



Hedging Price Risks of Farmers by Commodity Boards: A Simulation Applied to the Indian Natural Rubber Market

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Summary. — This paper investigates a hypothetical hedging scheme in a domestic commodity market under which a commodity board offers a forward contract to domestic producers and local traders and covers its commitments on an international futures exchange. It is aimed to quantify welfare gains to agents in the market and costs and benefits of the board empirically. The empirical work is based on the Indian natural rubber market and the Tokyo Commodity Exchange (TOCOM) for the period 1990–95. The hedging scheme is shown to increase welfare substantially, particularly welfare of growers. The costs of such a facility for the commodity board (basis risk) are negligible. If the forward price offered on the domestic market is a small fraction below the international futures price, the board can prevent losses at only slightly lower welfare gains. © 2001 Elsevier Science Ltd. All rights reserved.

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1. INTRODUCTION

Financial risk management instruments are often suggested as an effective way to reduce price uncertainty (see, e.g., Claessens & Duncan, 1993; UNCTAD, 1994a,b, 1995). This paper aims to quantify welfare gains of hedging price risks of domestic producers and local traders on an international futures exchange. A situation with and without such a hedging facility is compared with the help of a simulation exercise based on the Indian natural rubber market and the Tokyo Commodity Exchange (TOCOM). Under the proposed hypothetical hedging scheme, a commodity board in the domestic commodity market offers a forward contract to primary producers and stockholders against a fixed price. The board subsequently offsets its exposure by selling futures that correspond to its forward purchase commitments. When the primary producers and stockholders offer their production to the commodity board, the commodity board pays them the contracted price, closes out its futures positions, and sells the physical commodity. Welfare effects of the risk-averse players in the market, primary producers and stockholders, are considered. Costs for the board of operating such a scheme are also calculated in order

to quantify a break-even strategy and to assess its survival probability.

The impact of the introduction of futures markets in commodity markets has been studied extensively (e.g., McKinnon, 1967; Danthine, 1978; Newbery & Stiglitz, 1981; Turnovsky, 1983; Kawai, 1983; Turnovsky & Campbell, 1985; Gilbert, 1985, 1989). The main conclusion from these studies is that the introduction of futures markets increases welfare. Little empirical work has been done, however, in this area.¹ Further, I am not aware of empirical work that quantifies the welfare effects of providing forward contracts to producers and stockholders, based on empirically estimated risk aversion and cost parameters and endogenous (futures) prices. The same applies to costs for a commodity board of operating such a scheme.

Section 2 gives details on the proposed hedging scheme and elaborates on the empirical underpinnings of the simulation. Section 3

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addresses the behavior of the major agents. Section 4 relates the theoretical work to the data and Section 5 presents the results of the simulation exercise. The main findings are summarized in Section 6.

2. HOW TO DEAL WITH DOMESTIC PRICE RISKS?

Farmers of primary commodities in developing countries face substantial income risk due to price fluctuations. Apart from price support schemes from the government—a popular policy reaction to reduce income risk on the part of farmer—a number of alternative market-based techniques are practiced to deal with these income risks. Most prominent among these techniques is diversification: in order to reduce income risk farmers spread their sources of income, for example, by the cultivation of various crops, but also by having off-farm employment. Other market-based techniques to reduce income risk are also important, in particular for commodities. Harvested output is, for example, stored in order to sell commodities during a high-price period instead of a low-price period. Elsewhere (see Zant, 1998) it is shown that stockholding is an important device for small holders to reduce price risks. A relatively new technique is to hedge price risks on futures exchanges, or more in general to use so-called financial risk management instruments. These type of instruments have received increased attention in the recent policy discussion (see ITF, 1999). With respect to the use of these financial risk management instruments, important questions still need to be answered. For example, what is the size of the costs of hedging price risks, and what is the size of the welfare gains to be obtained of using such a facility? Below a hedging scheme is elaborated to investigate these issues.

The empirical work in this paper is based on data of the Indian natural rubber market. Smallholders, of whom a great majority has very tiny plots, account for the largest share in aggregate production and area of natural rubber. Price risks of cultivating natural rubber are to a small extent diversified, by cultivating other crops and having nonagricultural sources of income. The aggregate supply in this market has seen a tremendous growth in the 1980s and 1990s, largely due to promotion of cultivation of rubber by the government, increases in yield,

low production uncertainty and reasonable demand prospects. The share of Indian natural rubber in world supply is moderate but gradually increasing and ranges from 6.3% in 1990 to 8.3% in 1995 and approaches 10% at the turn of the century (*source*: International Rubber Study Group). Indian natural rubber production is also almost exclusively consumed domestically, mainly for tire manufacturing: the demand side is dominated by a limited number of large tire companies. The relatively small share of synthetic rubber in domestic consumption (only 20%) is peculiar to India and largely due to extensive promotion of natural rubber growing combined with restricted imports. Until the beginning of the 1990s the establishment of the State Trading Company (STC), import licensing and foreign exchange shortages have effectively isolated the Indian rubber market from the world market and this has ensured that domestic pricing and distribution is subject to domestic supply and demand conditions and government discretion. From the beginning of the 1990s onward prices are much more closely linked to world market prices.

In order to assess the welfare gains of hedging price risks, I assume that Indian natural rubber producers and stockholders can reduce their exposure to price risks by using a hypothetical voluntary hedging scheme. A (hypothetical) commodity board offers a forward contract to domestic primary producers and local traders, setting prices of the forward contract in light of the prevailing futures prices at the international futures exchange, in the current study the TOCOM.² Producers and stockholders specify desired quantities to be sold forward. The board, subsequently offsets its exposure by selling a quantity of futures on the TOCOM that matches its forward purchase commitments. At delivery time the board pays producers and stockholders the contracted price, closes out its futures positions, and sells the physical commodity in the market. Basis risk is borne by the commodity board.³ The hedging scheme has no impact on the manufacturers of rubber products, the consumers in the market. As their welfare is unaffected, consumers will not be considered further. The empirical work in this paper is based on data for the period 1990–95.

For such a hedging scheme to work effectively, the natural rubber market in India must be sufficiently integrated within the world market so that price developments, but not

necessarily price levels, are similar. A rough inspection of the data confirms this similarity for 1990–95 (see Figure 1). Further, size and scale of operations in the international futures exchange should guarantee that it functions adequately. I have chosen the TOCOM as the international exchange where the commodity board buys or sells its futures contract primarily because of this exchange's adequate liquidity. Futures contracts traded on the TOCOM have a contract period of six months, with one contract expiring each consecutive month and contracts named after the date of expiration. All market users have to deposit margin payments at the TOCOM, with a reduced tariff for members or associate members. Additional margin calls are required if prices change. Final payments are made at the time of closing the contract. Margin payments should not be considered as costs but as advance payments that eventually will be used to settle positions: only the interest required to finance these payments generates costs. TOCOM provides contracts in only one grade (RSS3). In terms of volume of domestic production of ribbed smoked sheets (RSS) in India, RMA4 is by far the most common grade.⁴ Although of slightly lower quality compared to the internationally used RSS3 grade, other Indian grades will be much less reliable to relate to world market prices, given the limited volume of supply or demand in these grades. As long as the premium on RSS3

is sufficiently small and prices of these grades move parallel, the lower quality should not obstruct a hedging operation. Basis risk, however, may be slightly higher.

Figure 2 summarizes the development of futures prices of natural rubber on the TOCOM. The figure shows the difference in monthly average price of an individual futures contract at two points in time: in the month that is six months prior to expiration ($p_{i,t-6}$) and in the month of expiration ($p_{i,t}$). Positive values imply that the "paper" part of hedging transactions of the board is generating a loss while negative values imply the reverse. The figure also shows the difference in the average monthly price between two different contracts at one point in time: a contract that will expire six months ahead ($p_{j+6,t}$) and a contract that expires in the current month ($p_{j,t}$). Futures market "language" terms positive values of this difference as a situation of contango and negative values as a situation of backwardation. As the figure shows, both situations alternate regularly,⁵ implying, among other things, that no systematic basis risk loss or profit is evident.

Elsewhere it is shown that stockholders in the Indian natural rubber market tend to look ahead around two to three months in their arbitrage behavior (see Zant, 1997, 1998). Hence, behavior with respect to future variables is postulated to refer to three months ahead (expected) values of these variables. In

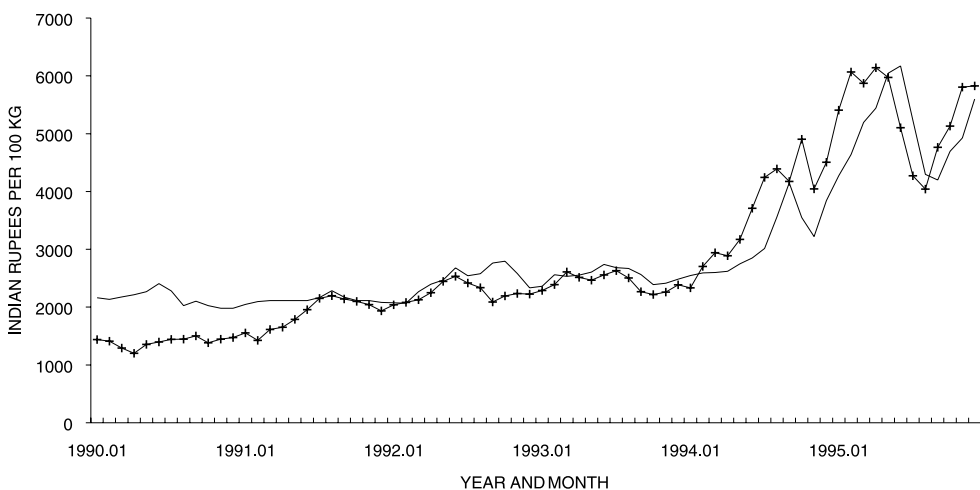


Figure 1. Domestic market price (–) and world market price (+), 1990–95. Note: World market prices are monthly average quotations at the closing of the market of expiring contracts on TOCOM. Prices are in Indian rupees. (Source: Indian Rubber Statistics, Rubber Board of India; Tokyo Commodity Exchange.)

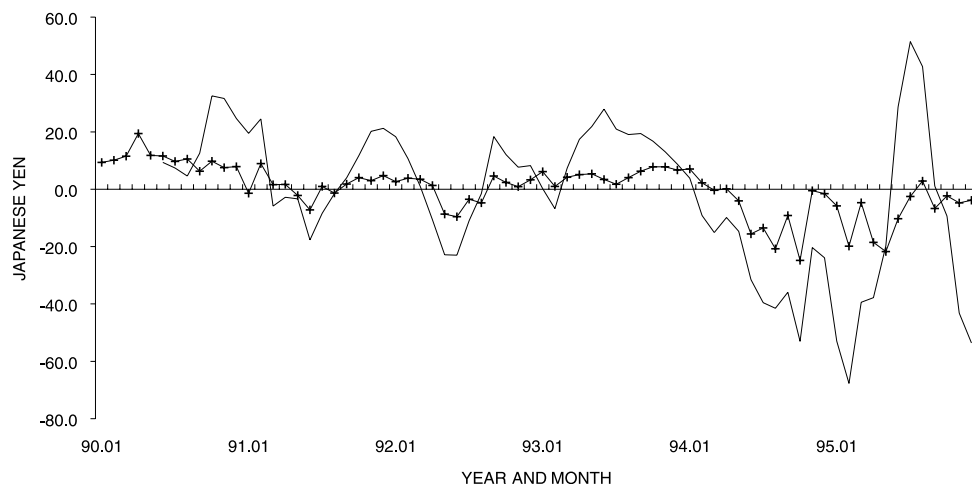


Figure 2. *Differences of futures prices on the Tokyo Commodity Exchange. (Source: Tokyo Commodity Exchange.)*

addition, I assume that growers have a comparable forward-looking behavior in their short-term decisions of hiring tappers for tapping trees. Likewise, in entering forward contracts growers and stockholders will be interested in selling crops or stocks three months ahead. Therefore, I assume that the board offers forward contracts for three months forward delivery, a contract that clearly allows hedging at the TOCOM. In order to keep the analysis technically feasible, all data are transformed into quarterly values and hence the sample stretches from the first quarter of 1990 (1990 I) to the last quarter of 1995 (1995 IV). Average prices of the four, five and six months ahead futures contracts are used to construct the one-quarter ahead futures price. Hence, in the first quarter of 1990, for example, the futures price for the second quarter is the average of the April 1990, May 1990 and June 1990 contract, as quoted in January, February and March.

I have chosen a commodity board to intermediate because these boards may have easier access to international financial markets, foreign exchange, and credit (as these boards are supported, eventually, by the government, they will have a relatively good credit status). Moreover, the boards ability to monitor potential users also might diminish problems that account for limitations in credit markets like imperfect information, adverse selection, and moral hazard. Due to reputation effects, contract enforcement will also be easier with intermediation by a commodity board. Finally,

such intermediation is most likely an attractive outlet for commodity boards that otherwise might become redundant in a process of liberalization. Intermediation in hedging activities, thus, both nicely fits in the objectives of commodity boards to support marketing of the commodity and does not distort the functioning of the market. The proposed hedging scheme may nevertheless, also be implemented by private sector intermediaries.⁶ Current circumstances in India, however, do not especially favor private sector intermediation: the private sector's limited access to international financial markets and to foreign exchange, as well as the country's sloppy infrastructure for hedging operations (see UNCTAD/World Bank, 1996) do not make this a viable option. I have chosen for hedging through futures because hedging with futures eliminates price risk, futures markets are liquid, and costs of futures trading are acceptable. The suggested hedging scheme does not obviate fluctuations of prices that reflect supply and demand conditions on the world market.

If domestic market prices rise above the forward contract price at the time of delivery, producers and stockholders have an incentive not to perform the forward contract. Obviously, the board needs to avoid such default as it is a potential source of financial loss. I assume, in the first place, that the board has enough power to enforce implementation of contracts. In practice one can think of imposing a penalty on defaulting, like exclusion from entering forward contracts in the future. In the

second place, I assume that individual forward contracts with the commodity board are not traded on an exchange. The board will, however, be quoting prices continuously, and clients will be permitted to buy back their own contracts at any moment they wish, at a price that equals the loss on the hedging operation. Nontradability reflects the absence of a futures exchange in the domestic market, then, and is not a necessary requirement for the analysis.

Additional to the assumptions on contract enforcement and nontradability, I assume limits to the quantity sold forward. Individual producers are not allowed to hedge more than their production, and stockholders are not allowed to hedge more than their base period stocks. Such an assumption is in line with practices among private banks that finance hedging operations. These private banks usually request that the hedge is limited to a deliverable quantity and use (future) production or stocks as collateral (see Ghosh, Gilbert, & Hughes Hallett, 1987, p. 158; Gilbert, 1989, p. 158). There is also ground not to allow more forward contracting than realized future supply. The board provides a facility to producers and stockholders to overcome price uncertainty. Hedging a larger quantity forward than physically available at the time of delivery is beyond the objective of the board. To implement this restriction, the board will stop buying forward contracts if the level of expected aggregate supply is realized. How is the board able to guarantee microeconomic consistency? An individual producer will be uncertain about the exact level of his future production and the board will find estimating future production of an individual producer even more difficult. Likewise, the board will also be unable to verify the level of base period stocks of individual stockholders. Hence, implementation of this restriction will be difficult in the case of an individual producer or stockholder. The answer is moral persuasion and penalties. Individual producers and stockholders will be urged not to sell forward more than their expected production, otherwise they might penalize their fellow producer or stockholder. Individual producers and stockholders that do not behave according to this rule would face a penalty of being excluded from forward contracting in the future (reputation effect). To summarize, regulation, moral persuasion, and penalties concomitantly rule out an individual producer or stockholder from buying forward or taking a long position.

3. BEHAVIORAL RELATIONSHIPS

In this section, I formalize the behavior of major players in the market with respect to risk, by using the theoretical framework developed by Newbery and Stiglitz (1981), Turnovsky (1983) and Kawai (1983). I consider a domestic commodity market in a price-taking open economy and identify three groups of players in that market: producers (g , from growers), stockholders (s), and the commodity board (b). Within this framework discussion of consumers, i.e., manufacturers of rubber products, is unnecessary as the proposed hedging scheme has no effect on consumers' prices and welfare.⁷ Producers earn an income by producing and selling a commodity. Stockholders store commodities and earn an income by exploiting differences in prices of the commodity over time. Stock demand is also assumed to be motivated by other considerations. The behavior of these players is considered with and without a futures market in a two-period model. In the first period, producers decide on the size of the planned crop. Both producers and stockholders can enter into forward contracts with the commodity board. Quantities per contract are determined by the producers and stockholders, and prices are determined by the board. Simultaneously, the commodity board sells futures on the international futures exchange. The second period is the harvesting period: farmers deliver their contracted quantities to the commodity board for the agreed price. Default is ruled out by assumption. Remaining production is sold in the market against the market price. Stockholders also deliver their contracted quantities to the board and sell the remaining part on the market. The commodity board settles its futures contracts on the international futures exchange and sells quantities of the commodity delivered by domestic producers and stockholders in the domestic market.⁸ In the following sections, I consider the behavior of each of the players in the market.

(a) Producers

Producers are risk-averse price-takers and maximize expected utility of profit

$$\sum_{t=1}^T E_{t-1}(U_g(\pi_{g,t})) \cdot \delta^t, \quad (1)$$

where $E_{t-1}(\cdot)$ is the expectation conditional on the information at time $t-1$; U_i is a strictly concave utility function of agent i ; $i=g$ (growers) or s (stockholders); $\pi_{i,t}$ is the profit of agent i at time t ; δ is the discounting factor, subject to a quadratic cost function.

I assume that utility functions have the property of constant absolute risk aversion (CARA):

$$U_g(\pi_{g,t}) = -\exp(-A_g \cdot \pi_{g,t}), \quad (2)$$

where A is the coefficient of absolute risk aversion.

I have chosen this function because it is useful for solving maximization problems, resulting in linear equations that can easily be aggregated. It has, however, the implausible property that with normally distributed profits the absolute risk premium is independent of wealth. For the purpose of this study, this implausible property should not be a problem as wealth can be shown not to be important in the short-run (Binswanger, 1980). Nevertheless, I am aware that the outcome of my simulations might be affected by the specification of the utility function (see e.g., Rolfo, 1980). If profits of producers ($\pi_{g,t}$) are distributed normally, maximization of the expected utility of profit is equivalent to maximization of

$$\sum_{t=1}^T [E_{t-1}(\pi_{g,t}) - \frac{1}{2}A_g \text{VAR}_{t-1}(\pi_{g,t})] \cdot \delta^t, \quad (3)$$

where $\text{VAR}_{t-1}(\cdot)$ is the variance conditional on information at time $t-1$.

Profit of producers in a situation Without Forward Contracts is characterized as

$$\pi_{g,t} = q_t \cdot p_t - \rho \cdot Z_g(q_t), \quad (4)$$

where q_t is the production at time t ; p_t is the real (spot) price at time t ; ρ is the $1 +$ interest rate; $Z_i(\cdot)$ is the cost function of agent i .

Maximization of expected utility of risky profit is calculated assuming certain production. In the case of a perennial crop like natural rubber, such an assumption is fairly reasonable: year-round harvesting of natural rubber causes shocks to even out during the year and as natural rubber is not a "fruit crop," it is much less vulnerable to (the timing of) adverse weather conditions; finally, the incidence of diseases, frost, and storm damage is relatively low in the case of natural rubber. Production

costs are assumed to have a quadratic specification:

$$Z_g(q_t) = \frac{1}{2}z_g \cdot q_t^2 \quad (5)$$

where $z_g > 0$.

Moments of Eqn. (4) are written as:

$$E_{t-1}(\pi_{g,t}) = q_t \cdot E_{t-1}(p_t) - \frac{1}{2}\rho z_g \cdot q_t^2, \quad (6)$$

$$\text{VAR}_{t-1}(\pi_{g,t}) = q_t^2 \text{VAR}_{t-1}(p_t). \quad (7)$$

An optimum requires

$$\partial E_{t-1}(U_g)/\partial q_t = 0. \quad (8)$$

From Eqn. (3), and Eqns. (5)–(8) optimal production is derived as:

$$q_t = \frac{E_{t-1}(p_t)}{\rho \cdot z_g + A_g \cdot \text{VAR}_{t-1}(p_t)}. \quad (9)$$

Eqn. (9) is a familiar result, saying that production is related positively to expected spot price ($E_{t-1}(p_t)$) and inversely to the discount factor (ρ), the cost parameter (z_g), the coefficient of absolute risk aversion (A_g), and the variance of spot price ($\text{VAR}_{t-1}(p_t)$). With risk neutrality ($A_g = 0$), production is only determined by expected price ($E_{t-1}(p_t)$) and not by its variance.

In a situation With Forward Contracts, profit of producers is characterized as:

$$\pi_{g,t} = q_t \cdot p_t - \rho \cdot Z_g(q_t) + f w_{g,t-1} \cdot (p_{fw,t-1} - p_t), \quad (10)$$

where $f w_{g,t-1}$ is the forward sales (quantity) by growers at time $t-1$; $p_{fw,t-1}$ is the real forward price at time $t-1$ offered by the board to domestic producers and local traders (in domestic currency).

Moments of Eqn. (10) are written as:

$$E_{t-1}(\pi_{g,t}) = q_t \cdot E_{t-1}(p_t) - \rho \cdot Z_g(q_t) + f w_{g,t-1} \cdot (p_{fw,t-1} - E(p_t)), \quad (11)$$

$$\text{VAR}_{t-1}(\pi_{g,t}) = (q_t - f w_{g,t-1})^2 \text{VAR}_{t-1}(p_t), \quad (12)$$

An optimum requires:

$$\partial E_{t-1}(U_g)/\partial q_t = \partial E_{t-1}(U_g)/\partial f w_{g,t-1} = 0. \quad (13)$$

From Eqns. (3) and (5), and Eqns. (11)–(13), I derive optimal production and optimal forward sales as:

$$q_t = \frac{p_{fw,t-1}}{\rho \cdot z_g} \quad (14)$$

and

$$fw_{g,t-1} = q_t + \frac{p_{fw,t-1} - E_{t-1}(p_t)}{A_g \cdot VAR_{t-1}(p_t)} \quad (15)$$

and, the nontradability of forward contracts and limits to forward sales⁹ lead to:

$$0 \leq fw_{g,t-1} \leq q_t. \quad (16)$$

Eqn. (14) shows that optimum production equals the forward price at time $t-1$ ($p_{fw,t-1}$) divided by the discounted cost parameter ($\rho \cdot z_g$), while the optimum quantity of forward contracts equals production plus the difference of the forward price at time $t-1$ and the expected spot price at time t ($p_{fw,t-1} - E_{t-1}(p_t)$), divided by the coefficient of absolute risk aversion (A_g) and the variance of price at time t ($VAR_{t-1}(p_t)$). Optimum production is independent of the attitude toward risk and the distribution of spot prices, which contrasts with the optimum quantity of forward contracts. Note that production is the same with and without forward contracts if expected prices equal forward prices and producers are near risk neutral or the variance of prices is zero (see Eqns. (14) and (9)). Eqn. (15) indicates that producers sell their entire future crop forward, unless the expectation of higher prices in the future compensates them enough for the increased uncertainty of future prices. Smaller values of the variance of prices ($VAR_{t-1}(p_t) \rightarrow 0$) or of the coefficient of absolute risk aversion ($A_g \rightarrow 0$) will push optimal quantities beyond the limits imposed by Eqn. (16).

(b) Stockholders

For stockholders, I make assumptions similar to those made for producers. Stockholders are also assumed to be risk-averse price-takers, to maximize expected utility of profit and to have CARA type utility functions and quadratic costs. Profit of stockholders in a situation Without Forward Contracts is characterized as:

$$\pi_{s,t} = s_{t-1} \cdot (p_t - \rho \cdot p_{t-1}) - Z_s(s_{t-1}), \quad (17)$$

where s_{t-1} is the purchases of stockholders at time $t-1$.

Costs of stockholding take the following quadratic form.

$$Z_s(s_{t-1}) = \frac{1}{2} z_s (s_{t-1} - s_{\text{target}})^2, \quad (18)$$

where $z_s > 0$; s_{target} is a target stockholding level.

Costs of stockholding are postulated to be determined by the difference between direct

carrying costs (warehouse costs, insurance fees, physical losses) and the benefits from having a larger stock, which reduces the probability of stock-out and loss of consumers and minimizes risk by making possible the exploitation of the variation of prices over time (see Newbery & Stiglitz, 1981, p. 196). These latter two motivations are incorporated into the model by including target stockholding (see, e.g., Ghosh *et al.*, 1987). Optimal stock demand for the situation Without Forward Contracts is derived by inserting the moments of the profit equation into the expected utility function and calculating the first order condition:

$$s_{t-1} = \frac{E_{t-1}(p_t) - \rho p_{t-1} + z_s \cdot s_{\text{target}}}{z_s + A_s \cdot VAR_{t-1}(p_t)}. \quad (19)$$

Eqn. (19) is, again, a familiar result, indicating that stockholding is positively related to the difference of expected spot price ($E_{t-1}(p_t)$), discounted spot price in the base period (ρp_{t-1}) and the target stockholding level (s_{target}), and inversely to the cost parameter (z_s), the coefficient of absolute risk aversion (A_s), and the variance of spot price ($VAR_{t-1}(p_t)$). With identical arbitrage opportunities ($E_{t-1}(p_t) - \rho p_{t-1}$), a higher volatility of prices ($VAR_{t-1}(p_t)$) will create less stock demand. With risk neutral stockholders ($A_s = 0$) or an infinitely small variance of price ($VAR_{t-1}(p_t) \rightarrow 0$), and expected price equal the discounted base period price ($E_{t-1}(p_t) = \rho p_{t-1}$), stockholding equals target-stockholding ($s_{t-1} = s_{\text{target}}$). Both with and without forward contracts, I impose non-negativity of stocks ($s_t \geq 0$ for all t). It should be noted, however, that in the actual calculation this never has become effective due to sufficient target stockholding.

In a situation With Forward Contracts, profit of stockholders is characterized as:

$$\begin{aligned} \pi_{s,t} = & s_{t-1} \cdot (p_t - \rho \cdot p_{t-1}) - Z_s(s_{t-1}) \\ & + fw_{s,t-1} \cdot (p_{fw,t-1} - p_t). \end{aligned} \quad (20)$$

Moments of Eqn. (20) are written as:

$$\begin{aligned} E_{t-1}(\pi_{s,t}) = & s_{t-1} \cdot (E_{t-1}(p_t) - \rho \cdot p_{t-1}) - Z_s(s_{t-1}) \\ & + fw_{s,t-1} \cdot (p_{fw,t-1} - E_{t-1}(p_t)), \end{aligned} \quad (21)$$

$$VAR_{t-1}(\pi_{s,t}) = (s_{t-1} - fw_{s,t-1})^2 VAR_{t-1}(p_t). \quad (22)$$

Optimal stockholding and optimal forward sales, based on the first order conditions of expected utility of profit, are derived as:

$$s_{t-1} = s_{\text{target}} + \frac{p_{\text{fw},t-1} - \rho \cdot p_{t-1}}{z_s} \quad (23)$$

and the optimal quantity of forward contracts as

$$f w_{s,t-1} = s_{t-1} + \frac{p_{\text{fw},t-1} - E_{t-1}(p_t)}{A_s \cdot \text{VAR}_{t-1}(p_t)} \quad (24)$$

and, the nontradability of forward contracts and limits to forward sales,¹⁰ again, lead to:

$$0 \leq f w_{s,t-1} \leq s_{t-1}. \quad (25)$$

From Eqns. (23) and (24) it follows that optimal purchases of stocks are positively determined by target stockholding (s_{target}) and the difference between the forward price and the (discounted) price at time $t-1$ ($p_{\text{fw},t-1} - \rho \cdot p_{t-1}$), and inversely by the cost parameter. The optimal quantity of forward contracts is positively determined by the optimal purchases of stocks and the difference of the forward price and the expected spot price ($p_{\text{fw},t-1} - E_{t-1}(p_t)$), and inversely by the coefficient of absolute risk aversion (A_s) and the variance of price at time t ($\text{VAR}_{t-1}(p_t)$). Hence, physical stock demand differs from the quantity of forward contracts depending on expectations. As in the case of producers, the probability distribution of spot prices and the coefficient of absolute risk aversion only influence the optimal quantity of forward contracts and not purchases of stocks.

(c) The commodity board

In a situation with forward contracts, the commodity board covers those forward contracts with domestic producers and local stockholders on the international futures exchange by selling futures. Other than this intermediary function with the international futures exchange, the board has no activities. The exact matching of the forward commitments of the commodity board depends on the size and timing of the futures contract on the international futures exchange. In the model, however, I will assume that the commitment of the board is covered perfectly, or:

$$f t_t = f w_{g,t} + f w_{s,t}, \quad (26)$$

where $f t_t$ is the futures sales (quantity) at time t .

Forward prices are determined by the international futures exchange. Futures prices in the empirical application are denominated in Japanese yen. Prices of forward contracts

offered by the board to domestic producers and local traders are, hence:

$$p_{\text{fw},t} = (1 + \tau_t) \cdot \text{rer}_{RY,t+1} \cdot P_{f,t}, \quad (27)$$

where $\text{rer}_{RY,t} \equiv er_{RY,t}/cpi_t$; $\text{rer}_{RY,t}$ is the real Indian rupee/Japanese yen exchange rate at time t ; $er_{RY,t}$ is the Indian rupee/Japanese yen exchange rate at time t ; cpi_t is the consumer price index for India at time t ; τ_t is the surcharge at time t ; $P_{f,t}$ is the futures price (for period $t+1$) at time t .

Note: upper case and lower case letters for prices refer to nominal and real prices.

Eqn. (27) defines the forward price offered to domestic producers and local traders as the product of futures price in Japanese yen, the rupee/yen exchange rate, and a surcharge imposed by the board. While Eqn. (27) does not imply that one has to pay a surcharge for trading on the international futures exchange, it does offer the board the possibility of imposing a surcharge on the forward price offered to growers and stockholders in order to increase the durability of the scheme or to maximize long-term welfare (or to do both). Futures prices on the international futures exchange are assumed not to be affected by the transactions of the commodity board. I assume perfect foresight with respect to future exchange rates in real terms. Where exchange rate risks are concerned, this assumption is justified by the possibility of hedging exchange rate risks effectively: the board could manage easily dollar-yen risks and there is an over-the-counter forward market for the rupee-dollar exchange rate, which the board could be authorized to use.¹¹ In practice, hedging these exchange rate risks may increase the basis risk of the complete hedging operation. In this exercise, however, effects of exchange rate fluctuations are assumed away which allows me to focus on the impact of using forward contracts.

Since the commodity board has taken over the basis risk, it is of interest if the commodity board breaks even, and what is the size of losses and profits. The basis risk of the hedging operation, i.e., the income of the board in the current exercise, is defined as:

$$y_{b,t} = f t_{t-1} \cdot [\text{rer}_{RY,t} \cdot P_{f,t-1} - \text{rer}_{RY,t} \cdot P_{\text{fexp},t}] - (p_{\text{fw},t-1} - p_t), \quad (28)$$

where $y_{b,t}$ is the income of the board at time t in constant prices; $P_{\text{fexp},t}$ is the futures price at delivery at time t .

The first part of Eqn. (28), $f_{t-1} \cdot (rer_{RY,t} \cdot P_{ft,t-1} - rer_{RY,t} \cdot P_{fexp,t})$, represents the transactions on the international futures exchange. The second part, $f_{t-1} \cdot (p_{fw,t-1} - p_t)$, represents the physical transactions on the domestic market. Together these terms constitute the basis risk of the operation.

Basis risk will be zero with forward prices determined by futures prices (and if $\tau_t = 0$ for all t , see Eqn. (27)), and with domestic spot prices equal to world market spot prices converted at the relevant exchange rate (note that futures prices at the time of expiration of contracts equal world market spot prices). Together with the endogenization of world market prices (both spot and futures), these factors mean that both income and expected income of the board in the model degenerate to zero in all periods. Fortunately, actually observed domestic prices and futures prices of expiring contracts differ from the model prediction, leaving scope for further analysis. Finally, without forward contracts, income of the board (y_b) is zero and the board has no economic existence. It should be noted that interest costs due to margin payments, omitted in the current study, could easily be incorporated in the above formalization.

4. EMPIRICAL IMPLEMENTATION

(a) *Expectation and variance of prices*

In this section, I explain the specification and estimation of expectation and variance of prices. These variables are determinants of the behavior of producers and stockholders. Shocks are assumed to originate from the world market, and the stochastic process describing these shocks is a subsidiary outcome of this work. I consider a domestic market in a small, open economy: in contrast with the period before the liberalization policy of the 1990s, domestic supply and demand conditions do not matter in the determination of domestic prices. These domestic prices, and, hence, also expectation and variance of domestic prices, are assumed instead to be completely determined on the world market. Time series properties of world market prices in the current model (P_w), the world market price of natural rubber in Japanese yen, and futures prices (P_f) are investigated with the help of Dickey–Fuller tests. With respect to world market prices, the outcome provides a basis for estimating a price

equation that characterizes expectation and variance of price. In Table 5 in the Appendix, the test statistics are presented.

The table shows that the world market price and futures price are integrated of the order 1 (or I(1)), although the statistics are not convincing in all test equations. A simple error correction specification of prices in first differences follows as an appropriate characterization of the price formation process, in particular:

$$(P_{w,t} - P_{w,t-1}) = n_0 + n_1 \cdot P_{w,t-1} + \varepsilon_{Pw,t}, \quad (29)$$

where $P_{w,t}$ is the world market price in Japanese yen

or, equivalently, a simple autoregressive specification:

$$P_{w,t} = n_0 + (1 + n_1) \cdot P_{w,t-1} + \varepsilon_{Pw,t}. \quad (30)$$

The estimation results of Eqn. (30) are documented in the Appendix.

The tests on the order of integration, reported in the Appendix, are applied to world market prices in Japanese yen. Price variables in the model, however, are in domestic prices (Indian rupees). To make the step from world market to domestic prices, I have assumed perfect foresight with respect to real exchange rates and, hence, $E_{t-1}(rer_t) = rer_t$ and $VAR_{t-1}(rer_t) = 0$. This assumption yields the following equation for expectation and variance of domestic price:¹²

$$E_{t-1}(p_t) = rer_t \cdot E_{t-1}(P_{w,t}) \text{ and} \quad (31)$$

$$VAR_{t-1}(p_t) = rer_t^2 \cdot VAR_{t-1}(P_{w,t}). \quad (32)$$

Prices of futures contracts need to be expressed in terms of expected prices, especially for the case of a dynamic simulation, or, formally: $P_{ft,t} = f(E_t(P_{w,t+1}))$. Substitution of expected world market price (the expected value of Eqn. 30), yields:

$$P_{ft,t} = f(n_0 + (1 + n_1) \cdot P_{w,t}). \quad (33)$$

A linear specification of the function that describes the relationship between futures price and world market price is suggested. Both series are shown to be I(1), as is clear from Table 5 (see Appendix), and, hence, a simple error correction formulation is specified:

$$\Delta P_{ft,t} = m_0 + m_1 \cdot P_{w,t} + m_2 \cdot \Delta P_{ft,t-1} + m_3 \cdot P_{w,t-1} + \varepsilon_{Pft,t}, \quad (34)$$

where Δ is the difference operator.

The estimation results are reported in the Appendix. The random shock in the model originates from Eqn. (30), but additionally from Eqn. (34). This estimation completes the determination of expectation and variance of prices as well as determination of the properties of the stochastic process underlying price formation on the world market.

(b) *Fitting behavioral equations to observations*

I continue by searching for appropriate parameters for the model based on realizations for the first quarter of 1990 through the last quarter of 1995. None of the agents in the Indian natural rubber market have been active on futures exchanges during the period under consideration. Hence, I confront the data with the "no policy" model (Eqns. (1)–(9) for growers and Eqns. (17)–(19) for stockholders). In the Indian natural rubber market, stockholding is done by manufacturers of rubber products, producers and traders. The available data distinguish two stockholding agents: producers and traders (so-called growers and dealers, abbreviated as gd), and manufacturers (abbreviated as mf). Hence, three series of variables need explanation, namely, production, stockholding by growers and dealers and stockholding by manufacturers. As mentioned before, consumption is left out of consideration as consumer welfare is assumed not to be affected by the hedging scheme. The strategy to find estimates of the key parameters of the model is explained and documented in the Appendix.

Table 1 summarizes selected parameters that are used in the simulation exercise. Quadratic

cost functions together with the selected coefficient therein imply average costs expressed as a percentage of the value of production of about 62%, and average costs expressed as a percentage of the value of beginning-of-period stocks as 0.9% in the case of stockholding by growers and dealers and 1.7% in the case of stockholding by manufacturers. These estimates seem acceptable in view of empirical observations (see also Newbery & Stiglitz (1981, Table 20.7), for estimates of storage costs). Relative risk aversion, calculated on the basis of the selected parameters and average profit per period, is 3.1 for growers, 2.1 for stockholders at the producers side and 1.4 for stockholders at the consumers side, indicating a relatively high-risk aversion of growers.

Often estimations do not allow an assessment of the selected values of the coefficients for risk aversion, cost functions, and target-stockholding as these estimations were made with the assumption of risk neutrality and endogenous prices that are determined on the domestic market. The selected parameters can be compared, however, to the choices made in some simulation exercises based on a similar theoretical framework (see Table 2). Rolfo (1980) calculates risk parameters for a number of cocoa producing countries based on a logarithmic utility function. Evaluated at the mean values of income, these risk parameters range from 24.7 to 39.7. The comparable risk parameter in the current simulation (the average of $A_g \cdot (p_t \cdot q_t - 0.5 \cdot z_g(q_t)^2)$) equals 3.1, i.e., far below the range of Rolfo's parameters. It should be noted, however, that most simulation studies take a value of $R = 1$. No comparable

Table 1. *Selected parameters*

	Growers	Stockholders (growers and dealers)	Stockholders (manufacturers)
Coefficient in quadratic cost function (z_i) ^a	0.213	0.371	0.503
Coefficient of absolute risk aversion (A_i) ^b	5.194	7.188	29.62
Coefficient of relative risk aversion (R_i) ^c	3.1	2.1	1.4

^a $\times 10^{-3}$.

^b $\times 10^{-6}$.

^c Calculated as $\dot{A}_i \cdot \text{profit}_{i,t}$, averaged over all periods.

Table 2. *Parameters compared with other studies*

	$1/z_g$	$1/(\rho \cdot z_g)$	$1/z_s$	$1/(\rho \cdot z_s)$	R_g
Rolfo (1980)					24.7–39.7
Kawai (1983)	0.4–3.0		1.2–1.8		
Turnovsky and Campbell (1985)		0.5–10.0		0.2–4.0	
Newbery and Stiglitz (1981)					0.5–2.0
This study	4.7	4.6	2.0; 2.7	2.0; 2.7	(1.4–)3.1

values for stockholders are calculated in Rolfo's study. In Kawai's simulation exercise focusing on the long-run variance of spot and futures prices (see Kawai, 1983), cost coefficients are slightly lower for producers and stockholders when compared to this study. In their attempt to shed light on the distribution of spot prices and the welfare of agents in the market after the introduction of a futures market, Turnovsky and Campbell (1985) use a parameter set that covers the values used in this study. Without information on income, the coefficient of absolute risk aversion used by Turnovsky and Campbell (with values between 0.001 and 0.1) cannot be compared. Furthermore, neither Kawai nor Turnovsky and Campbell give explicit empirical support for their selected parameters. Finally, Newbery and Stiglitz (1981, Chapter 7) propose a probable value of the coefficient of relative risk aversion of between 0.5 and 2.0. Compared with choices made in simulation studies using a similar theoretical framework, then, the selected values of parameters used here are similar to those chosen in other studies. In the simulation of welfare effects, I have used mean estimates of the risk parameter. On top of that I have used values of the risk parameter that are one standard deviation above and below the selected mean estimates.

Estimated behavioral equations (not shown) track the realizations reasonably well. The direction of development is correct in all but a few cases; the exceptions mainly concern a number of observations of stockholding by manufacturers. The risk of different agents measured as the product of absolute risk aversion and variance of revenue ($A_i \cdot \text{VAR}_{t-1} \pi_{i,t}$), increases tremendously in the later years of the sample period prices. In these years, price rises also increased the variance of prices and, consequently, the size of the risk of different agents. For all agents this impact on risk is clearly observed, but in the case of stockholding the impact is smaller, pointing at a risk aversion closer to risk neutrality.

5. SIMULATION

(a) *Calculating the costs of the commodity board: a static simulation*

The selected parameters as presented in Table 1 are used in the model with forward contracts (Eqns. (10)–(16) for growers, Eqns.

(20)–(25) for stockholders, and Eqns. (26)–(28) for the commodity board). Observed prices during 1990–95 should be considered as one out of many possible outcomes and, thus, not sufficiently representative to base an evaluation on. More reliable is an evaluation of the proposed hedging scheme that calculates average outcomes over a number of simulations using a random number generator that imposes a shock on the model. To begin, I run a static simulation, which gives all lagged endogenous variables their historical values. I have assumed that the futures price (Eqn. 34) and the world market price (Eqn. 30) are the source of the stochastic shock. The stochastic behavior of the world market price follows in a straightforward way from the disturbance term ($\varepsilon_{pw,t}$) in Eqn. (30). In the forward price, the stochastic behavior originates from the random disturbance term in the futures price equation ($\varepsilon_{pft,t}$), but also through dependence on stochastic world market prices (the term $m_1 \cdot \Delta P_{w,t}$ in Eqn. 34). In the static simulation, lagged values in these two price equations are historical observations. The random futures price converts into a random forward price by multiplication with the appropriate perfect foresight real exchange rate for one-quarter ahead. In the forward contract model (Eqns. (10)–(16) and Eqns. (20)–(25)), the random shock in the current forward price affects the decisions by producers and stockholders on current production and stocks (Eqns. (14) and (23)) and on the amount of hedging (Eqns. (15) and (24)). The random shock in the current world market price also affects stockholding (Eqns. (19) and (23)). Expectation and variance of price in these equations are non-stochastic and are given by Eqns. (31) and (32). Expected profit and expected utility for growers is calculated using Eqns. (11) and (3) in combination with Eqns. (11) and (12), and for stockholders using Eqn. (21) and the analogue of Eqn. (3) for stockholders in combination with Eqns. (21) and (22). For the next period, the same sequence of steps are made. A sample for the period 1990.1 to 1995.4 has been generated, calculating averages of 1000 iterations per quarter.

Figure 3 shows to what extent growers, stockholders at the production side, and stockholders at the manufacturing side cover their production or stock in this particular situation. Growers cover production to a large extent ranging from 31.4% to 100%, with an average of 74.5%. Stockholders have a lower risk aversion and consequently tend to cover a

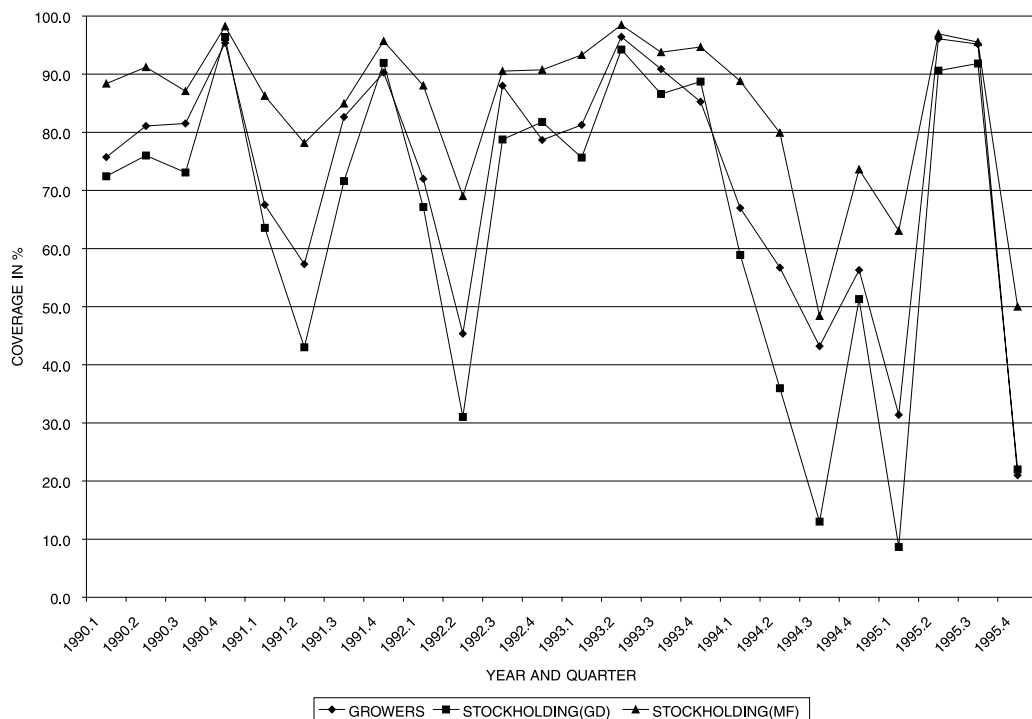


Figure 3. Coverage with forward contracts (static simulation).

smaller share than growers. On average, coverage of stockholding by growers and dealers is 66.8%. Despite their even lower risk aversion, average coverage of stockholding by manufacturers is 85.7%, a number attributable to their large target stockholding.

With world market price endogenized, little reason exists to simulate the income of the commodity board, which is zero by implication. Historically-observed prices, i.e., observed world market prices and observed prices of expiring contracts on the TOCOM, however, differ from the model predictions. Therefore, I have simulated the costs of the board using these prices. Figures 4 and 5 show revenue of the board evaluated at these *ex post* realized prices. Physical transactions in the Indian rubber market are evaluated at domestic market prices, and the futures transaction on the Tokyo International Rubber Exchange is evaluated at futures prices at the time of expiration. As Figure 4 shows, realized revenue becomes negative in the years 1994 and 1995 due to increases in prices in those years. Especially during 1994 and 1995, large basis risk losses are generated. This outcome should be

no surprise: in general, during a time of rising prices one can expect hedging to have a negative result. Large profits made in 1990 and the start of 1991 should not be given much weight: Figure 1 reveals that domestic prices are slightly out of pace with world market prices as opening-up of the Indian economy only started at that time. In Figure 5 the aggregate revenue is split up between revenue from the futures transaction on the international futures exchange and revenue from the physical transaction. The figures confirm the general purpose of the hedging scheme: losses or profits of the physical transaction are (partly) offset by profits or losses of the futures transaction. The figure also shows large profits of the physical transaction in 1990 and at the start of 1991 and large losses of the paper transaction in 1994 and 1995.

In these simulations, I have assumed that the forward prices offered by the board to domestic producers and local traders equal the futures prices in Indian rupees, or $\tau_t = 0$ for all t . With these assumptions and averaged over 1991–95, the board runs a small loss. But if the commodity board offers a slightly lower

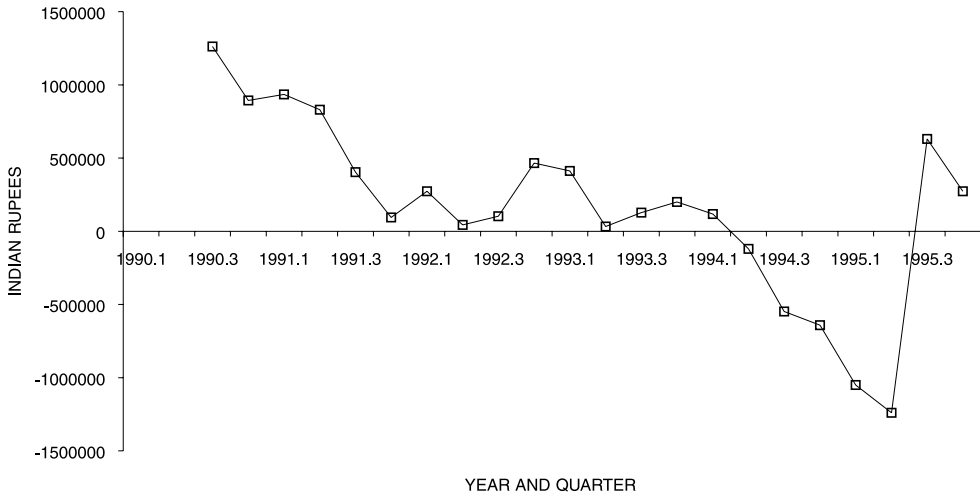


Figure 4. Revenue of the commodity board (aggregate).

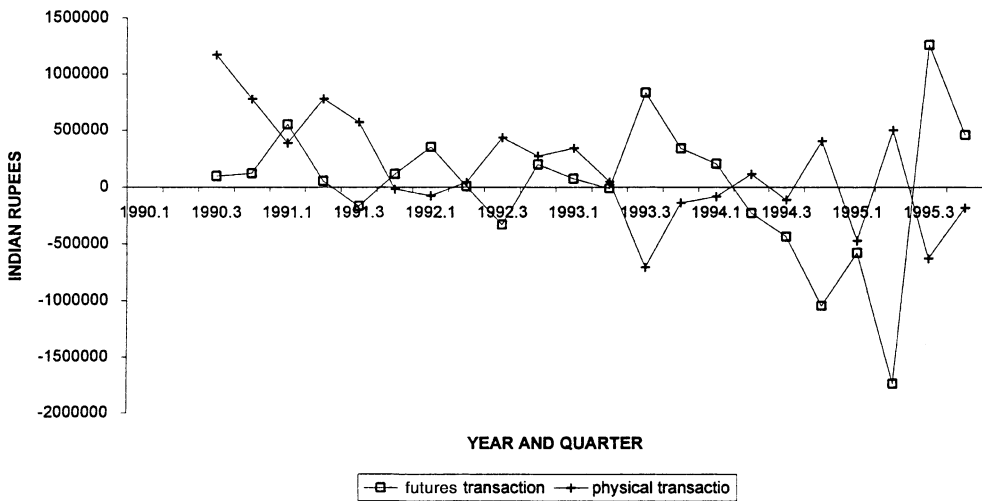


Figure 5. Revenue of the commodity board (split-up).

forward price instead of one that is exactly equivalent to the futures price converted at the relevant real exchange rate, it can improve its financial position. I assume that a surcharge (τ) is levied that is constant for the whole sample period and calculate the level of the surcharge that equalizes costs and benefits of the board. It turns out that only a moderate surcharge of between 2.4% and 2.8% is required to make revenue of the board break even (see Table 3). Such a procedure could also be applied to cover interest costs

due to margin payments. It should be noted that the current study does not account for these costs.

In addition, I have calculated the welfare gains of the introduction of forward contracts and the welfare costs of a break-even strategy of the board. To compare expected utility in a situation with and without forward contracts, I calculate the compensating variation, i.e., the amount of additional income required to make discounted expected utility in both situations equal. Practically I solve:

Table 3. *Surcharge of the board (τ) and accompanying welfare increases*

	Coefficient of absolute risk aversion ^a		
	Low	Medium	High
Break-even surcharge (in %) welfare ^b	2.4	2.7	2.8
Growers	6.1 (69.9)	8.8 (72.0)	11.2 (76.4)
Stockholding by growers and dealers	2.5 (50.3)	2.9 (46.9)	2.5 (38.4)
Stockholding by manufacturers	3.9 (68.8)	10.9 (81.0)	17.9 (85.3)

^a Low coefficients of absolute risk aversion: $A_g = 2.7, A_{sg} = 4.2, A_{sm} = 13.2$; medium: $A_g = 5.2, A_{sg} = 7.2, A_{sm} = 29.6$; high: $A_g = 7.7, A_{sg} = 10.2, A_{sm} = 46.1$; all coefficients of absolute risk aversion: $\times 10^{-6}$; upper and lower values of A_i are chosen as one standard deviation above and below the mean estimates of A_i . See also Table 4.

^b Compensating variation expressed as a percentage of base quarter (1990I) revenue of growers without forward contracts; the welfare increase with a break-even surcharge relative to the welfare increase without surcharge ($\tau = 0$) is presented in between parentheses.

$$\sum_{t=0}^T E_{t-1}(U_i(\pi_{i,t} + compvar_i)) \cdot \delta^t$$

$$= \sum_{t=0}^T E_{t-1}(U_i(\pi_{i,t}^*)) \cdot \delta^t, \quad (35)$$

where *compvar* is the compensating variation; $\delta = 1/(1+r)$; i denotes growers, stockholding by growers and dealers, and stockholding by manufacturers; an asterisk (*) indicates a situation with forward contracts.

From Newbery and Stiglitz (1981, p. 75), I calculate expected utility as:

$$E_{t-1}[U_i(\pi_{i,t})] = -E_{t-1}[\exp(-A_i \cdot \pi_{i,t})]$$

$$= -\exp[-A_i \cdot E_{t-1}(\pi_{i,t}) + 0.5A_i^2 \cdot VAR_{t-1}(\pi_{i,t})]. \quad (36)$$

In this calculation, the variable “compvar” is assumed to have the same value each period. In order to capture a sufficiently representative range of situations, I have simulated with the estimated mean value of the coefficient of absolute risk aversion as well as one standard deviation above and below this estimated mean value. The combination of the three low coefficients of risk aversion are denoted with “low” in Table 3, and “medium” and “high” are defined analogously.

The outcome of this exercise is also reported in Table 3. These figures show that the welfare gain under the break-even strategy of the board ranges from a low of 2.5% (stockholding by growers and dealers) to a high of 17.9% (stockholding by manufacturers). The welfare cost of the break-even strategy of the board is 20% to 30% in the case of growers and stockholding by manufacturers and 40% to 50% in the case of stockholding by growers and dealers, leaving a considerable welfare gain in most cases. There-

fore, financial failure easily can be avoided while maintaining a substantial welfare gain.

(b) *Calculating welfare effects of the use of forward contracts: a dynamic simulation*

The auto-regressive properties of the model justify a dynamic simulation. Here, the sequence of steps is analogous to those in a static simulation with the notable difference that the lagged endogenous variables are not historically observed values, but instead are generated by the model. Expected prices and variances are not stochastic by themselves, but become stochastic after some periods through this dynamic process. The calculation of expected utility with and without forward contracts enables a welfare evaluation.

Figure 6 shows to what extent growers, stockholders at the production side, and stockholders at the manufacturing side cover their production or stocks. Again growers sell the largest part of their production forward. Their coverage always moves above 82.4%, with an average of 89.9%. Stockholders at the production side cover a smaller share than growers. Nevertheless, their coverage is never lower than 70.2% and on average 81.5%. Stockholders at the manufacturing side have a minimum hedge ratio of 88.0%, and on average 92.9%.

Compared to the situation without forward contracts, the simulations reveal that production as well as stockholding by growers and dealers increase enormously: average growth of production is about 0.9 percentage point higher (per quarter). While capacity constraints might prevent such an increase in the growth rate, this figure shows the unambiguous incentive to production if uncertainty is reduced. Part of this growth automatically channels through to stockholders, increasing average growth of

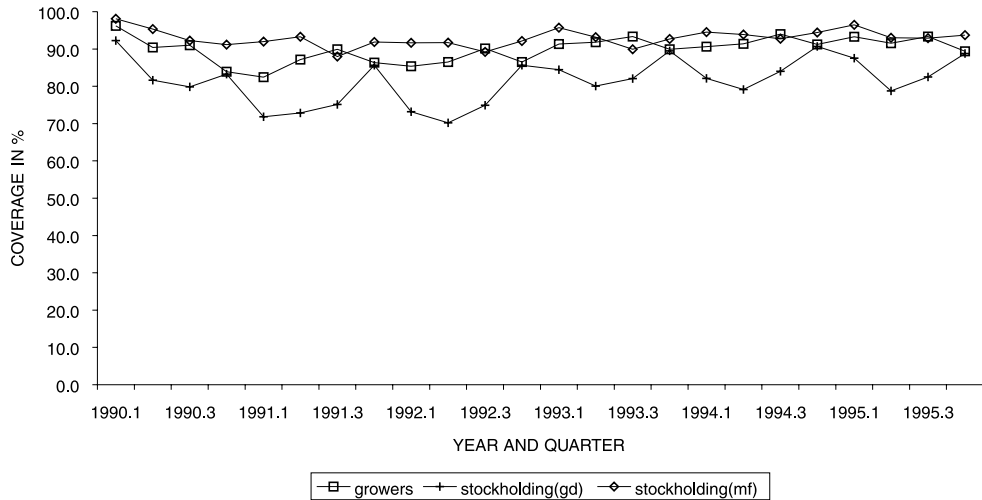


Figure 6. Coverage with forward contracts (dynamic simulation).

stocks for growers and dealers by about 1.0 percentage point and for manufacturers by about 1.9 percentage point.

Welfare gains are calculated by determining compensating variation as set out in Eqns. (35) and (36). Again, in order to capture a sufficiently representative range of situations I have simulated with the estimated mean value of the coefficient of absolute risk aversion as well as one standard deviation above and below this estimated mean value. In addition, a grid of plausible values of the discounting factor has been used. Table 4 summarizes the results of the welfare calculations based on the dynamic simulation. The following observations of the simulation results are worth reporting: all welfare gains are not only, as expected, positive but also of substantial size; with higher real interest rates the gain decreases in the case of growers and remains more or less stable or even increases slightly in the case of stockholders (due to the discounting of negative future

income); a higher risk aversion for each agent implies, as expected, a larger welfare increase; the spread of the growth in welfare is, however, particularly small in the case of growers and relatively large in the case of stockholders. More specifically, growers have to realise an increase in income of between 12.3% and 14.5% to make discounted expected utility equal as in the case of forward contracts. For stockholding, the change in income needed to equate discounted expected utility is, on average, less, but still substantial (between 3.2% and 19.0%).

Prior to evaluating this result some qualifications should be made. The calculated welfare gains exaggerate the true gains. Costs of operating on the TOCOM, mainly interest costs due to margin payments, are not incorporated in the model. These costs, however, will be low compared to the welfare gain and will not affect the main result: the average real interest rate is around 1.5% on a quarterly basis. In addition, commodity transactions which are hedged

Table 4. Welfare gains of providing forward contracts (compensating variation: expressed as a percentage of base quarter revenue of growers without forward contracts)

Activity	Production			Stockholding by growers and dealers			Stockholding by manufacturers		
	2.7	5.2	7.7	4.2	7.2	10.2	13.2	29.6	46.1
$r \setminus A_i^a$									
0.01	13.1	13.9	14.4	3.2	8.6	14.2	7.7	14.6	18.7
0.02	12.6	13.4	14.1	3.3	8.6	14.3	7.6	13.9	18.5
0.03	12.3	13.0	14.1	3.6	8.9	14.0	7.0	14.2	18.2

^a $\times 10^{-6}$; upper and lower values of A_i are chosen as one standard deviation above and below mean estimates of A_i ; simulation outcomes are obtained as averages from 1000 runs.

often can make use of credit at reduced interest rates. Nevertheless, these costs do affect the decision of growers and stockholders on how much to hedge; hence, the welfare gain of such a scheme will be slightly lower if these costs are incorporated. Next, relaxing the assumption of perfect foresight will entail additional costs due to the hedging of exchange rate risks. Further, this model assumes that growers and stockholders earn an income only with natural rubber. In practice, however, growers and stockholders in the Indian natural rubber market, but also in general, have diversified their risk by cultivating other crops, initiating other commercial business, or having a paid job outside agriculture. Although one can wonder if these activities are not created merely for lack of better risk reducing possibilities (such as the hedging scheme in the current study!), they decrease risk, and, hence, also decrease the welfare gain of transferring risk to a commodity exchange. The assumption of one income-earning crop in production and stockholding also takes away any possible welfare gain from price volatility.

Despite these qualifications of the result, large welfare gains remain. How is it possible that with such huge welfare gains, hedging facilities have not been established earlier, either through private sector initiatives or through some type of government intermediation? The absence of hedging should be explained by restrictions on the implementation of such a hedging scheme. Restriction on the foreign exchange requirements can be a serious impediment to hedging operations: the foreign reserve position in the recent years in India and, more in general, the foreign reserve position in any developing country may obstruct implementation of such schemes. The second cause that explains the absence of adequate hedging facilities is that the current financial infrastructure in India is not appropriately equipped to support hedging operations (see UNCTAD/World Bank, 1996).

6. SUMMARY AND CONCLUSION

In this paper, I calculated costs and benefits of an Indian commodity board of offering a forward contract to growers and local traders of natural rubber and simultaneously covering this commitment on the TOCOM. I also evaluated the welfare implications of such a scheme. The empirical work covers the period

1990–95. The applied approach considers production and stockholding, derives risk aversion and cost parameters from empirical observations, and uses observed spot and futures world market prices. Calculations show that risk aversion of growers is one-and-a-half to two times as high as that of local traders. Expected utility is substantially affected by risk in the case of growers and slightly less in the case of stockholding. The negative impact of risk on utility almost completely vanishes if forward contracts are available. The availability of forward contracts also has a substantial impact on the behavior of agents. Overall supply grows 1–1.5 percentage points faster, largely due to higher growth of production. Dynamic simulation shows that, for growers, an increase in income of between 12% and 15% is needed to make discounted expected utility the same as in the case of forward contracts. For stockholders, the change in discounted expected utility is equal or less but with a larger spread. Implementation of the policy entails basis risk that is assumed to be on the account of the board. Revenue of the board, averaged during 1991–95, is marginally negative. If the forward price offered by the board on the domestic market is a small fraction lower than that of the international futures exchange (e.g., a flat rate of 2.5–3.0% for the whole period), however, the board will be able to break even. This strategy is shown to be at a moderately sized welfare cost, leaving a considerable welfare gain from the introduction of forward contracts. In summary, providing domestic primary producers and local traders access to an international futures exchange increases welfare substantially. Intermediation by a commodity board can be implemented without making basis risk losses.

A number of caveats to this study should be mentioned: production is assumed to be certain. Although production is relatively certain in the case of natural rubber, some production uncertainty remains and should be allowed for in the analysis. Next, I assume perfect foresight with respect to exchange rates which is a strong assumption in view of depreciations and devaluations of the yen/dollar and rupee/dollar exchange rates. Moreover, the use of an exponential utility function might influence the outcome. Finally, costs of trading and in particular interest costs due to margin payments are not incorporated in the analysis. More work is needed to extend the current study to relax these assumptions.

NOTES

1. The more empirically-oriented studies of Rolfo (1980), and the ones in Claessens and Duncan (1993) are exceptions.
2. I have chosen to do the hedging operation on an international exchange instead of using a domestic exchange. This choice is far from trivial. Higher liquidity through improved access of all types of participants is regarded to be in favor of the use of international exchanges. On the other hand, the absence of foreign exchange requirements and exchange rate risks are considered to be the major advantages of using a domestic exchange, but also less basis risk and improved price discovery appear important factors that are in favor of using a domestic exchange (for a more detailed discussion see Zant, 1998, Chapter 6 and the references therein). Currently, no domestic commodity exchange, trading rubber futures is operational in the Indian natural rubber market. Given the experiences of international exchanges trading rubber futures, it appears questionable if sufficient interest may be raised in India for operating an international exchange. Nevertheless, a rigorous treatment of the issue, what is more beneficial to India—developing a new domestic exchange or using an existing international exchange—is considered outside the scope of this study.
3. Basis risk arises if the price development in the physical market is different from that on the futures market. With cash and futures prices moving completely parallel, the basis risk is zero, and a hedge will be perfect: a loss on the futures transaction will be exactly offset by a profit on the physical transaction, or vice versa.
4. Until 1995–96 quality grades of natural rubber in India were specified as RMA1 to RMA5, with quality becoming less the higher the grade number. RMA grades are only used in India. From 1995–96 onward by instruction of the Ministry of Commerce (see Rubber Board of India, 1996) domestic grades were renamed in line with international standards: RMA1 became RSS1, RMA2 became RSS2, etc. RSS grades originate from Malaysia and are a common quality denominator on the world market.
5. Because carrying commodities from one period to a future period entails costs, contango is seen as a normal situation, while backwardation is regarded as a temporary and abnormal situation on a futures exchange. Contango and backwardation have important implications in hedging long-term commitments by rolling over contracts.
6. Modeling private sector intermediation is, however, not without problems. Section 3 further elaborates these problems.
7. In the empirical work, I do consider the stockholding of manufacturers as manufacturers will arbitrage just like other stockholders.
8. The presumed sales of the commodity on the domestic market in this scheme primarily reflect the situation on the Indian natural rubber market: selling on the domestic market is not a necessary requirement of such a scheme.
9. In order to model private sector intermediation, one should relax these restrictions on forward contracting and allow both tradeability of contracts and uncovered forward contracting. Due to the representative agent approach, trade in contracts cannot be modelled in my framework without the specification of additional agents. Unlimited forward contracting, on the other hand, would affect price formation on the international futures exchange, which is assumed not to be affected by our scheme. Conclusions of our model with respect to welfare will not be affected by private sector intermediation.
10. Private sector intermediation requires the relaxation of this assumption. See Section 3(a) for details.
11. See Kofman (1991) for exchange rate risks in commodity trade.
12. Upper and lower case letters for prices refer to nominal and real prices.

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APPENDIX A. EMPIRICAL IMPLEMENTATION: EXPECTATION AND VARIANCE OF PRICES

See Table 5.

Estimation of Eqn. (30) generates

$$P_{w,t} = 0.023216 + 0.813645P_{w,t-1}$$

(1.3) (5.2)

absolute *t*-values are in parentheses below the coefficients.

Sample period: 1990I–1995IV
Sum of squared residuals = 0.599177×10^{-2}
Variance of residuals = 0.272353×10^{-3}
Adjusted *R*-squared = 0.531
Durbin's *h* = 0.301
F-statistic = 27.087
Likelihood function = 65.41

Table 5. *Testing the order of integration of world market price and futures price (period: 1990I–95IV)^a*

Variable	Lags	Hypothesis	ADF,nct,nt		ADF,ct		ADF,ct,t	
			1	4	1	4	1	4
P_w		(1)	0.31	0.54	−1.13	−1.63	−1.56	−1.38
		(2)	−3.80	−2.11	−3.79	−2.15	−4.11	−2.61
P_{ft}		(1)	0.24	0.39	−1.20	−1.79	−1.30	−1.18
		(2)	−4.02	−1.95	−3.94	−1.92	−4.56	−2.50
		McKinnon critical values (5%)	−1.96	−1.96	−3.00	−3.02	−3.62	−3.66

^a (1) $H_0 : I(1)$ against $H_A : I(0)$, in levels; (2) $H_0 : I(2)$ against $H_A : I(1)$, in first differences; where: ADF,(n)ct,(n)t = Augmented Dickey Fuller statistic, test equation with(out) a constant term (ct) and with(out) a trend variable (t).

The error term ($\varepsilon P_{w,t}$) can be shown to be normally distributed. It should be noted that this outcome is an unexpected but fairly comfortable result, most likely due to the small sample period. Unexpected, because both, theoretically and empirically it has been shown that prices in commodity market tend to depart from normality (see, e.g., Hughes Hallett & Ramanujam, 1990; Deaton & Laroque, 1992)—comfortable, because it would complicate the derivation of behavioral equations if prices were not normally distributed. The stochastic process of the model is partly caused by this equation.

Expectation and variance of prices, in Japanese yen, are implied by the estimated price equation above:

$$E_{t-1}(P_{w,t}) = 0.023216 + 0.813645P_{w,t-1},$$

$$VAR_{t-1}(P_{w,t}) = 0.272353 \times 10^{-3}.$$

The following result is obtained in estimating Eqn. (34):

$$\Delta P_{ft,t} = \underset{(0.7)}{0.00360} + \underset{(18.8)}{0.885904\Delta P_{w,t}} - \underset{(2.6)}{0.410659P_{ft,t-1}} + \underset{(2.6)}{0.379140P_{w,t-1}},$$

absolute t -values are presented in parentheses below the coefficients;

Sample period: 1990I–1995IV

Sum of squared residuals = 0.244805×10^{-3}

Variance of residuals = 0.122403×10^{-4}

Adjusted R -squared = 0.944

F -statistic = 131.270

Likelihood function = 103.863

FITTING BEHAVIORAL EQUATIONS TO OBSERVATIONS

In order to find the parameters of the model, behavioral equations have been estimated empirically. Both stockholders and producers are assumed to be subject to seasonal fluctuations, in addition to the derived behavior with respect to risk. This is controlled for by imposing a multiplicative seasonal pattern. The real interest rate on a quarterly basis is fixed to 1.5%, which corresponds roughly with observed values of the real interest rate during 1990–95. The real interest rate is calculated as the market rate of interest (commercial lending rate, ICLR) deflated by the consumer price index (consumer prices, CPIIFS) as given in the

International Financial Statistics of the International Monetary Fund. Values of coefficients of the quadratic cost function, coefficients of absolute risk aversion, and coefficients of target stockholding are selected on the basis of estimating equations with nonlinear least squares (NLS). Details on the strategy to run these estimations are presented below, agent by agent. An essential feature of this strategy is the need to use proper starting values for the NLS estimations.

In the case of production, I first look for plausible values of the cost parameter and of the absolute risk aversion parameter. Plausible values of the cost parameter are found by relating costs—according to the quadratic cost function—to the value of production or turnover ($1/2z_g \cdot q_t^2/p_t \cdot q_t$) and by calculating the average of this parameter over the whole sample period. The starting value of the cost parameter is chosen in such a way that this share is on average 50% (z_g is around 0.00015). For the coefficient of absolute risk aversion, I calculate the inverse of average income, assuming, for the moment, relative risk aversion to be equal to unity. Note that eventual values of relative risk aversion and cost parameter could very well be different, which in fact they are. With these selected values of the cost parameter and for the parameter of absolute risk aversion, I calculate

$$q_t^* = q_t / (E_{t-1}(p_t) / (\hat{z}_g \cdot \hat{A}_g \cdot VAR_{t-1}(p_t)))$$

and run the regression

$$q_t^* = a_0 + a_1 \cdot sd1 + a_2 \cdot sd2 + a_3 \cdot sd3$$

where $sd1$ to $sd3$ are quarterly dummies.

The estimated values of a_0 to a_3 and the selected values of z_g and A_g are used as starting values in the NLS estimation of the equation (cf. Eqn. (9)):

$$q_t = [\alpha_0 + \alpha_1 \cdot sd1 + \alpha_2 \cdot sd2 + \alpha_3 \cdot sd3] \cdot [E_{t-1}p_t / (\alpha_4 + \alpha_5 \cdot VAR_{t-1}p_t)].$$

As estimation with these starting values does not lead to convergence, the coefficient α_0 is given a fixed value (a_0 , obtained from the auxiliary estimation), and the log likelihood of the equation is maximized using a grid of values around this coefficient. In the case of production, a dummy for the observation 93IV has been imposed to control for an outlier. Dummies in this equation and also in the other two behavioral equations, are added purely to improve the significance of the key parameters,

the risk-aversion parameter, and the cost parameter. In the simulations these dummies are omitted. The following equation is selected:

$$q_t = [1.756 - 0.593sd1 - 0.533sd2 - 0.442sd3] \cdot [E_{t-1}(p_t)/(0.213 \times 10^{-3} + 5.194 \times 10^{-6} \cdot VAR_{t-1}(p_t))]$$

(7.4) (5.9) (5.0) (10.6) (2.1)

Absolute t -values are presented in parentheses below the coefficients.

Sample period: 1990I–95I

Log likelihood: –222.089

In the case of stockholding by growers and dealers, I postulate that the target stockholding level is specified as a linear function of production ($s_{target,gd,t} = \varphi_{gd} \cdot q_t$ with $\varphi_{gd} > 0$) and calculate a value for $\varphi_{gd} = 0.40$, which has been kept fixed throughout the estimations. Next, and along the same lines as with production, I look for plausible values of the cost parameter and for the parameter of absolute risk aversion. Plausible values of the cost parameter are found by relating costs to the value of stocks at the start of the period ($1/2z_{sgd} \cdot (s_{gd,t} - \varphi_{gd} \cdot q_t)^2 / (p_t \cdot s_{gd,t-1})$) and by calculating the average of this parameter over the whole sample period. Operational cost of stockholding as a percentage of the value of stocks at the start should be less than 5%. Consequently, the cost parameter in the case of stockholding by growers and dealers (z_{sgd}) should be in the neighborhood of 0.001 or lower. Moreover, as with production, I calculate a starting value of the coefficient of absolute risk aversion by taking the inverse of average income, assuming, for the moment, relative risk aversion to be equal to unity. With these selected values of the cost parameter and for the parameter of absolute risk aversion, I calculate

$$s_{gd,t}^* = s_{gd,t} / \left[(E_t p_{t+1} - 1.015 \cdot p_t - \hat{z}_{gd} \cdot \hat{\varphi}_{gd} \cdot q_t) / (\hat{z}_{gd} + \hat{A}_{gd} \cdot VAR_t p_{t+1}) \right]$$

and run the regression

$$s_{gd,t}^* = b_0 + b_1 \cdot sd1 + b_2 \cdot sd2 + b_3 \cdot sd3.$$

The estimated values of b_0 to b_3 and the selected values of z_{gd} and A_{gd} are used as starting values, while φ_{gd} has a fixed value, in the NLS estimation of the equation:

$$s_{gd,t} = [\beta_0 + \beta_1 \cdot sd1 + \beta_2 \cdot sd2 + \beta_3 \cdot sd3] \cdot [(E_t p_{t+1} - 1.015 \cdot p_t - 0.4 \cdot \beta_4 \cdot q_t) / (\beta_4 + \beta_5 \cdot VAR_t p_{t+1})]$$

In the case of stockholding by growers and dealers, two dummies for outliers have been imposed (93III and 93IV). The following equation is selected:

$$s_{gd,t} = [1.245 - 0.107 \cdot sd1 - 0.347 \cdot sd2 - 0.208 \cdot sd3] \cdot [(E_t p_{t+1} - 1.015 \cdot p_t + 0.371 \times 10^{-3} \cdot (0.40 \cdot q_t)) / (0.371 \times 10^{-3} + 7.188 \times 10^{-6} \cdot VAR_t p_{t+1})]$$

(18.8) (2.3) (7.2) (4.4) (4.8) (4.8) (2.4)

Absolute t -values are in parentheses below the coefficients.

Sample period: 1990I–94IV

Log likelihood: –179.601

A similar procedure is applied, with some modifications, to stockholding by manufacturers (target stockholding level is specified as a linear function of consumption ($s_{target,mf,t} = \varphi_{mf} \cdot c_t$ with $\varphi_{mf} > 0$; $\varphi_{mf} = 0.27$) and is fixed throughout the estimations). The following estimated equation is selected:

$$s_{mf,t} = [1.250 + 0.285 \cdot sd1 + 0.148 \cdot sd2 - 0.180 \cdot sd3] \cdot [(E_t p_{t+1} - 1.015 \cdot p_t + 0.530 \times 10^{-3} \cdot (0.27 \cdot c_t)) / (0.530 \times 10^{-3} + 29.62 \times 10^{-6} \cdot VAR_t p_{t+1})]$$

(8.5) (2.5) (1.5) (1.8) (2.0) (2.0) (1.8)

Absolute t -values are in parentheses below the coefficients.

Sample period: 1990I–94IV

Log likelihood: –183.965