the Gardner model and its subsequent extensions to numerous market power related problems. E.g., Brümmer et al. (2009) base their price-transmission analysis of Ukrainian wheat and flour markets on the basic model. Based on assumptions on the key variables entering the model (mainly on elasticities), it was possible to derive plausible magnitudes for the long-run relation between prices, which indeed confirmed their empirical results. Along similar lines, Hosseini and Shahbazi (2010) and Kinnucan and Tadjion (2014) exploit the basic model's zero-restrictions to test for perfect price transmission and to draw conclusions regarding the competitivenesses of the markets under consideration. Modifications of the model to allow for a non-competitive market environment include Holloway (1991) who assumes a conjectural-variations oligopoly with endogenous entry and Azzam (1998)'s extension towards a partially integrated oligopsonistic industry. Yu and Bouamra-Mechemache (2016) develop a model similar to Gardner to predict the effects of the implementation of production standards which reduce total output quantity.

3.2 Logic of model extension

This paper suggests an approach of explicitly modelling policies that interfere with the market of the agricultural input in situations of globally distributed production networks. The producers of inputs a and b are exporters located in different countries while the manufacturer of Q imports all inputs.

As Figure 3 shows, the market of the agricultural input is subject to policy interventions in input producing countries: policy A refers to export quotas (short-run effect) while policy B refers to legislature to reduce farm output (long-run effect). Agricultural input a is also affected by a seasonal component, as well as by the demand from manufacturers of Q. The industrial input is affected by the global economy, which, in turn, also affects demand for output Q.

Figure 3: Flow chart of causal chain



Source: own design
Bold refers to policy instruments, *italics* refer to external factors, and normal font to production quantities.

3.3 Model setup

First we set up demand and supply relations for the markets for agricultural input a, the non-agricultural (*industrial*) input b and composite output Q and subsequently derive the market equilibria.

We start with the supplies of the two inputs. Agricultural supply on the domestic market is provided by the inverse supply function:

$$p_a^D = h(a, U) \tag{1}$$

U is an exogenous shifter including natural shocks, as well as the policy to reduce supply in a linear fashion and therefore increases the reactivity of supply to price changes.

Equivalently, inverse supply of the industrial input b is given by

$$p_b = g(b, V) \tag{2}$$

V is an exogenous shifter, such as a tax or the global macroeconomic environment. Note that no superscript is included because no trade policy is assumed to exist on the market for b.

The demand for a and b stems from manufacturers who use inputs a and b to produce the composite output Q. Demand for the agricultural input a in the world is given by the assumption of perfect competition on the output market, i.e. manufacturers of Q equate the input price for the agricultural input a, p_a^W, to the value of its marginal product.

$$p_a^W = p_Q \frac{\partial Q}{\partial a} \tag{3}$$

Equivalently, demand for the industrial input b is given by

$$p_b = p_Q \frac{\partial Q}{\partial b} \tag{4}$$

Demand for the final product Q follows a standard demand function:

$$Q = D(p_Q, N) \tag{5}$$

Q represents the demand for output product quantity, p_Q is product price, N is an exogenous demand shifter, for instance income or macroeconomic variables.
The production of Q is given by a neoclassical production function f:

$$Q = f(a, b) \tag{6}$$

The elasticity of substitution between a and b in production of Q is given by $\sigma = (\frac{\partial Q}{\partial a}\frac{\partial Q}{\partial b})/Q(\frac{\partial^2 Q}{\partial a \partial b})$ (Allen, 1938, p. 343).

The equilibrium on the market for the agricultural input a is characterised by the export quota collectively introduced by the countries exporting a. The gross price p_a^W that manufacturers of Q have to pay for input a is the net price, p_a^L, inflated by the costs of the big exporter's export quota, represented by the *ad valorem equivalent* (AVE) of the quota. Based on Holloway (1991, p. 980), it is equal to the net price, multiplied by the AVE, and weighted by a proxy for the exporter's market power:

$$p_a^W = p_a^L(1 + t) \tag{7}$$

$(1+t)$ stands for the *effect* of a big exporter's policy instrument and p_a^L is the net price. In other words, t does not represent the mere tax but is furthermore weighted by the exporter's ability to exert market power, which can be understood as the *conjectural variation* of the exporter (Huang and Sexton, 1996). Conjectural variations express seller power by a single parameter and measure how strongly competitors react to changes in price or quantity supplied by the market participant under consideration. It varies between 0 (perfect competition) and 1 (monopoly).

3.4 Effects of policies

Now let us turn to the effects of a modification in the farm supply on the relation between the farm and industrial inputs. In order to assess how the policies are affecting the price formation process in the markets for the agricultural input and the industrial input, we solve the model for the relation between agricultural and industrial input price changes. This relation can also be interpreted as the elasticity of the agricultural input's price to a percentage change in the industrial input's price.[2]

$$\frac{E_{p_a^W,U}}{E_{p_b,U}} = \frac{\varepsilon_U}{(1+t)} \frac{(\varepsilon_b + S_a\sigma - S_b\eta_Q)}{S_a(\eta_Q+\sigma)} \tag{8}$$

The export tax enters in the denominator on the right hand side of equation (8), which means that increasing t will continuously detach the agricultural input price from the industrial input price. The effects of the output reduction are captured by $\varepsilon_U = \frac{\partial p_a}{\partial U}\frac{U}{p_a}$, on whose magnitude we cannot make an *ad hoc* assumption. The free-market situation, i.e. when neither Policy A (effect of export tax) nor Policy B (long-term reduction of farm output) are active is accounted for by setting $t = 0$ and $\varepsilon_U = 1$.

4 Application: global markets for natural and synthetic rubber

The combined market power of the rubber exporting countries that are organised within the TRC might allow them to affect global prices of natural rubber. The AETS policy of the TRC is the introduction of an export quota, represented by its AVE, which is only employed by policy-makers if the price is low.
This gives two cases:

Case 1: If the world price is low, the TRC introduces export tax $t_{AVE-TRC}$, the situation that is described by equation (8).

Case 2: If the world price is high, no export quota is issued.[3] Equation (8) simplifies to

$$\frac{E_{p_a^W,U}}{E^{p_b,U}} = \varepsilon_U \frac{(\varepsilon_b + S_a\sigma - S_b\eta_Q)}{S_a(\eta_Q+\sigma)} \tag{9}$$

[2]The derivation is provided in Appendix 8.1.

[3]There is no clear definition of what 'high' and 'low' prices are, the decision on when to implement measures is made rather spontaneously between the TRC's member countries.

Implications of equation (8) for the relation between input prices Brümmer et al. (2009) state some observations regarding the values of a number of variables in this model of which some can also be applied to this case. S_a and S_b can be generated from our data. The synthetic rubber price has been approximately 2505 US$ per ton and the natural rubber 2437 US$ per ton on average during 2011-2017. They enter in roughly the same amounts. So $S_a \approx 0.51$ and $S_b \approx 0.49$. Given that tires are complements to cars and represent a minor share of the car price the own price elasticity of demand for tires, η_Q, can be assumed to be negligible, so the respective terms can be omitted from the formula. Regarding the elasticity of substitution in production, however, we can – unlike Brümmer et al. (2009) – not assume σ to be very small because synthetic and natural rubber are indeed substitutes within a certain range. Interviews with tire manufacturers showed that natural rubber and synthetic rubber are close substitutes: the ratio between the two in terms of quantity can be varied easily between 45:55 and 55:45, depending on prices. Harder (2018) reports that 8% of all natural rubber demand in China could switch to synthetic rubber. This means that the elasticity of substitution in production $\sigma \gg 1$. For the prediction we assume $\sigma = 10^4$. The supply elasticity of natural and synthetic rubber are derived from the literature: Kopp and Sexton (2018) find a supply elasticity for natural rubber in Indonesia of $\varepsilon_a = 1.44$. Horowitz (1963) estimates a supply elasticity for synthetic rubber of $\varepsilon_b = 1.49$. Since we cannot make an *ad hoc* assumption on the magnitude of $\varepsilon_U = \frac{\partial p_a}{\partial U}\frac{U}{p_a}$, this parameter is to be estimated in the subsequent empirical analysis. Inserting these numbers into equation (8) yields

$$\frac{E_{p_a^W,U}}{E_{p_b,U}} = \frac{\varepsilon_U}{(1+t)}1.29 \tag{10}$$

This means that in the absence of policies ($\varepsilon_U = 1$ and $t = 0$) the long-run elasticity of the natural rubber price relative to the price of synthetic rubber is about 1.3, providing 'an indication of the expected magnitude of the long-run elasticity' of composite industrial input prices with respect to agricultural input prices (Brümmer et al., 2009, p. 215). In other words, price changes in the industrial good – synthetic rubber – are amplified by the factor 1.3 during transmission to the price for the agricultural good – natural rubber if no policies are active. The econometric estimation of $\frac{E_{p_a^W,U}}{E^{p_b,U}}$ will therefore allow an assessment of the success of the TRC in isolating the prices.

The theoretical model shows that the policy measures under consideration do indeed have the potential to decouple the reaction in prices. The next section provides empirical evidence on whether this potential was exploited.

5 Econometric analysis

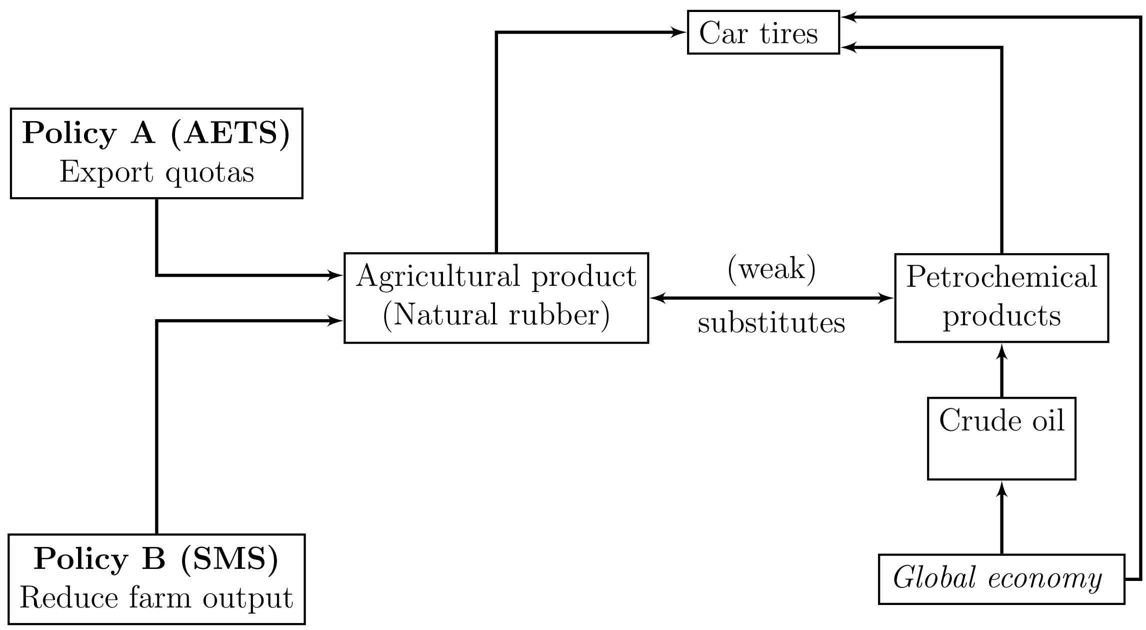
5.1 Vector Error Correction Model

The substitutability between natural and synthetic rubber suggests that the prices of these are correlated over time. The theoretical model from section 3 implies that policies targeting the supplies of natural rubber either via export reduction or farm output reduction impact its

[4] Appendix 8.2 provides a simulation for $\frac{E_{p_a^W,U}}{E_{p_b,U}}$ when inserting values for $\sigma \in [1; 25]$.

international price if the implementing countries are large enough. These impacts could be transmitted into the industrial input, i.e. prices of petrochemical products, including synthetic rubber. Both of which obviously are subject to the dynamics of the global economy and determine the framework for the tire market (figure 4).

Figure 4: Flow chart of causal chain applied to the rubber value chain



Source: own design
The global economy also affects the tire price because more cars are sold in times of high macroeconomic growth rates and new cars being marketed requires more tires than replacing tires of when cars are used for longer. We do not assume a direct effect of crude oil price on agricultural supply because energy costs are minor both in production of natural rubber and its processing.

In order to assess policy efficacy in a time series context, a number of methods have been implemented in the relevant literature (Ihle et al., 2012, provide a review of this literature). Two prominent options are regime dependent estimation and dummy variable approaches. The former entails estimation of different regimes in which policies have been operational or not, whereby the transition from a policy to a non-policy (or different policy) regime may be predefined (e.g. Thompson et al., 2000), or estimated (e.g. Brümmer et al., 2009). In the latter method, policies are simply controlled for using dummy variables. In this application one long term policy, SMS, and one short term policy, AETS, ought to be evaluated. Since SMS stretches over the entire time horizon and the AETS has been active for two periods of six months each, the dummy approach is preferred in this particular setting.

Given the long and short term policy structure of the TRC as well the usual suspicion that price data are non-stationary and $I(1)$, a Vector Error Correction Model (VECM) is estimated. In that, both prices are exposed to exogenous shocks from the oil price p^{CO}. Hence, in this context the oil price is not considered as a cointegrated variable, yet it must be allowed to impact the relationship exogenously. This approach has been adopted also by Ihle et al. (2012) who augmented the cointegration relation with exogenous policy variables. The same idea applies to the long term SMS policy. In accordance with Dickey et al. (1991), we include p^{CO} and the SMS policy variable in the long run equation and the residuals of which form the Error Correction Term (ECT) in the VECM representation. Given that the price series are cointegrated[5], the long run equation is formulated as

$$p_t^{NR} = \beta_0 + \beta_1 p_t^{SR} + \beta_2 p_t^{CO} + \beta_3 SMS_t + \epsilon_t \tag{11}$$

where p_t^{NR} is the price of natural rubber and corresponds to the price of the agricultural input, p_a^W, in equation (8). p^{SR} is the price of the industrial input, namely synthetic rubber and p_t^{CO} stands for the crude oil price. Additionally, the long term policy set of the SMS, SMS_t, is included.[6] ϵ_t is an $I(0)$ variable.

Establishing an indicator for or modelling the SMS policies poses a challenge since it is impossible to account for specific measures taken in given time periods. The SMS defines a target and the executive companies then contribute to the target by implementing a variety of measures. The dynamics of area cultivation over time certainly reflect these measures, however, they are highly endogenous to the prices. Since no measure for the actually implemented policies exists, we proxy the propensity of the governments and agencies to implement the measures. To test for robustness proxies are generated for the different measures and compared to each other. As a further robustness check we also capture the propensity to implement via a modelling approach as described below.

The SMS policy targets the reduction of rubber that is traded on the world market to increase the price in the long run. This is achieved through two sub-goals: reducing the productive area and promoting domestic consumption. Three instruments contribute to the former: limiting the establishment of new plantations, more frequent rejuvenation of trees, and crop diversification at farm level.

The first measure of SMS implementation is the promotion of domestic consumption by motivating local business and public sourcing to use more rubber. The private sector is incentivised to develop and produce more natural rubber based goods and the public sector procures goods that contain rubber, such as rubberised roads or dams (Anwar, 2017; International Tripartite Rubber Council, 2015). Since no panel data are available for the public procurement of all three countries, this application focuses on the private sector to proxy these policies. Since the main industry to use rubber are tire manufacturers, the measurement of choice is the output of the domestic tire industry: the possibly increased domestic demand for natural rubber due to SMS is proxied by the deviation of the output of the downstream industry (i.e. tire manufacturing) from its long-run trend, denoted by SMS_{TO}.

As a second measure the acceleration / slowing down of expansion of area under cultivation is proxied by a dummy variable, SMS_{ex}, which takes the value of 1 in case the change of area harvested a in t is larger than the change in $t-1$ and 0 otherwise. In other words, it distinguishes between slowing down or acceleration of area expansion. While this is also caused by an array of other factors, it will reflect the efforts of the implementing agencies.

$$SMS_{ex,t} = \begin{cases} 1 & if \quad \Delta a_t - \Delta a_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

The third measure to proxy the effects of this policy instrument was generated via a modelling approach: the rate of plantation encroachment is the result of small scale farmers' land use

[5] This is shown to be the case in section 5.3.

[6] The short term policy AETS enters in the estimation of the short-run dynamics.

decisions which are a function of three key determinants: the SMS policy, the expected price development of natural rubber and the expected price development of oil palm, the alternative cash crop growing in these geographical regions and climatic zones. We therefore isolate the policy effect by stripping the dynamics in the land area used for rubber production from the other two effects in terms of proportional changes:

$$\begin{aligned} \frac{A_t - A_{t-1}}{A_t} =& SMS_{ha,t} + \frac{p_t^{NR,expected} - p_{t-1}^{NR,expected}}{p_t^{NR,expected}} + \frac{p_t^{PO,expected} - p_{t-1}^{PO,expected}}{p_t^{PO,expected}} \\ \Leftrightarrow& \\ SMS_{ha,t} =& \frac{A_t - A_{t-1}}{A_t} - \frac{p_t^{NR,expected} - p_{t-1}^{NR,expected}}{p_t^{NR,expected}} - \frac{p_t^{PO,expected} - p_{t-1}^{PO,expected}}{p_t^{PO,expected}} \end{aligned} \tag{13}$$

where the expected price for natural rubber, $p^{NR,expected}$, and for palm oil, $p^{PO,expected}$, is proxied by yearly price indices of the two commodities.

It was considered to include lags of the SMS policy variable since the results of reducing/not expanding land area may take some time to take effect. We decided against, however, since a change of land area under cultivation in one year does indeed have already impacts in the same year since changes in land use policies influence traders decisions which drive the price.

We have therefore three proxies for the SMS policy that targets the long-run reduction of the international natural rubber supply: first is the deviation from the long-run trend of tire output, second is a dummy that captures acceleration or slowing down of rubber plantation expansion and third is a continuous variable that measures rubber plantation expansion, controlling for price effects. To test for the robustness of these measures we estimate the long run relation with each of them individually and also combine the first measure (tire exports) with each of the measures for area expansion.

Having estimated the cointegration relationship, the VECM specification becomes

$$\Delta p_t = \alpha' \beta (c \quad p_{t-1} \quad p_{t-1}^{CO} \quad SMS_{t-1})' + \sum_{i=1}^{k} \Gamma \Delta p_{t-i} + \gamma_1 \Delta p_{t-1}^{CO} + \gamma_2 AETS_t + e_t \tag{14}$$

The endogenous prices of natural and synthetic rubber are gathered in the 2×1 vector p_t. The vector in brackets is the cointegrating vector. The short term policy instrument enters the equation in form of the dummy variable $AETS_t$ and as k lags of the endogenous variable. e_t are independent Gaussian errors with mean zero. In the case of the short term relation, the short term policies are be formulated as a dummy variable which indicates periods in which the policy is operational and periods in which it is not.

5.2 Data

Translating the theoretical model into an empirical application requires proxies for petrochemical tire inputs, the agricultural input as well as the crude oil price. First, styrene butadine rubber prices have been obtained from Shanghai Shengiyshe Data Consulting Ltd. and are expressed in CNY per tonne. Second, the Standard Malaysian Rubber (SMR) price time series at the Malaysian rubber exchange in Kuala Lumpur in Ringgit per tonne and the West Texas

Intermediate crude oil price in US $ per barrel have been retrieved from Thompson Reuters Datastream. The panel hence consists of three time series covering roughly six and a half years or 1549 observations. The rubber prices have been converted in US $ using daily exchange rates. The three series are displayed in figure 5. Descriptive statistics are provided in table 1. For the policy data, government bills and documents have been reviewed to determine periods of active AETS, and data on area harvested have been drawn from FAOSTAT (FAO, 2017).

Figure 5: International crude Oil, synthetic and natural rubber prices, 2011-2017

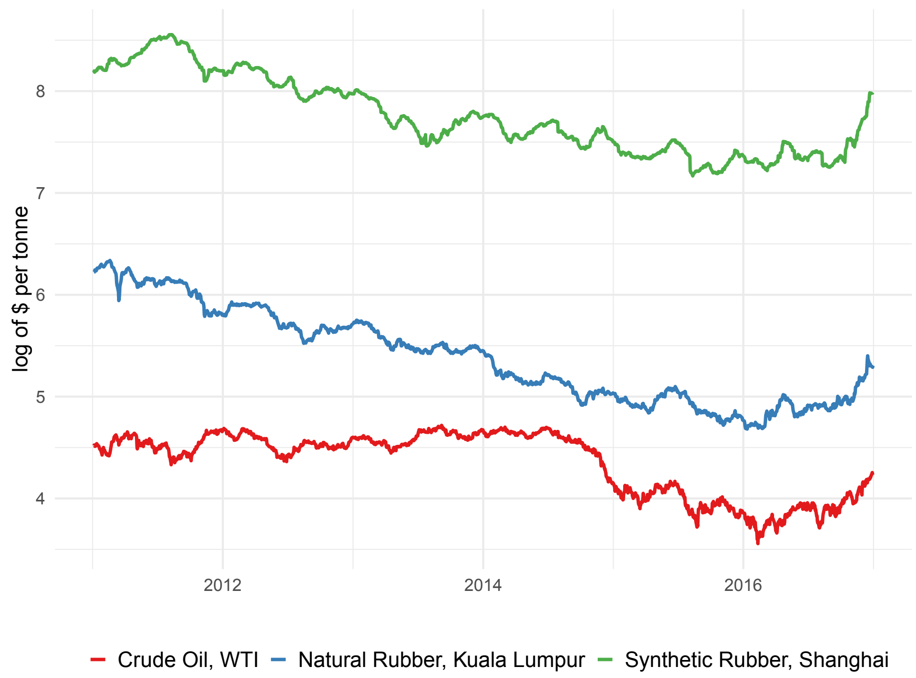


Table 1: Descriptive statistics of the variables entering the analysis

Statistic	N	Mean	St. Dev.	Min	Max
Crude oil	1484	78.6	24.7	26.2	112.4
Natural rubber	1484	800	318	436	1743
Synthetic rubber	1484	158907	6621	8821	34367

Styrene butadine rubber prices are expressed in CNY per tonne, the Standard Malaysian Rubber price time series in Ringgit per tonne, and the West Texas Intermediate crude oil price in US$ per barrel. The estimation was carried out with the logarithmised variables.

5.3 Results

Stationarity and order of integration In order to analyse univariate stationarity and determine the order of integration, all series are tested for unit roots using the ADF (Dickey and Fuller, 1979) and KPSS (Kwiatkowski et al., 1992) test routines. All tests bring about substantial evidence for non-stationarity of the data and for the variables to be $I(1)$ at significance levels of at least 5%. With respect to the analysis of interdependence of the time series this

Table 2: VECM Results

	Long run equation					VECM coefficients		
	constant	p^{SR}	p^{CO}	SMS_{TO}	SMS_{ha}	ECT	p^{CO}	$AETS$
p^{NR}	−3.19	0.97	0.28	−0.18	−0.31	0.01***	0.04*	0.00
	(0.06)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
p^{SR}						0.01*	−0.01	0.02
						(0.01)	(0.04)	(0.01)

Standard errors in parentheses. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Results reported here are based on the long-run model 4, the estimation in which the effect of the SMS policy is proxied by the development of the area harvested and the tire exports. The robustness checks for alternative proxies for the SMS variable can be found in appendix 8.3. The full results of the short-run dynamics are available in appendix 8.4.

implies testing for cointegration, that is testing for the existence of a long term equilibrium relationship.

Seasonality and structural breaks The standard decomposition revealed no seasonality. Neither did seasonal dummies make a significant difference. It is conceivable that the standard tests (ADF, KPSS, etc.) are biased by the structural breaks that we assume to be in the data (i.e. policy regimes). These structural breaks are captured by the variables capturing the policies. Apart from these, there are no *a priori* reasons to expect other structural breaks.

Cointegration The focus of the cointegration analysis lies on synthetic and natural rubber prices. Considering the substantial degree of substitutability between natural and synthetic rubber we would assume the two series to be cointegrated and following to some extend the Law of One Price (LOP). Both Johansen trace (Johansen, 1991) and eigenvalue, as well as the residual based Engle-Granger (Engle and Granger, 1987) testing procedures reveal the presence of a cointegrating relationship at a 5% significance level. The estimated long-run equation is depicted in table 2.

Vector Error Correction Model The coefficients of the error correction term are significant for natural rubber as well as in the synthetic rubber equation. That is, both rubber prices are cointegrated with adjustment speeds to deviations from the long run equilibrium of 10% daily in both natural and synthetic rubber prices. With regards to the AETS policies, we find a positive but small and statistically insignificant coefficient in both equations. Only the price of natural rubber reacts to short-run price dynamics of crude oil. These results are also displayed in table 2.

5.4 Discussion

Validation of conceptual framework The price for synthetic rubber and the price for natural rubber are correlated positively, showing that these two products are complements on the margin. This is in line with insights from interviews with tire manufacturers. The long-run relationship between natural and synthetic rubber prices were computed (based on equation 10) as $\ln p_a^W = 1.29$ in the absence of policies and estimated to be 0.97. This similarity in the order of magnitude validates the theoretical model.

Policy effectiveness The significant coefficients of the short run parameters indicate that even though policies have been operational, there has been no success in isolating the natural rubber price from price developments in the synthetic rubber markets. Prices are transmitted between the two markets. Additionally, the price dynamics of natural rubber are affected by changes in the crude oil price.

The $AETS$ policy of export quotas was only partially successful in reducing mutual dependence between natural and synthetic rubber prices on the long run: since the policy to reduce farm supply is already accounted for in the econometric model, the effect of the export quota can be derived from the difference between computation and estimation, subject to errors in the estimation and assumptions in the computation. $\frac{1}{1+t} \approx \frac{0.97}{1.29} = 0.75$, so $(1+t) \approx 1.33$. This is an indicator for the export quota having led to a minor detachment of the natural rubber price from the synthetic one's in the long run.
In the short run, the insignificant coefficient of $AETS$ indicates the absence of any empirical evidence for the efficacy of the AETS policy. That could be related to poor coordination, implementation and compliance as discussed earlier. While the governments usually agree unanimously on policies to be implemented, the execution of these has been sporadic and tentative at best. Nevertheless, these results might change quite substantially if export reductions were implemented more thoroughly. Additionally, we find no significant impacts upstream, that is p^{SR} is not affected by the short-run TRC rubber price policies.

The part of the SMS policy that leads to an increase of domestic use of natural rubber in tire production over the long run, proxied by SMS_{TO}, is negatively correlated with p^{NR}. Two transmission channels between the export of car tires from Indonesia, Thailand and Malaysia and the world price for natural rubber are thinkable: first is that the reduction of the natural rubber supply base in the rest of the world increases global prices, as intended by the TRC. However, adverse effects are also conceivable: an increase of tire exports can lead to an oversupply on the world market, leading to a reduction in the tire price which in turn results in a reduction of the world prices for the inputs. Since the TRC countries contribute a combined share of 8.4% to this 74 billion US$ market, which makes them collectively the second largest tire exporter in the world, this is indeed plausible[7]. The negative sign of the corresponding coefficient indicates that this is indeed happening. This means that – if the TRC's SMS policy indeed increased tire exports – the policy actually backfired, being associated with an actual reduction in the price.
The coefficient capturing the policy's effect on land expansion, SMS_{ha}, has the expected negative coefficient, indicating that the targeted reduction of land area did indeed lead to an increase in prices. The domestic rubber sectors have been subject to a dramatic price decrease between 2012 and 2015. While the determinants of the price fall are empirically not yet understood to a full extent, it is likely that increased production of non-TRC member countries, most notably India and Vietnam, in conjunction with a demand shift from Europe and the United States towards China and India, where tire legislation is laxer regarding minimum natural rubber contents, have contributed to the phenomenon. From a trade economics perspective, the comparative advantage of TRC member countries in supplying rubber to world markets appears to be decreasing giving not only rise to rubber sectors of other countries but also to other domestic sectors. The inefficacy of policy support underscores the strength of the shift of land use in the region. It is likely that already observable decreases in rubber production area in favour of oil palm production systems will continue to prevail.

[7]Numbers from http://www.worldstopexports.com/rubber-tires-exports-country (accessed on 06.01.2019).

Oil price The price of crude oil is a proxy for global business cycles and its positive correlation with the natural rubber price indicates that increased demand for all goods also increases the natural rubber prices on the long run.

The insignificant coefficient of the crude oil price in the p^{SR} equation surprises at first because one might expect crude oil prices to determine p^{SR} also in the short run since it is an input of synthetic rubber. Two factors explain this observation: it may first be caused by longer term contracts between synthetic rubber producers with their crude oil suppliers, or the former buying larger stocks of crude oil which last for extended periods. The second reason is, following the argumentation in the modelling section, the minor cost share of the crude oil input in synthetic rubber production: while the petrochemical input share p_b in tire production is 49%, the crude oil price represents only a minor share of 5.8% within the petrochemical products (Lee and Ni, 2002, Table 2).

6 Conclusions

While the effect of policies on the targeted market are often subject to analysis, the effect of a policy directed towards market A on a secondary market B are seldom discussed. This paper contributes in that respect by extending the well-established Gardner Model by two kinds of government interventions, namely the reduction of production quantity and an export tax. The theoretical model suggests that an export tax on intermediate input a introduced by a big exporter decouples the price of the industrial input p_b from the one of the agricultural input, p_a. The same holds for the other policy under review: if a large exporter of a implements policies that reduce the total output of a, the price of the other input p_b decreases the reaction of p_a to a change in p_b.

The world market for natural rubber, dominated by three large exporters which are organised in the Tripartite Rubber Council, provides an interesting application of the theoretical model. Policies implemented by the TRC, which unites Indonesia, Thailand and Malaysia, are a point in case for the application of these policies and are subject of the econometric application.

Empirical results are estimated using cointegration and VECM techniques where policies are modelled as potential exogenous drivers of price transmission and levels. The prices of natural rubber and synthetic rubber are well cointegrated and natural rubber is subject to crude oil price dynamics.

Regarding the policy effects this paper's results are partly in line with Verico (2013), who suggests that the TRC policy has been widely ineffective: the $AETS$ policy of export restriction appears to have partially detached the dynamics in synthetic rubber and crude oil from the natural rubber price. The SMS policy of supply restrictions did have two effects: while the slowing down of plantation expansion increased price levels, the increased domestic consumption seems to have back fired and led to a decrease of international natural rubber prices, assuming the validity of the proxy. The synthetic rubber price's reaction on natural rubber implies opposing effects of the SMS policies on that price. So our results stand in contrast to the conclusions of the implementing TRC institutions, who often claim that the policies have unambiguously contributed to price increments in the past. We attribute the lion's share of these to the development in synthetic rubber markets as well as the overall global economy, represented by the oil price.

7 References

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8 Appendix

8.1 Derivation of relation between agricultural and industrial input price changes

First we insert equations (1) and (3) into the equilibrium condition on the agricultural input market, equation (7), which yields

$$h(a,U)(1+t) = p_Q f_a \tag{15}$$

We now differentiate equation (15) with respect to W[8]

$$h_a \frac{\partial a}{\partial U}(1+t) = p_Q f_{aa}\frac{\partial a}{\partial U} + p_Q f_{ab}\frac{\partial b}{\partial U} + f_a \frac{\partial p_Q}{\partial U} \tag{16}$$

The next step is to derive the equivalent of equation (12) in Gardner (1975, p. 400), appended by the policy. To do so, the differentiations in equation (16) are replaced by elasticities, then input shares are included, and f_{aa} and f_{ab} are replaced.[9]

$$0 = -\left(\frac{S_b}{\sigma} + \frac{1}{\varepsilon_a}\right)\left(\frac{1}{1+t}\right) E_{aW} + \frac{S_b}{\sigma} E_{bW} + E_{p_Q W} - \varepsilon_{a,U} \tag{17}$$

The E refer to 'elasticities which take into account equilibrating adjustments in all three markets simultaneously' (Gardner, 1975, p. 400). Regarding notation, the first variable in the subscript indicates the variable that reacts to a shock stemming from the second one.

From (17) we derive the equivalent to equation (A.8) in Gardner (1975, p. 409), analogous to the appendix in Gardner:

$$E_{p_a^W,U} = \frac{\varepsilon_U \varepsilon_a \left(\varepsilon_b + S_a\sigma - S_b\eta_Q\right)}{(1+t)D} \tag{18}$$

Equation (18) describes the elasticity of the agricultural output price with respect to a shift and tilting in the agricultural supply. ε_U is the elasticity describing the reaction of p_a to U.[10] ε_U captures the effect of the policy induced reduction of the agricultural output resulting from a reduction of production capacity.

The industrial output's reaction to a supply shift in the agricultural output, $E_{p_b}^W$, is equivalent to equation A.17 in Gardner (1975, p. 409):

$$E_{b,U} = \frac{\varepsilon_a \varepsilon_b S_a(\eta_Q + \sigma)}{D} \tag{19}$$

[8]For the derivation of equation (16) see Gardner (1975, p. 400, equation (9)).

[9]For the derivation of equation (17), see Gardner (1975, p. 408, equation (A.8)). The difference to the cited equation is that Gardner differentiates with respect to N (shift in output demand) while this application does so with respect to W (shift in agricultural supply) as described in Gardner (1975, p. 402).

[10]Note the difference to $E_{a,U}$, which stands for the *total* elasticities, while ε_W accounts for the *partial* elasticity.

With $E_{b,U} = \varepsilon_b E_{p_b,U}$ we can derive the expression for $E_{p_b,U}$:[11]

$$E_{p_b,U} = \frac{\varepsilon_a S_a(\eta_Q + \sigma)}{D} \tag{20}$$

The relation between agricultural and industrial input price changes is generated by dividing equation (18) by equation (20):

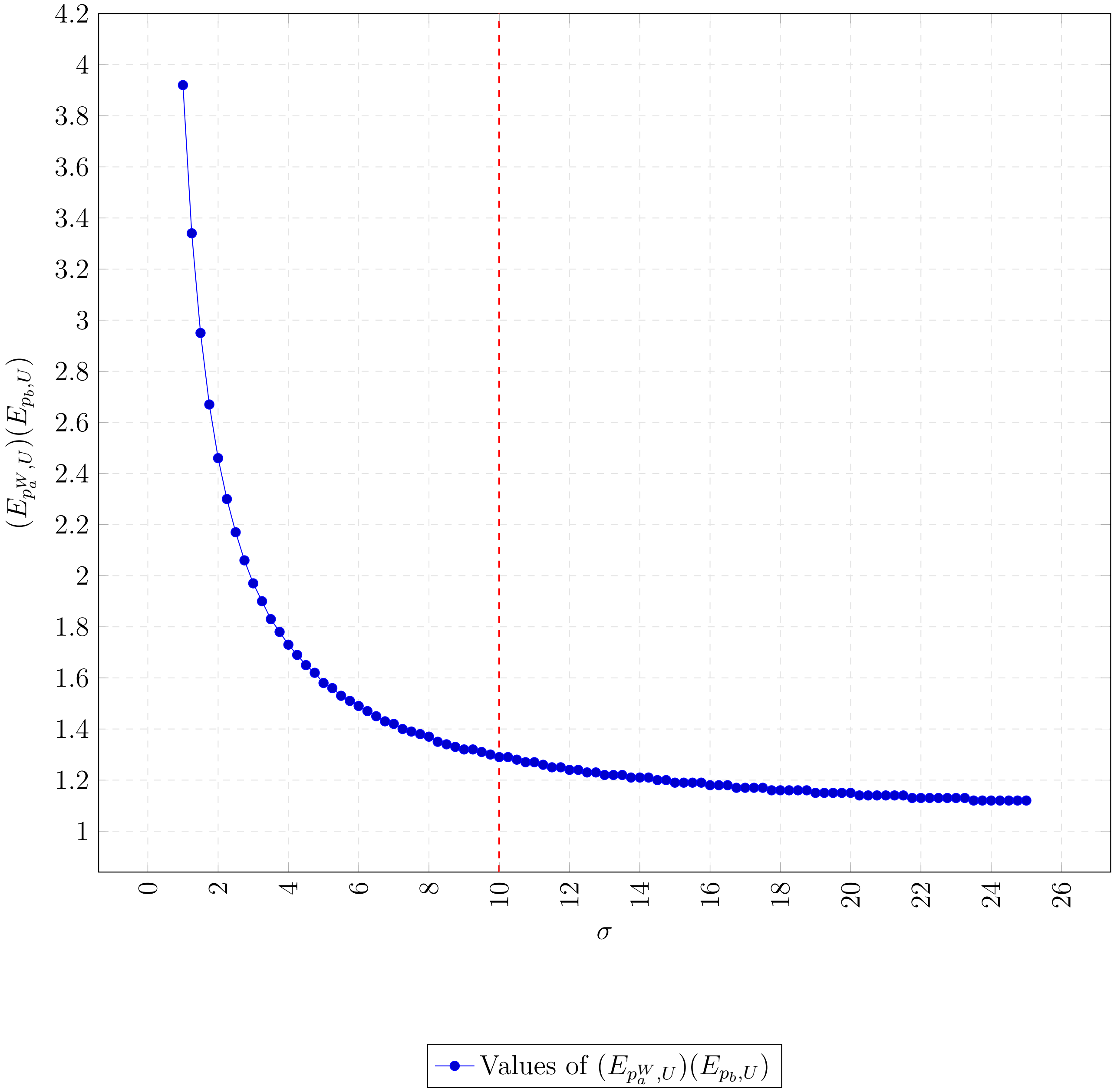
$$\frac{E_{p_a^W,U}}{E_{p_b,U}} = \frac{\varepsilon_U}{(1+t)} \frac{(\varepsilon_b + S_a\sigma - S_b\eta_Q)}{S_a(\eta_Q + \sigma)} \tag{21}$$

which is text equation (8).

[11]The equivalent calculation for good a is provided in Gardner (1975, p. 408).

8.2 Simulation of elasticities based on varying values for sigma

Figure 6: Simulation elasticity based on different values for σ. The red line indicates the value ($\sigma = 10$) that was used for the calculation in equation (10).



8.3 Robustness checks of *SMS* measure

Table 3: Long run regression models

	Model 1	Model 2	Model 3	Model 4	Model 5
(Intercept)	-3.47	-3.52	-3.53	-3.19	-3.35
	(0.07)	(0.06)	(0.06)	(0.06)	(0.07)
p^{SR}	1.05	1.14	1.07	0.97	1.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
p^{CO}	0.17	0.04	0.15	0.28	0.22
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
SMS_{ex}	-0.01	-0.17			
	(0.01)	(0.01)			
SMS_{TO}		-0.20	-0.07	-0.18	
		(0.01)	(0.01)	(0.01)	
SMS_{ha}				-0.31	-0.09
				(0.01)	(0.01)
R^2	0.93	0.95	0.94	0.95	0.93
Adj. R^2	0.93	0.95	0.94	0.95	0.93
Num. obs.	1484	1484	1484	1484	1484
RMSE	0.12	0.10	0.12	0.10	0.12

Standard errors in parentheses.

8.4 Results of short run regression

Table 4: VECM based on long run model 4

	NR	SR
ECTLag1	0.01^{***}	0.01^{*}
	(0.00)	(0.01)
NaturalRubberLag1	0.19^{***}	-0.03
	(0.03)	(0.06)
syntheticRubberLag1	0.01	-0.06^{*}
	(0.01)	(0.03)
NaturalRubberLag2	0.12^{***}	0.01
	(0.03)	(0.06)
syntheticRubberLag2	0.00	0.01
	(0.01)	(0.03)
NaturalRubberLag3	0.16^{***}	0.07
	(0.03)	(0.06)
syntheticRubberLag3	0.01	-0.04
	(0.01)	(0.03)
NaturalRubberLag4	0.08^{**}	0.03
	(0.03)	(0.06)
syntheticRubberLag4	0.01	0.01
	(0.01)	(0.03)
NaturalRubberLag5	-0.02	-0.02
	(0.03)	(0.06)
syntheticRubberLag5	-0.00	0.04
	(0.01)	(0.03)
NaturalRubberLag6	-0.01	0.08
	(0.03)	(0.06)
syntheticRubberLag6	0.01	-0.00
	(0.01)	(0.03)
NaturalRubberLag7	-0.07^{*}	0.00
	(0.03)	(0.06)
syntheticRubberLag7	0.01	-0.05^{*}
	(0.01)	(0.03)
NaturalRubberLag8	0.06^{*}	0.01
	(0.03)	(0.06)
syntheticRubberLag8	0.01	0.02
	(0.01)	(0.03)
NaturalRubberLag9	-0.03	0.05
	(0.03)	(0.06)
syntheticRubberLag9	0.00	0.03
	(0.01)	(0.03)
NaturalRubberLag10	0.08^{**}	-0.11
	(0.03)	(0.06)
syntheticRubberLag10	-0.00	-0.01
	(0.01)	(0.03)
CrudeOilLag1	0.04^{*}	-0.01
	(0.02)	(0.04)
AETS	0.00	0.02
	(0.01)	(0.01)
Num. obs.	1473	1473
RMSE	0.01	0.02

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$