Innovation and natural resource based development
Case of natural rubber sector in Kerala, India

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Abstract

It has long been held that natural resource abundance retards economic growth. Studies using innovation system perspective, however, suggest that natural resource abundance *per se* need not stand in the way of evolving a growing and diversified economy while the absence of learning and innovation could. In this context, the present study explores why Kerala has not been successful in evolving a diversified manufacturing sector despite natural resource abundance. This issue has been addressed by taking the case of natural rubber known for its R&D led output growth and productivity enhancement. Analytically, it draws insights from the ongoing discourse in the innovation system literature that distinguishes between narrow and broad approaches to innovation processes. It is argued that while the narrow approach to innovation could lead to increased productivity and growth of natural rubber under tariff protection, it could not help in evolving a vibrant rubber based industrial sector by harnessing backward and forward linkages. In sync with the studies that underline the complementary role of science based learning and experience based learning in accomplishing innovation led long term development, the paper makes the case for evolving broad innovation system in natural rubber that creates linkages among various actors and heterogeneous knowledge bases.

Key words: Natural resource based development, STI and DUI mode of learning, narrow and broad innovation system, natural rubber, Kerala

Introduction

The insight that natural-resource based economies may experience long term growth and welfare has been re-discovered during the latest decade drawing on historical and contemporary experience of developed economies (USA, Australia, New Zealand, Canada, Nordic countries).[2] This group of countries have experienced growth and welfare with a relatively large natural resource sector and/or specialisation within this type of production, combined with a relatively

[1] All the authors contributed equally and names are listed in alphabetical order.
[2] The studies considering natural resource abundance as a curse were criticized with regard to the methodology and indicator used for natural resource abundance, time period chosen and the conclusions arrived at. Further, another set of studies highlighted the role of institutions as well as innovations in turning resource curse into blessing for the countries.

small manufacturing sector and limited high-tech industry (David and Wright 1997; Wright and Czelusta 2002, Smith 2007; Fagerberg, Mowery and Verspagen 2009, Ville and Wicken 2013). We define this type of historical development as a natural resource based development path.

The economies which have followed a natural resource based development path constitute a heterogeneous group of countries shaped by differences in their types of core innovation processes. We distinguish between innovation processes that i) lead to increased productivity and growth within the existing natural resource industries; and ii) processes that contribute to diversification (into new products and industries) of the economy. While the first type of processes is important for growth in the shorter historical perspective, the latter constitute the core element for sustained long-term economic development. For the analysis of the different strategies we draw on the distinction between narrow and broad innovation systems. In our study the strategy of increasing production and productivity is supported by a narrow innovation system mainly focusing on science-based knowledge and technologies. We argue that this approach has been insufficient to promote diversification, and that a diversification strategy demands development of a broad innovation system which includes not only science based but also experience based knowledge.

We draw on this conceptual framework in the analysis of the development of the state of Kerala in India, which is richly endowed with natural resources (which includes cashew, coir, natural rubber, marine products, and forests among others). Many of these industries have experienced growth and increased productivity over long period of time, and have contributed to Kerala's achievement in terms of high per capita GDP and high human development. However, evidence suggests that Kerala has not been successful in diversifying into thriving new products and industries linked to the existing natural resource industries[3]. We approach this issue empirically by analyzing natural rubber, the largest resource based sector in Kerala.[4] Natural rubber

[3] Scholars have for a long time argued that Kerala has a "backward industrial structure" (Subrahmanian and Pillai 1986, Subrahmanian 1990) which was expected to slow down growth and development in the long run. However, some scholars (Harilal and Joseph 2003) have shown the revival of the Kerala economy since 1987. While they have called for greater role of science, technology and knowledge intensive sectors in sustaining Kerala's development trajectory; Kannan (2005) highlighted the role of human development in the revival of the Kerala economy.

[4] Natural rubber has evolved over the years as one of the largest resource based sectors in Kerala, as agriculture gradually shifted from rice cultivation to that of perennial tree crops (tea, coffee, coconut, cashew and spices) from 1970s (Joseph and Joseph 2005; Kannan and Pushpangadan 1990), and has become a prominent part of the plantation sector. In 2013-14, natural rubber occupied 26.73 per cent of net sown area and contributed to almost 45 per cent of agricultural GDP. In 2012, there were more than 1.1 million rubber holdings in Kerala, and nearly 10 per

production has been developed as a part of science-driven national strategy to make India independent of import. It has resulted in long term growth and productivity improvement (until 2011). However, this strategy did not contribute to industrial diversification and structural change, and we raise the following question: How to account for the combination of long term growth and productivity improvement, and relative lack of industrial diversification based on the natural rubber sector?

The paper is organised in the following way. Section 2 presents a brief overview of the existing literature with a view to locate the specific issues for enquiry and to provide the analytical framework of the study. Section 3 presents the empirical evidence for the existence of a narrow innovation system focused on creating linkages between science-based institutions and the production sector. Section 4 highlights the missing linkages required for broad based innovation system, which is necessary for facilitating a natural resource led development path under globalization. Section 5 provides concluding observations and the broad contours of a strategy for facilitating broad-based development.

2. Review of Literature

In this section we present some of the findings of the emerging literature on natural resource based development paths. Since the mid-20th century, economists have discussed the relationship between natural-resources and economic development (Prebisch 1950; Singer 1950, Hirschman 1958). During the 1990s, the discourse was intensively linked to the 'resource curse hypothesis', which states that there is an inverse relationship between abundance of natural resources in the economy and long run economic growth (Sachs and Warner 1995, 1997, 1999; Gylfason 2001; Sala-i-Martin and Subramanian 2003). In line with this, researchers within innovation studies have also argued that natural resource based development is problematic due to limited opportunities for learning and diversification through linkages (Andersen et al. 2015: 10).

This position has been challenged by recent studies of economies which have experienced a combination of long term growth and transformation with specialization in natural resources; drawing on both historical, developmental and innovation approaches. Andersen et al. (2015) describes how this new perspective builds on experiences from both high-income countries like

cent of the population of 35 million is directly or indirectly influenced by the performance of the industry (accessed from http://niti.gov.in/writereaddata/files/Kerala_Report_0.pdf on 1st August, 2016)

Australia, Norway, USA (David and Wright 1997, Smith 2007, Fagerberg, Mowery and Verspagen 2009: Ville and Wicken 2013); middle income countries in South America (Andersen 2012, Dantas 2011, Iizuka and Katz 2010; Marin and Smith 2011); and also low-income countries in Sub-Saharan Africa (Morris et al. 2012, Kaplinsky 2012, Teka 2011, Ovadia 2014).

The theoretical arguments for low learning in natural resource industries is based on the assumption that the natural resources are mainly extracted from nature and involves limited manufacturing processes as it happens in conventional industries. Since, extraction or harvesting demands minimal effort and involves limited number of actors, the scope for interactive learning and innovation is limited (Humphreys, Sachs and Stiglitz 2007).[5] This assumption has been challenged by various empirical studies. David and Wright (1997) for instance illustrates how modern natural resource industries have been transformed from simple harvesting of natural resources to knowledge intensive and learning industries and economies. In a historical analysis of the mining industry in the USA during the early 20th century, they describe a dynamic transformation of the industry, arguing that even the natural resource endowment itself was a social construct and an outcome of innovative activities involving knowledge and learning.[6] They also show how the mining industry became a core sector for the long term development of the US economy into a modern knowledge-based economy:

"We find … that late nineteenth century American mineral expansion embodied many of the features that typify modern knowledge-based economies: positive feedbacks to investments in knowledge, spillover benefits from one mining specialty to another, complementarities between public- and private-sector discoveries, and increasing returns to scale—both to firms and to the country as a whole". (David and Wright, 1997: 204-205).

This is illustrated in various types of natural resource industries – hard resources (minerals, oil) as well as soft resources such as agriculture (Smith 2007), marine products (Dietrich 1995[7]). These studies argue that problem solving activities in natural resource industries – as extension

[5] The authors claim (p. 4) that "unlike other sources of wealth, natural resource wealth does not need to be produced. It simply needs to be extracted … Since it is not a result of a production process, the generation of natural wealth can occur quite independently of other economic processes that take place in a country; it is in a number of ways "enclaved". For example, it can take place without major linkages to other sectors and it can take place without the participation of large segments of the domestic labor force".

[6] A critique of the assumption that nature, being freely available, is equal to harvested products is discussed in Andersen 2012.

[7] The study by Dietrich (1995) on fish farming shows that demand for technologies and knowledge bases ranges from various bio-related sciences, to mathematics, thermodynamics, acoustics, optics, materials technology, ICT, robotics, spectography, chromography, engineering, as well as transport theory, mechanics, welding, refrigeration technology and many others.

of resources, production technology, and improvement of product quality - involve learning processes in line with innovation processes in other sectors of the economy.

It is evident from the above studies that there is a close connection between long term development and increased diversification. The increased complexity emerges from interactions between various activities and capabilities in the economy. Thus viewed an economy with low diversification will have more challenges in developing further diversification (Andersen et al. 2015; Hidalgo et al. 2007). Innovation system studies typically consider structural change within industries as an outcome of innovation processes and inter-industry (vertical) linkages. Hirschman's (1958, 1981) unbalanced growth approach points to linkages between firms in distinctly different sectors inducing tensions and disequilibrium as source for innovation. He argued that linkages from natural resource industries – particularly backward linkages - were weak and therefore not a strong basis for economic development.[8] This assumption is also challenged by the emerging literature on natural resource dynamics. Backward diversification is seen as an outcome of problem solving and innovation in natural resource industry. The demand for knowledge and competence in innovation processes becomes a market potential for specialized organizations and firms providing technologies and knowledge. This dynamic relationship between the specialized knowledge intensive firms (enabling sector) providing input to innovation in firms in natural resource industries (recipient sectors) is a core process for industrial diversification. (Pol et al. 2002; Ville and Wicken 2013). In some countries, the enabling sector (capital goods, machinery, knowledge intensive services) and organisations (R&D, universities) have emerged as significant export industries (Finland is major exporter of machinery for forest industries; South Africa and Australia of mining equipment, Norway in offshore oil technology).

Diversification through forward linkages involves development of manufacturing production using the primary product or natural resource as input; including processing, semi-finished products and finished products directed towards business or consumer markets. This has been a common development path in high-income economies where old primary industries (like iron,

[8] Backward linkages works through its influence on the demand for the means of production and another inputs to the natural resource sector. Thereby stimulating sectors producing machinery as well as service sectors, along with demand for science and skills involving knowledge institutions. Forward linkages involves linkages with sectors that helps in adding value to the natural resource commodity.

steel), have been extended into processed semi-finished products (sheets of steel), used in finished products (ships, cars). Forward linkages emerge partly from the character of the primary product, i.e. demand for evolving new products through processing of particular soft commodities (like in natural rubber); or from strategies of the natural resource providers as part of achieving a stronger position in the commodity value chain (Morris et al. 2012: 36).

While backward linkages are developed as result of demand for inputs in problem solving or innovative activities within the natural resource firm, forward linkages involves engaging in new business opportunities in sectors where the firms have limited knowledge. The challenge for a producer of natural resource to enter into innovation process with the user industry, may be seen from a user-producer learning perspective. Lundvall (1992: 50) raises the fundamental question: "How can the producer know the needs of potential users, when markets separate users from producers". He claims that in the real world most markets are not pure and organised by anonymous relationship between buyers and sellers, but rather characterized by trust among involved partners which creates basis for mutual exchange of information and/or direct cooperation. Collaboration in innovation processes involving user-producer interaction across sectors (i.e. natural rubber producers and rubber manufacturing) therefore demands existence of organised markets involving social relations across industrial sectors.

2.1 Innovation system for industrial dynamics in natural rubber production

In this study we draw on innovation system literature and approaches to analyze the development of the natural rubber industry in India, using the distinction between narrow and broad approaches (Lundvall 2007). The narrow approach is in tune with the analysis of national science systems and national technology policies (Nelson 1993, Mowery and Oxley 1995). It is aimed at mapping indicators of national specialization and performance with respect to research and development efforts and interaction among science and technology organizations. The policy issues raised were almost exclusively in the realm of explicit S&T policy focusing on R&D. The R&D based narrow system can be characterized as involving predominantly STI (Science, Technology and Innovation) mode of learning. STI mode is based on the production and use of codified, scientific and technical knowledge (Jensen et al. 2007), and is a science-push/supply driven strategy for producing radical innovations (Asheim 2016). Contrary to the narrow approach, the broad approach 'includes all parts and aspects of the economic structure and the

institutional set-up affecting learning as well as searching and exploring – the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place' (Lundvall 2016: 97). This approach takes into account user producer interactions, social institutions, macroeconomic regulations, financial systems, education and communication infrastructures as far as these have impact on learning and competence building process (Gu and Lundvall 2006). Thus the broad approach, in addition to the STI mode of learning, gives due recognition to the experience-based DUI (Doing, Using and Interacting) mode of learning[9]. DUI mode of innovation is a user (market or demand) driven model and is particularly characterized by its focus on harnessing experience-based knowledge and it is centered more on competence building, organisational innovations and production of mostly incremental innovations (Asheim 2016). Along with R&D departments and universities, the DUI mode also focuses on interactive learning between users and producers (Isaken and Nilsson 2013).

Using the distinction between narrow and broad approach to innovation as an analytical tool in understanding the natural resource based development path in Kerala, we develop a model for the specific context of primary agricultural commodities. Similar to Green Revolution strategy in agriculture, the innovation process in natural rubber had its focus on R&D for enhancing crop productivity. The strategy was aimed at making India self-sufficient in natural rubber, which was regarded as a strategic industrial raw material in the post second world war period. This was basically a top-down/science push approach followed for developing and diffusing knowledge and technologies to the growers. The promotional measures of Rubber Board and Rubber Research Institute of India (RRII) were directed only towards increasing production and improving the productivity of the primary sector. This policy was based on the assumption that scientific knowledge was the main knowledge base, and that science based knowledge and technologies would flow easily from research institutes to the growers. Within this narrow approach[10] (see figure 1) the Rubber Board/RRII has remained as a dominant provider of knowledge for the rubber sector from the early phase. The interaction between RRII and other actors such as universities and other research institutes mostly centered on STI driven mode of

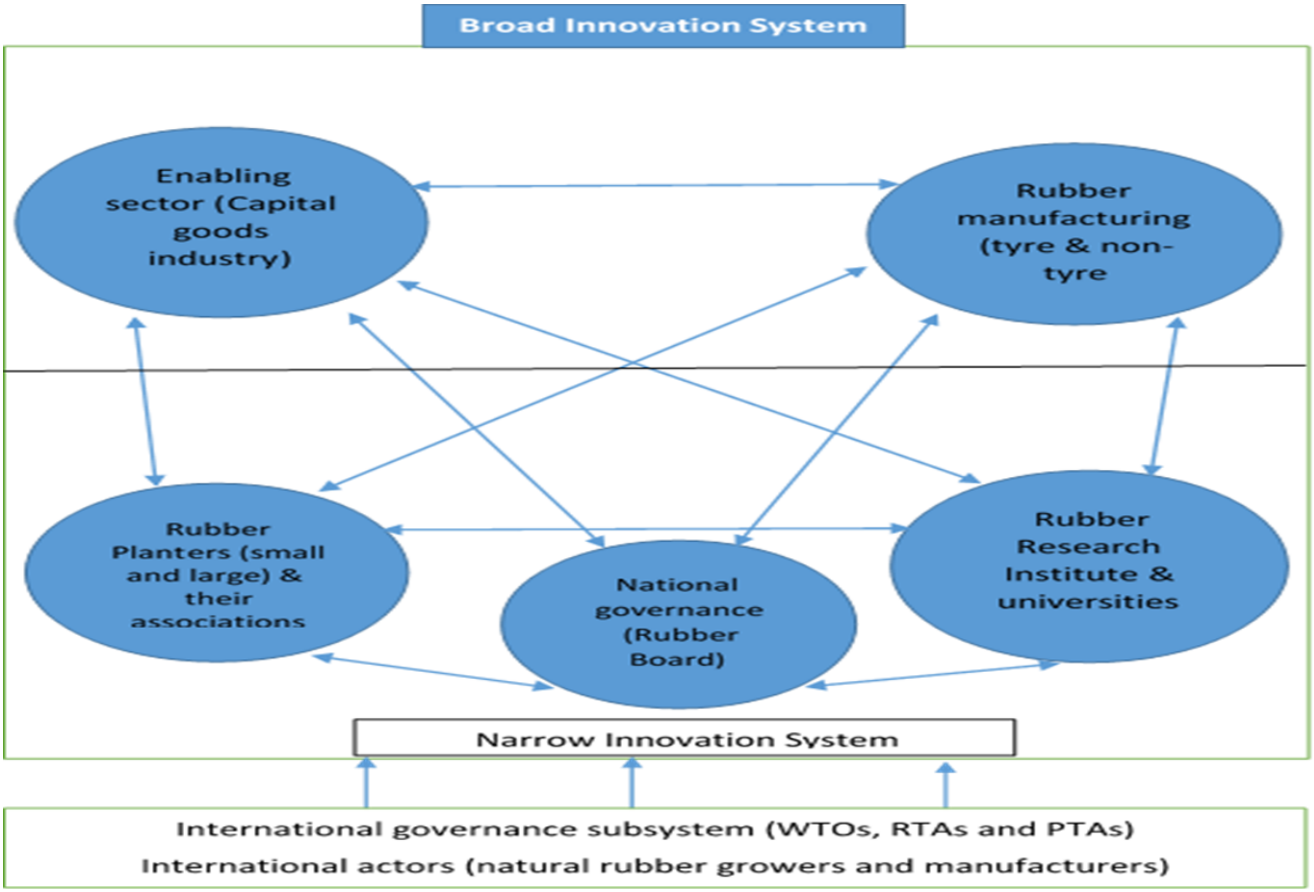
[9] For a discussion on the relative role of STI and DUI mode of learning on firm's innovation performance, please refer to Jensen et.al (2007), Parrilli and Heras (2016) and others

[10] Here it needs to be mentioned that unlike the model proposed by Andersen et.al. (2015) which includes enabling industry in the narrow innovation system, we consider it be a part of the broad innovation system.

learning, and the policy initiatives promoted flows of science based information between the research institutes and the growers of natural rubber and their associations.[11]

The narrow approach proved to be highly effective in the context of natural rubber in Kerala as long as it was protected from international competition through high tariff barriers. Natural rubber sector experienced both rapid growth and increased productivity over a long period of time. Systematic use of scientific knowledge promoting increased production and productivity by introducing high yielding varieties to the growers was a central part of this strategy. This is discussed in section 3.

Figure 1: Innovation System of Natural Rubber Sector



Source: Authors' compilation (based on Andersen et al. 2015: 33)

Based on our distinction between strategies for growth and productivity increase within vs. strategies for diversification based on the natural rubber industry, long term industrial

[11] Growers' associations such as Rubber Producers' Societies

development is dependent on diversification facilitated by interaction among diverse set of actors. We focus here on diversification creating production linkages both forward (processors or users of natural resources) and backward (R&D, capital goods, inputs, business services) (Hirschman 1981). The broad innovation system would include, beside the actors in the narrow innovation system, rubber goods manufacturing (tyre and non-tyre) and enabling industry (figure 1). The development of linkages involves interactive relationships across sectors, involving both STI-DUI modes of learning as governed by institutional interventions at the national level as well as international governance subsystem comprising WTO and Free Trade Agreements.

The mandate of the Rubber Board was to promote growth and productivity within the grower sector, and did not have an explicit mandate to contribute to wider economic industrial transformation linked to the production of natural rubber. The institutional architecture of the narrow innovation system did not support the development of an interactive interface between the grower sector, the users of natural rubber (rubber manufacturing, forward linkages) or the enabling sector (knowledge, technology, input to innovation activities, backward linkages). The focus was only on growers' performance in isolation from its other related sectors. The national institutional framework was in this way not established to promote interaction between growers and rubber manufacturing or enabling sectors; and did not include strategies for industrial diversification linked to natural rubber production, i.e. development of a broad innovation system. In section 4, we discuss empirically the challenges to develop a broad innovation system that facilitates the creation of backward and forward linkages and cross-sectoral interactive learning in natural rubber industry in Kerala.

The study is based mostly on the secondary data published by the Rubber Board, Rubber Research Institute of India, publications of the Central and State Governments. We also draw extensively from the various studies and interviews undertaken at the instance of National Research Programme on Plantation Development[12] sponsored by the Ministry of Commerce, Government of India.

[12] National Research Programme on Plantation Development (NRPPD) which is coordinated by one of the authors at Centre for Development Studies in Trivandrum with the involvement of other authors

3. Case description: natural rubber sector in Kerala

3.1 Evolution of narrow innovation system

As mentioned earlier, the narrow innovation system approach in natural rubber in Kerala focuses on promoting knowledge from science-based institutions to the production sector. The emergence of such model may be traced back to early 1950s.

The strategic importance of natural rubber as industrial raw material and India's heavy dependence on imports shaped the strategy of the first independent government towards the rubber industry (Joseph 2014). Its main objective was the long term expansion of natural rubber production. The institutional framework of the strategy was the Rubber Act of 1947 under which the Rubber Board of India was established and was empowered to undertake various activities for plantation development. In 1955, Rubber Board established the Rubber Research Institute of India (RRII) with the mandate to undertake research on all aspects of natural rubber production. Over the years, the RRII has built research linkages with several other research institutes and universities[13] across the country. The establishment of the Rubber Act, Rubber Board and RRII created the core elements of a support system of regulations, scientific knowledge and other inputs for expanding the natural rubber industry.

The support system defined scientific knowledge as a core basis for industrial methods and organization of the industry and it was mainly directed towards small scale growers. A central part of the strategy was Rubber Plantation Development Scheme (RPDS) consisting of three core elements; plantation development, productivity enhancement, and farmer group formation for the empowerment of growers (Kumar and Sharma 2006). Increased productivity involved adoption of high yielding varieties (HYV), distribution of efficient plantation inputs, and introduction of agro-management practices, plant protection, rain-guarding and scientific tapping.

Central for increasing productivity of plantations was the introduction of high yielding varieties. To begin with, RRII imported high yielding rubber clones and promoted the budding method instead of stumps and seedlings (Replanting Subsidy Scheme, 1957). This was followed by the

[13] Such as Indian Agricultural Research Institute (New Delhi), Indian Institute of Technology (Kharagpur), University of Agricultural Sciences and Indian Institute of Science (Bangalore), Cochin University of Science and Technology (Kochi), Tamil Nadu Agricultural University (Coimbatore), Kerala Agricultural University, Kerala University, Mahatma Gandhi University (Kottayam) http://rubberboard.org.in/AboutUs.asp?Id=33 (accessed on 9th April 2017).

RRII's attempt at evolving a clone suited for Kerala. This was a long lasting research project using natural selection mechanisms to search for clones adapted to local climate and soil condition. Of the number of varieties that were developed[14], RRII 105 turned out to be the most successful with highest yield level. The high yielding variety (HYV) was introduced in 1979 and officially released for commercial planting in 1980 as an integrated part of RPDS.

The rapid diffusion of new varieties was facilitated by the institutional setup under the RPDS and a large scale effort to diffuse the practices to small scale growers. The main institution was subsidies for planting during the gestation period (7 years) when farmers had no income from the rubber trees. All plantations which received subsidies had to follow the regulations established by the Rubber Board for efficient and science based production. In addition, Rubber Board established an efficient extension system to transfer knowledge from lab to field. Training programmes and campaigns were undertaken for small rubber growers to address issues like quality of latex, rubber sheet, unscientific practices, poor tapping practices, overuse of fertilizers and so on.

Further, in 1986, the rubber board initiated the formation of groups of small voluntary associations of small growers called Rubber Producer's Societies (RPSs). These societies play a major role in providing extension activities at the farm level and bringing the Board and growers together for two-way technical and development communication. The Rubber Board viewed RPS as attempts to enhance and empower the growers through these societies in the wake of lack of enough field staff (Rubber Board, Annual Report, 2010-11). The importance of empowerment of growers in the strategy is also reflected in promoting rubber sheets as main product. Making sheets is the simplest and oldest method of processing latex which could be carried out even by the small holders using indigenous technology (NRPPD 2015). Rubber sheets have longer shelf life in comparison to alternative forms of farm level output (like latex, scrap rubber), as such growers could store them and sell it whenever they fetch better price. This implies that production of rubber sheets would be remunerative for the natural rubber growers while ensuring better quality products for users.

[14] RRII has indeed introduced several high yielding clones. All together fifteen clone varieties have been evolved and released till date such as RRII 105, RRII 414, RRII 417, RRII 422, RRII 430, RRII 5, RRII 203, RRII 50, RRII 51, RRII 52, RRII 118, RRII 176, RRI 208, RRII 300, RRII 429. The most popular of them all is RRII 105 released in 1970s. RRII 414 & 430 was released in 2005 and RRII 417 & 422 in 2009.

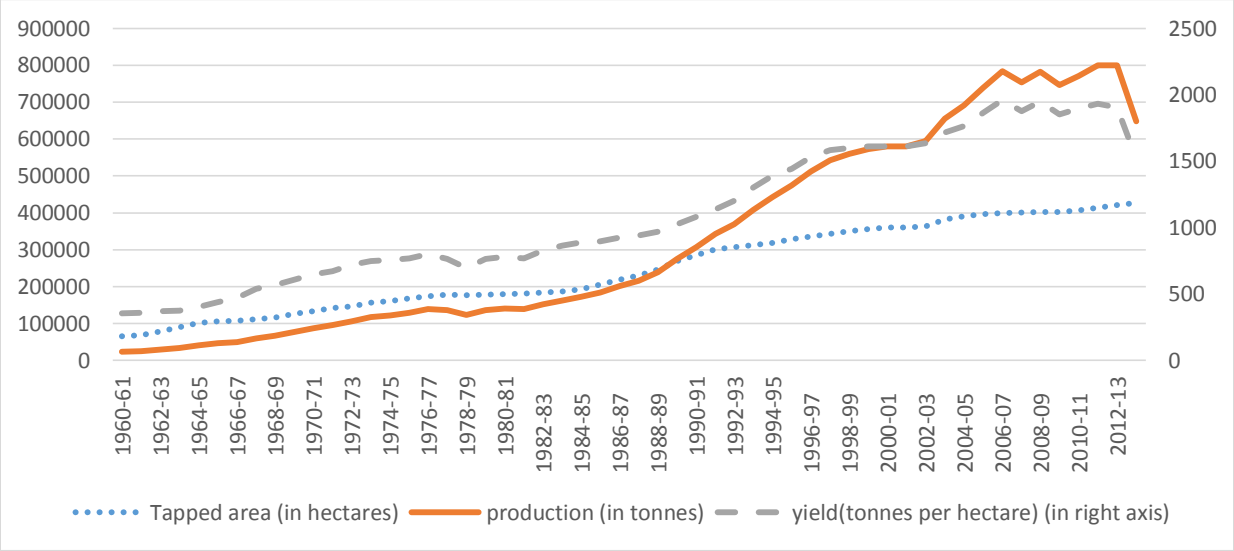
The policy of empowering growers may be seen as part of a wider strategy to create a decentralized economic structure in Kerala, with a large number of independent small scale producers. A large number of small land holders entered into rubber production and it acts as a source of livelihood to over 1.1 million small growers[15] with an average land holding size of 0.54 hectare (George et al. 1988; Joseph 2014) but contributing to 93 per cent of total production. The science based support system as well as processing of latex into rubber sheets were institutions supporting the wellbeing of a large number of independent small scale producers. The strategy was successful in fulfilling its objectives of increasing production and productivity **(**Rangachary 2006 as cited in Varkey and Kumar 2013). Mani and Santhakumar (2011) show that unlike coconut, natural rubber constituted a closely knit innovation system that facilitated the generation and diffusion of technologies underlying this development.

The production of natural rubber increased rapidly due to increased use of land and increased productivity (yield/production per unit area). The area under natural rubber plantations in 2012-13 (0.76 million hectare) was 9 times that of 1955-56 (84 thousand hectare). Kerala with a near monopoly in the production of natural rubber (George and Joseph 1992) accounted for more than 90% of total production in India.

Figure 2 illustrates that the tapped area, production and yield of natural rubber in Kerala showed a steady increase from 1950s to 2011-12. Estimates for Kerala show that the agricultural GSDP exhibited a growth of 2.53 per cent during 1990s, which further decelerated to 0.27 per cent during the decade after 2000. Earlier studies have highlighted the remarkable performance of natural rubber while the agricultural sector of Kerala recorded negligible or negative growth during 1970s and 1980s (Kannan and Pushpangadan 1990). From 1960 to 2010, the growth rate in the productivity of natural rubber has always been higher than that of other plantation crops in Kerala (see Table 1, note the decline in growth rate for 2010-14 will be discussed in later section).

[15] Over the years, the industry has transformed from being dominated by large grower/estates to small holdings. It needs to be noted that earlier the categorisation was below 20 hectares for small holders. In very recent years (2010-11 onwards), small holdings are considered as those with area below 10 hectares while estates are those with area above 10 hectares.

Figure 2: Trend in tapped area, production and yield of natural rubber in Kerala



Source: Data compiled from various issues of Indian Rubber Statistics, Rubber Board of India and Economic Review, Government of Kerala.

Table 1: Growth rate in the Yield of Major Crops in Kerala (1960-2014)

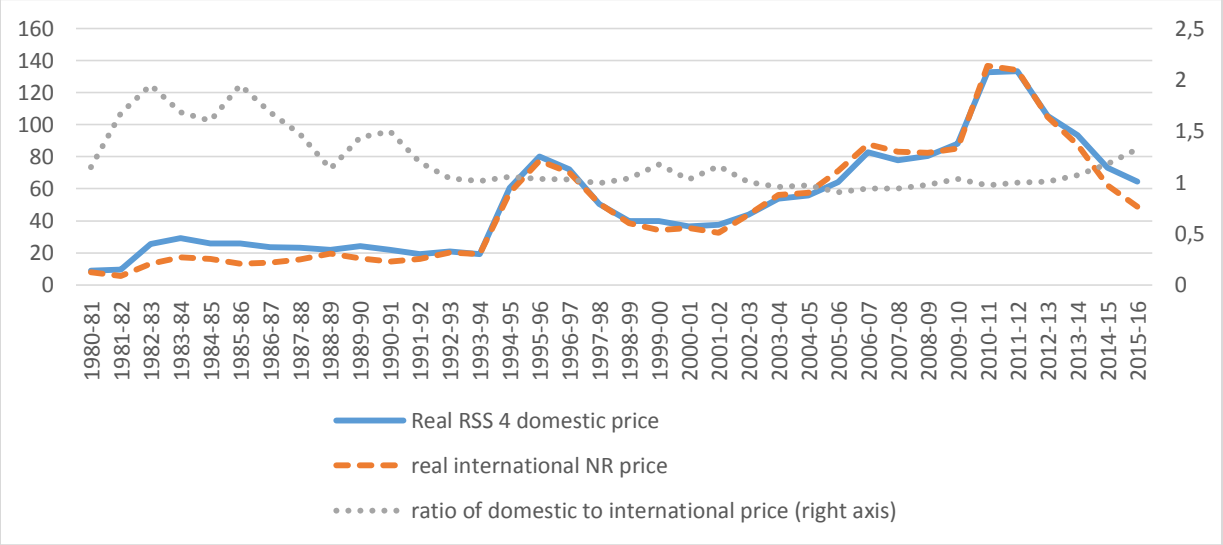
Year	NR	Tea	Coffee	Coconut
1960-70	8.91	0.28	-0.27	-1.49
1970-80	3.00	2.43	3.96	-1.80
1980-90	3.09	2.68	-2.85	1.27
1990-00	4.33	0.27	5.78	1.33
2000-10	2.04	-1.59	1.85	-1.48
2010-14	-10.55	8.63	0.64	2.22

Source: Estimates based on the data obtained from different commodity boards

Further, the long term real prices[16] for natural rubber showed a steady upward trend. Except for a slight decline in price during 1996-97, there is no major decline in price until 2011-12 (see figure 3). It could also be observed that the domestic price of natural rubber was significantly higher than the international price in the era of protected regime till mid-90s.

[16] We have calculated the real price by deflating it with Wholesale Price Index (2004-05=100).

Figure 3: Trend in real domestic and international price of natural rubber (1980 to 2015)



Source: Various issues of Indian Rubber Statistics, Rubber Board of India

The contribution of natural rubber sector towards the overall economic development of the state an issue that calls for a separate inquiry. Yet, there are evidence to suggest that in terms of conventional indicators, the better performance of natural rubber got translated in the improved standard of living of the people engaged in it. When we consider social welfare, Kottayam which is the main rubber producing district[17] among the fourteen districts in Kerala holds the second rank in HDI (Human Development Report, Kerala 2005). Kottayam is the first hundred per cent literate district in Kerala and is known for its educational attainments (Krishnan 1976; HDR 2005) financed to a great extent by surplus from natural rubber cultivation. The higher educational attainment also facilitated large scale migration out of the state wherein migration induced remittances account for over 35 per cent of GSDP. According to the Kerala Migration Survey (2014), the principal district of origin of student migrants was Kottayam and Pathanamthitta. This tends to suggest that growers' engagement in natural rubber cultivation enabled them to earn income that contributed towards their upward social mobility.

[17] The three main rubber growing districts in Kerala are Kottayam, Ernakulam and Pathanamthitta. 22 per cent of NATURAL RUBBER production is contributed by Kottayam, followed by Ernakulam (12 per cent) and Pathanamthitta (10 per cent).

3.2 The limits to the narrow innovation system

The decline in natural rubber prices starting from 2011-12 (see Figure 3) revealed a structural - economic, social and ecological (Chattopadhyay 2015) – crisis in Kerala's natural rubber industry. This happened in a period of open international competition where growers got exposed to external environment comprising greater number of actors, networks and new set of institutions. The formation of WTO and the Free Trade Agreements (FTAs) (Harilal and Joseph 1999) exposed hitherto protected small holders to open competition[18] from countries having substantial production and very limited domestic market (Joseph and George 2016).

The downward trend in prices from 2011-12 resulted in unprecedented decline in production and productivity (production per hectare). Total production dropped from 0.9 million tons in 2011-12 to 0.56 million tons in 2015-16. The production per hectare declined from 1896 kg per hectare in 2010-11 to 1183 kg per ha in 2014-15, recording a negative growth rate of 10.55% (see Table 1), and reflecting that prices act as one of the major determinants of the investment decision of the growers (Varkey and Kumar 2013; Mohanakumar and Chandy 2005). During the period of price fall, though farmers had area with plants of tappable age, they did not tap the trees on account of prices not being able to cover their cost of production (Parliamentary Committee Report 2015). Prices and production combined give an indication of the growers' income and the influence on welfare for a large number of smallholders.

Thus the narrow innovation system underlying the grower-centric strategy turned out to be insufficient to deal with these structural challenges.[19] In the following section, we discuss the limitations by drawing on our analytical framework focusing on the differences between narrow and broad innovation system in contributing to long-term economic development through industrial diversification linked to natural rubber production (figure 1).

4. Missing knowledge bases for forward and backward linkages

We focus on the dynamic process that entails the creation of the broad innovation system involving diverse knowledge bases and interactive learning, both DUI and STI among different actors which is needed to facilitate backward and forward linkages. We argue that such

[18] The tariff rate that prevailed prior to the WTO agreement was 70% and supplemented with non-tariff restrictions. As India became a signatory of WTO in April 1994, non-tariff measures have been removed and the tariff rate has significantly been curtailed – with MFN, tariff rate being only 20%.

[19] perils of such a policy has already been highlighted by scholars such as Harilal and Joseph (1998)

interactive learning spaces which are central for evolving a diversified industrial structure have been absent in the narrow innovation system for natural rubber in Kerala.

First, within the broad innovation system thinking, interactive learning between users and producers is at the core of long term dynamics involving growth and diversification. In our case, this is defined by the relationship between growers (producers of natural rubber) and rubber manufacturing industry (users of natural rubber). We start by discussing the relationship between growers in Kerala and the rubber manufacturing industry. This industry is often divided into tyre and non-tyre manufacturing sectors. Second, a broad innovation system for natural resource intensive industries also demands wider formal knowledge bases and institutions; defined as enabling industry. This type of industries develop as an outcome of interaction between users which is in demand for input into innovation processes, and firms with capabilities to provide solutions. Local producers of inputs, business services and capital goods may in this way be a source for gradual change and improvement of production in plantations. We illustrate the situation in Kerala by analyzing providers of technology for processing of rubber sheets in small scale plantations.

4.1 Forward linkages

As processing of latex into rubber sheets normally are undertaken by growers in the plantation, forward linkages will be limited to manufacturing of rubber-based products. The role of learning from interacting with users or customers is related to improved understanding and knowledge on specific needs and demand of individual users. This opens up opportunities for adapting the product or service to each user, and thus build competitiveness to succeed in the market.

Changing demand from tyre industry

The tyre industry accounts for around 70 per cent of natural rubber consumed in India. India is the world's second largest producer of tyres, consisting of 39 companies with 60 factories; three companies are among the world's largest producers. It has been a successful industry, covering a large number of different tyre qualities used in the rapidly expanding market for cars, trucks, buses and other vehicles in India (Jacob 2013). The companies procure its inputs globally and distribute finished products both in India and abroad. The expansion of the industry has from its origin been closely integrated to the global tyre sector and global value chains, using knowledge, technology, licenced by leading multinationals in the industry. However, it needs to be noted that

despite Kerala being the major state producing around 90 per cent of total natural rubber in India, only one tyre company, namely Apollo tyre, is based in the state and also this company's expansion took place mostly outside the state.

There are mainly two factors affecting the demand for natural rubber by the tyre industry. First, Jacob (2013) points out that India has been witnessing increasing preference for synthetic rubber over natural rubber. The relative share of natural rubber has declined gradually in the past 15 years from 78 per cent in 1997-98 to 64 per cent in 2015-16. This has been attributed to the changing composition of auto-tyre production involving increasing share of passenger car tyres that use natural rubber in relatively lesser proportion than synthetic rubber. Studies also have shown that in recent years with declining oil price, natural rubber has increasingly been substituted for synthetic rubber (Mohanakumar 2016). While the consumption of synthetic rubber recorded a growth rate of 6.9 per cent during 2011-12 to 2015-16, the consumption of natural rubber recorded a growth rate of only 0.76 per cent.

Along with sluggish growth in natural rubber consumption, there has been an increasing preference for block rubber (Technically Specified Rubber) instead of rubber sheets by the tyre industry. To illustrate, during 2011-12 to 2015-16, the consumption of block rubber recorded an annual compound growth rate of 14.46 per cent whereas that of rubber sheet was -7.07 per cent. As a result, the share of rubber sheets in total natural rubber consumption declined from 64 per cent in 2011-12 to 46 per cent in 2015-16 and that of block rubber increased from 26 percent to 43 per cent[20]. The increasing demand for block rubber was catered by imports which accounted for 70 per cent of the NR imports (Rubber Statistical News 2015). We see the shift to block rubber as a result of two main factors. First, block rubber has a lower market price compared to rubber sheets.[21] Despite an import duty of 25 per cent being imposed (Joseph and George 2016), manufacturers still find it cheaper to import block rubber rather than buy sheet rubber from domestic growers. The tyre manufacturers import cheaper block rubber from countries such as Thailand, Indonesia and Vietnam, and this has led to a reduced demand for domestic natural rubber. It is argued[22] that the shift towards imported block rubber is because the rubber sheets,

[20] These figures do not add up to 100 because the total consumption also includes latex.
[21] In December 2016, the price of per kg of sheet rubber was around Rs 140 which was 64 per cent higher than the price of block rubber (around Rs 85 per kg).
[22] This came up during the course of discussion with Rubber Board officials. It is also noted by Parliamentary Committee Report, 2015.

unlike block rubber, produced by millions of small holders lack homogeneity in quality. This made tyre manufacturers look for an alternative raw material, which gave way to the use of block rubber as a substitute for sheets.

However, rubber sheets still represent 27 per cent of total import of natural rubber (Rubber Statistical News 2015). This indicates that increase in import also represented a move away from procuring rubber sheets from Kerala growers. This may be due to higher prices in India compared to other producer countries, but might also be the result of differences in quality of rubber sheets between various producer regions (Parliamentary Committee Report 2015). If this is the case, we may argue that the problem is technological.

The narrow innovation system lacked institutions and platforms which could link the grower sector and the tyre industry. Unlike in the manufacturing sector wherein input suppliers, interact closely with the users, in natural rubber, the input reaches the manufacturers often through the traders[23] who act as intermediaries with hardly any interest in the production system other than the margins that they make. Thus in natural rubber, we have a typical situation as articulated by Lundvall (1992), wherein "markets separate users from producers" that rules out any room for interactive learning between them. The Rubber Board was the only institution, which could have worked as an intermediary between the growers and rubber manufacturers. However, its mandate was confined to production related issues of natural rubber with hardly role in building of forward linkages to support rubber manufacturing. This is reflected in the implementation of the Board's strategy, which only put limited resources into non-agricultural parts of the industry.

Stagnation in demand from local user sector

The alternative market for rubber growers is non-tyre rubber manufacturing. This part of rubber manufacturing accounts for 30% of total consumption of natural rubber in India; or close to 40% of total domestic production of natural rubber. The industry has different characteristics than the tyre sector; producing a diverse range of products in a large number (3500 items) – there are 5000 units in India which are mainly small and medium sized units. Within India, Kerala has the largest manufacturing sector with 870 production units; 375 of those have more than 10 persons engaged, involving about 22,000 people. About 60% of the rubber consumed in Kerala is used

[23] At present, there are 8153 dealers across India (see http://rubberboard.org.in/dealerdisplay.asp for more details)

by non-tyre companies – compared to 30% for India as a whole. One third of total non-tyre industry is located in Kerala, making this an industry specialization of the state.

Table 2 shows that compared to other states, Kerala has experienced an increase in the share of natural rubber consumption over the years. Its share has remained the highest among the major natural rubber consuming states in India from 1990 onwards. However, it needs to be noted that its share has been decreasing continuously since 2008-09. The non-tyre industry presents a dualistic structure. There are a few large scale manufacturers employing advanced technology, producing products relating to health care sector (Hindustan Latex Ltd). But these manufacturers do not use rubber sheets as input and is not a potential market for the existing grower industry. Most of the non-tyre manufacturing is dominated by small scale production units, making low value added products for low price markets with limited knowledge base. They lack internal capability for innovation, due to lack of knowledge and financial resources. These companies are not able to search systematically for new solutions and lack capability to develop or introduce new products and production technology. They produce mainly standard products for low-price markets. This part of the industry has experienced increased competition during the period of liberalisation and free trade. Competition from rubber manufacturers in other Asian countries, particularly China, has become more intense mostly for low-cost products. Most companies are at a disadvantageous position in comparison to their counterparts due to small scale of operation, low level of technology and environmental emission problems (Parliamentary committee report 2015). Studies have shown that with heightened import competition under globalization along with increasing price of raw materials, the small-scale non-tyre manufacturing units in Kerala are in distress (Mohanakumar 2014).

The narrow innovation system lacks resources, knowledge and capabilities to support transformation of this part of the rubber manufacturing industry to become dynamic and globally competitive. This could be seen in the context wherein the public support system directed towards growers never focused on the development of relevant strategies for creating a vibrant rubber manufacturing industry in Kerala. The non-tyre manufacturing units also could not be effective in evolving a platform for user-producer interface. This was possibly because most of the units in this segment were engaged in the production of low technology, non-standarised, low value products and could not be instrumental in specifying any quality standards for the natural rubber suppliers.

Table 2: Distribution of natural rubber consumption by states

State	1970-71	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2007-08	2008-09	2009-10	2010-11	2014-15
Andhra Pradesh	0	0	1.28	1.91	2.44	3.62	3.15	4.64	6.09	5.84	5.68	6.09	6.93
Bihar	0	0	0	0	0	0.22	0.21	0	0	0	0	0	0.00
Delhi	2.24	3.32	3.63	4.3	4.29	3.77	2.91	0.86	1.89	1.85	1.41	0.86	0.00
Goa & Daman	0	2.77	1.39	1.76	1.71	2.22	3.73	4.39	2.08	3.67	3.06	2.08	0.00
Gujarat	1.37	1.7	1.75	2.09	1.89	4.61	5.56	7.12	7.74	7.54	7.33	7.12	9.00
Haryana	5.13	8.84	8.62	7.91	6.24	5.94	6.12	4.81	5.77	5.73	5.43	4.81	3.43
Jharkhand	0	0	0	0	0	0	0	0.15	0	0.12	0.10	0.08	0.00
Karnataka	0.72	1.53	3.32	4.91	4.66	4.62	4.95	6.92	7.48	6.46	6.90	7.48	6.09
Kerala	**7.72**	**7.37**	**11.11**	**11.94**	**15.2**	**14.31**	**13.97**	**14.43**	**16.51**	**15.98**	**15.81**	**14.43**	**12.93**
Madhya Pradesh	0	0	0	0.39	1.13	3.65	4.39	3.83	3.87	3.40	3.55	3.87	3.21
Maharashtra	22.58	22.59	19.07	15.73	12.96	11.96	10.82	13.24	12.29	12.57	12.51	12.29	10.13
Orissa	0	0	0	0	0	3.21	3.81	3.95	4.65	3.88	4.15	3.95	0.93
Pondicherry	0	0	0	0	0	0.58	0.4	0.34	0	0.34	0.22	0.25	0.00
Punjab	2.61	4.57	7.62	11.44	12.67	11.8	13.12	8.35	9.7	9.38	8.15	8.35	6.63
Rajasthan	0	0	3.16	5.16	4.92	4.23	5.68	6.74	6.71	6.09	5.33	6.71	6.92
Tamil Nadu	20.12	16.63	9.82	8.04	5.82	4.92	5.16	6.18	9.45	7.38	7.35	9.45	19.90
Uttar Pradesh	1.33	7.7	13	12.41	12.84	12.4	8.82	4.05	4.56	5.87	9.02	8.89	3.62
West Bengal	35.52	21.72	15.79	11.6	11.61	7.59	6.85	3.88	2.59	3.45	3.30	2.59	1.22
Others	0.66	1.26	0.43	0.41	1.61	0.33	0.35	5.36	0.4	0.43	0.71	0.70	1.35
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Mohanakumar, 2014
Note: Figures from 2008-09 to 2014-15 updated from Indian Rubber Statistics, Vol. 35

4.2 Backward linkages

Backward linkages relate to providers of various types of inputs – products, services, capital goods - which enable firms to be innovative and hence improve competitiveness. The enabling sector constitutes important knowledge organisations – a distributed knowledge base – which firms in other industries can draw on for problem solving processes. The narrow innovation system focused mainly on agricultural aspects of the industry (efficient clones), and to a much lesser degree on a wider support system of independent companies providing a wider range of services, inputs and capital goods – an enabling sector to enable economic actors – growers and manufacturers - to be innovative and hence improve competitiveness.

To illustrate the role of the public support system in developing an enabling sector for the smallholder rubber growers, we focus on what we describe as the most crucial part of the production in relation to the users i.e. processing of latex into rubber sheets[24]. This includes rubber sheeting roller machines, sheet drying/smoking chambers and sheet washing machines. Of these, the most important one is perhaps the rubber rollers which enable the growers to convert latex into rubber sheets. Rubber sheet, unlike latex, is a storable product that enables the farmers to sell their product at a higher price.

The manufacturing of rubber rollers in Kerala could be traced to 1912 when the pioneering firm brought out the rubber rollers by copying a machine imported from Sri Lanka (formerly known as Ceylon). The long term growth in production of natural rubber has created increased demand for the capital goods like rubber rollers from mechanical workshops and industry in the state. However, only rather simple and less-efficient technology has been provided. With 98% of the holdings under less than two hectares, the demand was mostly for the conventional rubber rollers (Parliamentary Committee Report 2015). There are over 30 units engaged in the production of rubber rollers, all of them are small scale units with hardly any in-house R&D and very limited linkage with R&D institutes or universities. In the absence of any standardization, there has been intense competition from units offering low quality machines at lower prices that in turn has an adverse effect on the quality of rubber sheets produced.

The mandate of RRII was confined to increasing production and productivity and did not provide support for the development of an enabling industry. As a result, there was hardly any major technological change in rubber rollers used by a majority of small holders. However, there are certain recent innovations like the introduction of motorized rubber rollers, and a fully automatic rubber sheeting battery with a processing capacity of about 900 sheets per hour, introduced as late as in 2000. At present, there are only two firms supplying fully automatic rubber sheeting battery. During our discussion with the market leader, it was transpired that the demand for such machines are limited on account of the domination of small growers and the failure of the RPSs to establish group processing units. We see this as a clear indication of lack of interaction and learning processes involving growers and the enabling industry. The lackluster development of

[24] The milky fluid tapped from rubber trees is called latex. This is subjected to a process of coagulation that involves adding of water and acid to latex to make it into coagulum. With the help of rubber rollers, coagulum is converted to rubber sheets.

the enabling industry (rubber rollers) and the technological backwardness could also be seen as an offshoot of the narrow innovation system with its limited focus on evolving a vibrant enabling industry.

5. Conclusions and way forward

Scholars have argued that an abundance of natural resources can hurt economic growth and development. But a growing number of studies during the last decade following innovation system perspective tend to suggest that a country need not necessarily remain poor because of natural resource intensity. The transformation of primary industries from simple harvesting of natural resources to knowledge intensive and learning industries and economies requires processes involving the development and use of both scientific, technological as well as experience-based knowledge. Similar to the resource rich countries that were able to undergo this transformation, the state of Kerala has also been abundantly endowed with natural resources. However, evidence tends to suggest that Kerala has not been successful in evolving a diversified industrial structure based on natural resource. We discuss this by analysing the case of natural rubber - the largest resource-based sector in Kerala.

In analyzing the innovative behaviour of firms, studies have highlighted the complementary role of STI (science-based) and DUI (experience-based) modes of learning instead of independent modes for achieving better outcomes in terms of innovation and economic performance. On similar lines, studies on the development dynamics of natural resource intensive countries distinguishes between the narrow and broad approach to innovation in terms of the relative importance of the types of linkages developed in relation to the natural resource sector. The narrow approach emphasizes on linkages among R&D institutes and universities while broad approach considers linkages with user and producers involved in production to be equally important. Drawing from these two strands of studies, when linking innovation behaviour to development, the broad and narrow approach could be conceptualized in terms of the modes of learning. The broad approach relates to the combined STI-DUI mode of learning and narrow approach to STI mode. Keeping, this distinction in view, the paper argues that combined STI-

DUI mode of interaction (broad approach) is essential for sustained long-term natural resource based development.

The study observed that the natural rubber sector in Kerala adopted a narrow STI approach with focus on increasing production and productivity at the instance of Rubber Research Institute of India (RRII) under Ministry of Commerce. This has been accomplished by the development and diffusion of high yielding varieties along with new package of practices enabling Kerala to achieve highest productivity among the natural rubber producing countries. Higher productivity along with an assured price, often higher than the international price backed by tariff barriers, ensured steady growth in area under cultivation and prosperity for over 1.1 million natural rubber growers. The study, however, observed that the natural rubber sector was devoid of a broad innovation system involving an institutional architecture that facilitates the development of a vibrant and knowledge intensive rubber manufacturing industries or an enabling sector i.e. strong forward and backward linkages. Thus, with the narrow approach towards innovation system, the natural rubber sector remained a mere supplier of rubber sheets for the tyre manufacturing units located outside the state.

The perils of the narrow approach towards the innovation system became evident under globalization. With the opening up of the economy, the tyre manufacturers began to substitute cheaper block rubber and synthetic rubber for rubber sheets. Since nearly 75% of the production of rubber in Kerala is in the form of rubber sheets, this had dramatic impact on the market for the growers in the state. The prices recorded an unprecedented decline with its implications on the livelihood of the small growers. Today the natural rubber growers barely survive on the minimum support price offered by the State Government. The non-tyre manufacturing, a major source of demand for rubber sheets, is also in distress on account of heightened competition from international producers in low-price product segments.

It is argued (Smith 2007) that countries which followed a natural resource based development path have developed linkages from the resource bases, leading to major cluster development. Finland moved from forestry to paper production to chemicals for paper (forward linkages), and then to paper machinery (a major sector in which it is a world leader - backward linkages). Similarly, Sweden shifted from iron ore production to iron and steel, to fabricated metal products (ships, cars) and to production of machinery. It needs to be noted that the development

trajectories experienced by these resource rich countries was on account of knowledge upgrading and investment strategies in resource-based industries, through leveraging of resource bases into upstream and downstream industries; and knowledge creation via knowledge infrastructures.

This paper using the distinction between narrow and broad innovation systems, defines the types of processes missing in Kerala's 'science driven grower-centric' support system. We point to two core types of processes: (i) lack of interactive learning and interaction between growers and users of natural rubber (rubber-based manufacturing), and (ii) lack of interactive learning between growers and the enabling sector. We argue that the lack of this type of processes and institutions in the economy, is a main challenge for the future development along a natural resource based development path building on natural rubber.

In the context of the regional economy of Kerala wherein natural rubber accounts for about 45% of the agricultural GDP and hardly 7% of its GDP is contributed by the manufacturing sector, we argue that public policies should not only focus on production and processing of the primary product but also on developing both upstream and downstream industries. This calls for an urgent shift from the hitherto followed narrow approach to learning at the instance of the central government (Rubber Board) to broad based learning process. In this process, the regional government has a key role to play for exploiting the potential opportunities from both forward and backward linkages. This will *inter alia* involve facilitating the building of a broad innovation system[25] by bringing together different stakeholders - planters and planters associations, tyre, non-tyre manufacturers, their associations, rubber machinery producers, research institutions, universities - for harnessing both the science based and experience based learning and other capabilities.

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[25] The importance of this kind of a strategy to bring together all the actors in developing innovation strategy has been articulated with respect to building of inclusive innovation system by studies such as Andersen and Johnson (2015) and Andersen and Dannemand (2016)

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