

## **Oligopsony in the Tire Industry: A study of its Impacts on the Natural Rubber Industry in Thailand<sup>1</sup>**

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### **Abstract**

Natural rubber is a significant commodity for producer countries such as Thailand, Indonesia and Malaysia. Its market structure indicates an increasing degree of concentration, from the plantation to the transformation and end product production level that includes tire manufacture. Thus there now exists the potential for oligopsonistic market power in upstream markets. Specific to the natural rubber industry is the potential for its market structure characteristics to be considered at a country level. Given that a few multinational companies in tire producing industrialized countries import a large fraction of the worlds natural rubber production, they may be capable of exercising oligopsony market power on the small farms of developing countries producing the natural rubber. Thus there is the potential for oligopsony market power and its social welfare distortions to translate into a global level problem, with the possibility that welfare might be shifted from less developed countries producing the natural rubber input to more developed countries producing tires.

An optimality condition is applied to derive an oligopsony/oligopoly market power index based on the Lerner index which defines the degree of market power as the deviation of the input price from its shadow price as measured by the input's value of marginal product. The derived index can be expressed in a series of estimable elasticities. The model is

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<sup>1</sup> This article is the concise version of my DBA thesis, Faculty of Business, Charles Sturt University. See Trangadisaiikul (2009) for details. I am grateful to Professor Greg Walker for all the valuable comments and suggestions given to my thesis.

estimated using four different interpretations of the model's components. Hence results can be cross checked across four different approaches and transformed from a conventional industry/firm level to a global industry/country level to answer the research question.

To implement the market power index, the global tire demand, the global natural rubber supply and the tire production functions for the USA, France, Japan and Germany are estimated. Data for variables in each equation are analyzed and tested for nonstationarity prior to functional specification. From each individual country data, estimated coefficients are used for hypothesis tests for the existence of oligopsony market power as well as oligopoly market power. If the hypothesis tests reject the null hypothesis of competitive markets, the presence of oligopsony and/or oligopoly market power is indicated. Derived elasticities enable the derivation of corresponding market power indexes specific to each country.

Results imply that the tire industries in USA, France, Japan and Germany do display oligopsony power on the world natural rubber market. Policy implications are drawn using the elasticity values of the market power indexes. They call for policies aimed at raising the elasticity of demand for tire and supply of natural rubber and generating more competition in the global tire market and natural rubber input market.

## บทคัดย่อ

ยางธรรมชาติมีความสำคัญต่อประเทศผู้ผลิต เช่น ประเทศไทย อินโดนีเซีย และ มาเลเซีย แต่โครงสร้างตลาดของยางธรรมชาติมีลักษณะของการมีผู้ผลิตรายใหญ่ในจำนวนน้อยราย (การกระจุกตัวของผู้ผลิต) ลักษณะนี้มีเพิ่มขึ้นในแต่ละขั้นตอนของการแปรรูปผลผลิต เริ่มจากขั้นตอนการปลูกต้นยางพารา การแปรรูปน้ำยาง ไปจนถึงผลผลิตขั้นสุดท้าย ซึ่งรวมถึงยางล้อพาหนะด้วย แสดงให้เห็นถึงความเป็นไปได้ที่ฝ่ายซื้อซึ่งเป็นอุตสาหกรรมปลายน้ำจะมีอำนาจการผูกขาดตลาดต่อผู้ขายที่เป็นอุตสาหกรรมต้นน้ำ อนึ่ง ลักษณะเฉพาะของอุตสาหกรรมยางธรรมชาติคือ สามารถพิจารณาโครงสร้างตลาดในระดับประเทศได้ เนื่องจากบริษัทที่ผลิตยางล้อเป็นบริษัทข้ามชาติ ตั้งอยู่ในประเทศที่พัฒนาทางอุตสาหกรรมแล้ว และนำเข้ายางธรรมชาติเพื่อใช้เป็นวัตถุดิบในการผลิตยางล้อ การมีบริษัทสำคัญในการผลิตยางล้อน้อยราย ทำให้เป็นไปได้ที่บริษัทระดับประเทศเหล่านี้จะมีศักยภาพในการสร้างอำนาจตลาดผูกขาดการ

ซื้อต่อชาวสวนยางรายเล็กๆ ในประเทศกำลังพัฒนาซึ่งเป็นประเทศผู้ผลิตยางธรรมชาติ ดังนั้นจึงมีความเป็นไปได้ที่ผลในการบิดเบือนสวัสดิการทางสังคมจะมีผลในระดับโลก และสวัสดิการทางสังคมจะถูกย้ายจากประเทศด้อยพัฒนาที่ปลูกยางพาราสู่ประเทศพัฒนาแล้วผู้ผลิตยางล้อ ภาวะนี้เป็นแรงจูงใจให้เกิดการศึกษาดังที่ปรากฏนี้ เพื่อตอบคำถามแห่งการวิจัยนี้ว่ามีการใช้อำนาจผูกขาดการซื้อในตลาดยางธรรมชาติในฐานะซึ่งเป็นปัจจัยการผลิตของอุตสาหกรรมผลิตยางล้อของโลกหรือไม่

แนวทางวิจัยต้องครอบคลุมการผูกขาดตลาดทั้งด้านผลผลิต(ยางล้อ) และปัจจัยการผลิต(ยางธรรมชาติ) แบบจำลองที่ใช้วิจัยนี้สร้างจากทฤษฎีการผลิตสินค้าและการซื้อวัตถุดิบ โดยใช้ทฤษฎีของคูโนต์ที่วิเคราะห์การตอบโต้ของกลุ่ม และจัดรูปตามนิยามของเลินเนอร์อันเด็คซ์คือให้อำนาจการผูกขาดตลาดเป็นค่าที่แตกต่างของราคาดตลาดของปัจจัยการผลิตและราคาเงา (value of marginal product) ของปัจจัยการผลิตนั้น คำนวณได้ประกอบด้วยความยืดหยุ่นหลายๆค่า ซึ่งสามารถคำนวณได้จากการประมวลข้อมูลที่เกี่ยวข้อง แบบจำลองที่ใช้สามารถแปรความตามองก็ประกอบได้เป็นสี่แบบ ดังนั้นผลทั้งสี่ชุดที่ได้จากการคำนวณสามารถนำมาเปรียบเทียบกันได้ การใช้แบบจำลองนี้ได้แปลงจากระดับอุตสาหกรรมและบริษัทมาเป็นระดับโลกและประเทศผู้ผลิต ทั้งนี้เพื่อตอบคำถามการวิจัยที่ตั้งไว้ในการสร้างดัชนีวัดอำนาจผูกขาดตลาดจะประมาณการอุปสงค์ของโลกต่อยางล้อ อุปทานยางพาราของโลก และฟังก์ชันการผลิตยางล้อของประเทศสหรัฐอเมริกา ฝรั่งเศส ญี่ปุ่น และเยอรมัน ก่อนการประมาณการสมการต้องวิเคราะห์และตรวจลักษณะของข้อมูลของตัวแปรในแต่ละสมการ สัมประสิทธิ์ที่ได้จากการประมาณการใช้ทดสอบสมมุติฐานว่าผู้ผลิตใช้อำนาจผูกขาดตลาดผลผลิต และตลาดปัจจัยการผลิตหรือไม่ ถ้าการทดสอบสมมุติฐานสามารถปฏิเสธสมมุติฐานว่าตลาดมีการแข่งขันสมบูรณ์ ก็เป็นเครื่องชี้ว่ามีการใช้อำนาจผูกขาดตลาดผลผลิตและ/หรือตลาดปัจจัยการผลิต นำไปสู่การนำค่าความยืดหยุ่นที่ประมาณการได้มาคำนวณค่าดัชนีการผูกขาดตลาดของแต่ละประเทศ

ผลการวิจัยชี้ว่า สหรัฐ ฝรั่งเศส ญี่ปุ่น และเยอรมัน มีอำนาจผูกขาดการซื้อในตลาดยางพาราของโลก องค์ประกอบของดัชนีบ่งชี้ถึงนโยบายที่ควรนำมาใช้ กล่าวคือ ควรเพิ่มความยืดหยุ่นของอุปสงค์ต่อยางล้อ และความยืดหยุ่นของอุปทานยางพารา และควรสร้างการแข่งขันการขายในตลาดยางล้อ และการซื้อยางพาราในตลาดยางพาราของโลก

การวิจัยนี้ประยุกต์วิธีการวิเคราะห์อำนาจผูกขาดตลาดในระดับตลาดของหน่วยผลิตในอุตสาหกรรม เป็นระดับของประเทศผู้ผลิตในตลาดโลก ดังนั้นการวัดการขาดประสิทธิภาพทาง

เศรษฐกิจ จึงบ่งชี้ถึงการผันผวนสวัสดิการจากประเทศด้อยพัฒนาสู่ปลูกยางพาราสู่ประเทศที่พัฒนาอุตสาหกรรมแล้วและเป็นผู้ผลิตยางล้อ นอกจากนี้ยังได้ปรับปรุงวิธีสร้างดัชนีการวัดอำนาจการผูกขาดตลาดเป็นสี่แบบ ทำให้เปรียบเทียบและเพิ่มความเชื่อมั่นในผลลัพธ์ที่ได้

## 1. Introduction

Natural Rubber is a major factor of vehicle tire production. Currently major producing countries of natural rubber are Thailand, Indonesia and Malaysia. Thailand is the top producing country. The problem persisting during the studied period (1960-2000) was a low and downward trend of prices of natural rubber in the world market, causing difficulties to millions of rubber farmers in producing countries. At the same time the world tire industry and vehicle industry were growing rapidly as well as showing a tendency of growing concentration via mergers and takes over. The circumstance indicates a possibility of market power which could be exercised by a small number of natural rubber consuming firms producing tires. As the tire industry also has a characteristic of a group of concentrated multinational firms operating at the global level both at the output selling and input purchasing levels, the problems of the possibility of market power exercising becomes a tendency of income distribution from natural rubber producing countries to tire producing countries. Consequently this study tries to measure whether this market power exists.

The study focuses on the factor market side, i.e. the oligopsony market power of the tire producing and natural rubber consuming countries on the natural rubber producing countries. Section 2 presents the backgrounds both from the industry and theoretical perspectives, from which the general model was developed in section 3. The empirical analysis was conducted in section 4 and results are reported. In section 5, conclusions and policy recommendations are provided based on the results found.

## 2. The Background

### 2.1 Industry Background

The *Havea* tree produces up to 99% of world natural rubber. The tree was introduced to some Asian and African countries. Current major producing countries are Thailand, Indonesia and Malaysia. Planting natural rubber takes 5-7 years for the tree to mature. Latex can be transformed to different types of rubber stocks. Sheet rubber and block rubber are the most consumed types. Indonesia and Malaysia produce block rubber from most of the products. Thailand has both rubber sheets and block rubber. During WWII, natural rubber production was restricted and synthetic rubber was invented. Since then rubber consumption has comprised both natural rubber and synthetic rubber. Vehicle tire is the major industry consuming natural rubber. In Thailand domestic tire firms consume up to 43% of locally consumed natural rubber, but locally consumed natural rubber is only 10%-11% of the country's total natural rubber production. A vehicle tire consumes 4 pounds of natural rubber and 6 pound of synthetic rubber on average. The ratio varies by tire type and size. Natural rubber and synthetic rubber are substitutable to a degree according relative costs and types of tires.

Natural rubber is significant for each producing country, impacting upon many cultivating farmers. However, throughout our study there are several areas in the natural rubber industry that have potential for market power from the buyer side. The natural rubber producer industry at the country level is concentrated in the hands of a few manufacturers. The tire industry has the nature and background resulted from its industry evolution. The industry began a hundred years ago and has since passed through phases of invention, production innovation and structural change.<sup>2</sup> Firms that did not have sufficient production scale could

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<sup>2</sup> Key amongst these were the invention of cord tires and straight-side tires which replaced clincher tires in 1913, the invention of the Banbury mixer in 1916 to mix rubber with other compounds, the use of rayon as the fabric from which tire cords were made in 1930s, the subsequent replacement of rayon by nylon and the invention of synthetic rubber as a substitute for natural rubber in the 1940s, the invention of the tube tire in 1950s, the subsequent replacement of nylon by polyester and the invention of belted biased tire design in 1960s, and radial tires in the 1970s. Advances in technology and management improvements, such as the advent of mass marketing methods, generated lower marginal costs, higher output and lower prices.

not afford these technologies; consequently, they could not survive the competition (Gort & Klepper 1982, Jovanovic & MacDonald 1994, Klepper & Kenneth 2000 and Carree & Thurik 2000). Accordingly, marginal costs tend to be similar among firms and a few prominent firms dominate the world tire industry, e.g. Goodyear in the USA, Michelin in France, Bridgestone in Japan and Continental in Germany who produce and supply tires all over the world. In 2000, the top four producers based on country sale volume were Japan (30%), US (22%), France (19%) and Germany (7%). The four countries concentration ratio (CR4) is 79%. The top four producers based on company sales volume were Bridgestone Corp (20%), Groupe Michelin (19%), Goodyear Tire & Rubber (18%) and Continental A.G. (7%). CR4 is 64%.

As the tire producing countries do not produce natural rubber, this input is imported from supplying countries. Specifically, during the time studied by this thesis (1960-2000), countries such as Malaysia, Indonesia and Thailand supplied natural rubber to the key tire producing countries: namely the USA, France and Japan. Therefore, the world tire industry is concentrated and comprises a few multinational producers that not only are operating in a global industry but are also purchasing inputs such as natural rubber from country level suppliers. Hence there is potential for market power to be exercised on the global level tire market (oligopoly) and in the natural rubber markets from the buyer side (oligopsony). In a review of natural rubber supply studies it was found that the natural rubber industry is competitive at its primary level of supply chain, namely the plantation activity. Rubber farmers are the first unit in the supply chain. The Thai natural rubber industry comprises of a lot of small farmers with a homogenous product namely the latex supply. Supply is price sensitive in the short run as farmers can vary tapping intensity and tree uprooting rates in responses to price changes despite the fact that in the long term natural rubber planting is based on perennial crop theory (Burger & Smit (1997).

Previous estimates of natural rubber elasticity for Thailand, Indonesia and Malaysia are 0.22, 0.29 and 0.14 respectively (Burger & Smit, 1997). During 1980-2000, the International Natural Rubber Organization (INRO) operated a buffer stock of natural rubber in order to stabilize its prices. Accordingly, Na Ranong & Triumvorakul (2002) found that INRO

was able to generate some profits from the buying and selling of its stocks, (except for the INRO's last term) and achieve a degree of prices stability. However, the problem for INRO was the conflict of interest between importing (buyer) and exporting (seller) members and the resultant prices which were not advantageous for natural rubber producers. Previous estimates of US tire demand elasticity are -0.76 (Jovanovic & Macdonald, 1994) and -0.48 (Carree & Thurik, 2000). Tire demand has two components namely demand from new vehicle production and demand for replacement tires. New vehicles' demand for tires does not have a price effect since it is a small item relative to the cost of the whole vehicle. Demand for tires from vehicles in-use responds to tire prices.

## **2.2 Theoretical Background**

Theoretical background was reviewed focusing on the theory of production and price in output markets and employment and price in input markets. It was first framed for a perfectly competitive market that was then used as a benchmark to evaluate production and employment in imperfectly competitive markets. Consequently, the deviation from the competitive standard is considered potential evidence of market power. The review of the literature on measuring market power identified the conjectural variation approach being most relevance for the approach adopted in this research.

Typically studies using this approach adopt a duality theory approach namely the application of Shephard's Lemma and Hotelling's Lemma to derive demand functions for inputs and supply functions for outputs respectively. Based on a foundation concept of Lerner index for the measurement of market power that market power is the difference in output price and marginal cost divided by output price, the degree of oligopsony power is defined as the deviation of actual input prices from the value of their marginal products (shadow price) with the shadow price being derived from the profit maximization conditions. Findings support the claim that the higher the degree of imperfect competition, the higher is the degree of

oligopsony/oligopoly market power and vice versa<sup>3</sup>.

### 3. The General Model

The theoretical model is derived from that developed by Chang & Tremblay (1991). The derived index is able to be interpreted for a number of different market structures. The theoretical approach of this study requires modeling both product and input markets for a specific output and input commodity. It comprises an output product demand function, the input supply function and the output product production function. Then the market power index is derived from the firm's optimality condition for profit maximization with respect to the employment of the specific input. Subsequently, the market power index was extended via identification of four different interpretations according to alternative interpretations of various components of the original model. In the next sector, the theoretical model developed is converted to an empirical form for estimation. Market power indexes are then derived for each of the four alternative model interpretations to evaluate whether oligopsony market power is present at a country level for natural rubber inputs into the global tire manufacturing market. The model and its variant versions developed for this study are derived as follows.

#### Output Demand Function

The output commodity is assumed homogeneous and produced by  $i$  producing firms. The inverse demand function for this output commodity is given by.

$$P = p(Q) \quad (1)$$

Where:  $P$  is output price,  $Q = \sum q_i$  is market output and  $q_i$  is the output of firm  $i$  for  $i = 1, 2, 3 \dots n$  firms in the industry. A non-competitive output market is possible if  $n$  is small enough

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<sup>3</sup> The weakness and strength of the conjectural variation approach are extensively addressed in the literature. A critique for the framework is that it is a static analysis i.e., given other things remain static, it analyses whether output price, marginal resource cost and input price are equal or not. However, a time trend could be added to address the dynamics of the model.



such as when entry may be blocked by technology, which requires some minimal scale sufficiency.

### Input Supply Function

To produce this commodity, firm  $i$  requires inputs  $x_{ki}$ , where  $k = 1 \dots m$ . In this study the specific input of interest ( $x_{1i}$ ) is natural rubber which is from this point on denoted as  $xr_i$ . The firm also employs some other inputs which are traded in competitive markets. As in the output case, if  $n$  is small, then non-competitive buyer behavior is possible in the market for  $xr_i$ . Let the inverse market supply of the specific input  $XR$  be given by:

$$WR = h_1(XR) \quad (2)$$

Where:  $WR$  is the per unit price of  $XR$  and  $XR = \sum x_{rj}$  is total supply of the specific input  $XR$  from  $j$  supplier firms. In addition:  $\frac{dWR}{dXR} > 0$ .

### Output Production Function

Let the production function of the firm be

$$q_i = f_i(x_{ki}) \quad (3)$$

According to economic theory, the problem of the firm is to choose the optimal level of inputs, including  $xr$  and all other inputs such as physical capital in order to maximize the firm's profit.<sup>4</sup>

### 3.1 Optimality Condition and the Derivation of Market Power Index for Model 1

The firm's profit function comprises:

$$\pi_i = P \cdot q_i - WR \cdot xr_i - \sum_{k=2}^m W_k \cdot x_{ki} \quad (4)$$

where  $\pi_i$  denotes firm  $i$ 's profits,  $W_k$  and  $x_k$ ,  $k = 2, \dots, m$  are the vectors of prices and quantities of other inputs respectively. Output prices ( $P$ ) and input prices ( $WR$ ) are market determined prices as identified in (1) and (2). Hence (4) can also be represented as:

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<sup>4</sup> For capital the input price would be the rental price of capital.

$$\pi_i = p(Q) \cdot q_i - h_1(XR) \cdot xr_i - \sum_{k=2}^m W_k \cdot x_{ki} \quad (4a)$$

The input employment levels that maximize the firms' profits are derived from the conditions  $\frac{\partial \pi_i}{\partial xr_i} = 0$  and  $\frac{\partial \pi_i}{\partial x_{ki}} = 0$  respectively. Given that input  $xr$  is the focus of our model we derive the optimality condition for purchase of  $xr$  as follows.

$$\frac{dP}{dQ} \cdot \frac{dQ}{dq_i} \cdot \frac{\partial q_i}{\partial xr_i} \cdot q_i + \frac{\partial q_i}{\partial xr_i} \cdot P - \frac{dWR}{dXR} \cdot \frac{dXR}{dxr_i} \cdot xr_i - WR = 0 ; \text{ for input } xr_i \quad (5)$$

Our index for measuring input price distortions is defined as the difference between the value of the marginal product of the input ( $VMP$ ) and the input price ( $WR$ ) divided by the value of the marginal product ( $VMP$ ). This can be presented in the following form.

$$MPI_{XRi} \equiv \frac{P(MP_{XRi}) - WR}{P(MP_{XRi})} ; \text{ where } VMP \text{ is given by } P(MP_{XRi}).$$

The  $MPI_{XRi}$  is derived by rearranging the optimality condition (5) such that it comprises measurable variables in the form of marginal products and elasticities. First we rearrange (5) as follows.

$$\left[ \frac{dP}{dQ} \cdot \frac{Q}{P} \right] \left[ \frac{dQ}{dq_i} \cdot \frac{q_i}{Q} \right] \left[ \frac{\partial q_i}{\partial xr_i} \cdot P \right] + \left[ \frac{\partial q_i}{\partial xr_i} \cdot P \right] - \left[ \frac{dWR}{dXR} \cdot \frac{XR}{WR} \right] \left[ \frac{dXR}{dxr_i} \cdot \frac{xr_i}{XR} \right] WR - WR = 0 \quad (6)$$

Within (6) we can identify a number of standard variables and denote these variables as follows.

$$\alpha_i \equiv \frac{dQ}{dq_i} \cdot \frac{q_i}{Q} : \text{ is the } i\text{'th firm's output conjectural elasticity with respect to total}$$

industry output.

$$\beta_i \equiv \frac{dXR}{dxr_i} \cdot \frac{xr_i}{XR} : \text{ is the } i\text{'th firm's input conjectural elasticity with respect to the}$$

industry's total factor demand for  $XR$ .

$\eta \equiv \frac{\partial P}{\partial Q} \cdot \frac{Q}{P}$ : is the inverse price elasticity of demand for product  $Q$  as derived from

the inverse demand curve.

$\varepsilon \equiv \frac{\partial WR}{\partial XR} \cdot \frac{XR}{WR}$ : is the inverse price elasticity of supply for input  $XR$  as derived from

the inverse supply curve.

$MP_{XRi} \equiv \frac{\partial q_i}{\partial x_{r_i}}$ : is the marginal product of the  $XR$  of the  $i$  firm.

Substitution of these elasticity terms into (6) provides for the following more convenient expression.

$$\eta \cdot \alpha_i \cdot P \cdot MP_{XRi} + P \cdot MP_{XRi} - \varepsilon \cdot \beta_i \cdot WR - WR = 0 \quad (7)$$

Rearranging and simplifying (7) yields

$$MPI_{XRi} = \frac{VMP_{XRi} - WR}{VMP_{XRi}} = \frac{P \cdot MP_{XRi} - WR}{P \cdot MP_{XRi}} = \frac{\varepsilon \cdot \beta_i - \eta \cdot \alpha_i}{1 + \varepsilon \cdot \beta_i} \quad (8)$$

For empirical application, the market power index in (8) requires estimation of each of the four elasticities:  $(\varepsilon, \eta, \alpha_p, \beta_p)$ . Four approaches are identified for estimation of  $MPI_{XRi}$ . The first approach (Model 1), we denote as  $MPI_{XRi1}$  such that:

$$MPI_{XRi1} = \frac{\varepsilon \cdot \beta_{i1} - \eta \cdot \alpha_{i1}}{1 + \varepsilon \cdot \beta_{i1}} \quad (9)$$

The values for  $\eta$  and  $\varepsilon$  will be derived from empirical estimation of equations (1) and (2) respectively. The values for  $\alpha_{i1}$  and  $\beta_{i1}$  can be derived by the estimation of the optimality equation (5) in the following format.

Rewrite (5) as:

$$WR = \theta_{11} \cdot \hat{P}_i + \theta_{21} \cdot \hat{q}_{i1} - \theta_{31} \cdot \hat{x}_{r_{i1}} \quad (10)$$

Where:

$$\theta_{21} = \frac{dQ}{dq_i} \quad (11)$$

$$\theta_{31} = \frac{dXR}{dx_{r_i}} \quad (12)$$

$$\hat{P}_i = \frac{\partial q_i}{\partial x_{r_i}} \cdot P \quad (13)$$

$$\hat{q}_{i1} = \frac{dP}{dQ} \cdot \frac{\partial q_i}{\partial x_{r_i}} \cdot q_i \quad (14)$$

$$\hat{x}_{r_{i1}} = \frac{dWR}{dXR} \cdot x_{r_i} \quad (15)$$

Three key components of the variables in (10) are: the slope of the output demand curve ( $\frac{dP}{dQ}$ ); the slope of the input supply curve ( $\frac{dWR}{dXR}$ ) and the marginal product of the input  $x_{r_i}$  ( $\frac{\partial q_i}{\partial x_{r_i}}$ ) which are estimated from equations (1), (2) and (3) respectively.

After estimating equation (10) the values for  $\theta_{21}$  and  $\theta_{31}$  are then used to calculate the two conjectural elasticities  $\alpha_i$  and  $\beta_i$  as:

$$\alpha_{i1} = \theta_{21} \cdot \frac{q_i}{Q} \quad (16)$$

$$\beta_{i1} = \theta_{31} \cdot \frac{x_{r_i}}{XR} \quad (17)$$

Substituting the estimates for  $\eta$ ,  $\varepsilon$ ,  $\alpha_{i1}$ ,  $\beta_{i1}$  allows the market power index in (9)

$$MPI_{XRi1} = \frac{\varepsilon \cdot \beta_{i1} - \eta \cdot \alpha_{i1}}{1 + \varepsilon \cdot \beta_{i1}} \text{ to be obtained.}$$

In addition, equation (10) provides criteria to test whether the input market is competitive. As the marginal revenue product ( $MRP$ ) is defined as the effect on revenue due to the marginal increase in the input  $x_{r_i}$ , it follows that <sup>5</sup>

$$MRP = \frac{\partial(P \cdot q_i)}{\partial q_i} \cdot \frac{\partial q_i}{\partial x_{r_i}} = [P \cdot (1 - \frac{1}{|\eta|})] \cdot \frac{\partial q_i}{\partial x_{r_i}}$$

At the same time, the marginal cost of buying the input  $x_{r_i}$  is the input price ( $WR$ ). To maximize its profit, firm  $i$  wants to buy the input at the quantity such that its price  $WR$  equals the  $MRP$ . This gives  $WR = [P \cdot (1 - \frac{1}{|\eta|})] \cdot \frac{\partial q_i}{\partial x_{r_i}}$  (Varian, 1996). In a competitive output market,  $|\eta|$  is  $\infty$ ,  $(1 - \frac{1}{|\eta|})$

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<sup>5</sup>  $MRP = \frac{\partial(P \cdot q_i)}{\partial q_i} \cdot \frac{\partial q_i}{\partial x_{r_i}} = (P + \frac{\partial P}{\partial q_i} q_i) \cdot \frac{\partial q_i}{\partial x_{r_i}}$   
 $= [P \cdot (1 + \frac{\partial P}{\partial q_i} \frac{q_i}{P})] \cdot \frac{\partial q_i}{\partial x_{r_i}} = [P \cdot (1 + \frac{1}{\eta})] \cdot \frac{\partial q_i}{\partial x_{r_i}} = [P \cdot (1 - \frac{1}{|\eta|})] \cdot \frac{\partial q_i}{\partial x_{r_i}}$

$=1$  and  $WR = P \cdot \frac{\partial q_i}{\partial x r_i}$ , which is the value of marginal product (*VMP*). Hence,  $\theta_{11}$  equals 1 for a competitive market. For non-competitive market,  $0 \leq |\eta| < \infty$ ,  $(1 - \frac{1}{|\eta|}) < 1$ , meaning  $\theta_{11} < 1$ . thus, the range of  $\theta_{11}$  is  $\leq 1$ . Consequently, the null hypothesis of input market efficiency (no market power) can be stated in terms of the three coefficients in (10) as  $H_0: \theta_{11} = 1, \theta_{21} = \theta_{31} = 0$ . If  $H_0$  is not rejected then:  $WR = \frac{\partial q_i}{\partial x r_i} \cdot P$  and hence the input  $xr_i$  is being paid the value of its marginal product. Further, if  $\theta_{21} = \theta_{31} = 0$ , then  $\alpha_{il} = \beta_{il} = 0$  and  $MPI_{XRIl} = 0$ , thus indicating a perfectly competitive input market. Rejection of  $H_0$  indicates the presence of non-competitive markets. In particular, significant positive values of  $\theta_{21}$  indicate the presence of oligopoly in the output market and significant positive values of  $\theta_{31}$  indicate the presence of oligopsony in the input market. The interpretation of MPI and the presence of various market structures are considered in 3.5.

### 3.2 Optimality Conditions and Derivation of Market Power Index for Model 2

The derived MPI in (9) above differs from that developed by Chang & Tremblay (1991) article. Critical differences arise due to interpretation of the elasticities  $\eta$  and  $\epsilon$  and the subsequent construction of the MPI. Chang & Tremblay defined output commodity demand elasticity as:  $-\frac{\partial Q}{\partial P} \cdot \frac{P}{Q}$ . This is the conventional price elasticity of demand for a normal demand curve ( $Q = p(P)$ ). In the market power index derived for this study demand elasticity is defined as:  $\frac{\partial P}{\partial Q} \frac{Q}{P}$  as reflects its estimation from an inverse demand curve  $P = p(Q)$ . Hence  $\eta$  as defined for the inverse demand curve becomes  $-1/\eta = \eta^*$  for the Chang & Tremblay model. Similarly the input supply elasticity ( $\epsilon$ ) in the derivation above is defined as  $\frac{\partial WR}{\partial XR} \frac{XR}{WR}$  as reflects its intended derivation from the inverse supply curve  $WR = h_i(XR)$ . However, Chang & Tremblay defined  $\epsilon$  as:  $\frac{\partial XR}{\partial WR} \frac{WR}{XR}$ , as would be derived from a normal supply function. Hence  $\epsilon$  as defined for the inverse supply curve becomes  $1/\epsilon = \epsilon^*$  for the Chang & Tremblay model.

As a consequence Chang & Tremblay (1991) express their market power index as:

$$MPI_{XRi2} = \frac{\frac{\beta_i}{\varepsilon^*} + \frac{\alpha_i}{\eta^*}}{1 + \frac{\beta_i}{\varepsilon^*}} ;$$

The mix of inverse and direct elasticities raises both theoretical and estimation questions that are not addressed by Chang & Tremblay (1991) who recommended that the direct elasticities ( $\eta^*$  and  $\varepsilon^*$ ) be derived from econometric estimations of inverse demand curves (that is as  $\eta$  and  $\varepsilon$ ) and then inverted to obtain  $\eta^*$  and  $\varepsilon^*$ . It is not considered valid to assume  $-1/\eta = \eta^*$  and  $1/\varepsilon = \varepsilon^*$ . These elasticities are derived from different functional forms with different theoretical foundations in respect of the causal relationships between dependent and independent variables. Econometric assumptions can be violated by incorrect model specifications. The assumption that inverse elasticities are equivalent to direct elasticities by implication assumes that inverse functional forms are equivalent to direct functional forms.

However, it is possible to derive the Chang and Tremblay index without transgressing the theoretical foundations. This index we refer to as Model 2 and its derivation is as follows.

$$Q = q(P) \quad (18)$$

Where  $Q$  is market output,  $P$  is output price and  $\eta^* \equiv \frac{\partial Q}{\partial P} \cdot \frac{P}{Q}$  is the direct price elasticity of demand for product  $Q$  as derived from the direct demand curve.

$$XR = h_2(WR) \quad (19)$$

Where  $XR$  is the market supply of the specific input,  $WR$  is the per unit price of  $XR$  and  $\varepsilon^* \equiv \frac{\partial XR}{\partial WR} \cdot \frac{WR}{XR}$ : is the direct price elasticity of supply for input  $XR$  as derived from the direct supply curve.

The value for the market power of Model 2, namely  $MPI_{XRi2}$  is

$$MPI_{XRi2} = \frac{\frac{\beta_{i2}}{\varepsilon^*} + \frac{\alpha_{i2}}{\eta^*}}{1 + \frac{\beta_{i2}}{\varepsilon^*}} \quad (20)$$

For empirical application, analogous to that adopted for Model 1, estimate equations (18) for  $\eta^*$ , equation (19) for  $\mathcal{E}^*$  and in parallel to Model 1, estimate equation (10) using the direct elasticity versions of tire demand and natural rubber supply and denote as estimate equation (10.2) as contrast to (10.1) for Model 1. This gives the calculation of the conjectural elasticity estimates denoted:  $\alpha_{i2} = \theta_{22} \cdot \frac{q_i}{Q}$ , and  $\beta_{i2} = \theta_{32} \cdot \frac{xr_i}{XR}$ . Substituting values for  $\eta^*$ ,  $\mathcal{E}^*$ ,  $\alpha_{i2}$ , and  $\beta_{i2}$  into (20), a value for the  $MPI_{XRi2}$  is derived.

### 3.3 The Derivation of Market Power Index for Model 3

An alternative approach to the derivation of the conjectural elasticities  $\alpha_i$  and  $\beta_i$  is possible. Consider the following approach that uses direct estimation of the  $i$ 'th firm's (or in this case the  $i$ 'th country's) observed response to industry changes. This is then used to develop a proxy measure for the individual firm's conjectures on industry responses to its behaviour. Fundamentally this approach simply measures the average response, over the studied time period, in each individual firm's (or country's) market share of the global industry. Given:

$$Q = f_2(q_i) \quad (21)$$

$$XR = f_3(xr_i) \quad (22)$$

For  $i = \text{US, France, Japan and Germany}$ . The values:

$$\alpha_{i3} = \frac{dQ}{dq_i} \cdot \frac{q_i}{Q} \quad ; \text{ and,} \quad (23)$$

$$\beta_{i3} = \frac{dXR}{dxr_i} \cdot \frac{xr_i}{XR} \quad ; \text{ can then be derived. The market power index is:} \quad (24)$$

$$MPI_{XRi3} = \frac{\mathcal{E} \cdot \beta_{i3} - \eta \cdot \alpha_{i3}}{1 + \mathcal{E} \cdot \beta_{i3}} \quad (25)$$

For empirical application, we estimate the following equations: equation (1) for  $\eta$ , equation (2) for  $\mathcal{E}$ , equation (21) for  $\alpha_{i3}$ , and equation (22) for  $\beta_{i3}$ . Substituting values for:  $\eta$ ,  $\mathcal{E}$ ,  $\alpha_{i3}$  and  $\beta_{i3}$  into the market power expression (25), delivers a value for the market power index for Model 3.

### 3.4 The Derivation of Market Power Index for Model 4

For this model the conjectural elasticity values from (23) and (24) are applied to direct versions for tire demand (18) and natural rubber supply (19), to provide the market power index:

$$MPI_{XRi4} = \frac{\frac{\beta_{i3}}{\varepsilon^*} + \frac{\alpha_{i3}}{\eta^*}}{1 + \frac{\beta_{i3}}{\varepsilon^*}}. \quad (26)$$

For empirical application, we estimate equation (19) for  $\eta^*$ , equation (20) for  $\varepsilon^*$ , equation (21) for  $\alpha_{i3}$ , and equation (22) for  $\beta_{i3}$ . Substituting these values provides the Market Power Index (26), for Model 4 which provides for an alternative estimation approach for the Chang and Tremblay version of the market power index.

However, the estimated  $\alpha_{i3}$  here is derived from a post-event measurement of the quantity of tire produced ( $q_i$ ). Hence to interpret the estimated term  $\alpha_{i3}$  as a conjectural elasticity requires the assumption that the prevailing observed response is the same as the firm conjectured pre-event. This implies that ex ante conjectured behaviour of the firm is always correct. Although this is not the case for every behaviour, it helps provide a frame of possible outcomes to be used as robust testing with outcomes from Model 1 and Model 2.

Consequently, four models have been developed to test for the existence of oligopsony market power. Model 1 and Model 2 use indirectly estimated conjectural elasticities for tire and natural rubber industries market. Model 1 differs from Model 2 in that Model 1 uses an inverse tire demand elasticity and an inverse natural rubber supply elasticity whereas Model 2 uses a direct tire demand elasticity and a direct natural rubber supply elasticity. In contrast, Model 3 and Model 4 use directly estimated conjectural elasticities. Analogous to Models 1 and 2, Model 3 uses the inverse tire demand elasticity and inverse natural rubber supply elasticity whereas Model 4 uses the direct tire demand elasticity and the direct natural rubber supply elasticity.



### 3.5 Interpretation of the Market Power Index

The market power index ( $MPI_{XRi}$ ) measures the economic rents, i.e. a portion of the value of the marginal product which is not covered by market prices hence could be gained by the oligopsonist and oligopolist firms. Consequently, it implies that the pricing mechanism is not perfect and thus inefficiency might be evident in input and output allocation.

The index has some useful properties that should be examined. Firstly, by its definition, the value of  $MPI_{XRi}$  ranges from 0 to 1. It is 0 when input XR receives a price that equals the value of its marginal product:  $WR = P \cdot MP_{XRi}$ . It approaches 1 as the input price approaches 0. Between these two extreme cases, the higher the  $MPI_{XRi}$ , the greater is the inefficiency in resource allocation. Secondly, the  $MPI_{XRi}$  index is general since it covers a variety of market structures.

Accordingly, Table 1 illustrates diverse types of market structures and their impact on the value of the  $MPI_{XRi}$  index. It can be seen that the index is general in that it covers cases like the Lerner case (competitive input market and monopoly output market), the Cournot equilibrium case (equal market shares in either markets) and the Robinson classic case (monopsony input market and monopoly output market).

It can be seen also that the level of  $MPI_{XRi}$  is determined by the values of  $\eta$ ,  $\varepsilon$ ,  $\alpha_i$ , and  $\beta_i$ . Consequently inefficiency in resource allocation is increased by low values of  $\eta$ , and  $\varepsilon$ , and high values of  $\alpha_i$  and  $\beta_i$ <sup>6</sup>.

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<sup>6</sup> From Chang & Tremblay (1991) pp. 407, when defining the industry market power index for input (natural rubber) market as  $\sum (MPI_{XRi} \cdot \frac{XR_i}{XR})$ , it approaches the Herfindahl-Hirshman index in the input

market if  $\frac{\frac{dXR}{dxr_i}}{(\varepsilon + \beta_i)} = 1$ . Similarly, when defining the industry market power index for output (tire) market as

$\sum (MPI_{XRi} \cdot \frac{q_i}{Q})$  it approaches the Herfindahl-Hirshman index in the output market if  $\frac{\frac{dQ}{dq_i}}{\eta} = 1$ .

**Table 1**  
**Market Power Index and Market Structures**

Market structure: Input / Output			$MPI_{XRi}$
$\beta_i = 0$	1: $\beta_i=0, \alpha_i=0$	Competitive / Competitive	0
	2: $\beta_i=0, 0<\alpha_i<1$	Competitive / Oligopoly	$MPI_{XRi} = -\eta \cdot \alpha_i$
	3: $\beta_i=0, \alpha_i=1$	Competitive / Monopoly (Lerner case)	$MPI_{XRi} = -\eta$
$0 \leq \beta_i \leq 1$	4: $0<\beta_i<1, \alpha_i=0$	Oligopsony / Competitive	$MPI_{XRi} = \frac{\varepsilon \cdot \beta_i}{1 + \varepsilon \cdot \beta_i}$
	5: $0<\beta_i<1, 0<\alpha_i<1$	Oligopsony / Oligopoly $\frac{x_{11}}{X_1} = \frac{x_{12}}{X_1}$ or $\frac{q_1}{Q} = \frac{q_2}{Q}$ , implies Cournot case of equal market shares.	$MPI_{XRi} = \frac{\varepsilon \cdot \beta_i - \eta \cdot \alpha_i}{1 + \varepsilon \cdot \beta_i}$
	6: $0<\beta_i<1, \alpha_i=1$	Oligopsony / Monopoly	$MPI_{XRi} = \frac{\varepsilon \cdot \beta_i - \eta}{1 + \varepsilon \cdot \beta_i}$
$\beta_i = 1$	7: $\beta_i=1, \alpha_i=0$	Monopsony / Competitive	$MPI_{XRi} = \frac{\varepsilon}{1 + \varepsilon}$
	8: $\beta_i=1, 0<\alpha_i<1$	Monopsony / Oligopoly	$MPI_{XRi} = \frac{\varepsilon - \eta \cdot \alpha_i}{1 + \varepsilon}$
	9: $\beta_i=1, \alpha_i=1$	Monopsony / Monopoly (Robinson case)	$MPI_{XRi} = \frac{\varepsilon - \eta}{1 + \varepsilon}$

### 3.6 Application of the Model to Global Natural Rubber and Tire Industries

Characteristics of the tire industry and natural rubber industry as presented in 2.1 render it appropriate to shift the model from an industry/firm level to global/country level. However,

the application of a firm level model to country level model poses theoretical as well as conceptual and empirical considerations. The literature argues it is possible to substitute industry-level data for firm-level data if the firms in the industry are assumed to have linear and parallel expansion paths such that the values of marginal products and marginal costs are constant and equal across firms. This is the so-called Gorman polar form of production technology. It allows for different firms to have different cost curves but the curves are all linear and parallel (Appelbaum, 1982). With many small competing natural rubber producers this is not considered an unreasonable assumption. Hence, in equilibrium each firm equates marginal costs to its perceived marginal revenue and their conjectural elasticities are hence equal across firms.<sup>7</sup> The general model is thus capable of application from its original industry/firm level to global industry/country level. This application requires all industry level variables to be reinterpreted as global variables and firm level variables to be reinterpreted as country level variables.

#### **4. Empirical Analysis**

This section provides the empirical application of the general model developed in section 3. Regression analysis was employed for the analysis. Data used for the analysis are between 1960-2000. The first step requires specification of functional forms for estimation of each of the general model equations. As model specification is contingent on data characteristics, variables for each equation are analyzed and tested for nonstationarity prior to functional specification. Standard approaches to testing for nonstationarity were applied to all key variables. Results using both Dickey-Fuller (DF & ADF) and Phillips-Perron (PP) tests confirm nonstationarity across all series. However, further testing confirmed all series were stationary in first difference form (integrated to order one I(1)). The results were consistent for all variables using PP tests but a small number of variables failed to reject the null hypothesis

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<sup>7</sup> However, it can be argued that conjectural elasticities are not constant over time. This is due to the changing structure of the industry. Accordingly, the aggregate value of the conjectural elasticities over time changes too (Gohin 2003).

of nonstationarity using the DF and ADF approach. The stationary tests can be provided upon request.

The regression estimations were in log-log form and undertaken using the non-linear algorithm in SHAZAM V9.0. This algorithm provides standard tests for autocorrelation (Durbin-Watson and Lagrange Multiplier) that were used to determine an appropriate order of autocorrelation correction to apply each individual equation. Heteroscedasticity is a more serious problem for cross sectional than time series data however standard diagnostic tests provided by the SHAZAM algorithm did not reveal any significant problems. Multicollinearity was tested by careful examination of the impact of variations in model specification on coefficient estimates,  $R^2$  and t-statistics. An error term is not identified for all equations. Functional forms and estimation results are given in Table 2.1 with variable definitions in Table 2.2.

**Table 2**  
**Functional Forms and Estimation Results**

Item	2.1 Functional Forms and Estimation Results
1	<p>Equation (1) Inverse Tire Demand Function Estimation Results</p> $\ln(P) = -0.17 - 3.08 \ln(Q) + 5.00^{\#} \ln(VP) + 3.09 \ln(VI) \cdot \ln(Q) - 5.62 \ln(GDPPUS)$ <p style="text-align: center;"> <span style="margin-right: 100px;">(1.96) (5.04)</span> <span style="margin-right: 100px;">(4.71)</span> <span>(5.15)</span> </p> <p style="text-align: center;"> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">***</span> <span>***</span> </p> <p>DW= 2.0164 <math>R^2 = 0.8080</math></p>
2	<p>Equation (2) Inverse Natural Rubber Supply Function Estimation Results</p> $\ln(WR) = 3.96 + 3.49 \ln(XR) - 1.10 \ln(XR_{t-2}) - 0.74 \ln(RAIN) \cdot \ln(XR)$ <p style="text-align: center;"> <span style="margin-right: 100px;">(11.95) (10.86)</span> <span style="margin-right: 100px;">(3.83)</span> <span>(5.61)</span> </p> <p style="text-align: center;"> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">***</span> <span>***</span> </p> $-1.05 \ln(WR_{t-3}) - 0.31 \ln(ERJA) - 0.23 \ln(ERTH)$ <p style="text-align: center;"> <span style="margin-right: 100px;">(5.59)</span> <span style="margin-right: 100px;">(2.24)</span> <span style="margin-right: 100px;">(2.49)</span> <span>(6.04)</span> </p> <p style="text-align: center;"> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">**</span> <span style="margin-right: 100px;">**</span> <span>***</span> </p> $-0.60 \ln(ERSP) - 5.19 \ln(RQM) - 0.21 \ln(T)$ <p style="text-align: center;"> <span style="margin-right: 100px;">(7.35)</span> <span style="margin-right: 100px;">(9.37)</span> <span>(13.77)</span> </p> <p style="text-align: center;"> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">***</span> <span>***</span> </p> <p>DW = 1.9675 <math>R^2 = 0.9848</math></p>
3	<p>Equation (18) Direct Tire Demand Estimation Results</p> $\ln(Q) = -1.10 - 0.37 \ln(P) + 0.50 \ln(VP) - 0.24 \ln(VI) + 0.36 \ln(T)$ <p style="text-align: center;"> <span style="margin-right: 100px;">(4.60) (5.03)</span> <span style="margin-right: 100px;">(6.01)</span> <span style="margin-right: 100px;">(2.23)</span> <span>(4.55)</span> </p> <p style="text-align: center;"> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">***</span> <span style="margin-right: 100px;">***</span> <span>**</span> <span>***</span> </p> <p>DW= 1.9700 <math>R^2 = 0.9955</math></p>

Item	2.1 Functional Forms and Estimation Results
4	<p>Equation (19) Direct Natural Rubber Supply Function Estimation Results</p> $\ln(XR) = -0.99 + 0.16 \ln(WR) - 0.06 \ln(ERJA) \cdot \ln(WR) - 0.04 \ln(ERJA) \cdot \ln(WR)$ <p style="text-align: center;">(20.45) (6.22) (2.68) (2.05)</p> <p style="text-align: center;">*** ** ** *</p> $+ 0.29 \ln(ERTH) + 0.05 DRXSM + 0.05 T$ <p style="text-align: center;">(5.80) (2.03) (16.43)</p> <p style="text-align: center;">*** ** ***</p> <p>DW=1.9933 R<sup>2</sup> = 0.9965</p>
Table 2 cont. 5	<p>Equation (3US): US Tire Production Estimation Results</p> $q_{US} = 0.53 + 0.37 x_{US} + 0.42 x_{US} - 2 \cdot 0.02 x_{US}^{1/2} \cdot x_{US}^{1/2} \cdot WO - 0.69 VI_{US} + 0.02 T$ <p style="text-align: center;">(3.31) (6.35) (7.49) (1.99) (2.11) (2.26)</p> <p style="text-align: center;">*** ** *** ** *</p> <p>DW=1.8821 R<sup>2</sup> = 0.9796</p>
6	<p>Equation (3FR) France's Tire Production Estimation Results</p> $q_{FR} = -0.14 + 0.68 x_{FR} + 0.11 x_{FR} - 2 \cdot 0.04 x_{FR}^{1/2} \cdot x_{FR}^{1/2} \cdot WO + 0.30 VP_{FR} + 0.01 T$ <p style="text-align: center;">(5.8) (9.56) (3.25) (21.07) (16.97) (5.43)</p> <p style="text-align: center;">*** ** *** *** ** *</p> <p>DW= 1.9816 R<sup>2</sup> = 0.9932</p>
7	<p>Equation (3JA) Japan's Tire Production Function Estimation Results</p> $q_{JA} = -0.17 + 0.80 x_{JA} + 0.37 x_{JA} - 2 \cdot 0.01 x_{JA}^{1/2} \cdot x_{JA}^{1/2} \cdot WO - 0.01 x_{JA} \cdot T + 0.01 T$ <p style="text-align: center;">(5.16) (8.06) (6.28) (1.85) (4.08) (3.10)</p> <p style="text-align: center;">*** ** *** * *** **</p> <p>DW = 1.8738 R<sup>2</sup> = 0.9979</p>

Item	2.1 Functional Forms and Estimation Results
8	<p>Equation (3GR) Germany's Tire Production Function Estimation Results</p> $q_{GR} = \underset{(1.89)}{0.37} + \underset{(2.81)}{0.39} x_{GR} + \underset{(3.45)}{0.41} x_{GR}^s - 2 \cdot \underset{(2.14)}{0.03} x_{GR}^{1/2} \cdot x_{GR}^{1/2} \cdot WO$ <p style="text-align: center;">* *      * *      * * *      * *</p> $+ \underset{(1.95)}{0.70} (V_{GR}) \cdot D_{91} - \underset{(2.11)}{1.21} D_{91}$ <p style="text-align: center;">*                      * *</p> <p>DW = 1.8709 R<sup>2</sup> = 0.9748</p>
Table 2 cont 9	<p>Equation (10.1US) Optimality Function for US Tire Manufacturing (Model 1) Estimation Results</p> $WR = \underset{(6.05)}{1.19} \hat{P}_{US} + \underset{(2.82)}{0.07} \hat{q}_{US} - \underset{(10.05)}{0.19} \hat{x}_{rUS}$ <p>(A)      * * *      * * *      * * *</p> <p>(<math>\theta_1 &gt; 1</math> whereas theory predicts <math>\theta_1 \leq 1</math>)</p> $WR = \underset{(4.43)}{0.23} - \underset{(13.45)}{0.21} \hat{x}_{rUS}$ <p>(B)      * * *      * * *</p> <p>DW = 1.9861 R<sup>2</sup> = 0.9123</p> <p>DW = 1.9331 R<sup>2</sup> = 0.8954</p>
10	<p>Equation (10.1FR) Optimality Function for France's Tire Manufacturing (Model 1) Estimation Results</p> $WR = \underset{(1.99)}{0.31} \hat{P}_{FR} + \underset{(1.72)}{0.06} \hat{q}_{FR} - \underset{(15.73)}{0.26} \hat{x}_{rFR}$ <p style="text-align: center;">* *              *              * * *</p> <p>DW = 1.9950 R<sup>2</sup> = 0.9620</p>

Item	2.1 Functional Forms and Estimation Results
11	<p>Equation (10.1JA) Optimality Function for Japan's Tire Manufacturing (Model 1)</p> <p>Estimation Results</p> $WR = 0.17 \hat{P}_{JA} - 0.09 \hat{q}_{JA} - 0.28 \hat{xr}_{JA}$ <p>(A) (0.31) (0.59) (13.05) DW= 1.9963 R<sup>2</sup>= 0.9488</p> <p style="text-align: center;">***</p> <p>(<math>\theta_1</math> and <math>\theta_2</math> are not significant)</p> $WR = 0.51 \hat{P}_{JA} - 0.28 \hat{xr}_{JA}$ <p>(B) (4.92) (13.05) DW= 2.0055 R<sup>2</sup>=0.9485</p> <p style="text-align: center;">*** **</p>
12	<p>Equation (10.1GR) Optimality Function for German Tire Manufacturing (Model 1)</p> <p>Estimation Results</p> $WR = 0.49 \hat{P}_{GR} + 0.07 \hat{q}_{GR} - 0.26 \hat{xr}_{GR}$ <p>(2.21) (1.82) (14.83)</p> <p style="text-align: center;">* * ***</p> <p style="text-align: right;">DW=1.9737 R<sup>2</sup>=0.9597</p>
Table 2 cont 13	<p>Equation (10.2US) Optimality Function for US Tire Manufacturing (Model 2)</p> <p>Estimation Results</p> $WR = 2.11 \hat{P}_{US} + 0.60 \hat{q}_{US} - 0.12 \hat{xr}_{US}$ <p>(A) (8.64) (6.77) (14.02) DW=1.9934 R<sup>2</sup>= 0.9582</p> <p style="text-align: center;">*** *** ***</p> <p>(<math>\theta_1 &gt; 1</math> whereas theory predicts <math>\theta_1 \leq 1</math>)</p> $WR = 0.56 \hat{P}_{US} - 0.11 \hat{xr}_{US}$ <p>(B) (2.19) (10.47) DW= 1.7696 R<sup>2</sup>= 0.9229</p> <p style="text-align: center;">** ***</p>



Item	2.1 Functional Forms and Estimation Results
14	<p>Equation (10.2FR) France's Optimality Function (Model 2) Estimation Results</p> $WR = 0.80 \hat{P}_{FR} + 0.11 \hat{q}_{FR} - 0.09 \hat{xr}_{FR}$ <p>(A) (1.57) (0.58) (7.73) DW=1.9001 R<sup>2</sup>=0.8990</p> <p style="text-align: center;">***</p> <p>(<math>\theta_1</math> and <math>\theta_2</math> are not significant)</p> $WR = 0.52 \hat{P}_{FR} - 0.09 \hat{xr}_{FR}$ <p>(B) (3.90) (8.17) DW=1.8958 R<sup>2</sup>=0.8989</p> <p style="text-align: center;">***      ***</p>
15	<p>Equation (10.2JA) Optimality Function for Japan's Tire Manufacturing (Model 2) Estimation Results</p> $WR = 1.15 \hat{P}_{JA} + 0.31 \hat{q}_{JA} - 0.13 \hat{xr}_{JA}$ <p>(A) (6.03) (3.00) (7.94) DW=1.9196 R<sup>2</sup>= 0.9065</p> <p style="text-align: center;">***      ***      ***</p> <p>(<math>\theta_1 &gt; 1</math> whereas theory predicts <math>\theta_1 \leq 1</math>)</p> $WR = 0.74 \hat{P}_{JA} - 0.11 \hat{xr}_{JA}$ <p>(B) (4.82) (7.09) <math>\theta_{32}</math> DW=1.9229 R<sup>2</sup>= 0.8870</p> <p style="text-align: center;">***      ***</p>

Item	2.1 Functional Forms and Estimation Results
Table2 cont 16	<p>Equation (10.2GR) Optimality Function for German Tire Manufacturing (Model 2)</p> <p>Estimation Results <math>WR = \theta_{12} \cdot \hat{P}_{GR} + \theta_{22} \cdot \hat{q}_{GR} - \theta_{32} \cdot \hat{x}r_{GR}</math></p> $WR = 2.75 \hat{P}_{GR} + 0.77 \hat{q}_{GR} - 0.11 \hat{x}r_{GR}$ <p>(A) (3.85) (2.82) (7.76) DW=1.8524 R<sup>2</sup>=0.9148 *** ** ***</p> <p>(<math>\theta_1 &gt; 1</math> whereas theory predicts <math>\theta_1 \leq 1</math>)</p> $WR = 0.27 - 0.10 \hat{x}r_{GR}$ <p>(B) (3.76) (10.65) DW=1.9326 R<sup>2</sup>= 0.9071 *** ***</p>
17	<p>Estimation Results for (21): Countries' Conjectural Elasticities in Global Tire Industry</p> $Q = -0.28 + 0.34 q_{US} + 0.17 q_{FR} + 0.12 q_{JA} + 0.14 q_{GR} + 0.01 T$ <p>(21.20)(18.20) (7.00) (8.89) (5.13) (23.73) *** **</p> <p>DW = 2.00 R<sup>2</sup> = 0.9996</p>
18	<p>Estimation Results for (22): Countries' Conjectural Elasticities in Global Natural Rubber Supply Market.</p> $XR = 0.01 + 0.17 xr_{US} + 0.30 xr_{FR} + 0.29 xr_{JA} + 0.05 xr_{GR} + 0.19 xr_{GR} \cdot D91$ <p>(0.19)(3.64) (3.47) (8.46) 0.53 (2.59) *** **</p> <p>-0.07WO (4.07) ***</p> <p>DW = 1.9563 R<sup>2</sup> = 0.9951</p>

Item	2.1 Functional Forms and Estimation Results
.	<p><sup>#</sup> In equation (1) denotes imposed value. The argument that each new vehicle needs at least 5 tires is applied by fixing <math>VP</math>'s coefficient = 5. This reflects the need to deduct <math>5VP</math> from total tire output in the demand equation because it will not be altered by tire price changes. See Carree &amp; Thurik (2000) for more details.</p> <p>Equations (10.1US), (10.1FR), (10.1JA) and (10.1GR) refer to estimated results of equation (10) for US, FR, JA and GR for Model 1. In contrast, equations (10.2US), (10.2FR), (10.2JA) and (10.2GR) refer to estimated results of equation (10) for US, FR, JA and GR for Model 2.</p> <p>*** denotes rejection of null hypothesis at less than 1% level of significance.</p> <p>** denotes rejection of null hypothesis at 5% level of significance.</p> <p>* denotes rejection of null hypothesis at 10 % level of significance.</p>

2.2 Variables		
Variable	Description	Source
<i>CPIJA</i>	Japan's consumer price index	United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). <a href="http://www.unescap.org/">http://www.unescap.org/</a>
<i>CPISP</i>	Singapore's consumer price index	United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). <a href="http://www.unescap.org/">http://www.unescap.org/</a>
<i>CPITH</i>	Thailand's consumer price index	United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). <a href="http://www.unescap.org/">http://www.unescap.org/</a>
<i>CPIUS1</i>	US consumer price index	US Bureau of Labor Statistics. <a href="http://www.bls.gov">http://www.bls.gov</a>

2.2 Variables		
Variable	Description	Source
<i>D91</i>	a dummy variable assigned to incorporate the effect of data structural break caused by the reunification in 1991	(Dummy variable)
<i>DRXSM</i>	Structural change dummy variable for a change in the mix of natural rubber and synthetic rubber following introduction of the radial tire .(1970 - 2000 = 1)	(Dummy variable)
Table2 cont. <i>ERJA</i>	Japan's currency exchange rates (100Yen/\$US)	The Bank of Thailand. <a href="http://www.bot.or.th">http://www.bot.or.th</a>
<i>ERSP</i>	Singapore's currency exchange rates(\$\$/ \$US)	The Bank of Thailand. <a href="http://www.bot.or.th">http://www.bot.or.th</a>
<i>ERTH</i>	Thailand's currency exchange rates (Baht/\$US)	The Bank of Thailand. <a href="http://www.bot.or.th">http://www.bot.or.th</a>
<i>INRO</i>	The International Natural Rubber Organization	(Dummy variable)
<i>GDPPUS</i>	US per capita income	The World Bank. <a href="http://www.worldbank.org/">http://www.worldbank.org/</a>
<i>P</i>	Tire prices: US tire price index	US Bureau of Labor Statistics. <a href="http://www.bls.gov">http://www.bls.gov</a>
<i>Q</i>	World tire production	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
<i>q<sub>FR</sub></i>	Tire production (France's passenger car tires and truck tires)	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
<i>q<sub>GR</sub></i>	Tire production (Germany's passenger car tires and truck tires).	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>

2.2 Variables		
Variable	Description	Source
$q_{JA}$	Tire production (Japanese passenger car tires and truck tires)	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$q_{US}$	Tire production (US passenger car tires and truck tires)	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
Table 2.2 cont. $RAIN$	Rainfall quantity	The Royal Irrigation Department, Thailand. <a href="http://www.rid.go.th/">http://www.rid.go.th/</a>
$RQM$	Top seven countries' quantity / total quantity ratio. Top seven tire producing countries are US, France, Japan, Germany, Italy, UK and India.	Compiled from International Rubber Study Group
$T$	A time trend.	-
$VI$	World passenger car and commercial vehicles in-use.	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
Table2 cont. $VI_{GR}$	Vehicle in-use in Germany (only Passenger cars).	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$VI_{US}$	Total vehicle in-use in the US.(passenger car and commercial vehicle)	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$VP$	World passenger car and commercial vehicle production	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$VP_{FR}$	Total vehicle production in France (passenger car and commercial vehicle)	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$WO$	World crude oil price, Spot Oil Price (West Texas Intermediate)	Federal Reserve Bank of St. Louis, Economic Research. <a href="http://research.stlouisfed.org">http://research.stlouisfed.org</a>
$WR$	Natural Rubber Price: RSS1 natural rubber prices, fob Malaysia ringgit/ton	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>

2.2 Variables		
Variable	Description	Source
$WS_{t-3}$	Synthetic rubber price lagged by 3 years	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$XR$	World Natural Rubber Production	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$xr_{FR}$	Quantity of natural rubber used in Tire sector in France.	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$xr_{GR}$	Quantity of natural rubber used in tire sector in Germany.	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
$xr_{JA}$	Quantity of natural rubber used in Tire sector in Japan.	International Rubber Study Group. <a href="http://www.rubberstudy.com/">http://www.rubberstudy.com/</a>
Table 2.2 cont. $xr_{US}$	Quantity of natural rubber used in tire sector in the US.	International Rubber Study Group
$xs_{FR}$	Quantity of synthetic rubber used in Tire sector in France.	International Rubber Study Group
$xs_{GR}$	Quantity of synthetic rubber used in tire sector in Germany.	International Rubber Study Group
$xs_{JA}$	Quantity of synthetic rubber used in tire sector in Japan.	International Rubber Study Group
Table2 cont. $xs_{US}$	Quantity of synthetic rubber used in tire sector in the US.	International Rubber Study Group

From the estimations in Table 2, the elasticity estimates were derived from both inverse and direct demand and supply functions (items 1-4: equations 1, 2, 18, 19). The values of natural rubber marginal productivity for tire production for each country were derived from individual country's tire production functions (items 5-8: equation 3US, 3FR, 3JA, 3GR) as displayed in Table A1 in the Appendix.

The estimations for  $\theta_1$ ,  $\theta_2$  and  $\theta_3$  were derived from the estimations of the optimality equations (10) in the section 3. Estimation equations 10.1US, 10.1FR, 10.1JA and 10.1GR (items 9-12) refer to estimated results from Model 1 for USA, France, Japan and Germany. This gave each country's conjectural elasticities  $\alpha_i$ ,  $\beta_i$  and the  $MPI_i$  for Model 1, identified as in section 3, equations (16), (17) and (9) where  $MPI_{XRi1} = \frac{\varepsilon \cdot \beta_{i1} - \eta \cdot \alpha_{i1}}{1 + \varepsilon \cdot \beta_{i1}}$ .

Similarly, each country's conjectural elasticities  $\alpha_i$ ,  $\beta_i$  for Model 2 were obtained from the  $\theta_2$  and  $\theta_3$  estimates from the estimations for equations 10.2US, 10.2FR, 10.2JA and 10.2GR (items 13-16). Then the  $MPI_i$  for Model 2 was derived, as identified in equation (20)

$$\text{in section 3: } MPI_{XRi2} = \frac{\frac{\beta_{i2}}{\varepsilon^*} + \frac{\alpha_{i2}}{\eta^*}}{1 + \frac{\beta_{i2}}{\varepsilon^*}}.$$

Remarkably were the results from some estimation that involve difficulty hence require supplementary estimations to derive qualified outcomes. The problems were:

- a)  $\theta_1$  in the initial estimations for France's Model 2 (10.2FR) and Japan's Model 1 (10.1JA) were insignificant.
- b)  $\theta_1$  in the initial estimations from US's Model 1 (10.1US) and Model 2 (10.2US), Japan's Model 2 (10.2JA) and Germany' Model 2 (10.2GR) were greater than 1 whereas theory predicts  $\theta_1 \leq 1$ ; hence they were theoretically inconsistent and called for further investigations.

As the critical test for oligopsony is based on the conjectural elasticity  $\beta_i$ , A competitive input market is implied by  $\beta_i = 0$ . Oligopsony is implied by  $0 < \beta_i < 1$  and monopsony is implied by  $\beta_i = 1$ . Hence, the estimations involving problems were resolved by supplementary estimations (B) restricting  $\theta_2 = 0$  or allow for a constant term to accommodate the combined effects of  $\theta_1$  and  $\theta_2$ .

All outcomes in the supplementary estimations confirmed the rejection of the null that  $\theta_3 = 0$  as found in their corresponding initial estimations (A), with some lower  $MPI_{XRi}$  results.

Thus even if it was assumed that output market was competitive, market power evidence still existed.

To obtain the  $\alpha_{i3}$  and  $\beta_{i3}$  for Model 3, equations (21) and (22) were estimated as listed in items 17 and 18 in Table 2. Consequently, the  $MPI_{XRi3} = \frac{\varepsilon \cdot \beta_{i3} - \eta \cdot \alpha_{i3}}{1 + \varepsilon \cdot \beta_{i3}}$  for Model 3 was derived as identified in equation (25) in section 3. The  $MPI_{XRi4} = \frac{\frac{\beta_{i3}}{\varepsilon^*} + \frac{\alpha_{i3}}{\eta^*}}{1 + \frac{\beta_{i3}}{\varepsilon^*}}$  for

Model 4 was obtained as described in equation (26).

The hypothesis tests and the derived values of each country's conjectural elasticity in the world markets of tire and natural rubber and the corresponding market power indexes from all of the four models are reported in Table A2 in the Appendix. Both initial estimation (A) and supplementary estimation (B) for Model 1 and Model 2 for each country are listed.

Finally Table 3 compares the market power index for each country. The MPI values reported are selected from preferred models. Results that involve statistically insignificant estimates (initial estimations (A) for France' Model 2 and Japan's Model 1) as well as theoretically conflicting estimates (initial estimations (A) for US's Model 1 & 2, Japan's Model 2 and Germany's Model 2) are provided in the corresponding remarks. The outcomes from Model 3 & 4 are consistent with Model 1 and Model 2 with higher levels of the MPI index for each country.

Results indicate that US has the top market power index, judged by Model 2, 3, and 4. France has the second highest level of market power, judged by Model 1, 3, and 4. Japan has the third highest level of market power, judged by Model 1, 3, and 4. Germany has the least market power, judged by Model 3 and Model 4. Model 3 and Model 4 give similar ranking results.

Thus, estimated results imply that the tire industry in US, France, Japan and Germany have market power (oligopsony) on the world natural rubber market. Results are reconciled between inverse and direct function approaches for tire demand and natural rubber supply. In



addition, in each approach outcomes are confirmed between the derived and directly estimated conjectural elasticities in tire and natural rubber markets. Results from empirical estimations are reconciled between initial and supplementary estimations.

**Table 3**  
**Market Power Index**

Country	$MPI_{Xri}$			
	Model 1	Model 2	Model 3	Model 4
	Inverse Elasticity ( $\eta, \varepsilon$ )	Direct Elasticity ( $\eta^*, \varepsilon^*$ )	Inverse Elasticity ( $\eta, \varepsilon$ )	Direct Elasticity ( $\eta^*, \varepsilon^*$ )
	Indirectly estimated conjectural elasticities ( $\alpha_{i1}, \beta_{i1}$ )	Indirectly estimated conjectural elasticities ( $\alpha_{i2}, \beta_{i2}$ )	Directly estimated conjectural elasticities ( $\alpha_{i3}, \beta_{i3}$ )	
	$MPI_{Xri1}$	$MPI_{Xri2}$	$MPI_{Xri3}$	$MPI_{Xri4}$
<b>U.S.</b> <sup>#1</sup>	0.4133	0.4180	1.0442	0.9598
<b>France</b> <sup>#2</sup>	0.5608	0.3740	0.7672	0.8190
<b>Japan</b> <sup>#3</sup>	0.4754	0.3950	0.6787	0.7673
<b>Germany</b> <sup>#4</sup>	0.5805	0.3934	0.5907	0.5935
<sup>#1</sup> Other estimates for $MPI_{US}$ are 0.5243 from Model 1 estimation A and 1.3517 from Model 2 estimation A, but they are derived from $\theta_1 > 1$ whereas theory predicts $\theta_1 \leq 1$ . <sup>#2</sup> Other estimates from Model 2 estimation A for $MPI_{FR}$ gave statistically insignificant estimates for $\theta_1$ and $\theta_2$ hence are not reported. <sup>#3</sup> Other estimates from Model 1 estimation A gave statistically insignificant estimates for $\theta_1$ and $\theta_2$ hence are not reported. The other outcome of 0.8937 from Model 2 estimation A is derived from $\theta_1 > 1$ whereas theory predicts $\theta_1 \leq 1$ . <sup>#4</sup> Other estimates from Models 2 estimation A for $MPI_{GR}$ is 1.6314. It is derived from $\theta_1 > 1$ whereas theory predicts $\theta_1 \leq 1$ .				

## 5. Conclusions and Policy Recommendations

As the results reveal the existence of market power from the natural rubber buying countries on the natural rubber selling countries, it is important to look for some policies to alleviate, if could not eliminate, the degree of the market power, in order to help improving the economic efficiency as well as the social welfare of the natural rubber farmers. One of the approaches could be considered from the components of the market power index formula, namely the tire demand price elasticity ( $\eta$ ), the natural rubber supply price elasticity ( $\mathcal{E}$ ), the tire industry output selling conjectural elasticity ( $\alpha$ ), and the natural rubber industry buyer conjectural elasticity ( $\beta$ ). As discussed in 3.5: inefficiency in resource allocation is increased by low values of  $\eta$ , and  $\mathcal{E}$ , and high values of  $\alpha_i$  and  $\beta_i$ .

The tire demand price elasticity ( $\eta$ ) is difficult to manage as tires are essential to vehicle safety hence consumers tend to have high brand loyalty. It is also of small sections of new vehicle production and are fixed to five pieces per unit hence has low elasticity demand. The tire industry output selling conjectural elasticity ( $\alpha$ ) as well as the natural rubber industry buyer conjectural elasticity ( $\beta$ ) could be reduced by enhancing more tire producing firms. Whereas famous and outstanding tire brands are dominating the global markets, options might be for natural rubber producing countries to penetrate new markets in other countries namely the emerging economies from the previous Union of Soviet Socialist Republics (USSR) and the growing economy of China. To support the expansion of independent domestic tire manufacturing industry in such economies could help dilute the existing oligopsony market power of the dominant western country manufacturers. Finally the natural rubber supply price elasticity ( $\mathcal{E}$ ) could be raised by policy makers, via appropriate measures. Whereas some agricultural policies widely employed by countries are to increase demand for the specific crops or to provide direct grants, in markets dominated by market power from the buyer such as this, the benefit would only be expropriated by the buyers. Hence, to raise supply elasticity should be more effective as identified by the MPI components, i.e., a high natural rubber supply elasticity ( $\mathcal{E}$ ) would reduce the degree of market power. Consequently, a strategy to

achieve some degree of higher supply elasticity for agricultural commodity is to provide income insurance to farmers , price and income alike (Jones, 1994). With higher security in earnings, farmers would have higher flexibility to choose to sell their products at a time of better prices, resulting to a higher supply elasticity ( $\epsilon$ ).Income insurance could also be managed through a fund. These will not be a cost to general tax payers. Improving the quality of natural rubber such as to produce more processed rubber (block rubber) could help to generate more value added hence higher prices to natural rubber.

In closing, the results obtained, the derived interpretation and policy recommendation above are limited by the model construction used that applied the firm/industry theory to a country/world context using aggregate data at the country and world level. In addition, as in any study, model specification and equation functional forms employed have effects on estimation results too.

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## Appendix

### Appendix 1. The Derivation of equation (8)

From equation (7)

$$P.MP_{XRi}(\eta \cdot \alpha_i + 1) = WR(\varepsilon \cdot \beta_i + 1)$$

Bringing key variables to the right hand side yields:

$$\frac{WR}{P.MP_{XRi}} = \frac{\eta \cdot \alpha_i + 1}{\varepsilon \cdot \beta_i + 1}$$

Multiply both sides by -1 and add  $(P.MP_{XRi} / P.MP_{XRi})$  to both sides.

$$\frac{P.MP_{XRi}}{P.MP_{XRi}} - \frac{WR}{P.MP_{XRi}} = 1 - \frac{\eta \cdot \alpha_i + 1}{1 + \varepsilon \cdot \beta_i}$$

Simplify as follows:

$$\frac{P.MP_{XRi} - WR}{P.MP_{XRi}} = \frac{\varepsilon \cdot \beta_i - \eta \cdot \alpha_i}{1 + \varepsilon \cdot \beta_i}$$

## Appendix 2. Estimated Coefficients.

**Table A1:**  
**Demand and Supply Elasticity Estimates and Natural Rubber**  
**Marginal Product Estimates**

<b>Demand and Supply Elasticity Estimates</b>	Inverse Function	Direct Function
World inverse tire demand elasticity	$\eta = -3.3439$	$1/\eta^* = -2.6989$
World direct tire demand elasticity	$1/\eta = -0.3804$	$\eta^* = -0.3705$
World inverse natural rubber supply elasticity	$\varepsilon = 3.3405$	$1/\varepsilon^* = 6.8768$
World direct natural rubber supply elasticity	$1/\varepsilon = 0.3005$	$\varepsilon^* = 0.1494$
Table A1 (cont.)		
<b>Natural Rubber Marginal Product Estimates</b>		
U.S. ( $v_{US}$ )	0.3556	
France ( $v_{FR}$ )	0.6343	
Japan ( $v_{JA}$ )	0.5673	
Germany ( $v_{GR}$ )	0.3654	

### Appendix 3. Calculated Conjectural Elasticities and Hypothesis tests

**Table A2:**  
**Summary of Hypothesis Test<sup>#1</sup>, Conjectural Elasticities, and  $MPI_i$**

Hypothesis Test Summary <sup>#1</sup>					Conjectural Elasticities and $MPI_i$		
<b>4US</b>	H0: $\theta_1 = 1$	H0: $\theta_2 = 0$	H0: $\theta_3 = 0$	H0: $\theta_1=1,$ $\theta_2=0,$ $\theta_3=0$	$\alpha_i$	$\beta_i$	$MPI_{X_{Ri}}$
<b>US</b>							
<b>Model1 (10.1US)</b>							
Estimate A	Not reject <sup>#2</sup>	Reject	Reject	Reject	0.0732 <sup>#2</sup>	0.1884 <sup>#2</sup>	0.5243 <sup>#2</sup>
Estimate B	-	-	Reject		-	0.2124	0.4133
<b>Model2(10.2US)</b>							
Estimate A	Reject <sup>#2</sup>	Reject	Reject	Reject	0.6171 <sup>#2</sup>	0.1239 <sup>#2</sup>	1.3517 <sup>#2,#3</sup>
Estimate B	Reject	-	Reject	Reject	-	0.1086	0.4180
<b>Model3</b>	-				0.3385	0.1709	1.0442 <sup>#3</sup>
<b>Model4</b>							0.9598

Table A2 (cont.) Hypothesis Test Summary <sup>#1</sup>					Conjectural Elasticities and $MPI_i$		
<b>4 FR</b>	H0: $\theta_1 = 1$	H0: $\theta_2 = 0$	H0: $\theta_3 = 0$	H0: $\theta_1=1,$ $\theta_2=0,$ $\theta_3=0$	$\alpha_i$	$\beta_i$	$MPI_{X_{Ri}}$





Table A2 (cont.)							
Hypothesis Test Summary <sup>#1</sup>					Conjectural Elasticities and $MPI_i$		
4GR	H0: $\theta_1 = 1$	H0: $\theta_2 = 0$	H0: $\theta_3 = 0$	H0: $\theta_1=1,$ $\theta_2=0,$ $\theta_3=0$	$\alpha_i$	$\beta_i$	$MPI_{XRI}$
Germany							
Model1(10.1GR)							
Estimate A	Reject	Reject	Reject	Reject	0.0721	0.2616	0.5805
Model 2(10.2GR)							
Estimate A	Reject <sup># 2</sup>	Reject	Reject	Reject	0.7819 <sup>#2</sup>	0.1109 <sup>#2</sup>	1.6314 <sup>#2,#3</sup>
Estimate B	-	-	Reject	-		0.0991	0.3934
Model 3					0.1427	0.1046	0.5907
Model 4							0.5935
Hypothesis Test Summary <sup>#1</sup>					Conjectural Elasticities and $MPI_i$		
(table A2 cont.)	H0: $\theta_1 = 1$	H0: $\theta_2 = 0$	H0: $\theta_3 = 0$	H0: $\theta_1=1,$ $\theta_2=0,$ $\theta_3=0$	$\alpha_i$	$\beta_i$	$MPI_{XRI}$
<div><sup>#1</sup> All <math>\theta</math> estimates are significant unless otherwise stated.</div> <div><sup>#2</sup> <math>\theta_1 &gt; 1</math> whereas theory predicts <math>\theta_1 \leq 1</math>.</div> <div><sup>#3</sup> Theory predicts <math>MPI \leq 1</math> US.</div> <div><sup>#4</sup> <math>\theta_1</math> and <math>\theta_2</math> are not significant.</div>							

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