

Price and Stock Formation with Rational Expectations in the Indian Natural Rubber Market

by Wouter Zant



PRICE AND STOCK FORMATION WITH RATIONAL EXPECTATIONS IN THE INDIAN NATURAL RUBBER MARKET

by Wouter Zant¹

¹ The author is associated with the Economic and Social Institute (ESI/VU) of the Free University, Amsterdam. This paper is an adapted version of the short run model used in the study of the Indian rubber economy by ESI/VU and the Rubber Board of India (see Burger, Haridasan, Smit, Unny and Zant (1993)). Financial support of the Indo Dutch Programme on Alternative Developments (IDPAD) is gratefully acknowledged. Thanks to all people in India who contributed to my knowledge of the Indian rubber market. Special thanks to R.G. Unny of the Rubber Board of India who kindly and patiently discussed numerous subjects with me and supplied whatever data I required. I am indebted to colleagues of the ESI/VU for comments on earlier versions of this paper. All responsibility for the contents of this paper remains with the author.



PRICE AND STOCK FORMATION WITH RATIONAL EXPECTATIONS IN THE INDIAN NATURAL RUBBER MARKET

by Wouter Zant

CONTENTS

1. Introduction.
2. Some issues in the current discussion on commodity modelling.
3. The Indian rubber market.
4. A general model structure.
5. Estimating equations of a quarterly model.
 - 5.1. Production of natural rubber.
 - 5.2. Stocks of natural rubber with growers and dealers.
 - 5.3. Stocks of natural rubber with manufacturers of rubber products.
 - 5.4. Consumption of natural rubber.
6. Historic simulations with a quarterly model.
7. Summary and conclusion

Appendices

References

PRICE AND STOCK FORMATION WITH RATIONAL EXPECTATIONS IN THE INDIAN NATURAL RUBBER MARKET

by Wouter Zant

1. Introduction

Commodity modelling has received a large amount of attention in the literature, both empirically and theoretically. In building empirical commodity models researchers often encounter a lack of data on stocks, or data on stocks that seem highly unreliable. Confronted with this problem modellers proceed by deriving and estimating reduced-form price equations instead of behavioural stock equations. Although this practice is often hard to avoid since it is sufficient for forecasting purposes and appropriate for the formulation of global models, it appears to be vulnerable to criticism. The purpose of this paper is to present an empirical model that explicitly takes this criticism into account and estimates behavioural equations for consumers, producers and stockholders directly. The model - a quarterly model of the Indian rubber market - focuses particularly on the explanation of short run price and stock formation, and thus on the behaviour of stockholders. Speculative, precautionary and transaction motives to hold stocks are hypothesised to dominate this behaviour. The formation of price expectations - required to test speculative behaviour - is rational, or less restrictive, forward-looking and model consistent. An equilibrium condition determines market prices. Successive price policies are accounted for. With the hypothesized stock behaviour, positive stocks are consistent with equilibrium.

The paper is organised as follows. In Section 2 some relevant topics in the literature are discussed. In Section 3 a brief description of the Indian rubber market is presented. In Section 4 the model is presented and explained. In Section 5 the behavioural equations are estimated. Finally, in Section 6 a historic simulation with the estimated model is presented and evaluated.

2. Some issues in the current discussion on commodity modelling

There is a vast body of empirical work on modelling commodity markets². We do not intend to present an exhaustive summary of empirical commodity modelling: instead, we will briefly touch some common characteristics of these models as well as some issues that are currently in the centre of discussion in commodity modelling. These issues are in particular the level of (dis)aggregation and reduced form versus structural form estimations.

The emphasis on the global modelling of commodity markets has led to a high level of aggregation over time, agents and regions. In the preparation of a proper database for global models a number of conceptual problems have to be resolved. Moreover, numerous assumptions are required and a multitude of approximations have to be made in order to make data of different countries and regions fit global models. It is difficult and often impossible to allow for institutional differences between countries, because this would make these models intractable. The required aggregation frequently involves a considerable loss of detail. Last but not least, the behaviour of (groups of) economic agents is hard to perceive under such circumstances.

The emphasis on building global models has also contributed to the elaboration of relative simple modelling approaches. A common way to construct a commodity market model is to postulate a consumption equation, a production equation and an equilibrium condition. On the basis of these equations a price equation is derived. The empirical work then focuses on the estimation of this price equation (see eg. Labys, Lesourd, Uri and Guvenen (1991, p.18)). A number of criticisms of this approach are summarised below. Trivedi (1990) states: 'Several recent econometric models of commodities (..) begin by specifying a price equation as an inverted inventory demand equation. Typically such equations are overparameterised, often because post simulation stage variables are added just to improve the tracking performance'. Using reduced-form price equations can hardly be expected to capture behaviour of (groups of) agents in particular institutional settings. As all behaviour is cast in one equation, little additional information can be drawn with respect to behaviour of specific agents. Often the (price) expectations are only formulated indirectly. The cause of misspecification is hard to detect in reduced-form estimations (see comment of Wickens on Trivedi in Winters and Sapsford (1990)). The quality of stock variables is often

² For an extensive although somewhat outdated overview of commodity models by commodity see Labys and Pollak (1984). Some recent models are Burger and Smit (1988), Vogelvang (1988), Akiyama and Trivedi (1987).

questionable. Using stock variables in the price equation then seems to be a questionable procedure as well: '...this merely translates a problem of poor fit into a problem of measurement error (see Gilbert (1990)). The disadvantages discussed in the previous paragraph clearly point in favour of commodity models consisting of separately estimated behavioural equations. We can conclude that using reduced-form price equations, although being a highly concise treatment of a highly complex subject, has evoked serious criticism. Estimating stock equations, however, confronts the researcher with some additional problems. For these reasons some authors (see eg. Gilbert (1990)) claim that it is preferable not to estimate behavioural stock equations. First, the quality of the stock data is usually low (failing the market clearing identity) and stock data are usually incomplete. Second, data do not correspond to the speculative demand concept developed in theoretical work on stockholding (see Newbery and Stiglitz (1981), Ghosh et al. (1987), Gilbert (1988), Newbery (1990), Deaton and Laroque (1992)). Third, the theory on stock behaviour seems to be partial and not adequate for the full explanation of stock behaviour. Fourth, the use of either expected prices or futures prices, required to estimate speculative demand, entails problems related to the information content of these prices (with perfect arbitrage the difference between current and expected prices is fully explained by the interest rate: this result is derived in Appendix 1).

In this paper a short run model is developed of the Indian rubber economy. The behavioural equations in this model are estimated directly. Four groups of agents are distinguished: producers, stockholding growers & dealers, stockholding manufacturers and consumers. The treatment of consumer and producer behaviour, however, is simple. In formalising behaviour of stockholders an attempt is made to incorporate recent theoretical insights. Attempts are made to formalise and find empirical confirmation of speculative demand, precautionary demand and transactions demand in holding stocks. The formation of forward looking model-consistent price expectations is central to speculative demand. In the light of the above mentioned problems, we note the following. The data set used for the model is both complete and meets the market clearing identity. The quality of the data-set, and in particular the quality of the data on stockholding, is considered appropriate. Additional details on the data-set are presented in Section 5. At the outset we do not know if the conceptual distinctions made in the data correspond with the theory. To our understanding this is to a large extent an empirical matter. Since the model describes the commodity market of a single country, relatively isolated from the world-market (see Section 3, below),

a certain degree of disaggregation is possible, and price policies, subsidies and, to some extent, other forms of regulation can be incorporated. Especially in view of expectations this seems indispensable. Gilbert (1990, p.43) notes in this respect that 'attempting to incorporate forward looking behaviour in a commodity market model is only sensible within a model which incorporates sufficient institutional detail to allow the modeller to reflect the information actually available in the market'. It is attempted to link up with work of others on forward looking model-consistent price expectations (see Gilbert (1990), Gilbert and Palaskas (1990)).

3. The Indian rubber market.

India has a long tradition of producing natural rubber. Favourable environmental conditions to grow rubber trees, especially in the southern states (Kerala, and to a lesser extent Tamil Nadu and Karnathaka), have contributed to this situation. By far the biggest part of domestic consumption is supplied by domestic producers (see Table 1). Small amounts of rubber have been imported, except for the period 1972-77. Export of natural rubber is negligible. Synthetic rubber is produced in relatively small amounts. The dominant position of natural rubber relative to synthetic rubber, both in production and in consumption, is peculiar to India, and contrary to the situation on the world-market in which synthetic rubber has a dominant position. In relation to world-production of natural rubber, India has a modest but increasing share, growing from 5 to 7% in 1985-1990. This figure, however, should not be seen as an indication of India's position in natural rubber on the world-market. As pointed out below the Indian rubber economy has been virtually isolated from the world-market and to a large extent still is. The world-market prices of natural and synthetic rubber (RSS3, Singapore and SBR export values, respectively), excluding import duties, move in general somewhat below those for domestically produced natural rubber (RMA4), while, duties included, these prices are, on the whole, somewhat above the prices of domestically produced natural rubber^{3,4}. On top of this, all foreign transactions require a

³ RMA4 and RSS3 refer to specific quality grades of natural rubber; RMA grades are only used in India; RSS originates from Malaysia and is a common quality denominator on the world market. RMA4 is equivalent to RSS3; SBR = Styrene Butadiene Rubber.

⁴ During some periods the world market price of NR, including import duties, moves more or less on the same level as the price of domestically produced natural rubber.

Table 1

Production, import, consumption and export of rubber in India
(all variables in million tonnes)

	Production			Import			Consumption			Export		
	NR	SR	RR	NR	SR	RR	NR	SR	RR	NR	SR	RR
1970	92	30	16	2	5	0	87	33	14	0	0	0
1980	153	25	29	9	17	0	174	47	27	0	0	1
1990	330	57	46	52	46	0	364	100	46	0	0	1

with: NR = natural rubber; SR = synthetic rubber; RR = reclaimed rubber;
Source: Indian Rubber Statistics, Rubber Board of India

license. Especially in times of scarcity of foreign exchange this creates a barrier to imports. At the end of 1968 the State Trading Corporation (STC), a public sector enterprise engaged in all foreign trade transactions in natural rubber (as well as other commodities), was brought into the natural rubber field to import natural rubber and regulate supplies so that the gap between indigenous supply and demand could be bridged without damaging the interest of domestic producers. Initially, the STC functioned more or less as an advisory body for monitoring and regulating imports. From 1978-79 the country became a net importer and the STC has been authorised to import and distribute natural rubber to actual users. In fact, from the end of 1968 to 1982 the STC had a monopoly on import of natural rubber. With the establishment of the STC the government has a firm grip on the impact of the world-market on the domestic natural rubber economy. We can conclude that high import duties, both for synthetic and natural rubber, import licensing, foreign exchange shortages, and the establishment of the STC, have effectively isolated the Indian rubber economy from the world-market. Since 1982 a separate scheme is operated for exporters of rubber goods so that these exporters are allowed to import natural rubber duty-free for manufacturing export goods⁵. This enables manufacturers to compete in the international market. Although imports by manufacturers are gradually gaining importance, they are still small compared to imports by the STC. The export promotion scheme is just a small step towards a greater integration of the private sector with the world-market.

Distribution of imported natural rubber by the STC to manufacturers of rubber

⁵ This regulation is restricted to large tyre and tube manufacturers.

products - so-called releases - should be carefully distinguished from imports as such. In general the STC first puts the imported natural rubber in stock. Releases of natural rubber by the STC, i.e. the depletion of these stocks, occur whenever prices of natural rubber rise and/or manufacturers of rubber products experience shortages in buying inputs for their production process. In the case of maximum prices the release of imported rubber of the STC is directly related to the price development: as soon as the price hits the ceiling the STC intervenes in the market by releasing stocks of natural rubber. The domestic price of natural rubber in India was statutorily controlled by the government from May 1942 to September 1981 with a short break of about 15 months starting in October 1946. In Figure 1 the market price of RMA4 is shown together with the notified maximum and minimum prices (resp. ceiling and floor prices), whenever operational. Minimum and maximum prices were calculated on the basis of studies on the costs of production and were revised every now and then⁶. Officially the policy is intended to serve two goals. Prices should provide incentives to producers to expand and modernise cultivation and production of natural rubber. Prices should at the same time be 'reasonable' to manufacturers of rubber products. During the period from 1970-71 to 1977-78 the STC had to enter the domestic market and carry out price support operations including the export of small quantities, as domestic supply was in excess of the demand, mainly as a result of the slack in demand caused by the energy crises. From September 1981 to February 1986 there was no effective control on the domestic price of natural rubber. The STC operations were thought to be sufficient to regulate the prices, but the market price fluctuated sharply during 1981-83 due to (at times) inadequate import and (at times) excess imports, and unexpected variations in production due to climatic changes. There was a conflict of opinions among the rubber growers and the rubber users with respect to the demand-supply gap and the reasonable price of natural rubber. It was felt that it would no longer be possible to ensure stability in natural rubber prices based on releases of imported natural rubber during the lean season alone. Accordingly in February 1986 a Buffer Stocking Scheme was introduced on a pilot basis to ensure the stability of the market price of natural rubber so that rubber producers could be assured of a reasonable return on their investment and rubber goods manufacturers of an adequate supply at a reasonable price. The features of the scheme are:

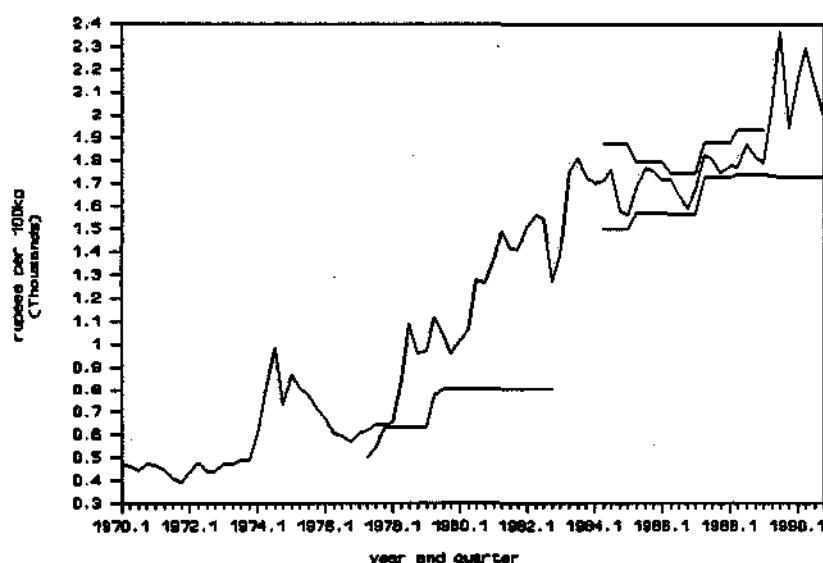
⁶ In some issues of the Indian Rubber Statistics summary statistics are presented on the 'Structure of Notified Price of RMA1 Grade Rubber' in the past.

- fixation of the benchmark-price for natural rubber on the basis of the cost of production;
- lower and upper trigger price level fixed at Rs. 300 per tonne below and above the benchmark-price;
- the STC enters the market when the market indicator price of natural rubber⁷ falls below the lower trigger price level and releases natural rubber when the market indicator price is above the upper trigger price level;
- the market intervention by the STC should ensure that the price of natural rubber does not fall below the floor price or go above the ceiling price. These prices are fixed at Rs. 500 per tonne above and below the benchmark-price.

The STC carried out procurement practices of natural rubber to support prices during peak production periods in 1986, 1988, 1991 and 1992 and released natural rubber to the user industry in all the years in the lean season to arrest the upward price trend. Under the scheme, the buffer stock should at least contain 2500 tonnes at any time. This minimum requirement should be drawn down at the beginning of peak season.

Figure 1

Notified maximum and minimum price and market price of natural rubber (RMA4)



Source: Indian Rubber Statistics, Rubber Board of India

4. A general model structure

In the formal model of the Indian natural rubber market we focus on natural rubber and treat possible substitutes (synthetic and reclaimed rubber) as exogenous, because of the dominant position of natural rubber in the Indian rubber market (see Table 1). Besides, prices of reclaimed rubber and synthetic rubber move respectively far below, and somewhat above natural rubber prices for the whole sample period. Central to the model is the market clearing equation:

$$c + \bar{x} + \nabla n_{mf} + \nabla n_{gd} + \text{proc}_{sc} = q + m_{mf} + \bar{r}_{sc} \quad (1)$$

where c = consumption of natural rubber; x = export of natural rubber; ∇n_{mf} = stock formation by manufacturers; ∇n_{gd} = stock formation by growers and dealers; proc_{sc} = procurement of natural rubber by the STC; q = production of natural rubber; m_{mf} = import of natural rubber by manufacturers of rubber products; r_{sc} = releases of natural rubber by the STC; a bar denotes an exogenous variable.

The left hand side of equation (1) presents the demand for natural rubber: domestic consumption of natural rubber (c), exports (x), and stock formation by manufacturers (∇n_{mf}), stock formation by growers and dealers (∇n_{gd}) and procurement by the State Trading Corporation. As exports of natural rubber have been negligible in the period under consideration they are made exogenous. The right hand side of equation (1) represents supply and consists of the production of natural rubber (q), the imports by manufacturers of rubber products (m_{mf}) and the market releases by the STC (r_{sc}). Imports by the State Trading Corporation (STC) do not contribute directly to the supply of rubber in the Indian economy: these imports only create a change in stocks with the STC and, thereby, enable the STC to increase domestic supply. Only when imports are released by the STC they are part of supply as is clear from equation (1). As set out above (see Section 3), direct imports of natural rubber by the private sector - imports by manufacturers of rubber products - only came into being in 1982 and are heavily regulated. According to the export promotion scheme export earnings are required to import. These imports are quantitatively of moderate importance. For these reasons we take these imports as exogenous.

The market for natural rubber is cleared by price and quantity adjustments. This is realised by assuming the demand and supply components to be sufficiently price elastic: the quantities consumed and placed in stock are inversely related to the fluctuations of rubber

prices while production is positively related to these fluctuations. The process of price and quantity adjustment, affecting both supply and demand, continues until equilibrium is realised. Mere quantity adjustment takes place if the price hits an exogenous maximum or minimum level. At the maximum price the STC increases its market releases to keep the price below or equal to the maximum level:

$$p \leq p_{\max} \quad \perp \quad r_{stc} \geq \overline{r_{stc}} \quad (2)$$

where p is market price of natural rubber; $p_{\max}$ = maximum notified price of RMA4; r_{stc} = releases of natural rubber by the STC; a bar denotes an exogenous variable; $\perp$ indicates that at least one of the two expressions must hold as an equality.

From equation (2) it follows that the releases by the STC are partly endogenous and partly exogenous. The endogenous part is related to maintaining maximum prices. The exogenous part is related to the particular policy of the STC with respect to the supply of imported natural rubber to domestic manufacturers of rubber products. Hence, these releases depend on government policy and are therefore taken to be exogenous.

Likewise the STC intervenes in the market by means of its procurement, if the minimum price is reached:

$$p \geq p_{\min} \quad \perp \quad \text{proc}_{stc} \geq 0 \quad (3)$$

where p is market price of natural rubber; $p_{\min}$ = minimum notified price of RMA4; proc_{stc} = procurement of natural rubber by the STC; $\perp$ indicates that at least one of the two expressions must hold as an equality.

Next to the market price of natural rubber, the price responsive endogenous variables are assumed to depend on expected prices and a number of predetermined variables. Current and lagged exogenous and lagged endogenous variables have been lumped together (z)⁸. These behavioural equations read:

$$q = q(z, p, p^e) \quad (4)$$

$$n_{st} = n_{st}(z, q, p, p^e) \quad (5)$$

$$n_{mf} = n_{mf}(z, p, p^e) \quad (6)$$

⁸ From the empirical part it is apparent that z is specified in such a way that the order condition is satisfied for all behavioural equations of this model; without numerical calculation the rank condition is assumed to be satisfied as well, in which case all equations are identified.

$$c = c(z, p, p^e) \quad (7)$$

where q = production of natural rubber; n_{gd} = stocks with growers and dealers; n_{mf} = stock with manufacturers of rubber products; c = consumption of natural rubber; p = market price of RMA4; z contains a number of current and lagged exogenous and lagged endogenous variables; the superfix e indicates expectation on (current and) future values of a particular variable.

The model contains seven equations and seven unknowns ($p, q, n_{gd}, n_{mf}, c, r_{stc}, proc_{stc}$). The derivation of forward looking model-consistent price expectations is presented in appendix 2. The next section reports on the derivation and econometric estimations of the behavioural equations. To conclude this section we present some identities which were implicit in the discussion above.

$$m = m_{stc} + m_{mf} \quad (8)$$

$$\nabla n_{gd} = n_{gd} - n_{gd,t-1} \quad (9)$$

$$\nabla n_{mf} = n_{mf} - n_{mf,t-1} \quad (10)$$

$$\nabla n_{stc} = m_{stc} - r_{stc} + proc_{stc} \quad (11)$$

where m = total import of natural rubber; m_{stc} = import of natural rubber by the State Trading Corporation (STC); m_{mf} = import of natural rubber by manufacturers of rubber products; ∇n_{gd} = stock formation by growers and dealers; ∇n_{mf} = stock formation by manufacturers; ∇n_{stc} = stock formation by the STC; r_{stc} = releases of natural rubber by the STC; $proc_{stc}$ = procurement of natural rubber by the STC.

Total imports (m) is given by the sum of imports by the State Trading Corporation (m_{stc}) and imports by the manufacturers of rubber products (m_{mf}). Stock formation is the difference of current and one period lagged stocks. Stock formation by the STC (∇n_{stc}) is equal to the imports by the STC (m_{stc}) plus the procurement ($proc_{stc}$) minus the releases (r_{stc}).

5. Estimating equations of a quarterly model

The equations are estimated and the model is run with quarterly data. With a few exceptions these quarterly data are calculated from monthly series. Data are obtained from the Indian Rubber Statistics, published by the Rubber Board of India (several issues), and

from the Rubber Board of India on request. In particular, the time series on releases and procurement by the State Trading Corporation, required to calculate the market clearing identity, are not published and had to be supplied on request. Stock variables are measured at the end of the period. The data meet the market clearing identity as formulated in equation (1), apart from minor errors that are negligible compared with the magnitude of the variables. All prices in the model are deflated by the general consumer price index. The split up of releases into an exogenous and endogenous part has been calculated. The data of the sample are attributed to a period with and without maximum prices. The relationship describing the behaviour of the STC with respect to exogenous releases is estimated with data of the sample in which no maximum prices were effective (78.1-86.1): according to our model these releases are entirely exogenous. A simple rule-of-thumb behaviour is assumed according to which the STC releases the amount of rubber that is expected to be required to fill the gap between consumption and production: with adaptive expectations these releases are related to the gap between production and consumption 4-quarters back. Lagged prices are assumed to affect exogenous releases as well. Projections with the estimated release equation generate the exogenous releases during the Buffer Stocking Scheme.

The estimation results for equations (4), (5), (6) and (7) are presented below. Although the proper estimation of these equations would require the use of simultaneous estimation methods, for simplicity an 'equation by equation' - approach was preferred and whenever required, Two Stage Least Squares (2SLS) were applied to each equation in turn. With 2SLS estimations all the explanatory variables of the specific estimated equation are used as instruments. On top of this a choice of the following variables are added to the list of instruments: production (q), lagged stocks with growers and dealers ($n_{gd,t-1}$), lagged stocks with manufacturers ($n_{mf,t-1}$) and lagged consumption (c_{t-1}). Equations are estimated with error-correction (see Davidson et al. (1974), Engle and Granger (1987)). Particularly in estimating relationships that describe stock behaviour this proves necessary in order to account for non-linearities⁹. Tests on the order of integration of variables are reported in Appendix 4. Cointegration tests are reported in the main text. Estimating with error

⁹ In the literature much energy is devoted to formulating an adequate theoretical basis for non-linearities in prices due to the non-negativity of stocks (Williams and Wright (1991), Gilbert (1988), Deaton and Laroque (1992)). It is (implicitly) suggested that if one does not model these non-linearities but applies a linear approximation, error correction in stock equations is required to take account of these non-linearities. Gilbert says on this issue (1990, p. 52) '...in a linear approximation (of a commodity price response function) to the non-linear model it may be necessary (to use an error correction mechanism)'.

correction is applied both in the two step method, as well as implicitly in short run equations. In most cases the estimation results hardly differed. In case of 2SLS estimations the two step method is applied. Estimation results on long-run relationships are reported separately. (Co)integration tests are executed and test statistics are presented. Estimations methods and transformations are reported in the Tables.

5.1. Production of natural rubber

The production of a perennial crop like natural rubber shows a specific long-run dynamic pattern. Rubber trees only start to produce rubber after a relatively long gestation period of 5 to 7 years. After this immaturity period the annual yield of trees depends on the age of the tree, the particular variety of the tree (eg. GG1/2, TJIR1 and RRIM600), the tapping intensity, the availability of labour and seasonal conditions to the extent that these conditions are different over the years. After some 25 to 35 years a decision about replanting or uprooting is made. It can realistically be assumed that estate managers and small-holders with a rubber tree plantation behave as profit-maximizers. Hence, long-run expected net revenues, and thus expected prices will determine replanting, new planting and discarding of rubber trees (see eg. Akiyama and Trivedi (1987)). Procurement prices for natural rubber, an income guarantee for rubber producers, and, in general, support policies to stabilise prices of natural rubber, may influence these expectations and hence have an impact on discarding and new-planting, or investments in rubber trees. The same can be argued of investment subsidies that are provided by the government. Experiences in the period from 1950 to 1990 confirm that a substantial part of the increase in area under rubber is due to subsidies or other forms of direct government involvement in new planting. The spurt in planting activities due to the improvement of rubber prices after the introduction of cash subsidy for new planting since 1987 is just another example.

Elsewhere (see Burger, Haridasan, Smit, Unny and Zant (1993)) a detailed description is presented of a method to calculate so-called normal or long-run production. Areas planted with rubber trees, distinguished by age and varieties (clones) applied in rubber tree cultivation, and yields, also distinguished by age and variety, and including technical progress in the production process (tapping method, rainguarding, irrigation), explain the specific long-run dynamics of this perennial crop. The behaviour of small-holders and estate managers with respect to area (new-planting, discarding and uprooting) and yield is formulated

endogenously along the lines sketched above. The vintage approach is summarised with the formula:

$$q_n = \sum_c \sum_v y_{c,v} a_{c,v}$$

$$y_{c,v} = y_{c,v}(z)$$

$$a_{c,v} = a_{c,v}(z)$$

where q_n = normal or long-run production of natural rubber
 $y_{c,v}$ = yield per ha. of clone (variety) c of vintage v ;
 $a_{c,v}$ = area in ha. with clone c of vintage v

The equation expresses the normal or long-run production of natural rubber (q_n) as the product of area (a) and yield (y), both specified by vintage and variety, and next, summed over vintages and varieties. These two variables are explained by z and contains a number of current and lagged exogenous and lagged endogenous variables. The focus in this model, however, is on the short run. We therefore proceed by using the lagged deviation(s) of actual production from normal production as an explanatory variable in the short run behaviour. This, in fact, is identical to assuming error correction. The long-run relationship reads:

$$q = q_n + \epsilon_t$$

Because normal or long-run production is derived elsewhere we will not formally test the long-run relationship but simply postulate it.

The short run production of natural rubber is mainly determined by a distinctive seasonal pattern. There are two peak months during the year, in particular the months May and November/December, with production highest in the latter period. Production of natural rubber reaches an extreme low level in the months February and June/July. A number of variables have been used to explain seasonal fluctuations. Firstly, we have used rainfall in millimetres per quarter as rainfall will have, with some delay, an impact on the capacity of trees to generate rubber. Rainfall stimulates rubber output per tree and, on the other hand, a lack of rainfall has a negative impact on output per tree. Secondly, tapping of rubber trees is not possible during showers, unless the trees are protected (rainguarding), in which case tapping is not hindered. Rainguarding, however, is not widely practiced among small-holders. With a small number of rainfall days, the loss in output is offset by increased output during the days directly after the rainfall. However, a large number of rainfall days

(more than 15 per month) does have a negative impact on production. The least number of rainfall days required to have such a negative impact is determined with a grid procedure and turned out to be 40 rainfall days per quarter. Finally, production in the first quarter is negatively influenced, not only because of the adverse weather conditions, but also because labourers are sent on leave or take leave in February or March. A specification including all seasonal dummies to allow for all other seasonal variation not accounted for with the suggested variables, seems superior. However, the estimations including these dummies disturb the significance of the coefficients of the weather variables, probably as a result of multicollinearity. Hence, dummies for quarters are included if they leave the significance of the weather variables unaffected. Producers may be able in the very short run and to a small extent, to increase/decrease production with an increase/decrease of prices, by increasing or decreasing tapping intensity. This is investigated empirically. This price-elasticity, however, must be distinguished from a long-run price-elasticity that reflects price responsiveness of new-planting, replanting and discarding decisions (see above; also see Akiyama and Trivedi (1987)).

The following semi-logarithmic relationship is estimated:

$$\nabla q = \alpha_0 + \sum \alpha_{1,i} \text{rfmm}_{t-i} + \alpha_2 \text{rfnd40} + \sum \alpha_{3,j} \text{dq}(j) + \alpha_4 \nabla p + \alpha_5 \epsilon_{1,t-1}$$

where	q	= production of natural rubber;
	rfmm	= rainfall in mm.;
	rfnd40	= number of days with rainfall (per quarter) exceeding 40;
	dq(j)	= dummy for the j-th quarter;
	p	= price of NR deflated by the general consumer price index;

The estimation results are presented in Table 2. The estimations have a high correlation coefficient. From the Table it is clear that we did not succeed in finding evidence for a positive impact of price on production of natural rubber: lagged (not shown), current (see Table) and expected prices (not shown) are all insignificant and/or have wrong signs. Even estimations with an additional set of dummies for strikes of tappers, droughts, extreme rainfall and other unexpected events (not shown) did not improve this price elasticity. The weather variables are significant: rainfall in mm has a one or two period lagged positive impact, while the number of rainfall days exceeding 40 has an instantaneous negative impact. Error correction is significant and has a considerable size. Deviations from the long-run path are corrected with a lag of around two periods. Equation 2 of Table 2 has been selected for historic simulations (see Section 6).

Table 2 **Production of natural rubber**
Dependent variable: production of natural rubber (∇q)

equation	1	2
sample period	73.3-90.4	73.3-90.4
estimation method	2SLS	OLS
C	.18 (4.1)	.17 (5.9)
rfmm _{t-1}	.000123 (1.9)	.000242 (9.3)
rfnd40	-.0035 (1.0)	-.0088 (5.0)
dumq1	-.69 (10.2)	-.81 (28.0)
dumq3	-.20 (2.8)	-.22 (4.8)
$\epsilon_{1,t-1}$	-.90 (3.5)	-.53 (4.2)
∇p	-1.46 (2.3)	
R2	.86	.94
DW	2.2	2.0

The dependent variable is in first differences of natural logarithms. All seasonal variables (dumq(n), rfmm, rfnd40) are not transformed; all other variables are transformed in first differences of natural logarithms; C = constant term; dumq(n) = dummy for the n-th quarter; rfmm = rainfall in mm.; rfnd40 = number of rainfall days exceeding 40; p = price of natural rubber deflated by the general consumer price index; $\epsilon_{1,t-1}$ = error correction variable; t-statistics are presented in brackets below the coefficient; R2 = coefficient of correlation adjusted for degrees of freedom.

5.2. Stocks with growers and dealers

Stocks are held for several reasons: speculative demand, precautionary demand and transactions demand can be distinguished. Speculative demand for stocks is related to the income to be earned from the difference of current and future prices. Transaction demand for stocks is related to a continuous flow of goods required for production (or consumption).

Precautionary stocks are kept to be able to service fluctuating and uncertain requirements of others. From these motives it is derived that stock demand is a function of consumption, the returns on holding stocks and the initial stocks (see Appendix 1). It is postulated that in the long-run stocks are determined by the consumption of natural rubber, or more specifically the transaction demand for rubber: eventually stocks with growers and dealers are determined by the requirements of production. The existence of such a long-run relationship is corroborated by the agreements made between consumers and producers on stockholding. Operational stocks are held in India according to norms that are agreed upon between consumers, producers, dealers and the State Trading Corporation (see National Council of Applied Economic Research (1980)). Operational stocks held by growers and dealers until 1974 were equivalent to 6 weeks of total Indian consumption (3 weeks held by growers and 3 weeks held by dealers). Following the acceptance of the Tandon Committee Report on Bank Credit in 1975 the total stock norm was reduced to 12 weeks (from 16 weeks), implying 4 weeks of stocks held by growers and dealers. However, the All India Rubber Industries Association recommended a total stock norm of 18 weeks, with a 10 weeks stock held by growers and dealers (5 weeks held by growers and 5 weeks held by dealers). The correspondence between stocks and consumption is evident from the data (see Appendix 3). The data clearly show to what extent the above mentioned norms have been put into practice. From these data a structural break in this long-run relationship is inferred in the year 1976-77. This corresponds more or less to the change in norms described above. For this reason the sample period in the estimations has been adjusted. The long-run double logarithmic relationship reads:

$$n_{gt} = \beta_0 + \beta_1 c + \epsilon_2$$

where n_{gt} = stocks of natural rubber with growers and dealers;
 c = consumption of natural rubber

Before running regressions it is necessary to determine the order of integration. Tests are executed and test statistics are summarised in Appendix 4. It is shown that both variables are integrated of the first order (I(1)). From the regression equation below it is inferred that stocks of natural rubber with growers and dealers and consumption of natural rubber are cointegrated series. The estimation of the long-run relationship generates:

$$n_{gd} = 1.30 + .81 c \quad \text{sample period: 1977.4-1990.4}$$

(.7) (4.9)

$$R^2 = .31; \quad DF = -5.67; \quad ADF = -4.87;$$

(variables are transformed logarithmically; t-values are shown in parentheses below the coefficient; R^2 = coefficient of correlation adjusted for degrees of freedom; (A)DF = (Augmented) Dickey Fuller test statistic; The null hypothesis of cointegration cannot be rejected¹⁰).

For the short run it is assumed that stocks with growers and dealers are determined by stocks in the past. The demand for stocks will decline with the size of stocks at the start of the period (see Appendix 1). The return on holding stocks will determine demand for stocks as well. This return is equal to expected price minus costs, and must be compared with the return on alternative investments. The current price is the most important component of the unit cost of stockholding. Hence, the return on holding stocks is approximated with taking up current and expected prices in the equation. In Appendix 2 a method is set out to compute a rational expectation of future prices. The method consists of the calculation of estimated price expectations on the basis of expected supply and demand balances and follows suggestions made in the literature (see Gilbert (1990), Trivedi (1990)). Finally, it is assumed that huge fluctuations in production create substantial and to some extent forced stock formation by growers and dealers in times of intensive tapping, and depletion of stocks with growers and dealers in the lean season. Hence, production is included as an explanatory variable for stocks with growers and dealers as well. An error correction mechanism is added to account for corrections on deviations of the long-run path. The following loglinear equation in first differences is used as short run equation:

$$\nabla n_{gd} = \gamma_0 + \gamma_1 \nabla n_{gd,t-1} + \gamma_2 \nabla q + \sum \gamma_{3j} \nabla p_{t+j}^e + \gamma_4 \nabla p + \gamma_5 \epsilon_{2,t-1}$$

where n_{gd} = stocks of natural rubber with growers and dealers;
 q = production of natural rubber;
 p = price of natural rubber deflated by the general consumer price index;
 p_{t+j}^e = j-th period expected price;

The estimation results are summarised in Table 3. All specifications are estimated with OLS and 2SLS. Error correction is applied in a two step estimation of long-run and

¹⁰ Critical values for two integrating variables with a sample size of 100 are: DF 3.37; and ADF 3.17; and with a sample size of 50: DF 3.67; and ADF 3.25; Critical values of in between sample sizes are calculated by interpolation. Sources of critical values are presented in appendix 4.

Table 3 Stocks of natural rubber with growers and dealersDependent variable: Stocks of natural rubber with growers and dealers (∇n_{gd})

equation no	1	2*	3	4*	5	6*	7	8*
sample period	78.4-90.2	78.4-90.2	78.4-90.2	78.4-90.2	78.4-90.2	78.2-90.2	78.2-90.2	78.2-90.2
estimation method	OLS	OLS	OLS	OLS	2SLS	2SLS	2SLS	2SLS
explanatory variable								
C	.16 (.2)	.16 (.2)	.12 (.2)	.10 (.2)	-.00 (.0)	.00 (.0)	-.00 (.1)	-.00 (.2)
$\nabla n_{gd,t-1}$	-.13 (1.4)	-.13 (1.5)			-.23 (.8)	-.14 (.9)		
∇q	.51 (7.0)	.51 (7.1)	.56 (9.3)	.56 (9.4)	.41 (1.4)	.50 (3.9)	.62 (6.6)	.59 (7.7)
∇p	-1.30 (4.7)	-1.29 (5.4)	-1.16 (4.4)	-1.05 (5.6)	-2.09 (1.0)	-1.30 (2.3)	-.49 (.6)	-.87 (3.0)
∇p^*_{t+2}	1.24 (2.5)	1.29 (5.4)	.83 (2.0)	1.05 (5.6)	1.22 (2.0)	1.30 (2.3)	1.13 (1.9)	.87 (3.0)
$\epsilon_{2,t-1}$	-.25 (2.7)	-.25 (2.8)	-.31 (3.8)	-.31 (3.9)	-.23 (2.0)	-.24 (2.3)	-.28 (2.8)	-.29 (3.0)
R2	.89	.89	.89	.89	.84	.84	.84	.84
DW	1.9	1.9	2.1	1.9	1.9	1.8	1.9	2.0

Variables are transformed in first differences of natural logarithms; First differences of natural logarithms of all variables are stationary (see Appendix 4)¹¹; C = constant term; n_{gd} = stocks of natural rubber with growers and dealers; q = production of natural rubber; p = price of natural rubber deflated by the general consumer price index; p^*_{t+2} = 2 periods ahead expected price; $\epsilon_{2,t-1}$ = error correction variable; t-statistics are presented in brackets below the coefficient; R2 = coefficient of correlation adjusted for degrees of freedom; DW = Durbin-Watson statistic; list of instruments in 2SLS (next to explanatory variables in current equation): q , $n_{gd,t-1}$, $n_{mf,t-1}$, c_{t-1} ; equations with a * are estimated with the restriction $\Sigma \gamma_{3,j} = -\gamma_4$;

¹¹ It is only sensible to estimate an short run equation in which all variables are stationary. Tests results on the order of integration of the variables are reported in appendix 4.

short run equations in case of 2SLS estimations (equation (5) to (8)) and implicitly in equation (1) to (4). From Appendix 1 it follows that the restriction $\Sigma\gamma_{3j} = -\gamma_4$ should hold, if deterioration and storage costs of stocks are negligible, and if a constant rate of interest is assumed. Equations (2), (4), (6) and (8) are estimated with this restriction. With some exceptions the coefficients are significant and have the proper sign. The equations show a good fit: the estimations have a high correlation coefficient, ranging from .84 to .89. This is to a large extent caused by the dependence on production of natural rubber: some 70% or more of the variation is explained by this variable. From the size of the production elasticity of stock demand and the fluctuation of production itself, it is inferred that a large part of stock formation by growers and dealers is due to fluctuations in the production process. The hypothesis of speculative stock demand as set out in Appendix 1, is partly corroborated. One-period forward looking price expectation did not generate acceptable results. Only two-period forward looking price expectations proved successful. In case of estimations with 2SLS the significance of the coefficients of future expected prices deteriorates. With the above mentioned restriction, however, it improves again. Using an F-test this restriction cannot be rejected in all equations. The calculated F statistics $[(RSS_R - RSS_U)/d]/[RSS_U/(n-k)]$ have the value of resp .013, .361, .148, and .267 for equations (1)/(2), (3)/(4), (5)/(6) and (7)/(8). These values are smaller than the critical values (relevant critical values are $F_{1,40} = 4.08$; $F_{1,60} = 4.00$) and hence the null hypothesis of $\Sigma\gamma_3 = -\gamma_4$ cannot be rejected with a significance of 5%. The elasticity of demand with respect to current and future expected natural rubber prices with restriction varies from (+/-) .87 to 1.30. The impact of initial stocks on stock behaviour, a variable that reflects precautionary stock behaviour, is weakly, and in some cases hardly significant. It nevertheless shows the proper sign and is almost significant in the equation (1) and (2). The error correction has a reasonable significance and a relatively small size (in between -.23 and -.31) indicating a slow convergence: deviations from the long-run path are corrected with a lag of around 3 to 5 periods. Equation 6 of Table 3 has been selected for simulations (see Section 6) because of the estimation technique, the specification, and the signs and significance of the coefficients.

5.3. Stocks of natural rubber with manufacturers of rubber products

For manufacturers of rubber products stocks serve as a buffer to avoid restrictions on their requirements of rubber input and to feed the production process. But also speculative

motives to hold stocks might be relevant. Indeed, again there is no a priori reason to assume that one of the suggested motives to hold stock does not apply to stock behaviour of manufacturers. Hence, stock demand depends on consumption, returns on holding stock and initial stocks. We develop the relationships of stock demand by manufacturers of rubber products along the same lines as in the case of stock demand by growers and dealers. Again, it is assumed that in the long-run stocks of natural rubber with manufacturers are determined by consumption of natural rubber. A long-run relationship based on the transaction demand is postulated: it is believed that, in the end, stocks at manufacturers of rubber products are fully determined by the requirements of production (see Appendix 1). According to the norms mentioned above (see National Council of Applied Economic Research (1980)) the operational stocks with manufacturers amounted to 8 weeks of total Indian consumption until 1974. Following the acceptance of the Tandon Committee Report on Bank Credit in 1975 the major rubber consumers agreed to bring down stocks held by manufacturers to 6 weeks. The All India Rubber Industries Association, however, recommended a 4 weeks stock held by manufacturers of rubber products. Empirically (see Appendix 4) it can be observed that consumption closely follows the long-run trend. This relationship, however, is much more pronounced than for stocks with growers and dealers. Again from these Figures a structural break in the long-run relationship is inferred in the year 1976-77, and the sample period is adjusted accordingly. The double logarithmic long-run relationship reads:

$$n_{mr} = \delta_0 + \delta_1 c + \epsilon_3$$

where n_{mr} = stocks of natural rubber with manufacturers of rubber products;
 c = consumption of natural rubber

Again, test results on the order of integration, reported in Appendix 4, show that both variables are I(1), and from the regression equation below it follows that these variables are cointegrated series. The estimation of the long-run relationship generates (variables are transformed logarithmically):

$$n_{mr} = 1.18 + .80 c \quad \text{sample period: 1977.4-1990.4}$$

(1.3) (9.2)

$$R^2 = .62; \quad DF = -6.3; \quad ADF = -4.3;$$

(variables are transformed logarithmically; t-values are shown in parentheses below the coefficient; R^2 = coefficient of correlation adjusted for degrees of freedom; (A)DF = (Augmented) Dickey Fuller test statistic; The null hypothesis of cointegration cannot be rejected, for critical values see footnote 10).

In the short run the same determinants are assumed to apply as in the case of stocks with growers and dealers (for a derivation, see Appendix 1 and 2), with the exception that stock formation by manufacturers will, of course, not be forced by the production of natural rubber itself. An error correction term is added, based on the long-run relationship set out above. The following loglinear equation in first differences is the basis for estimations of a short run equation:

$$\nabla n_{mf} = \zeta_0 + \zeta_1 \nabla n_{mf,t-1} + \sum \zeta_{2,j} \nabla p_{t+j}^* + \zeta_3 \nabla p + \zeta_4 \epsilon_{3,t-1}$$

where n_{mf} = stocks of natural rubber with manufacturers of rubber products;
 p = price of natural rubber deflated by the general consumer price index;
 p_{t+j}^* = j-th period expected price;

The estimation results are summarised in Table 4. All specifications are estimated both with OLS and 2SLS. In case of 2SLS the same instruments were chosen as in the case of stocks with growers and dealers. Error correction is applied in a two step estimation of long-run and short run equation with 2SLS estimations (equation (5) to (8)) and implicitly in equation (1) to (4). The estimations have a somewhat lower correlation coefficient than in the case of the stocks with growers and dealers, and range from .54 to .58. With some exceptions coefficients are significant and have the proper sign. One period forward looking behaviour is significant in all equations, pointing at speculative behaviour in stock demand of manufacturers of rubber products. Elasticities with respect to both relative current and expected price of natural rubber are less sensitive to changes in specification than in the case of stocks with growers and dealers. The restriction on the coefficient of current and future expected prices cannot be rejected. Using an F test, the calculated F statistics $[(RSS_R - RSS_U)/d]/[RSS_U/(n-k)]$ have values of respectively .591, .195, .058, and .000 for equations (1)/(2), (3)/(4), (5)/(6) and (7)/(8). Relevant critical values for these cases are $F_{1,40} = 4.08$, $F_{1,60} = 4.00$. The null hypothesis of $\sum \zeta_{2,j} = -\zeta_3$ cannot be rejected with a significance of 5%. With this restriction the elasticity of demand with respect to these variables ranges from (+/-) .69 to .99. Precautionary stock behaviour reflected in the coefficient of lagged stocks is again rather weakly significant and, hence, not convincing. It nevertheless shows the proper sign and has a plausible order of magnitude. The error correction is highly significant and of considerable size in all equations (in between -.73 and -.89), indicating a very fast convergence. From the estimations it is clear that the size of error correction increases if initial stocks are left out of the equation. Equation 6 of Table 4 has been selected for

simulations (see Section 6), in view of the R2, the t-values and signs of the coefficients, and the estimation technique.

Table 4 Stocks of natural rubber with manufacturers of rubber products
Dependent variable: Stocks of natural rubber with manufacturers of rubber products (∇n_{mmf})

equation no	1	2*	3	4*	5	6*	7	8*
sample period	78.2-90.3	78.2-90.3	78.1-90.3	78.1-90.3	78.1-90.3	78.2-90.3	78.2-90.3	78.2-90.3
estimation method	OLS	OLS	OLS	OLS	2SLS	2SLS	2SLS	2SLS
explanatory variable								
C	.56 (1.0)	.60 (1.1)	.61 (1.3)	.63 (1.4)	.02 (.9)	.02 (.9)	.02 (.7)	.02 (.7)
$\nabla n_{mmf,t-1}$	-.19 (1.5)	-.17 (1.4)			-.19 (1.5)	-.18 (1.5)		
∇p	-.63 (2.7)	-.73 (3.8)	-.64 (2.7)	-.69 (3.7)	-.79 (1.5)	-.90 (3.1)	-.82 (1.5)	-.83 (2.9)
∇p^e_{t+1}	1.03 (2.4)	.73 (3.8)	.86 (2.1)	.69 (3.7)	.99 (2.1)	.90 (3.1)	.84 (1.8)	.83 (2.9)
$\epsilon_{3,t-1}$	-.73 (4.5)	-.75 (4.7)	-.89 (7.1)	-.89 (7.2)	-.73 (4.3)	-.73 (4.4)	-.89 (6.7)	-.89 (6.9)
R2	.58	.58	.56	.57	.54	.55	.53	.54
DW	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1

Variables are transformed in first differences of natural logarithms; First differences of natural logarithms of all variables are stationary (see Appendix 4); C = constant term; n_{mmf} = stocks of natural rubber with manufacturers of rubber products; p = price of natural rubber deflated by the general consumer price index; p^e_{t+1} = 1 period ahead expected price; $\epsilon_{3,t-1}$ = error correction variable; t-statistics are presented in brackets below the coefficient; R2 = coefficient of correlation adjusted for degrees of freedom; DW = Durbin-Watson statistic; With 2SLS estimations the following instruments are used for price (p) are: C, q, $n_{gd,t-1}$, $n_{mmf,t-1}$, C_{t-1} ; * these equations are estimated with the restriction $\Sigma \zeta_{2j} = -\zeta_3$.

5.4. Consumption of natural rubber

Natural rubber is 'consumed' by producers of rubber products. By far the largest share of natural rubber - around 65% (see Burger, Haridasan, Smit, Unny and Zant (1993)) is consumed by tyre and tube producers. The remaining share of rubber consumption is related to the manufacturing of a group of miscellaneous rubber products, including footwear, belts and hoses, latex foam and dipped goods, battery boxes and cables & wires. The production of these miscellaneous rubber products is directly linked with industrial production. The former category, the production of tyres and tubes, depends on demand for tyres and tubes. This demand for tyres can be split up in original equipment and replacement demand. Original equipment demand depends on production of new vehicles. Replacement demand is due to the wear-and-tear of tyres on vehicles and is related to the number of vehicles in use. The number of vehicles in use depends on sales of vehicles in the past and scrappage: aggregating these sales in the past - the vintages - and subtracting scrappage of worn out vehicles, constitutes the number of vehicles in use. Sales of vehicles, the final component required to complete these relationships, are the outcome of demand and supply of vehicles. In Burger, Haridasan, Smit, Unny and Zant (1993) a detailed framework is elaborated and empirically specified, to account for these relationships. However, such a detailed framework is beyond the scope of the current model: instead, a simple loglinear relationship between consumption of natural rubber and gross industrial product is assumed to reflect long-run behaviour of consumption, and a reasonable approximation of the above mentioned framework:

$$c = \eta_0 + \eta_1 \text{ gip} + \epsilon_t$$

where c = consumption of natural rubber;
 gip = gross industrial product

From Appendix 4, in which the test results on the order of integration are presented, it follows that both variables are I(1). Estimating the above equation with OLS generates:

$$c = 6.03 + 1.01 \text{ gip} \quad \text{sample period: 78.1-90.4}$$

(47.0) (38.3)

$$R^2 = .97; \quad DF = -6.8; \quad ADF = -9.1;$$

(variables are transformed logarithmically; t-values are shown in parentheses below the coefficient; R^2 = coefficient of correlation adjusted for degrees of freedom; (A)DF = (Augmented) Dickey Fuller test statistic; the null hypothesis of cointegration cannot be rejected)

It can realistically be assumed that manufacturers of rubber products maximize profits or minimize costs, to the extent that the relationships set out above permit such behaviour. Factor demand equations can be derived on the basis of first order conditions for a maximum. From this it follows that consumption demand for natural rubber depends negatively on current prices of natural rubber. Next to this behaviour, a speculative motive similar to the one that motivates stock demand by manufacturers might apply to consumption. Manufacturers of rubber products require a continuous stream of input of rubber to feed their production process. They will follow a buying and stock policy to avoid both price rises or shortages. The following loglinear short run relationship is estimated:

$$\nabla c = \theta_0 + \sum \theta_{1,i} \nabla p_{t+i}^* + \theta_2 \nabla p + \theta_3 \epsilon_{4,t+1}$$

where c = consumption of natural rubber;
 p_{t+i}^* = i -th period expected price;
 p = price of natural rubber deflated by the general consumer price index;

The estimation results are presented in Table 5. The long-run equation is estimated implicitly in equation (1), (2) and (3). The coefficients of the implicitly estimated long run equation (not shown) hardly differ from the one above: they all point at an elasticity with respect to gross industrial product of around 1. From the estimations it is clear that we did not succeed in finding a significant impact of current prices. Only with restriction that coefficients of current and future prices are equal but opposite in sign - a restriction that follows from the speculative motive (see Appendix 1) - a significant impact of current prices is generated (not shown). The restriction on the coefficient of current and future expected prices must be rejected. Using an F test, the calculated F statistics $[(RSS_R - RSS_U)/d] / [RSS_U/(n-k)]$ have values of resp 14.9, and 1.77 for equations (1)/(2) and (4)/(5). Relevant critical values in these cases are $F_{1,40} = 4.08$ and $F_{1,60} = 4.00$. The null hypothesis of the restriction $\sum \theta_{1,i} = -\theta_2$ should be rejected with a significance of 5% if imposed on equation (1) and, almost, with a significance of 10% if imposed on equation (4). The overall fit of the equation is not impressive. However, we are not particularly worried, because the long-run equation shows such extraordinary high correlation coefficients. Equation 3 of Table 5 has been selected for simulations.

Table 5 Consumption of natural rubberDependent variable: Consumption of natural rubber (∇c)

equation no.	1	2*	3	4	5*
sample period	78.1-90.2	78.1-90.2	78.1-90.2	78.2-90.2	78.2-90.2
estimation method	OLS	OLS	OLS	2SLS	2SLS
explanatory variable					
C	2.16 (7.5)	2.04 (5.8)	2.2 (7.8)	.01 (2.7)	.01 (2.6)
∇gip	.19 (2.0)	.35 (3.6)	.19 (2.1)	.25 (2.5)	.31 (3.4)
∇p^*_{t+2}	.61 (4.5)	.12 (2.4)	.59 (4.7)	.45 (3.0)	.27 (4.7)
p	.02 (.4)	-.12 (2.4)		-.14 (1.3)	-.27 (4.7)
$\epsilon_{4,t-1}$	-.57 (4.9)	-.50 (3.8)	-.58 (5.1)	-.67 (5.0)	-.70 (5.2)
R2	.47	.31	.48	.48	.47
DW	2.2	2.2	2.1	1.9	1.9

Variables are transformed in first differences of natural logarithms; First differences of natural logarithms of all variables are stationary (see Appendix 4); C = constant term; gip = gross industrial product; p = price of natural rubber deflated by the general consumer price index; p^*_{t+i} = i-period ahead expected price of natural rubber; $\epsilon_{4,t-1}$ = error correction variable; t-statistics are presented in brackets below the coefficient; R2 = coefficient of correlation adjusted for degrees of freedom; DW = Durbin-Watson statistic; Equations with an asterisk (*) are estimated with the restriction $\Sigma \theta_{1,i} = -\theta_2$.

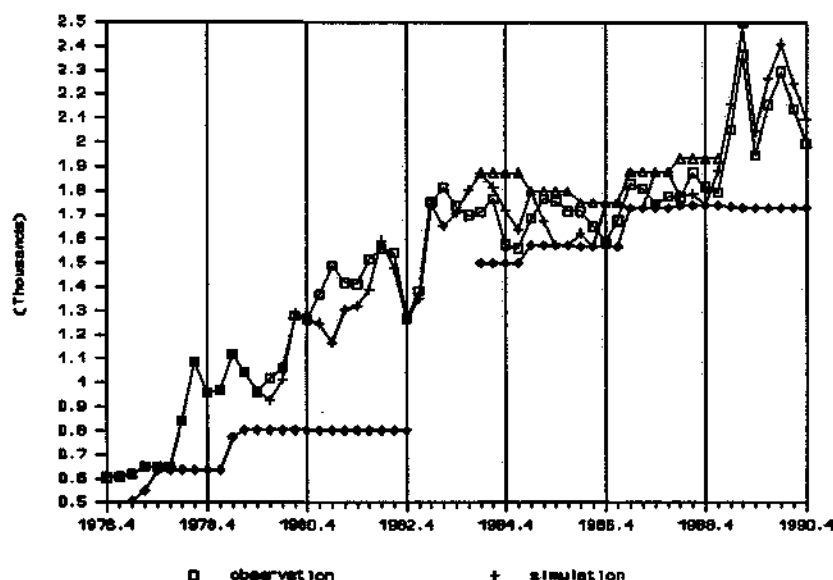
6. Historic simulations with the quarterly model

In order to get a better view on the performance of the model and in particular to find its weaknesses, static simulations are run and related to historical data, starting in 1980.1. With these static simulation endogenous variables of current periods are calculated by the model, while predetermined variables (ie. exogenous and lagged endogenous variables) are observed values. In Figure 2 the domestic price of natural rubber (RMA4) together with the simulated price is presented. Note that variables are evaluated in level, while all estimations

are run in loglevels or first differences of loglevels.

The simulation results seem reasonable. Some qualifications, however, are appropriate. It turned out to be necessary to add a considerable number of dummies¹² in both the production and consumption equation to avoid extreme deviations. Even relatively good estimation results of consumption and production of natural rubber cannot prevent the need for these dummies: in the case of errors the order of magnitude of these variables compared to changes in stocks immediately causes enormous deviations of simulated over actual price. However, the tracking of historic prices is reasonable for a large number of periods. The simulation shows that the presented method for the construction of commodity models provides useful insights into the behavioural equations within a consistent framework.

Figure 2 Price of natural rubber: static simulation



¹² The use of dummies, although not applied in the presented estimations at all, is acceptable in a considerable number of years, at least in the case of production of natural rubber. In particular we refer to a number of strikes, periods with extreme rainfall or droughts and some government policies, all events that can be considered unexpected and exogenous. A list with these exogenous influences is available on request.

7. Summary and conclusion

In this paper a model is developed of the Indian rubber market. Contrary to the usual approach in commodity modelling, in which estimations are run with derived reduced-form price equations, behavioural equations of producers, stockholders and consumers are estimated directly. The estimation results of the behavioural equations are good. From the estimated equations it can be deduced that both production and consumption are inelastic with respect to prices. Enormous fluctuations in production, mainly due to seasonality, together with a rather trendlike development of consumption, both inelastic in the short run, cause prices to fluctuate widely. Stockholders, however, show substantial response to price fluctuations. Clear evidence is found of an impact of forward looking price expectations among stockholders: the hypothesis of speculative behaviour in stockholding is corroborated. Evidence of precautionary demand in stockholding is not convincing. Transaction demand on the other hand is powerfully reflected in the long run behaviour of stockholders. The model performance on historic time-series is not impressive, largely because the estimation errors in production and consumption, being of a substantially different order of magnitude, lead to enormous price fluctuations, and thus disturb the simulation process. This sensitivity of price formation to errors in production and consumption corroborates the experience of other researchers¹³. Nevertheless, with the help of some dummies, the tracking of historic prices is reasonable for a large number of periods.

¹³ Some researchers therefore limit their efforts to reduced form estimations of commodity models. With direct estimation of behavioural equations '... the price is forced to move too much in order to clear the market in forecasting or model simulation' (Ghosh, Gilbert and Hughes Hallett (1987), p.35).

Appendix 1

Deriving a stock demand equation

The derivation of stock demand is based on Ghosh et al. (1987), Gilbert (1988) and Gilbert (1990). We present a simple version of their derivation. Stocks are held for several reasons, all of which motivate demand for stocks. A distinction is made between the transaction, the precautionary and the speculative motives. To begin with the last one, we postulate that agents who are led by the speculative motive hold stocks with the intention to sell these stocks in the future for a higher price. More specifically it is assumed that a speculative agent is interested in deriving income from wealth by buying stock and selling it in the future for a price that outweighs costs and foregone interest income. Formally we have¹⁴:

$$\text{if } n \geq 0 \text{ then } (1-\delta) p^e - p - w \geq r p$$

where

δ	=	rate of deterioration of stocks
w	=	storage cost
p	=	market price of RMA4;
r	=	rate of return on alternative investment

The superfix e indicates expectation on future values of a particular variable;

This inequality, however, is not compatible with market equilibrium: if the expected return to stockholding still exceeds the return on alternative investments, stockholders will continue to buy more stock. This increase in demand will simultaneously push the current price upward, and decrease, in its turn, stock demand, as the expected return decreases. This process continues until the expected return is equal to the return on other investments. In that case stockholders are not willing to hold any additional stock. In other words: equilibrium is realised. With full arbitrage the following condition will be met:

$$(1-\delta) p^e - p - w - r p \leq 0 \perp n \geq 0$$

($\perp$ indicates that at least one of the two expressions must hold as an equality)

In the case deterioration and storage costs are assumed to be negligible ($\delta = w = 0$) perfect arbitrage implies that in equilibrium our condition changes to

$$p^e \leq (1+r) p \perp n \geq 0$$

and thus the expected change in price can be approximated as

¹⁴ The notation of Gilbert is slightly adjusted in order to make variables correspond with the variables in the current model.

$$\dot{p} \leq r \perp n \geq 0$$

(a dot on a variable indicates a rate of change)

From this equation it follows that with positive stocks and under perfect arbitrage, the expected change in price will be equal to the interest rate. Gilbert shows that this condition will hold with both risk neutrality and risk aversion with many speculators. To explain this the excess real rate of return on speculative activities is rewritten as:

$$e_{t+1} = [p_{t+1} / (1+r)] - p$$

The expected utility of a pure speculator is defined as $E u(W + ne)$, where W = initial wealth. Pure speculation means that no utility is derived from consumption and no income is obtained from production. The first order condition for maximizing utility is

$$E[u'(W + ne_{t+1})e_{t+1}] = 0$$

Substitution of e_{t+1} generates

$$(1+r)p E[u'(W + ne_{t+1})e_{t+1}] = E[u'(W + ne_{t+1})p_{t+1}]$$

A first order expansion of $u'(W + ne_{t+1})$ is

$$u'(W + ne_{t+1}) \approx u'(W) + u''(W)ne_{t+1} = u'(W) (1 - \rho ne_{t+1}/W)$$

where $\rho = -Wu''/u'$, the standard coefficient of relative risk aversion. Then

$$E[u'(W + ne_{t+1})e_{t+1}] \approx u'(W) E[(1 - \rho ne_{t+1}/W)e_{t+1}] = 0$$

$$E[e_{t+1} - \rho ne_{t+1}^2/W] = 0$$

and where $Ee_{t+1} = e^*$ and $\text{VAR}(e_{t+1}) = \sigma_e^2$

we obtain: $n/W = e^* / [\rho (e^{*2} + \sigma_e^2)]$

Speculative demand for stocks is positively related to the expected excess return e^* . This relationship tends to linearity as the expected excess return of holding stocks (e^*), or the standard coefficient of relative risk aversion (ρ) tends to zero. The number of speculators operating in the market is denoted with nr_{spec} and they are assumed to have identical wealth W . If the number of speculators increases, the expected return on speculation will decrease and thus $e^* = \xi(nr_{\text{spec}})$ with $\xi' < 0$. If the number of speculators, nr_{spec} , becomes large the expected return, e^* , will tend to zero and thus a market with a large number of risk averse

speculators behaves identical as in the case of risk neutrality.

Next to speculative demand for holding stocks, a transactions and precautionary demand for holding stocks is distinguished. Even if the speculative return is negative, it is assumed that holding stocks can be attractive as it generates a 'convenience' yield. Precautionary demand is associated with stochastic requirements of products from customers. An individual supplier will optimise between the cost of holding additional stocks and the loss of not being able to satisfy customers needs, both currently and in the future. Analytically it can be derived that the convenience yield associated with precautionary stockholding is identical with the reduction in costs of unsatisfied current and future demand. If we define x = stochastic demand, and $E(x) = \mu$ then we can write

$$y_{\text{precaution}} = k \int_{\mu}^{\infty} g(x) dx$$

where $y_{\text{precaution}}$ = convenience yield of precautionary stocks;
 k = unit cost of unsatisfied demand;
 $g(x)$ = probability density function of demand.

The convenience yield related with precautionary stocks, or the change in costs, due to loss of sales and realised with a change in stocks, obviously will be smaller the higher the level of initial stocks, because the probability of not satisfying customers needs will then become smaller. The following relationship applies:

$$y_{\text{precaution}} = y_{\text{precaution}}(n_{t-1})$$

where $\partial(y_{\text{precaution}})/\partial(n_{t-1}) < 0$; and if $n_{t-1} \rightarrow \infty$ then $y_{\text{precaution}} \rightarrow 0$

Transactions demand for stocks is interpreted as working stocks in a production process. The convenience yield created by this type of stocks has to be associated with the marginal product revenue generated with production if these stocks are available (or the loss in the case these production inputs have to be collected by workers). Assuming a CES production function we can write:

$$Q = A [\vartheta n^{\gamma} + (1-\vartheta) L^{\gamma}]^{1/\gamma}$$

where Q = output,
 L = labour input

we obtain for the marginal revenue product of stocks

$$\partial Q / \partial n = \vartheta A^{\gamma} (Q/n)^{1/\sigma}$$

with the elasticity of substitution $\sigma = 1/(1+\gamma)$

and from this we obtain:

$$y_{\text{transaction}} = h n^{-1/\sigma}$$

where

$y_{\text{transaction}}$	= convenience yield of transaction stocks;
h	= $h(c)$
n	= stock
σ	= elasticity of substitution

in which h is a function of the level of commodity demand (c). The relationship shows that the convenience yield of transaction stocks is a linear function of demand and hyperbolic in (initial) stocks. To summarise, precautionary and transaction demand for holding stocks is a function of convenience yield, while convenience yield is an increasing function of demand and a declining function of the initial stocks level, being infinitely high with zero initial stocks.

Combining speculative, precautionary and transaction demand for stocks, and assuming negligible storage and deterioration costs, and a constant rate of interest, we have the following general relationship for demand of stocks:

$$n = n \{ n_{t-1}, c, [p^* - p] \}$$

This relationship is used as a basis for estimations.

Appendix 2

Deriving a rational expectation of prices of natural rubber.

To arrive at an expression of forward looking, model-consistent expected price we will first assume the absence of price intervention. From Section 3 it is clear that for a considerable period neither minimum nor maximum prices have been effective. The formal derivation of the expected price with rational expectations without price bounds is set out below. A summary version of the model looks as follows:

$$\nabla q = \alpha_0 + \sum \alpha_{1,j} \text{rfmm}_{t-1} + \alpha_2 \text{rfnd40} + \sum \alpha_{3,j} dq(j) + \alpha_5 \epsilon_{1,t-1} + u_1 \quad (1)$$

$$m = \overline{m} \quad (2)$$

$$\nabla n_{gd} = \gamma_0 + \gamma_1 \nabla n_{gd,t-1} + \gamma_2 \nabla q + \sum \gamma_{3,j} \nabla p^*_{t+j} + \gamma_4 \nabla p + \gamma_5 \epsilon_{2,t-1} + u_2 \quad (3)$$

$$\nabla n_{mf} = \zeta_0 + \zeta_1 \nabla n_{mf,t-1} + \sum \zeta_{2,j} \nabla p^*_{t+j} + \zeta_3 \nabla p + \zeta_4 \epsilon_{3,t-1} + u_3 \quad (4)$$

$$\nabla c = \theta_0 + \sum \theta_{1,j} \nabla p^*_{t+j} + \theta_2 \nabla p + \theta_3 \epsilon_{4,t-1} + u_4 \quad (5)$$

$$q + m = \nabla n_{mf} + \nabla n_{gd} + c \quad (6)$$

where $p^*_{t+j} = E \{ p_{t+j} \mid \text{information up to } t \}$ and $u_i \sim 0, \sigma^2$ for $i = 1$ to 4

(for an explanation of other variables, see Section 4; contrary to the equations in the main text, variables are not transformed in natural logarithms)

Substituting (1) to (5) into (6) gives:

$$\begin{aligned} q_{t-1} + \alpha_0 + \sum \alpha_{1,j} \text{rfmm}_{t-1} + \alpha_2 \text{rfnd40} + \sum \alpha_{3,j} dq(j) + \alpha_5 \epsilon_{1,t-1} + u_1 + \overline{m} = \\ \gamma_0 + \gamma_1 \nabla n_{gd,t-1} + \gamma_2 \nabla q + \sum \gamma_{3,j} \nabla p^*_{t+j} + \gamma_4 \nabla p + \gamma_5 \epsilon_{2,t-1} + u_2 \\ \zeta_0 + \zeta_1 \nabla n_{mf,t-1} + \sum \zeta_{2,j} \nabla p^*_{t+j} + \zeta_3 \nabla p + \zeta_4 \epsilon_{3,t-1} + u_3 \\ c_{t-1} + \theta_0 + \sum \theta_{1,j} \nabla p^*_{t+j} + \theta_2 \nabla p + \theta_3 \epsilon_{4,t-1} + u_4 \end{aligned}$$

This equation can be rewritten in a more convenient way as follows

$$\nabla p = \sum \phi_j \nabla p^*_{t+j} + Z \quad (7)$$

where $\phi_j = (\gamma_4 + \zeta_3 + \theta_2)^{-1} * -(\gamma_{3,j} + \zeta_{2,j} + \theta_{1,j})$

$$\begin{aligned} \text{and } Z &= (\gamma_4 + \zeta_3 + \theta_2)^{-1} * [q_1 + \alpha_0 + \sum \alpha_{1,j} \text{rfmm}_{t,i} + \alpha_2 \text{rfnd40} + \sum \alpha_{3,j} dq(j) + \\ &\alpha_5 \epsilon_{1,t-1} + u_1 + m - \gamma_0 - \gamma_1 \nabla n_{gd,t-1} - \gamma_2 \nabla q - \gamma_3 \epsilon_{2,t-1} - u_2 \\ &- \zeta_0 - \zeta_1 \nabla n_{mf,t-1} - \zeta_4 \epsilon_{3,t-1} - u_3 - c_1 - \theta_0 - \theta_3 \epsilon_{4,t-1} - u_4] \end{aligned}$$

If all expectations refer to the next period¹⁵, or $j = 1$, we have

$$\nabla p = \phi_1 \nabla p_{t+1}^e + Z \quad (8)$$

Taking conditional mathematical expectations of both sides with respect to the information available at time t we have

$$E(\nabla p) = \nabla p^e = \phi_1 \nabla p_{t+1}^e + E(Z) \quad (9)$$

and thus

$$\nabla p_{t+1}^e = \phi_1 \nabla p_{t+2}^e + E(Z_{t+1}) \quad (10)$$

$$\nabla p_{t+2}^e = \phi_1 \nabla p_{t+3}^e + E(Z_{t+2}) \quad (11)$$

etc.

Substituting (11) into (10) we have

$$\nabla p_{t+1}^e = \phi_1 (\phi_1 \nabla p_{t+3}^e + E(Z_{t+2})) + E(Z_{t+1}) \quad (12)$$

With no expected deviations from long run relationships, or $E(\epsilon_i) = 0$ for $i = 1$ to 4, and remembering that $E(u_i) = 0$ for $i=1$ to 4, equation (12) can be written as

$$\begin{aligned} \nabla p_{t+1}^e &= \phi_1^2 \nabla p_{t+3}^e + \\ &\phi_1 \psi * [E(q_{t+2} + m_{t+2} - c_{t+1}) - \gamma_1 \nabla n_{gd,t+1} - \gamma_2 E(\nabla q_{t+2}) - \zeta_1 \nabla n_{mf,t+1}] + \\ &\psi * [E(q_{t+1} + m_{t+1} - c_t) - \gamma_1 \nabla n_{gd,t} - \gamma_2 E(\nabla q_{t+1}) - \zeta_1 \nabla n_{mf,t}] \end{aligned} \quad (13)$$

where $\psi = (-\gamma_0 - \zeta_0 - \theta_0) / (\gamma_4 + \zeta_3 + \theta_2)$

Repeated substitution of the part ∇p_{t+k}^e in equation (13) with $k = 3, 4, 5$ etc., reveals that, with the restriction that $|\phi_1| < 1$, and thus $\phi_1^m = 0$ with $m \rightarrow \infty$, the future expected price

¹⁵ With $j = 1$ and some additional restrictions on the coefficients this model of expectation formation is identical to the extended version of Muth's model of inventory speculation as presented in Pesaran (1987, pp 112-117). Pesaran shows that under plausible a priori values of the coefficients the speculative inventory model will have a unique solution. Under some conditions (namely stationarity of the elements of Z) Pesaran argues that the general stationary solution is applicable to all versions of the speculative inventory model (..).

can be written as a geometrically declining function of $E(Z_{t+k})$, or:

$$\nabla p_{t+1}^* = \sum_{i=0}^{\infty} \phi_1^i E[Z_{t+1+i}] \quad \text{for } |\phi_1| < 1 \quad (13)$$

The derivation for the expression of ∇p_{t+1}^* in case $j = 1$ to 3 (indeed, it is assumed that in the case of speculative demand, at most, future expected prices of three periods ahead are relevant) is straightforward and can be developed along similar lines: the same result is generated, only with different coefficients.

With respect to the future variables the following decisions are taken. Long-run analysis on production generates approximations for expected production: in formula it is assumed that $E(q) = q_n$ ¹⁶. Remember that import of natural rubber in our model consists of releases by the STC (r_{stc}) and import by manufacturers of rubber products (m_{mfr} , see also Section 4). Expectational values of stocks at growers and dealers, stocks at manufacturers, imports and consumption are constructed with a first order autoregressive process including seasonal dummies¹⁷. Actual prices are used as dependent variable. Estimation results of equation (13) with $i = 0$ are presented in Table 1A. In view of the price policies, in particular the Buffer Stocking Scheme (see Section 2), estimations are run with a restricted sample period (1978.4-1984.1).

The estimation results are not impressive. However, as long as the signs of the coefficients are correct, the poor estimation result is not of major concern. The correctness of signs is, however, also rather limited. In fact only expected stocks at growers and dealers and normal production have correct signs. From the numerous experiments with stock demand equations in which future expected prices as developed in this appendix is an explanatory variable, it followed that equation (3) in case of stocks at growers and dealers,

¹⁶ These calculated long run values are on an annual basis, and, hence, a constant quarterly seasonal pattern is superimposed. This seasonal pattern is calculated by estimating the following regression with quarterly data:

$q_{nr} = \varphi_i * q_{nr, avg}$ with $i = 1$ to 4, and $q_{nr, avg}$ = annual average (actual) production of natural rubber divided by 4; φ_i takes a non-zero value in quarter i and zero in other quarters; Subsequently the quarterly normal production of natural rubber is calculated by multiplying annual normal production (divided by 4) with the estimated φ_i 's.

¹⁷ Estimations are run in loglevels. Estimation results are not shown separately, but available on request.

Table 1A Creating a rational price expectationDependent variable: Price of NR deflated by the general consumer price index (∇p)

equation no.	1	2	3	4
sample period	78.3-84.1	78.3-84.1	78.4-84.1	78.4-84.1
estimation method	OLS	OLS	OLS	OLS
explanatory variable				
C	-.003 (.1)	-.002 (.1)	-.005 (.3)	.002 (.1)
∇q_n	-.308 (1.0)	-.464 (2.6)		-.219 (4.3)
$\nabla q_{n,t+1}$	-.020 (.2)			
$\nabla q_{n,t-1}$				-.161 (3.0)
$\nabla n_{gd,t-1}^e$	-.122 (1.4)	-.137 (2.1)	-.088 (1.8)	
∇n_{gd}^e	-.173 (1.5)		-.191 (3.9)	
$\nabla n_{mf,t-1}^e$	.074 (.6)	.123 (1.3)		
∇n_{mf}^e	-.075 (.6)			
$(q_n + m^e - c_{t-1}^e)$	.472 (1.3)	.529 (1.8)		
R2	.34	.32	.39	.44
DW	2.3	1.9	2.1	2.0

Variables are transformed in first differences of natural logarithms; dependent variable is the price of natural rubber deflated by the general consumer price index (∇p); C = constant term; q_n = normal production of natural rubber; m^e = expected import of natural rubber; c^e = expected consumption of natural rubber; n_{gd}^e = expected stocks at growers and dealers; n_{mf}^e = expected stocks at manufacturers of rubber products; t-statistics are presented in brackets below the coefficient; R2 = coefficient of correlation adjusted for degrees of freedom; DW = Durbin-Watson statistic;

and equation (4) in case of manufacturers of rubber products (as well as consumption of natural rubber), generated future price expectations that performed nicely in these equations. These specifications are also consistent with the expression derived for future expected price and are therefore selected. The use of different future price expectation can be argued as follows: information on future production of natural rubber is far more widespread in the rubber market, and with much less uncertainty, than information on future stocks. Hence, for some groups of agents expectations on future prices of natural rubber might be dominated by expectations on future production of natural rubber. Finally, the future price expectation, constructed on the basis of equation (3) and (4), are truncated for the period of the Buffer Stocking Scheme to the extent that they never go beyond maximum or minimum prices.

Running regressions for the whole sample period on the basis of the above derived specification (equation (13)) is not acceptable on theoretical grounds. Indeed, during the period of 1984 the second quarter to 1989 the first quarter the Buffer Stocking Scheme has been operative, a price policy with maximum and minimum prices. Price expectations will be affected under such a scheme: with effective maximum prices, prices cannot be expected to increase in the future and with effective minimum prices, prices cannot be expected to decrease in the future. More general, price increases/decreases will be limited by the (exogenous) maximum/minimum price. In the literature some procedures are suggested to account for price policies in the formation of price expectations (see Chanda and Maddala (1983), Maddala (1983), Maddala and Shonkwiler (1985)). The suggested procedure starts with partitioning the sample in three parts: observations are taken together in which the actual price is the market price, in which the actual price is the minimum price ($p = p_{\min}$) and in which the actual price is the maximum price ($p = p_{\max}$). For all three regimes the model is reformulated separately. In our case this involves introducing exogenous values of the maximum price ($p_{\max}$) and the minimum price ($p_{\min}$) in equation (3), (4) and (5). A likelihood function is formulated on the basis of these regime specific price expectations and is estimated with maximum likelihood (FIML). Unfortunately our model is estimated in first differences of natural logarithms, a transformation that does not allow the above mentioned partitioning. We proceed by deriving a reduced form for future price expectation, assuming all equations to be in levels, future expectations to refer to the next period ($j = 1$) and taking $p = p_{\max}$ and $p = p_{\min}$ respectively. Future expected prices can be derived to be a linear function of minimum or maximum prices, and expected production, consumption and

stocks. In a regression equation all three regimes are taken together. Estimation results are not reported. In the regressions in the main text experiments have been undertaken by inserting these price expectation in the above constructed price expectation for the BSS period. Estimations with such price expectations hardly improved estimated results. For these reasons we do not report these estimations.

Gilbert (1990) distinguishes three ways to operationalise rational expectations in empirical models:

1. to use the forward or futures price for the unobserved expected price;
2. to generate a fitted price on the basis of an ARIMA process;
3. to substitute the actual for the unobserved expected price and estimate with instrumental variables (IV).

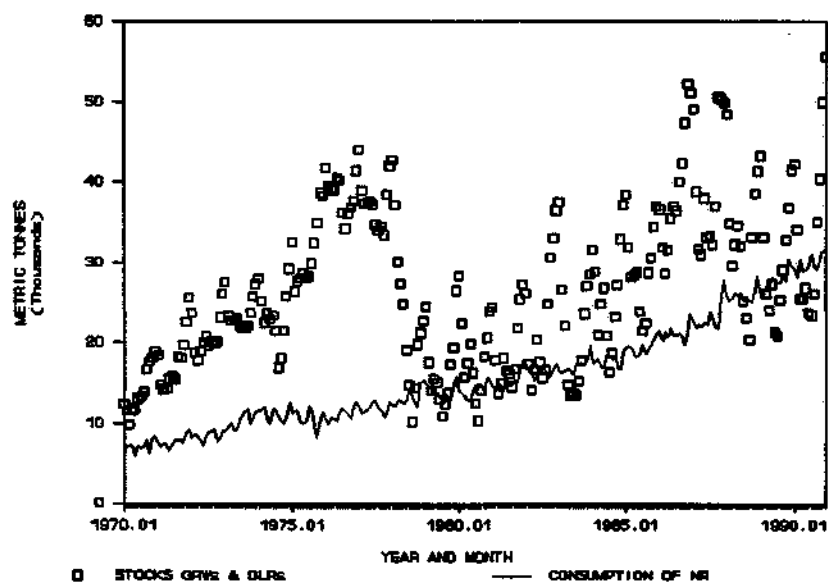
All methods seem to have certain disadvantages. A forward or future price of natural rubber is not available in the Indian rubber market; with perfect arbitrage these prices will also bear little information (see Appendix 1); to calculate a fitted price with an ARIMA process does not seem to be model-consistent and is vulnerable to the Lucas-critique; to use variables in regressions that are calculated from previous regressions introduces measurement error in the constructed variables, and this gives rise to biased coefficient standard errors and t-statistics. Gilbert and Palaskas (1990) argue that it is not recommended to correct for measurement error by means of ML estimation.

Our method comes closest to the third one. The measurement error is assumed to be negligible. In our model expected balances determine rational price expectations and thus current prices. In other words, expected and current balances simultaneously determine current prices. This is recognised in the literature as a necessary requirement in price formation (see Ghosh *et al.* (1987)).

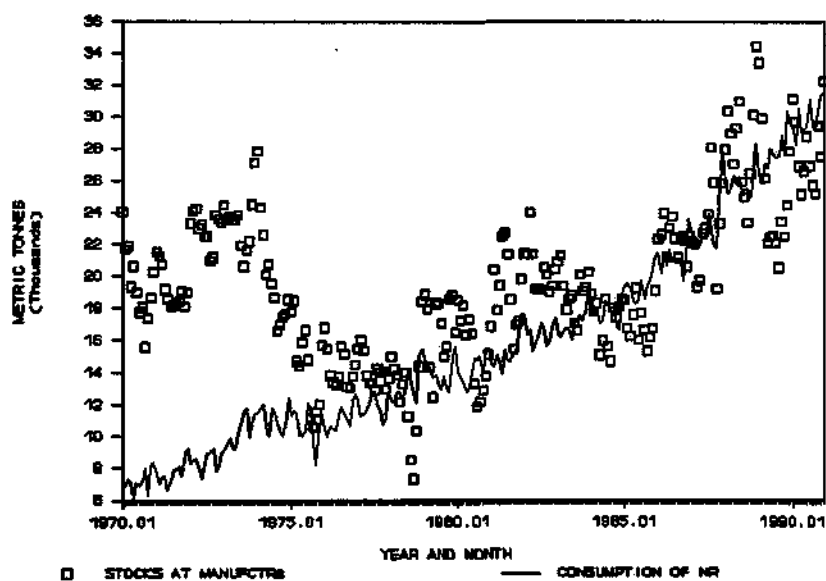
Appendix 3

Figure 1A

Stocks of natural rubber with growers and dealers (levels) and consumption of natural rubber
Source: Indian Rubber Statistics

Figure 2A

Stocks of natural rubber with manufacturers (levels) and consumption of natural rubber
Source: Indian Rubber Statistics



Appendix 4

Testing the order of integration of variables

variable	$H_0: I(1)$		$H_0: I(2)$	
	in (log) levels		in first differences	
	DF	ADF	DF	ADF
q_n	-4.4	-2.3	-17.1	-10.0
n_{gd}	-4.3	-3.3	-12.3	-9.4
n_{mf}	-3.6	-1.9	-15.5	-9.5
c	-.5	-.5	-14.2	-8.0
p	-2.5	-2.3	-9.8	-7.9
gip	-1.1	-.9	-8.8	-12.5
$rfmm$			-8.5	-17.2
$rfnd40$			-9.0	-11.3

where:

DF = Dickey Fuller statistic; ADF = Augmented Dickey Fuller statistic;

q_n = normal production of natural rubber; n_{gd} = stocks of natural rubber with growers and dealers; n_{mf} = stocks of natural rubber with manufacturers; c = consumption of natural rubber; p = price of natural rubber relative to the general consumer price index; gip = gross industrial product; $rfmm$ = rainfall per quarter in mm, registered at the Rubber Research Institute of India; $rfnd40$ = number of days with rainfall exceeding 40 (per quarter), source see $rfmm$.

sample periods:

1970.1/2-1990.4 : n_{gd} , n_{mf} , c , p
 1973.4-1990.4 : $rfmm$, $rfnd40$ (these variables are required to be stationary
 ($H_0: I(0)$); hence, the first difference of these variables is not
 evaluated);
 1976.2/3-1990.4 : gip .

critical values are

for 50 observations: DF -1.95 and ADF -4.12;

for 100 observations: DF -1.95 and ADF -3.73;

and are taken from: Engle and Yoo (1987), Sargan and Bhargava (1983), Fuller (1976) and Blangiewicz and Charemza (1989). The required critical values for in between sample sizes are calculated by interpolation.

From the right part of the Table, the test statistics on variables in first differences of logarithms, it is immediately clear that the null hypothesis is rejected firmly, for all variables without exception. From the variables in levels, however, the DF test is not conclusive: in the case of n_{pd} , n_{mmf} and q_m these statistics indicate rejection of the null hypothesis of integration of the first order ($I(1)$), but for the other variables the DF and ADF test statistics clearly suggest that the null hypothesis of integration cannot be rejected (c ; p ; gip). From the plot of n_{pd} and n_{mmf} (see Appendix 3) it can be inferred that structural breaks (step effects) and outliers (pulse effects) possibly cause rejecting integration. Indeed, if these test statistics are calculated over specific parts of the sample period, or the step and pulse effects are corrected for, the null hypothesis of integration cannot be rejected. These test results are not presented, however. In the case of q_m the rejection of the null hypothesis is entirely due to the seasonal pattern: if test statistics are calculated for annual data the null hypothesis cannot be rejected.

To summarise, we can conclude that the logarithm of all variables are $I(1)$, or integrated of the order 1. The test statistics of the weather variables ($rfmm$, $rfnd40$) indicate stationarity of these variables ($I(0)$).

References

- Akiyama, T. and P.K. Trivedi (1987), 'A Global Tea Model: Specification, Estimation, and Simulation', World Bank Staff Commodity Working Paper, no. 17;
- Burger, K., V. Haridasan, H.P. Smit, R.G. Unny and W. Zant (1993), The Indian Rubber Economy: Analysis, Policies and Outlook, Research Report, Rubber Board of India, Kottayam / Economic and Social Institute, Free University, Amsterdam (forthcoming);
- Burger, K., and H.P. Smit (1989), 'Long Term and Short Term Analysis of the Natural Rubber Market', Weltwirtschaftliches Archiv, 125/4;
- Blangiewicz, M. and W. Charemza (1989), 'Cointegration in Small Samples: Empirical Percentiles, Drifting Moments and Customised Testing', University of Leicester;
- Chanda, A., and G.S. Maddala (1983), 'Methods of Estimation for Models of Markets with Bounded Price Variation under Rational Expectations', Economics Letters, 13 pp. 181-184, North Holland; and 'Erratum', id, 15, pp. 195-196;
- Davidson, J.E.H., D.F. Hendry, F. Sbra and S. Yeo (1978), 'Econometric Modelling of the Aggregate Time-Series Relationship between Consumers' Expenditure and Income in the United Kingdom', Economic Journal, Vol. 88, pp. 661-92;
- Deaton, A. and G. Laroque (1992), 'On the Behaviour of Commodity Prices', Review of Economic Studies, 59, 1-23;
- Engle, R.F. and C.W.J. Granger (1987), 'Co-integration and Error correction: Representation Estimation and Testing', Econometrica, 55, pp. 251-276;
- Engle, R.F. and B.S. Yoo (1987), 'Forecasting and Testing in Co-integrated Systems', Journal of Econometrics, 35, 143-159;
- Fuller, W. (1976), Introduction to Statistical Time Series, New York, John Wiley;
- Ghosh, S., C.L. Gilbert and A.J. Hughes Hallett (1987), Stabilising Speculative Commodity Markets, Clarendon Press Oxford;
- Gilbert, C.L. (1988), 'Optimal and Competitive Storage Rules: The Gustafson Problem Revisited' in Guvenen (ed.), International Commodity Market Models and Policy Analysis, Kluwer Academic Publishers;
- Gilbert, C.L. (1990), 'The Rational Expectations Hypothesis in Models of Primary Commodity Markets', The World Bank, International Economics Department, Working Paper;
- Gilbert, C.L., and T.B. Palaskas (1990), 'Modelling Expectation Formation in Primary Commodity Markets' in L.A. Winters and D. Sapsford (eds.), Primary Commodity Prices: Economic Models and Policy, Cambridge University Press;

- Labys, W.C. and P.K. Pollak (1984), Commodity Models for Forecasting and Policy Analysis, London/Sydney/New York;
- Labys, W.C., J.B. Lesourd, N.D. Uri and O. Guvenen (1991), 'New Horizons in International Commodity Market Modelling' in Labys, W.C., J.B. Lesourd, and O. Guvenen (1992), International Commodity Market Models. Advances in Methodology and Application, Chapman & Hall;
- Maddala, G.S. (1983), 'Methods for Estimation for Models of Markets with Bounded Price Variation', International Economic Review, 24, pp 361-387;
- Maddala, G.S. (1990), 'Estimation of Dynamic Disequilibrium Models with Rational Expectations: the Case of Commodity Markets' in L.A. Winters and D. Sapsford (eds.), Primary Commodity Prices: Economic Models and Policy, Cambridge University Press;
- National Council of Applied Economic Research (1980), 'Ten Year Perspective Plan for Rubber, 1980-81 to 1989-90, Cambridge Press, Delhi;
- Newbery, D.M. and J.E. Stiglitz (1981), The Theory of Commodity Price Stabilisation, Oxford, Oxford University Press;
- Newbery, D.M. (1990), 'Commodity Price Stabilization', in M. Scott and D. Lal (eds.), Public Policy and Economic Development, Oxford Clarendon Press;
- Pesaran, M.H. (1987), The Limits to Rational Expectations, Basil Blackwell, Oxford;
- Sargan, J.D. and A. Bhargava (1983), 'Testing Residuals from Least Squares Regression for being generated by the Gaussian Random Walk', Econometrica, 51, 153-174;
- Shonkwiler, J.S. and G.S. Maddala (1985), 'Modelling Expectations of Bounded Prices: An Application to the market for Corn', The Review of Economics and Statistics;
- Trivedi, P.K. (1990), 'The Prices of Perennial Crops: the Role of Rational Expectations and Commodity Stocks' in L.A. Winters and D. Sapsford (eds.), Primary Commodity Prices: Economic Models and Policy, Cambridge University Press;
- Vogelvang, B. (1988), A Quarterly Econometric Model of The world Coffee Economy; Free University of Press, Amsterdam.
- Winters, L.A., and D. Sapsford (1991), eds., Primary Commodity Prices: Economic Models and Policy, Cambridge University Press;
- Williams, J.C and B.D. Wright (1991), Storage and Commodity Markets, Cambridge University Press;