Can the South East Asian Rubber Cartel Manipulate Natural and Synthetic Rubber Prices?

Thomas Kopp*[1], Bernhard Dalheimer[1], Zulkifli Alamsyah[2], Mira Herlambang[2], and Bernhard Brümmer[1]

[1]University of Goettingen, Germany
[2]Universitas Jambi, Indonesia

Abstract

Agriculture is one of the most-regulated sectors in many countries. In globally distributed production networks the effects of many sector specific policies may spill over to other sectors and result in possibly unwanted by-effects. The questions that this paper seeks to address is what are the effects of an exogenous policy shock in one input market on another input market? And do different policies cause different reactions? This paper addresses these questions by modeling policy effects by extending the well-established Gardner Model by two policy interventions. The model is applied to the markets for natural and synthetic rubber which is dominated by three big exporters of natural rubber who have collectively introduced policies to gain price control. Results of our Vector Error Correction approach indicate that the prices are indeed cointegrated but that the policy measures have been largely ineffective. This can be explained by week coordination by the members of the cartel.

Keywords: VECM; Gardner-Model; Policy Interventions; Rubber; Indonesia.

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*thomas.kopp@agr.uni-goettingen.de (Corresponding author).

1. Introduction

International trade in intermediate products has increased largely in the last decades and has become equally important to the trade in final products (Jones, 2000). This development has been fostered by technological development that decreased transport and other transaction costs, as well as political developments, such as the liberalization of input markets. Evidence for the liberalization of input markets is ample for emerging economies, such as Chile (Pavcnik, 2002), China (A. K. Khandelwal et al., 2013), India (Topalova and A. Khandelwal, 2011), and Indonesia (Amiti and Konings, 2007). Bas and Strauss-Kahn (2015) show that manufacturers of final goods profit from input trade liberalization, especially when specializing in high-quality products.

In contrast to the trend of a generally increasing liberalization of markets, the agricultural sector remains one of the most protected ones. Governments continue to intervene heavily in 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 often impose export restrictions on agricultural goods before other sectors.

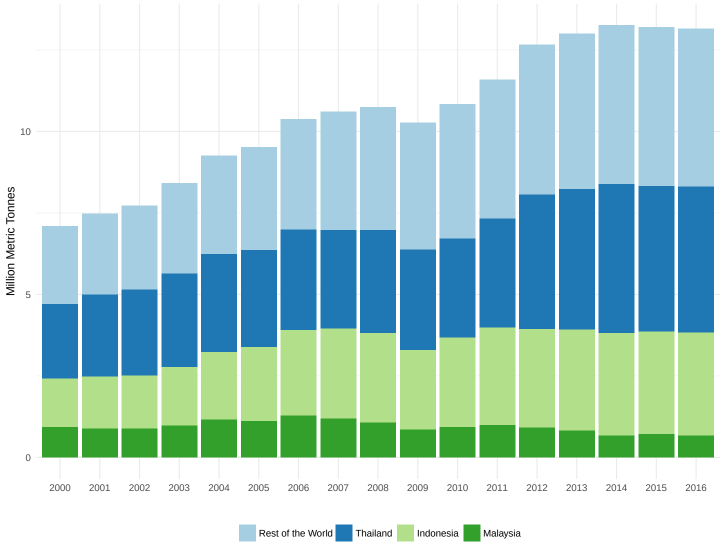
In globally distributed production networks the effects of many policies targeting one specific sector might spill over to other sectors – including ones in other regions – and result in unwanted by-effects. Especially in a developing country context, the prices for agricultural goods are important to smallholders. Since these prices are known to be extremely variable it is important to know how these are formed. The questions that this paper seeks to answer are therefore to assess the effects of an exogenous policy shock in one input market onto another input market and, secondly, to give an indication on whether different policies cause different reactions.

These questions are addressed by modeling policy effects through an extension of the well-established Gardner Model by two kinds of policy interventions. The first intervention is a long-term reduction of output quantities and the second one is an export tax. The theoretical considerations are subsequently applied to the markets for natural and synthetic rubber. Employing a Vector Error Correction Model (VECM), we first analyze whether these markets are integrated which is the necessary condition for policy effects spilling across markets and regions and second assess the nature of the cointegrating relationship. Results indicate that the prices are indeed cointegrated but that the policy measures have been largely ineffective.

To sum up, this paper extends the Gardner Model by two policy instruments applied by a big exporter. The empirical part applies a VECM to the markets for synthetic and natural rubber, as well as crude oil. It builds on a combination of the well-established approaches of spatial and vertical price transmission together in one estimation.

The paper is structured as follows: the following Section 2 provides the background of the policies of the Tripartite Rubber Council, the rubber cartel 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.

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



2. The rubber cartel in South East Asia

The Tripartite Rubber Council (TRC) has been launched in November 2001 in an agreement between Indonesia, Malaysia and Thailand. In terms of both production as well as export volumes they 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 worlds production (FAO, 2017).

Yet, the seemingly extraordinary market power stemming from the provision of two thirds of global supply, has not translated into international price dynamics as desired by the member countries. The governments have recognized the need to act on supporting farmers in facing improved prices (Ministry of Industry and trade, 2002). In an effort to gain more power over prices, the member states have established a trio of distinct policy measures which are supposed to pressure international prices upwards in both long and short term horizons (Verico, 2013).

First, the Supply Management Scheme (SMS) is intended as a long term strategy to influence prices via restraining supply. Particularly the measures include rejuvenation, plot diversification, promoting domestic consumption, and limiting the establishment of new plantations. In its first implementation in 2002, the SMS was set to aim at a reduction of farm output by 4% per annum. The program goals where then redefined in the aftermath of the global financial crisis to reduce production volumes by 215.000 tonnes per annum. The latest agreement refers to the 2017 to 2025 period and envisages additional limitations of area expansions and output for all member countries, which are yet to be determined precisely.

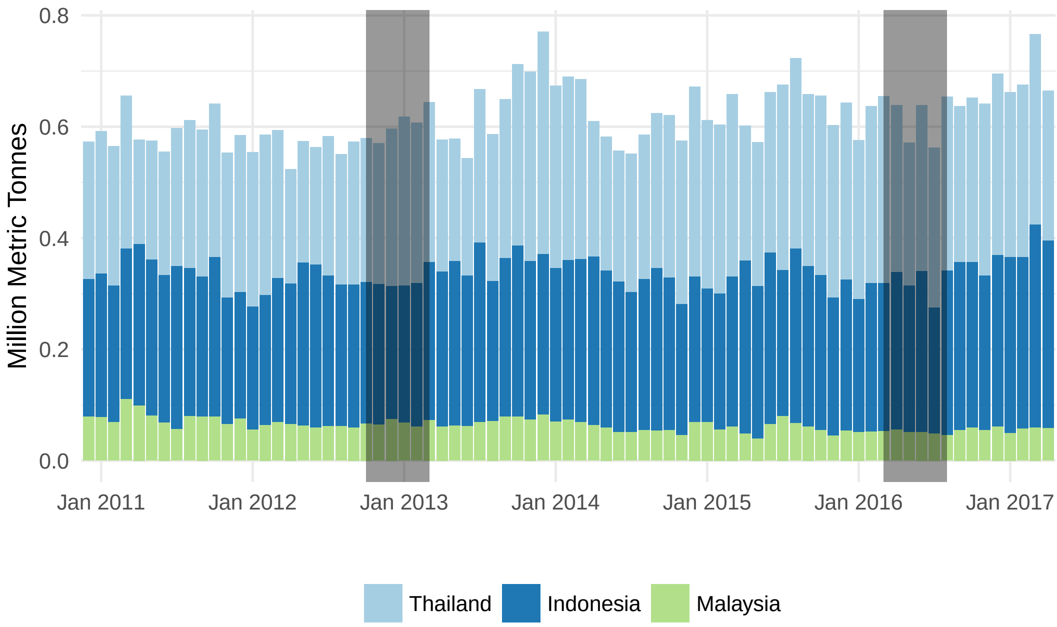
Second, export quotas are applied under the framework of the Agreed Export Tonnage Scheme (AETS). In the short term, this tool provides the potential to limit supplies on the international markets. In practice, the AETS is an export restriction shaped similarly as a quota. The governing bodies agree to the amounts of export reduction. However, the reference period has not clearly been identified which would allow the derivation of de facto quotas. Similar to the SMS, the AETS has been active from the very start of the council. In 2002 the goal of an export reduction of 10% has been set out in combination with the aforementioned production reduction of 4% under SMS. From 2009 on, the AETS have been defined as export reduction in tonnes and subsequently been introduced as a response to low prices. For the first time in 2009 export have been aimed at being reduced by 700.000 tonnes per year, in 2012/2013 by $300,000$ tonnes and in 2016 again by $700,000$.

Third, within the Strategic Market Operation (SMO) program, mostly market information systems are envisaged to support and evaluate other international agreements and policies, in particular both SMS and AETS. Furthermore, governments agree to purchase excess supplies and thereby thin markets to reach certain price levels accordingly. However, due to a lack of funding within the consortium, only Thailand has bought market surpluses. Hence, the SMO is intended as a long term with regards to improved information systems and monitoring, and short term as in stocks are supposed to be bought in times of low prices.

The implementation of these policies is carried out under the supervision of the International Tripartite Rubber Consortium Ltd. (ITRC), which has been founded jointly by the three member governments (Verico, 2013). Policy interventions are agreed in international meetings and then assigned to ITRC for coordination and implementation. Subsequently, in each member country, a National Tripartite Rubber Corporation (NTRC) is responsible for execution of upstream policies. In Indonesia the rubber processing industry is organized in the Association of Rubber Businesses Indonesia, GAPKINDO (Kopp and Brümmer, 2017), which has also been declared as the NTRC (Ministry of Industry and trade, 2002). Similarly, in Thailand and Malaysia, the Thai Rubber Association and the Malaysian Rubber Board respectively are in charge of implementing set policies in collaboration with ITRC.

The success of the intergovernmental union and their policy framework is unclear, as the body of literature is marginal. Only few scientific studies analyzing 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 also 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 black 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

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



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 shocks. For instance, the mere announcement of restrictive policy may also 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

We base our analysis on the model introduced by Bruce Gardner (1975). 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, including factors influencing production such as weather, as well as factors influencing demand, such as the global macroeconomic environment.

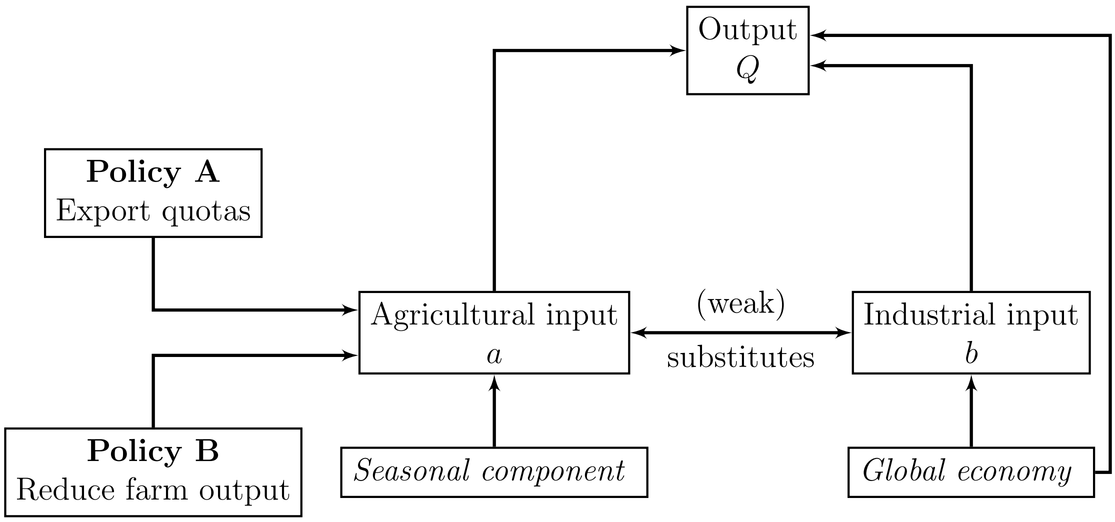
The Gardner Model has served as the workhorse model for many decades. It has been applied to various questions related to market power and underwent according modifications. Brümmer et al. (2009) base their price-transmission analysis of the Ukrainian wheat and flour market on this model and make assumptions on the key variables entering the model (mainly on elasticities) which allows an interpretation of the estimated co-integrating relationship closer to the observed data. Along a similar line, Hosseini and Shahbazi (2010) and Kinnucan and Tadjion (2014) exploit the model's zero-restrictions to test for perfect price transmission and draw conclusions for the competitivenesses of the markets under consideration. Modifications of the model to allow for a noncompetitive 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. Buzby et al. (1994) employ the Gardner Model to simulate the effects of government interventions, in this case a ban on a crucial input.

3.2 Intuition

This paper suggests a way 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 printed **text** refers to policy instruments, *text* in italics refers to external factors, and normal text refers to production quantities.

3.3 Model development

3.3.1 Output market for product Q (composite good):

Demand:

$$Q = D(p_Q, N) \tag{1}$$

Q represents the demand for output product quantity, p_Q is product price, N is an exogenous demand shifter (including macroeconomic environment).

Production of Q is given by:

$$Q = f(a, b) \tag{2}$$

where a is the agricultural input and b the non-agricultural ("industrial") input. 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].

3.3.2 Input price formation - demand side

Manufacturers of Q use a and b to produce Q. Demand for the agricultural input a is given by the assumption of perfect competition on the output market, i.e. input price p_a equals the marginal value product of Q, given by the partial derivative of production function (2) with respect to a multiplied by product price.

$$p_{a-GROSS} = p_Q \frac{\partial Q}{\partial a} \tag{3}$$

Demand-side policy A:

The gross price that manufacturers of Q have to pay for input a is inflated by the export tax of the big exporter. The gross price is the net price multiplied by the export tax, weighted by a proxy for the exporter's market power, based on Holloway (1991)[p. 980]: $p_{a-GROSS} = p_a(1+t)$. $(1+t)$ stands for the *effect* of a big exporter's policy instrument, so t does not represent the tax, but is adjusted by a factor that proxies the amount of the exporter's market power. The proxy for the exporter's market power is simply its market share. So equation (3) becomes:

$$\frac{p_a(1+t)}{p_Q} = \frac{\partial Q}{\partial a} \tag{4}$$

Equivalently, demand for the industrial input b is given by

$$p_b = p_Q \frac{\partial Q}{\partial b} \tag{5}$$

3.3.3 Input price formation - supply side

Agricultural supply is given by the inverse supply function:

$$p_a = h(a, W) \tag{6}$$

where W is an exogenous shifter. This includes weather or any policy that shifts the supply function.

Supply-side policy B:
To model policy B of the exporter's government to reduce farm output – which shifts and tilts the inverse supply function – more explicitly, parameter λ is added which requires the reformulation of equation (6):

$$p_a^* = k(a, U, \lambda) = \lambda h(a, W) = \lambda p_a \tag{7}$$

where λ (≥ 1) stands for a policy that increases input prices in a linear fashion, therefore reduces the supply and increases the reactivity of supply to price changes.

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

$$p_b = g(b, V) \tag{8}$$

in which V is an exogenous shifter, such as a tax or the global macroeconomic environment.

3.3.4 Own price elasticities:

Define η_Q as own price elasticity of Q,

$$\eta_Q := \frac{\frac{\partial Q}{Q}}{\frac{\partial p_Q}{p_Q}} = \frac{\partial Q}{\partial p_Q}\frac{p_Q}{Q} \tag{9}$$

Equivalently, the own price elasticity of the industrial input supply is given by

$$\varepsilon_b := \frac{\partial b}{\partial p_b}\frac{p_b}{b} \tag{10}$$

and for the agricultural input supply by

$$\varepsilon_a := \frac{\partial a}{\partial \lambda p_a}\frac{\lambda p_a}{a} \tag{11}$$

3.3.5 Cost shares

Total cost shares of inputs a and b in Q are referred to as S_a and S_b and defined as:

$$S_a := \frac{p_a a}{p_Q Q} \tag{12}$$

and

$$S_b := \frac{p_b b}{p_Q Q} \tag{13}$$

3.3.6 Proportional changes

Variables in dot notation refer to proportional changes:

$$\begin{aligned} \dot{Q} \ &:= \frac{Q_{t+1} - Q_t}{Q_t} \\ &= \frac{\partial Q}{Q} \text{ in continuous form} \\ &= \eta_Q \dot{p_Q} \end{aligned} \tag{14}$$

Equivalently:

$$\dot{a} = \varepsilon_a \lambda \dot{p_a} \tag{15}$$

and

$$\dot{b} = \varepsilon_b \dot{p_b} \tag{16}$$

Based on these we generate the equivalent to equation (19) in Gardner (1975) – augmented by the policy effects – to predict the reaction of the industrial input price/output price-ratio to policies affecting the agricultural input:[1]

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{S_b(\sigma + \lambda\varepsilon_a)(1 + S_a t)}{\lambda\varepsilon_a(1 + S_a t)^2 + S_b\sigma - S_a(1 + t)\eta_Q} \tag{17}$$

3.4 Effects of policies

When neither Policy A (export tax $t = 0$) nor Policy B (long-term reduction of farm output, i.e. $\lambda = 1$) are active, equation (17) collapses to the standard Gardner equation. If the policies are active, their effects on the other market are generated by calculating the partial derivatives with respect to the variables indicating the policies:

(1): The effect of the export tax targeting the agricultural input on the non-agricultural input price ($t > 0$):

$$\frac{\partial \frac{\dot{p_Q}}{\dot{p_b}}}{\partial t} = -\lambda\varepsilon_a - \lambda\varepsilon_a S_a^2 t^2 - 2S_a t\lambda\varepsilon_a - S_a\eta_Q + \eta_Q + S_b\sigma \tag{18}$$

With increasing t, this term is < 0, which means that an export tax introduced by a big exporter on product a leads to an increase of input price b relative to the overall output price p_Q.[2]

(2): The effect of the policy to reduce production of a on the non-agricultural input price ($\lambda p_a \geq p_a$):

$$\frac{\partial \frac{\dot{p_Q}}{\dot{p_b}}}{\partial \lambda} = -S_a\sigma - S_a\eta_Q - S_a\eta_Q t - 2\sigma S_a t - \sigma S_a^2 t^2 \tag{19}$$

this is unambiguously < 0, so a policy of big exporter to reduce output a leads to an increase of input price b relative to the overall output price p_Q.[3]

4. Application: global markets for natural and synthetic rubber

4.1 Model adjustment

The combined market power of the rubber exporting countries that are organized within the TRC might allow them to affect global prices of natural rubber. The AETS policy of the cartel is the introduction of an export quota. The quota is modeled as an export tax by including the *ad valorem equivalent* (AVE) of the quota into the demand which

[1]The derivation is provided in Appendix 8.1.
[2]The derivation is provided in Appendix 8.2
[3]The derivation is provided in Appendix 8.3.

is only employed if the price is below a certain threshold.
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 (17).

Case 2: If the world price is high, no export quota is used.[4] Equation (17) simplifies to

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{S_b(\sigma + \lambda\varepsilon_a)}{\lambda\varepsilon_a + S_b\sigma - S_a\eta_Q} \tag{20}$$

4.2 Implications of equation (17) for the long-run relation

Equation (17) gives the long-run relation between one input price and the output price as explained in Brümmer et al. (2009), who explain $\frac{\dot{p_X}}{\dot{p_b}}$ as the "elasticity of a processed product price (P_x) with respect to the agricultural raw product price", or – in other words – the adjustment of the input price caused by a change in the output price. The same authors also 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 found in our data. The synthetic rubber price is - on average - 1000 US$ per ton and the natural rubber on average 500 US$ per ton. They enter in roughly the same amounts. So $S_a^* \approx 0.66$ and $S_b \approx 0.33$. Concerning η_X, Brümmer et al. (2009) state that "Since the demand for flour is presumably quite price-inelastic, the last term in the denominator ($S_b\eta_Q$) can be neglected.". In the case at hand, the demand for tires on the world market is also quite in-elastic, so this term can be omitted without generating excessive deviation from the real data in this case as well. About the elasticity of substitution in production, however, we can – unlike Brümmer et al. (2009) – not assume σ to be very small because the synthetic and natural rubber are indeed substitutes within a certain range. So equation (17) can be reduced to:

TK: Bernhard, can you put here the correct numbers (replace 1000USD and 500USD)? Then I can calculate the correct ones for equation 21.

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{0.66(\sigma + \lambda\varepsilon_a)(1 + 0.33t)}{\lambda\varepsilon_a(1 + 0.33t)^2 + 0.66\sigma} \tag{21}$$

5. Econometric analysis

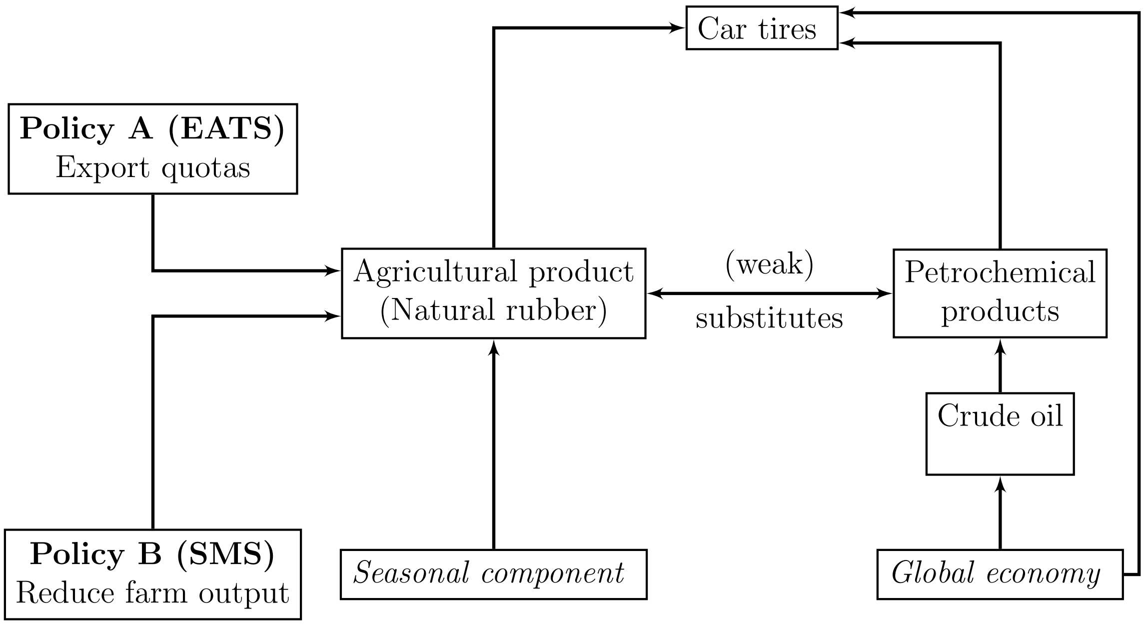
5.1 Vector Error Correction Model

The substitutability between natural and synthetic rubber imposes 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 international price. In the case that the implementing partners are large enough, these impacts could be transmitted into the industrial input, i.e. synthetic rubber prices. Both of which obviously are subject to the dynamics of the global economy and determine the framework for the tire market. This framework is depicted in figure 4.

In order to assess policy efficacy in a time series context, a number of methods have been implemented in the relevant literature. Two prominent options are regime dependent

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

Figure 4: Flow chart of causal chain, application to rubber value chain



Source: own design
The global economy also affects the tire price because more cars are sold and new cars need more tires than replacing old tires.
We don't assume a direct effect of crude oil price on agricultural supply because energy costs are minor both in agric. production and in rubber processing. Seasonal component: In times of supply shortage (each rainy season) raw rubber stays in the processors' inventories for shorter times.

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 (**Thompson2000**), or estimated (e.g. Brümmer et al., 2009). In the latter method, policies are simply controlled for using dummy variables. Since, TRC policies are either long term, that is implemented over the entire time period, or short term, but then implemented in two periods only lasting 6 months each, the dummy approach is preferred in this particular setting.

Given the long and short term structure of policy as well the usual suspicion that price data are non-stationary and $I(1)$, a Vector Error Correction Model (VECM) may be estimated. Additionally both prices are exposed to exogenous shocks from the oil price. Hence, in this context they oil price is not considered as an 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 D. a. Dickey et al., 1991, we include P^{CO} and the AETS policy dummy 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, the long run equation is formulated as

$$p_t^{NR} = \beta_0 + \beta_1 p_t^{SR} + \beta_2 p_t^{CO} + \beta_3 SMS_t + \epsilon_t \tag{22}$$

Where p_t^{NR} is the price of natural rubber and corresponds to the agricultural input in equation 17. p^{SR} is the price of the industrial input, namely synthetic rubber and ϵ_t is an $I(0)$ variable. Additionally, the long term behavior of the crude oil price is included as well as the long term policy set of the SMS. Finding an indicator or modeling these is quite cumbersome, since it is impossible to account for specific activities in given time periods. The SMS rather defines a target of, say land reduction, and the executive companies then are implementing these via a variety of measures. The dynamics of area cultivation over time certainly reflects these measures, however, it is also highly endogenous to the prices. In a attempt to circumvent this problem, we set up a dummy variable

$$SMS_t = \begin{cases} 1 & if \quad \Delta a_t - \Delta a_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$$

which takes the value of 1 in case the change of are 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 admittedly is caused by an array of factors, it will reflect the efforts of the implementors, at least to a certain extend.

Having estimated the cointegration relationship, the VECM specification becomes

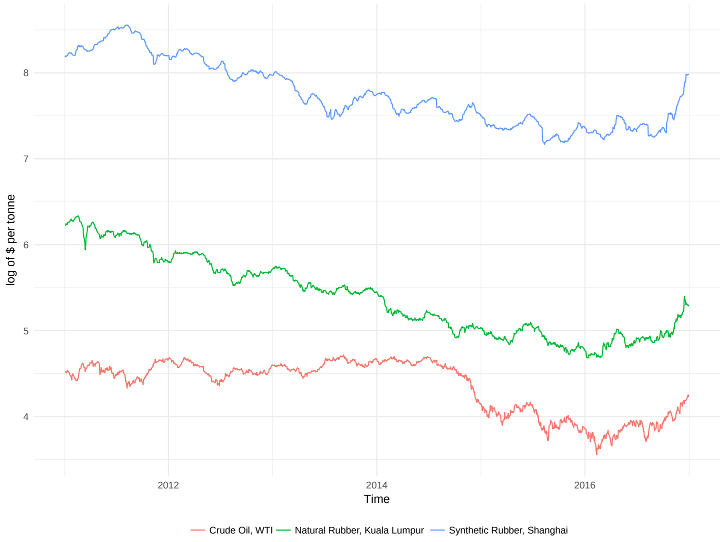
$$\Delta p_t = \alpha' \beta (p_{t-1} \quad p_{t-1}^{CO} \quad SMS_{t-1})' + \sum_{i=1}^{k} \Gamma \Delta p_{t-k} + \gamma_1 \Delta p_{t-1}^{CO} + \gamma_2 AETS_t + e_t \tag{23}$$

Here the endogenous prices of natural and synthetic rubber are gathered in the 2×1 vector p_t. The term in brackets stems from the cointegrating vector. The short term policy instrument enters the equation in form of a dummy variable as well as k lags of the endogenous variable. e_t are independent Gaussian variables with mean zero. In the case of the short term relation, the short term policies may simply be formulated as a dummy variable which indicates periods in which the policy is operational and periods in which it was 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 from the Malaysian rubber exchange in Kuala Lumpur in Ringgit per tonne and the West Texas Intermediate crude oil price in \$ 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. For the policy data, government bills and documents have been reviewed to determine periods of active AETS, and data on area harvested has been drawn from FAOSTAT (FAO, 2017).

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



5.3 Results

Stationarity and Order of Integration In order to analyze univariate stationarity and determine the order of integration, all series are tested for unit root using the ADF (D. A. 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 implies testing for cointegration, that is testing for the existence of a long term equilibrium relationship.

Cointegration Our theoretical model implies strict exogeneity of the global economy, i.e. the crude oil price. Therefore 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 so some extend the LOP. Both Johansen (Johansen, 1991) trace and eigenvalue as well as the the residual based Engle-Granger (Engle and Granger, 1987) testing procedure reveal the presence of a cointegration relationship at a 5% significance level. The estimated long tun equation is depicted in table 1. The coefficient of the policy is not significant implying that the SMS policy of the TRC has not shown impact during the period under investigation.

Vector Error Correction Model The coefficients of the error correction term is significant for natural rubber as well as in the synthetic rubber equation. That is, both rubber prices are cointegrated with adjustment speeds to deviation from the long run equilibrium of .6 and .7 % daily in natural and synthetic rubber prices respectively. In other words, even though policies have been operational, there has been no success in isolating the natural rubber price from price developments in the synthetic rubber

Table 1: VECM Results

	Long run equation				VECM coefficients		
	constant	p^{SR}	p^{CO}	SMS	ECT	p^{CO}	AETS
p^{NR}	-3.499^{***}	1.007^{***}	0.245^{***}	0.009	-0.006^{***}	0.121^{***}	0.010
	(0.071)	(0.011)	(0.013)	(0.007)	(0.003)	(0.019)	(0.006)
p^{SR}					0.007^{**}	0.009	0.000
					(0.002)	(0.013)	(0.001)

markets. Prices are transmitted between the two markets. Additionally, the price of natural rubber is subject to changes of the crude oil price. A quite surprising result is the insignificant coefficient of the crude oil price in the p^{SR} equation. We would expect crude oil prices to determine the SBR price since it is an input of SBR. This could indicate that synthetic rubber prices are more demand driven than impacted from supply shocks.

With regards to the AETS policies, we find a positive but insignificant coefficient Yet, the extend of which is very low. The absence of empirical evidence for the efficacy of TRC policy 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 which 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 SBR prices are not affected by the TRC rubber price policies.

6. Conclusions

While the effect of policies on the market that the policies are designed for are often subject to analysis, the effect of a policy directed towards market A on market B are seldomly 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 considerations predict that an export tax on intermediate input a introduced by a big exporter results in an increase of input price b relative to the overall output price p_Q on the world market. The same holds for the other policy under review: if a big exporter of a implements policies that reduce the total output of a, the price of the other input p_b increases relative to p_Q.

The world market for natural rubber, dominated by three big exporters that are organized in a cartel, provides an interesting application of the theoretical model. Indonesia, Thailand and Malaysia form the Tripartite Rubber Council which has implemented exactly the two aforementioned policies during the last decades.

Empirical results are estimated using cointegration and VECM techniques where policies are modeled as potential exogenous drivers of price transmission and levels. It is found that the prices of natural rubber, synthetic rubber are well cointegrated and natural rubber is subject to crude oil price dynamics. These results are in line with Verico (2013), who suggests that the TRC policy has been widely ineffective. On the other hand, our results stand in sharp contrast to the conclusions of the implementing TRC institutions, who often claim that the policies have 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 equation (17)

Differentiate Q:

$$
\begin{aligned}
Q &= f(a,b) \\
\partial Q &= \frac{\partial Q}{\partial a}da + \frac{\partial Q}{\partial b}db \\
\frac{\partial Q}{Q} &= \frac{\partial Q}{\partial a}\frac{a}{Q}\frac{da}{a} + \frac{\partial Q}{\partial b}\frac{b}{Q}\frac{db}{b} \\
\dot{Q} &= \frac{\partial Q}{\partial a}\frac{a}{Q}\dot{a} + \frac{\partial Q}{\partial b}\frac{b}{Q}\dot{b}
\end{aligned} \tag{24}
$$

Substitute input demands (4) and (5), together with costs shares (12) and (13) into (24):

$$\dot{Q} = S_a(1+t)\dot{a} + S_b\dot{b} \tag{25}$$

Differentiate p_a:[5]

$$
\begin{aligned}
p_a =& p_Q f_a \\
&\text{i.e.:} \\
p_a =& p_Q \frac{\partial Q}{\partial a} \\
\dot{p_a} =& \frac{-S_b}{\sigma}\dot{a} + \frac{S_b}{\sigma}\dot{b} + \dot{p_Q}
\end{aligned} \tag{26}
$$

Equivalently:

$$\dot{p_b} = \frac{-\lambda S_a(1+t)}{\sigma}\dot{b} + \frac{\lambda S_a(1+t)}{\sigma}\dot{a} + \dot{p_Q} \tag{27}$$

This yields a system of the following six equations with six unknowns:

$$\dot{Q} = S_a(1+t)\dot{a} + S_b\dot{b} \tag{28}$$

$$\dot{p_a} = \frac{-S_b}{\sigma}\dot{a} + \frac{S_b}{\sigma}\dot{b} + \dot{p_Q} \tag{29}$$

.

$$\dot{p_b} = \frac{-S_a(1+t)}{\sigma}\dot{b} + \frac{S_a(1+t)}{\sigma}\dot{a} + \dot{p_Q} \tag{30}$$

$$\dot{Q} = \eta_Q\dot{p_Q} \tag{31}$$

$$\dot{a} = \lambda\varepsilon_a\dot{p_a} \tag{32}$$

$$\dot{b} = \varepsilon_b\dot{p_b} \tag{33}$$

The target of this exercise is to predict effects of the policies active on the agricultural market on the industrial input price in relation to the output price p_Q, that is $\frac{\dot{p_Q}}{\dot{p_b}}$. We first substitute equations (31) and (32) into equations (28), (29) and (30)

$$\eta_Q\dot{p_Q} = S_a(1+t)\lambda\varepsilon_a\dot{p_a} + S_b\dot{b} \tag{34}$$

$$\dot{p_a} = \frac{-S_b}{\sigma}\lambda\varepsilon_a\dot{p_a} + \frac{S_b}{\sigma}\dot{b} + \dot{p_Q} \tag{35}$$

[5] The following is equivalent to equation (12) in Gardner.

.

$$\dot{p_b} = \frac{-S_a(1+t)}{\sigma}\dot{b} + \frac{S_a(1+t)}{\sigma}\lambda\varepsilon_a\dot{p_a} + \dot{p_Q} \tag{36}$$

Now solve equation (34) for $\dot{b}$:

$$\dot{b} = \frac{\eta_Q\dot{p_Q} - S_a(1+t)\lambda\varepsilon_a\dot{p_a}}{S_b} \tag{37}$$

and replace $\dot{b}$ from (37) into (35) and (36):

$$\dot{p_a} = \frac{-S_b}{\sigma}\lambda\varepsilon_a\dot{p_a} + \frac{S_b}{\sigma}\frac{\eta_Q\dot{p_Q} - S_a(1+t)\lambda\varepsilon_a\dot{p_a}}{S_b} + \dot{p_Q} \tag{38}$$

.

$$\dot{p_b} = \frac{-S_a(1+t)}{\sigma}\frac{\eta_Q\dot{p_Q} - S_a(1+t)\lambda\varepsilon_a\dot{p_a}}{S_b} + \frac{S_a(1+t)}{\sigma}\lambda\varepsilon_a\dot{p_a} + \dot{p_Q} \tag{39}$$

Now solve (39) for $\dot{p_a}$

$$\dot{p_b} - \dot{p_Q} + \frac{\eta_Q\dot{p_Q}S_a(1+t)}{S_b\sigma} = \frac{S_a^2(1+t)^2\lambda\varepsilon_a\dot{p_a}}{S_b\sigma} + \frac{S_a(1+t)}{\sigma}\lambda\varepsilon_a\dot{p_a} \tag{40}$$

which is equivalent to:

$$\dot{p_b} - \dot{p_Q} + \frac{\eta_Q\dot{p_Q}S_a(1+t)}{S_b\sigma} = \dot{p_a}\left(\frac{S_a^2(1+t)^2\lambda\varepsilon_a}{S_b\sigma} + \frac{S_a(1+t)\lambda\varepsilon_a}{\sigma}\right) \tag{41}$$

Dividing by the term in brackets yields

$$\frac{\dot{p_b} - \dot{p_Q} + \frac{\eta_Q\dot{p_Q}S_a(1+t)}{S_b\sigma}}{\frac{S_a^2(1+t)^2\lambda\varepsilon_a}{S_b\sigma} + \frac{S_a(1+t)\lambda\varepsilon_a}{\sigma}} = \dot{p_a} \tag{42}$$

Simplifying on the LHS yields

$$\frac{\dot{p_b}S_b\sigma - \dot{p_Q}S_b\sigma + \eta_Q\dot{p_Q}S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} = \dot{p_a} \tag{43}$$

Replace $\dot{p_a}$ from (43) in (38):

$$\begin{aligned}\frac{\dot{p_b}S_b\sigma - \dot{p_Q}S_b\sigma + \eta_Q\dot{p_Q}S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} = \\ &\frac{-S_b}{\sigma}\lambda\varepsilon_a\frac{\dot{p_b}S_b\sigma - \dot{p_Q}S_b\sigma + \eta_Q\dot{p_Q}S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} \\ &+ \frac{S_b}{\sigma}\frac{\eta_Q\dot{p_Q} - S_a(1+t)\lambda\varepsilon_a\frac{\dot{p_b}S_b\sigma - \dot{p_Q}S_b\sigma + \eta_Q\dot{p_Q}S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b}}{S_b} \\ &+ \dot{p_Q}\end{aligned} \tag{44}$$

Rearranging yields:

$$\dot{p_Q} = \frac{\dot{p_b} S_b \sigma - \dot{p_Q} S_b \sigma + \eta_Q \dot{p_Q} S_a (1+t)}{S_a^2 (1+t)^2 \lambda \varepsilon_a + S_a (1+t) \lambda \varepsilon_a S_b} - \frac{(-S_b \lambda \varepsilon_a)(\dot{p_b} S_b \sigma - \dot{p_Q} S_b \sigma + \eta_Q \dot{p_Q} S_a (1+t))}{\sigma (S_a^2 (1+t)^2 \lambda \varepsilon_a + S_a (1+t) \lambda \varepsilon_a S_b)} - \frac{S_b \left(\eta_Q \dot{p_Q} - S_a (1+t) \lambda \varepsilon_a \frac{\dot{p_b} S_b \sigma - \dot{p_Q} S_b \sigma + \eta_Q \dot{p_Q} S_a (1+t)}{S_a^2 (1+t)^2 \lambda \varepsilon_a + S_a (1+t) \lambda \varepsilon_a S_b} \right)}{\sigma S_b} \tag{45}$$

Simplifying yields:

$$\dot{p_Q} = \frac{\dot{p_b} S_b \sigma - \dot{p_Q} S_b \sigma + \eta_Q \dot{p_Q} S_a (1+t)}{S_a^2 (1+t)^2 \lambda \varepsilon_a + S_a (1+t) \lambda \varepsilon_a S_b} + \frac{\dot{p_b} S_b^2 - \dot{p_Q} S_b^2 + \eta_Q \dot{p_Q} S_a (1+t) S_b \sigma^{-1}}{S_a^2 (1+t)^2 + S_a (1+t) S_b} - \frac{\eta_Q \dot{p_Q}}{\sigma} + \frac{S_a (1+t) \lambda \varepsilon_a \frac{\dot{p_b} S_b \sigma - \dot{p_Q} S_b \sigma + \eta_Q \dot{p_Q} S_a (1+t)}{S_a^2 (1+t)^2 \lambda \varepsilon_a + S_a (1+t) \lambda \varepsilon_a S_b}}{\sigma} \tag{46}$$

Simplifying further yields:

$$\dot{p_Q} = \frac{\dot{p_b} S_b \sigma - \dot{p_Q} S_b \sigma + \eta_Q \dot{p_Q} S_a (1+t)}{S_a^2 (1+t)^2 \lambda \varepsilon_a + S_a (1+t) \varepsilon_a S_b} + \frac{\dot{p_b} S_b^2 - \dot{p_Q} S_b^2 + \eta_Q \dot{p_Q} S_a (1+t) S_b \sigma^{-1}}{S_a^2 (1+t)^2 + S_a (1+t) S_b} - \frac{\eta_Q \dot{p_Q}}{\sigma} + \frac{\dot{p_b} S_b - \dot{p_Q} S_b + \eta_Q \dot{p_Q} S_a (1+t) \sigma^{-1}}{S_a (1+t) + S_b} \tag{47}$$

Bring all terms including $\dot{p_Q}$ on the LHS and the ones including $\dot{p_b}$ on the RHS:

$$\begin{aligned}\dot{p_Q} &- \frac{-\dot{p_Q}S_b\sigma + \eta_Q\dot{p_Q}S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} - \frac{-\dot{p_Q}S_b^2 + \eta_Q\dot{p_Q}S_a(1+t)S_b\sigma^{-1}}{S_a^2(1+t)^2 + S_a(1+t)S_b} + \frac{\eta_Q\dot{p_Q}}{\sigma} - \frac{-\dot{p_Q}S_b + \eta_Q\dot{p_Q}S_a(1+t)\sigma^{-1}}{S_a(1+t)+S_b} \\ &= \frac{\dot{p_b}S_b\sigma}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} + \frac{\dot{p_b}S_b^2}{S_a^2(1+t)^2 + S_a(1+t)S_b} + \frac{\dot{p_b}S_b}{S_a(1+t)+S_b}\end{aligned} \tag{48}$$

502 Factor out $\dot{p_Q}$ and $\dot{p_b}$, respectively:

$$\begin{aligned}\dot{p_Q} &\left(1 - \frac{-S_b\sigma + \eta_Q S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} - \frac{-S_b^2 + \eta_Q S_a(1+t)S_b\sigma^{-1}}{S_a^2(1+t)^2 + S_a(1+t)S_b} + \frac{\eta_Q}{\sigma} - \frac{-S_b + \eta_Q S_a(1+t)\sigma^{-1}}{S_a(1+t)+S_b}\right) \\ &= \dot{p_b}\left(\frac{S_b\sigma}{S_a^2(1+t)^2\lambda\varepsilon_a + S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b^2}{S_a^2(1+t)^2 + S_a(1+t)S_b} + \frac{S_b}{S_a(1+t)+S_b}\right)\end{aligned} \tag{49}$$

Divide by LHS without $\dot{p_Q}$ and by $\dot{p_b}$:

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{\frac{S_b\sigma}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b^2}{S_a^2(1+t)^2+S_a(1+t)S_b} + \frac{S_b}{S_a(1+t)+S_b}}{1 - \frac{-S_b\sigma+\eta_Q S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} - \frac{-S_b^2+\eta_Q S_a(1+t)S_b\sigma^{-1}}{S_a^2(1+t)^2+S_a(1+t)S_b} + \frac{\eta_Q}{\sigma} - \frac{-S_b+\eta_Q S_a(1+t)\sigma^{-1}}{S_a(1+t)+S_b}} \tag{50}$$

Extend within numerator and denominator:

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{\frac{S_b\sigma}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b^2\lambda\varepsilon_a}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b S_a(1+t)\lambda\varepsilon_a}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b}}{\frac{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b\sigma-\eta_Q S_a(1+t)}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b^2\lambda\varepsilon_a-\eta_Q S_a(1+t)S_b\lambda\varepsilon_a\sigma^{-1}}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{(S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b)(\eta_Q\sigma^{-1})}{S_a^2(1+t)^2\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b} + \frac{S_b S_a(1+t)\lambda\varepsilon_a-\eta_Q S_a^2(1+t)^2\lambda\varepsilon_a\sigma^{-1}}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b}} \tag{51}$$

Simplify:

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{\frac{S_b\sigma+S_b^2\lambda\varepsilon_a+S_b S_a(1+t)\lambda\varepsilon_a}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b}}{\frac{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b+S_b\sigma-\eta_Q S_a(1+t)+S_b^2\lambda\varepsilon_a-\eta_Q S_a(1+t)S_b\lambda\varepsilon_a\sigma^{-1}+S_a^2(1+t)^2\lambda\varepsilon_a\eta_Q\sigma^{-1}+S_a(1+t)\lambda\varepsilon_a S_b\eta_Q\sigma^{-1}+S_b S_a(1+t)\lambda\varepsilon_a-\eta_Q S_a^2(1+t)^2\lambda\varepsilon_a\sigma^{-1}}{S_a^2(1+t)^2\lambda\varepsilon_a+S_a(1+t)\lambda\varepsilon_a S_b}} \tag{52}$$

Simplify:

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{S_b\sigma + S_b^2\lambda\varepsilon_a + S_bS_a(1+t)\lambda\varepsilon_a}{S_a^2(1+t)^2\lambda\varepsilon_a + 2S_bS_a(1+t)\lambda\varepsilon_a + S_b\sigma - \eta_Q S_a(1+t) + S_b^2\lambda\varepsilon_a} \tag{53}$$

Simplify:

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{S_b(\sigma + \lambda\varepsilon_a(S_b + S_a(1+t)))}{\lambda\varepsilon_a(S_a(1+t) + S_b)^2 + S_b\sigma - S_a(1+t)\eta_Q} \tag{54}$$

Since the shares add up to one, i.e. $S_a(1+t) + S_b = 1 + S_at$, we get the equivalent to equation (19) from Gardner (1975),[6] augmented by the policy effects, which predicts the reaction of the industrial input price/output price-ratio to policies affecting the agricultural input:

$$\frac{\dot{p_Q}}{\dot{p_b}} = \frac{S_b(\sigma + \lambda\varepsilon_a)(1 + S_at)}{\lambda\varepsilon_a(1 + S_at)^2 + S_b\sigma - S_a(1+t)\eta_Q} \tag{55}$$

8.2 Effect of t

- Quotient rule: when $y = \frac{u}{u}$, then $y' = \frac{u'v - uv'}{v^2}$. Since we only want know the sign, we can omit the denominator which is always positive.
- $u'v - uv'$:
- $S_bS_a(\sigma + \lambda\varepsilon_a)(\lambda\varepsilon_a(1 + S_at)^2 + S_b\sigma - S_a(1+t)\eta_Q) - (S_b(\sigma + \lambda\varepsilon_a)(1 + S_at))(2\lambda\varepsilon_a(1 + S_at)S_a - S_a\eta_Q)$
- If this is < 0, the tax on market a has a *positive* effect on the price of b as a share of the price of output Q.
- $(S_bS_a\sigma + S_bS_a\lambda\varepsilon_a)(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2t^2 + 2\lambda\varepsilon_a S_at + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (S_b\sigma + S_b\lambda\varepsilon_a)(1 + S_at)(2S_a\lambda\varepsilon_a + 2S_a^2t\lambda\varepsilon_a - S_a\eta_Q) < 0$
- Factor out and delete S_b (> 0, so the inequality symbol does not change):
- $(S_a\sigma + S_a\lambda\varepsilon_a)(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2t^2 + 2\lambda\varepsilon_a S_at + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (\sigma + \lambda\varepsilon_a)(1 + S_at)(2S_a\lambda\varepsilon_a + 2S_a^2t\lambda\varepsilon_a - S_a\eta_Q) < 0$
- Factor out and delete S_a (> 0, so the inequality symbol does not change):
- $(\sigma + \lambda\varepsilon_a)(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2t^2 + 2\lambda\varepsilon_a S_at + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (\sigma + \lambda\varepsilon_a)(1 + S_at)(2\lambda\varepsilon_a + 2S_at\lambda\varepsilon_a - \eta_Q) < 0$
- Delete $(\sigma + \lambda\varepsilon_a)$ (> 0, so the inequality symbol does not change):
- $(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2t^2 + 2\lambda\varepsilon_a S_at + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (1 + S_at)(2\lambda\varepsilon_a + 2S_at\lambda\varepsilon_a - \eta_Q) < 0$
- Expand second term further
- $(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2t^2 + 2\lambda\varepsilon_a S_at + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (2\lambda\varepsilon_a + 2S_at\lambda\varepsilon_a - \eta_Q + 2S_at\lambda\varepsilon_a + 2S_a^2t^2\lambda\varepsilon_a - S_at\eta_Q) < 0$

[6] With the difference that Gardner (1975) eventually solves for the price ratio between *agricultural* input and the output while we solve for the price ratio between *industrial* input and the output.

- Simplify
- $\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t - 2\lambda\varepsilon_a - 2S_a t\lambda\varepsilon_a + \eta_Q - 2S_a t\lambda\varepsilon_a - 2S_a^2 t^2\lambda\varepsilon_a + S_a t\eta_Q < 0$
- Simplify
- $-\lambda\varepsilon_a - \lambda\varepsilon_a S_a^2 t^2 - 2S_a t\lambda\varepsilon_a - S_a\eta_Q + \eta_Q + S_b\sigma < 0$
- With increasing t, this holds true.

8.3 Effect of *lambda*

- Quotient rule: when $y = \frac{u}{u}$, then $y' = \frac{u'v - uv'}{v^2}$. Since we only want know the sign, we can omit the denominator which is always positive.
- $u'v - uv'$:
- $(S_b\varepsilon_a(1+S_a t))(\lambda\varepsilon_a(1+S_a t)^2 + S_b\sigma - S_a(1+t)\eta_Q) - (S_b(\sigma+\lambda\varepsilon_a)(1+S_a t))(\varepsilon_a(1+S_a t)^2)$
- If this is < 0, the policy to reduce agricultural supply λ has a *positive* effect on the price of b as a share of the price of output Q.
- Expand:
- $(S_b\varepsilon_a + S_a t S_b\varepsilon_a)(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (S_b\sigma + S_b\lambda\varepsilon_a)(1 + S_a t)(\varepsilon_a(1 + S_a t)^2) < 0$
- Factor out and delete S_b (> 0, so the inequality symbol does not change):
- $(\varepsilon_a + S_a t\varepsilon_a)(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (\sigma + \lambda\varepsilon_a)(1 + S_a t)(\varepsilon_a(1 + S_a t)^2) < 0$
- Factor out and delete ε_a (> 0, so the inequality symbol does not change):
- $(1+S_a t)(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (\sigma+\lambda\varepsilon_a)(1+S_a t)(1+S_a t)^2 < 0$
- Delete $(1 + S_a t)$ (> 0, so the inequality symbol does not change):
- $(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (\sigma + \lambda\varepsilon_a)(1 + S_a t)^2 < 0$
- Expand
- $(\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t) - (\sigma + \lambda\varepsilon_a)(1 + 2S_a t + S_a^2 t^2) < 0$
- Expand further and simplify
- $\lambda\varepsilon_a + \lambda\varepsilon_a S_a^2 t^2 + 2\lambda\varepsilon_a S_a t + S_b\sigma - S_a\eta_Q - S_a\eta_Q t - \sigma - 2\sigma S_a t - \sigma S_a^2 t^2 - \lambda\varepsilon_a - 2\lambda\varepsilon_a S_a t - \lambda\varepsilon_a S_a^2 t^2 < 0$
- Simplify
- $+S_b\sigma - S_a\eta_Q - S_a\eta_Q t - \sigma - 2\sigma S_a t - \sigma S_a^2 t^2 < 0$
- Given that $S_b = 1 - S_a$ we can simplify further:
- $-S_a\sigma - S_a\eta_Q - S_a\eta_Q t - 2\sigma S_a t - \sigma S_a^2 t^2 < 0$

- This is unambiguously true.