Risk Management Using Futures Contracts: The Impact of Spot Market Contracts and Production Horizons on the Optimal Hedge Ratio

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Paper prepared for presentation at the 99th EAAE Seminar 'Trust and Risk in Business Networks', Bonn, Germany, February 8-10, 2006

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Abstract

We specify a principal-agent marketing channel involving producers, wholesalers, retailers and a futures market. Our hedge ratio for producers appears to be much lower than the common price-risk minimising ones as we account for producers' vertical contracts and, by using annual data, their production horizon. The Dutch ware potato marketing channel and its futures market in Amsterdam show that possibly through decreases in producers' and wholesalers' risk aversions, their optimal dynamic hedge ratios decreased from 38% and 12%, respectively, in 1982 to 18% and 10%, respectively, in 2003. These results comply with the decreased futures volume traded in Amsterdam over the years.

Keywords: *Principal-Agent Model; Risk Management; Futures and Spot Market Contracts, Production Horizons; Food Marketing Channels*

1. Introduction

Risk is prevalent in commodity marketing channels (e.g. Knoeber and Thurman, 1995). Marketing channel members (MCMs) can manage their risk by hedging in a futures market. A futures contract (futures for short) is a standardised agreement traded on an organised exchange (the futures market) to deliver a specific amount of a commodity at a specified future time, price and place. A primary use of futures involves shifting risk from a firm that desires less risk (the hedger) to a party who is willing to accept the risk in exchange for an expected profit (the speculator). Speculators are not always spot-market traders and therefore, futures positions are often offset prior to expiration. For example, crop producers can protect themselves from declines in prices of expected outputs by selling futures contracts at the beginning of the growing period and buying back futures at the time their product is ready to be sold in the spot market. As futures and spot prices are positively correlated, losses and gains in the two markets tend to offset each other, leaving the hedger with a return close to what was expected (e.g. Ederington, 1979).

Output variability reduces the risk reduction capacity of hedging for crop growers, however, making it advisable for them to sell futures up to a quantity less than the expected harvest (e.g. Moschini and Lapan, 1995). Moreover, although futures and spot prices tend to move in parallel, these movements are not usually identical; this results in basis risk (where basis is defined as the local spot price minus the futures price). As can be demonstrated by the minimum-variance criterion, this is also why the common price-risk minimising hedge ratio (hedge ratio is defined as the futures position in kg divided by the spot position in kg) can be less than 1. Consequently, for crop producers and all other traders wishing to reduce risk by hedging with futures contracts, the hedge ratio is of critical importance (e.g. Dawson et al., 2000).

Previous studies on time-varying hedge ratios use high-frequency data (i.e. daily and weekly data), and neglect the contractual relationships in the spot marketing channel (e.g. Pennings and Meulenberg, 1997). In contrast, high-frequency data such as daily or hourly observations are rarely considered by crop producers when they have to decide about their production scheme. Supply models with adaptive expectations (e.g. Nerlove, 1958 and Askari and Cummings, 1977) have shown that crop producers base such decisions on an average of prices over a number of years, rather than on the price quotation of a single trading day. Furthermore, vertical contractual relationships between the MCMs determine how much risk each MCM bear (e.g. Pennings and Wansink, 2004) and hence, each risk-averse MCM's optimal hedge ratio. Principal-agent theory is a widely used economic approach towards modeling these contractual relationships (e.g. Milgrom and Roberts, 1992). Consequently, in this paper we use the classic model in agency theory to derive the optimal hedge ratios. We do not only use annual data that conforms to the producers' decision horizon, but also take the contractual relationships in the spot marketing channel into account.

For this purpose we specify a three-stage principal-agent marketing channel model involving producers, wholesalers, retailers and a futures market, where risk-averse producers and wholesalers trade futures in order to manage their risks. The rest of the paper is structured as follows. We present the model in Section 2. The empirical application and results are presented in Section 3. Finally, conclusion and discussion are presented in Section 4.

2. The Theoretical Model

In our model, we consider a product that is produced by farmers, processed and distributed to retailers by processors/wholesalers (wholesalers for short) and finally sold to consumers by retailers. The retail value of the product (i.e. at consumer prices) is specified as $x = e + \varepsilon$, where x is the actual retail value, $e = E(x)$ is the (common knowledge) expectation of the retail value, and ε is the random component of the retail value, which is assumed to be normally distributed with mean zero (i.e. $E(\varepsilon) = 0$) and variance σ_ε^2. We assume a hypothetical linear contract between the retailers and the wholesalers as follows: $W_w = \alpha_w x + \beta_w$, where W_w is the total compensation payment from the retailers to the wholesalers, α_w is the incentive parameter, $\alpha_w x$ is the variable compensation payment, and β_w is the fixed compensation.

Similarly, the contractual relationship between the wholesalers and the producers is specified as $W_p = \alpha_p \alpha_w x + \beta_p$, where W_p is the total compensation payment from the wholesalers to the producers, α_p is the variable-revenue sharing parameter between the wholesalers and the producers (i.e. the proportion of the wholesalers' variable revenue that is received by the producers), $\alpha_p \alpha_w$ is the actual incentive parameter from the wholesalers to the producers, and $\alpha_p \alpha_w x$ and β_p are the variable and fixed compensation payments to the producers, respectively.

The wholesalers' and producers' expected cost of effort are specified as $C_w = 0.5 c_w e^2 + d_w$ and $C_p = 0.5 c_p e^2 + d_p$, respectively, where d_w and d_p denote trend terms that may reflect technological changes in production, and c_w and c_p are the increases in the marginal costs. Net of fixed retail costs, the retailers' profit is $\pi_r = x - W_w$ with variance $Var(\pi_r) = (1 - \alpha_w)^2 \sigma_\varepsilon^2$ as can be seen from the expressions above. Since the product is one of the many stock-keeping units in each retailer's assortment, we assume that the retailers do not care about this variance. In contrast, in the model, we allow the risk-averse producers and wholesalers to trade futures besides their contractual relationships in the marketing channel, to hedge against the risks incurred in the product's spot market. Accordingly, the producers profit π_p , resulting from selling futures of their produce and the contractual relationship with the wholesalers, is given by $\pi_p = W_p - C_p + Z_p(F_{t,t-1} - F_{t,t})$, where $Z_p(F_{t,t-1} - F_{t,t})$ represents the producers' gain or loss from selling futures, in which Z_p is the quantity of produce sold in the futures market at time $t-1$ and bought back at time t; $F_{t,t-1}$ is the futures price at time $t-1$; and $F_{t,t}$ is the futures price at time t. Thus, the producers' result of holding a hedging position can be either positive or negative, depending on whether the futures price at maturity when the position is closed is below or above the price at which the position was initiated. The difference in the futures price between time $t-1$ and t is assumed to follow a random walk with drift as follows: $F_{t,t-1} - F_{t,t} = \mu_F + \varepsilon_{Ft}$, where μ_F , denoting the drift term, reflects storage and interest costs, and ε_{Ft} is the error term with zero mean and variance σ_F^2 . In the same vein, the wholesalers' net result from their long hedge and the contractual relationship with the retailers is given as $\pi_w = W_w - C_w - W_p - Z_w(F_{t,t-1} - F_{t,t})$, where $Z_w(F_{t,t-1} - F_{t,t})$ represents the wholesaler's gain or loss from buying futures, in which Z_w is the quantity of produce bought at time $t-1$ and sold at time t. Similarly, the wholesaler's result of holding a hedging position can also be either positive or negative, depending on whether the futures price at maturity is below or above the futures price at which the position was initiated.

Producers and wholesalers do not only form expectations regarding their respective profits, they are also aware of the uncertainty in these expectations. We use the variance in producers' and wholesalers' profits as a proxy for their risk. The variance of the producers' profit is $Var(\pi_p) = \alpha_p^2 \alpha_w^2 \sigma_\varepsilon^2 + Z_p^2 \sigma_F^2 + 2\alpha_p \alpha_w Z_p \sigma_{\varepsilon F}$, where $\sigma_{\varepsilon F}$ denotes the covariance between ε_t and ε_{Ft}. Similarly, the variance of the wholesalers' profit appears to be $Var(\pi_w) = (1-\alpha_p)^2 \alpha_w^2 \sigma_\varepsilon^2 + Z_w^2 \sigma_F^2 - 2(1-\alpha_p)\alpha_w Z_w \sigma_{\varepsilon F}$. Given that the risk aversions of producers and wholesalers comply with the constant absolute risk aversion (CARA) preference and that their profits are normally distributed, then their objective functions are equivalent to the maximisation of their respective certainty equivalents of profits $CE(\pi) = E(\pi) - 0.5\rho Var(\pi)$ (i.e. the profits with risk that yield an identical level of satisfaction as the profits with no risk), where $\rho > 0$ is the Arrow-Pratt coefficient of absolute risk aversion.

The producers' objective function is then as follows:
$$\underset{e, Z_p}{Max}\{\alpha_p \alpha_w e + \beta_p - d_p - 0.5c_p e^2 + \mu_F z_p$$
$$-0.5\rho_p \alpha_p^2 \alpha_w^2 \sigma_\varepsilon^2 - 0.5\rho_p z_p^2 \sigma_F^2 - \rho_p \alpha_p \alpha_w z_p \sigma_{\varepsilon F}\}$$, of which the first-order conditions are $e = \alpha_p \alpha_w / c_p$ (also known as the incentive constraint) and $Z_p = (\mu_F - \rho_p \alpha_p \alpha_w \sigma_{\varepsilon F})/\rho_p \sigma_F^2$. Having defined the objective function of the producers, it is important to elaborate on the constraints in the contract between the producers (i.e. the agent) and the wholesalers (i.e. the principal). In the contract with the producers, the wholesalers are not only subjected to the incentive compatibility constraint, but also to the participation constraint. The participation constraint asserts that the producers equate their reservation wage $\overline{W}_p$ (i.e. the wage they can obtain without risk in an alternative job) to their certainty equivalent of profit. From this constraint and the two first-order conditions the producers' fixed compensation β_p is then derived as $\beta_p = \overline{W}_p + d_p - 0.5\alpha_p^2 \alpha_w^2 / c_p - 0.5\mu_F^2 / \rho_p \sigma_F^2$
$$+0.5\rho_p \alpha_p^2 \alpha_w^2 \sigma_\varepsilon^2 + \alpha_p \alpha_w \mu_F \sigma_{\varepsilon F} / \sigma_F^2 - 0.5\rho_p \alpha_p^2 \alpha_w^2 \sigma_{\varepsilon F}^2 / \sigma_F^2$$

Having derived the conditions for the parameters in the contract offered by the wholesalers to the producers, we now turn to the derivation of the optimality conditions for the parameters in the contract offered by the retailers to the wholesalers. From the expressions above we can derive that the wholesalers maximise the certainty equivalent of profit as follows:
$$\underset{\alpha_p, Z_w}{Max}\{(1-\alpha_p)\alpha_w^2 \alpha_p / c_p + \beta_w - d_w - 0.5c_w \alpha_p^2 \alpha_w^2 / c_p^2 - \overline{W}_p - d_p + 0.5\alpha_p^2 \alpha_w^2 / c_p + 0.5\mu_F^2 / \rho_p \sigma_F^2$$
$$-0.5\rho_p \alpha_p^2 \alpha_w^2 \sigma_\varepsilon^2 - \alpha_p \alpha_w \mu_F \sigma_{\varepsilon F} / \sigma_F^2 + 0.5\rho_p \alpha_p^2 \alpha_w^2 \sigma_{\varepsilon F}^2 / \sigma_F^2 - \mu_F Z_w - 0.5\rho_w(1-\alpha_p)^2 \alpha_w^2 \sigma_\varepsilon^2$$
$$-0.5\rho_w Z_w^2 \sigma_F^2 + \rho_w(1-\alpha_p)\alpha_w Z_w \sigma_{\varepsilon F}\}$$ to obtain the two first-order conditions $\alpha_p = (1 - c_p \mu_F \sigma_{\varepsilon F} / \alpha_w \sigma_F^2 + c_p \rho_w \sigma_\varepsilon^2 - c_p \rho_w Z_w \sigma_{\varepsilon F} / \alpha_w)/(1 + c_w / c_p + c_p \rho_p S + c_p \rho_w \sigma_\varepsilon^2)$ and $Z_w = [\rho_w(1-\alpha_p)\alpha_w \sigma_{\varepsilon F} - \mu_F]/\rho_w \sigma_F^2$, where $S \equiv (\sigma_\varepsilon^2 \sigma_F^2 - \sigma_{\varepsilon F}^2)/\sigma_F^2$. Like the producers, the wholesalers consider a participation constraint, according to which the certainty equivalent of

the wholesalers' profit, $CE(\pi_w)$, equals the wholesalers' reservation wage, $\overline{W}_w$. From this condition, and after inserting the first-order condition for Z_w, the wholesalers' fixed compensation is derived as $\beta_w = \overline{W}_w + d_w + \overline{W}_p + d_p - \alpha_w^2 \alpha_p / c_p + 0.5 c_w \alpha_p^2 \alpha_w^2 / c_p^2 + 0.5 \alpha_p^2 \alpha_w^2 / c_p$

$$-0.5 \mu_F^2 / \rho_p \sigma_F^2 + 0.5 \rho_p \alpha_p^2 \alpha_w^2 S + \mu_F \alpha_w \sigma_{\varepsilon F} / \sigma_F^2 - 0.5 \mu_F^2 / \rho_w \sigma_F^2 + 0.5 \rho_w (1 - \alpha_p)^2 \alpha_w^2 S$$

We now turn to the objective function of the risk-neutral retailers. They maximises their expectation of profits $E(\pi_r) = e - E(W_w)$ as follows: $\underset{\alpha_w}{Max}\{\alpha_p \alpha_w / c_p - \overline{W}_w - d_w - \overline{W}_p - d_p$

$$-0.5 c_w \alpha_p^2 \alpha_w^2 / c_p^2 - 0.5 \alpha_p^2 \alpha_w^2 / c_p + 0.5 \mu_F^2 / \rho_p \sigma_F^2 - 0.5 \rho_p \alpha_p^2 \alpha_w^2 S - \mu_F \alpha_w \sigma_{\varepsilon F} / \sigma_F^2 + 0.5 \mu_F^2 / \rho_w \sigma_F^2$$

$$-0.5 \rho_w (1 - \alpha_p)^2 \alpha_w^2 S\}$$ for which the first-order condition yields $\alpha_w = [1 - c_p \mu_F \sigma_{\varepsilon F} / \alpha_p \sigma_F^2] /$

$[c_w \alpha_p / c_p + \alpha_p + c_p \rho_p \alpha_p S + c_p \rho_w (1 - \alpha_p)^2 S / \alpha_p]$. Recall from the linear contract between the retailers (i.e. the principal) and wholesalers (i.e. the agent) that the revenue-sharing parameter is given by α_w. In the contract for the producers the revenue-sharing parameter is $\alpha_p \alpha_w$. Consequently, if α_p is a constant parameter, then both revenue-sharing parameters may still be time varying through α_w. In line with this notion and for purpose of empirical testing to be discussed in the next section, we consider α_w, β_w, β_p, ρ_w, ρ_p, Z_w and Z_p as unknown variables, which can be solved by the equations above. In this respect it is of interest to discuss the derivation of the solutions for ρ_w and ρ_p below.

If we substitute the expression for Z_w in the expression for α_p we obtain the following expression for the producers' revenue-sharing parameter α_p in their contracts with the wholesalers: $\alpha_p = [1 + c_p \rho_w S] / [1 + c_w / c_p + c_p (\rho_p + \rho_w) S]$. Rewriting this expression yields the following equation for the producers' risk parameter: $\rho_p = \rho_w (1 - \alpha_p) / \alpha_p +$ $(1 - \alpha_p - \alpha_p c_w / c_p) / \alpha_p c_p S$. Next, substituting this expression for ρ_p and the rewritten incentive constraint $\alpha_w = c_p e / \alpha_p$ into the first-order condition of the expected profit maximisation problem of the retailers solved above, we obtain the wholesaler's risk parameter as follows: $\rho_w = [(\sigma_F^2 \alpha_p - \sigma_F^2 c_p e - c_p \mu_F \sigma_{\varepsilon F}) \alpha_p] / [(1 - \alpha_p) c_p^2 e \sigma_F^2 S]$. Subsequently, substituting this expression for ρ_w in the last expression for ρ_p we derived, we obtain for the risk parameter of the producers: $\rho_p = [\sigma_F^2 \alpha_p^2 - 2\sigma_F^2 \alpha_p c_p e - \alpha_p c_p \mu_F \sigma_{\varepsilon F} + c_p e \sigma_F^2 - \alpha_p c_w e \sigma_F^2] / [\alpha_p c_p^2 e \sigma_F^2 S]$. These risk parameters are one of the determinants of the producers' and wholesalers' hedge ratios. In the model, we assume that the quantity produced q is the same as the quantity consumed. The optimal hedge ratios for the producers and wholesalers, respectively, are given by $h_p^* = Z_p / E(q)$ and $h_w^* = Z_w / E(q)$, where Z_p and Z_w are as defined above and $E(q)$ denotes the expected output.

3. Empirical Application: Data, Estimation and Results

We apply our model to the Dutch ware potato industry. Every year, some eight million tons of ware potatoes are produced in the Netherlands, mainly on family farms. Most ware potatoes are sold to wholesalers and most of the wholesale trade has become concentrated in relatively few hands, as the major users, particularly the large retailers, processors and export markets, demand large quantities with tight specifications which only the larger wholesalers can meet. Because of this development in the market, the need has arisen to procure potatoes before harvest. In this respect, the potato futures contract of the Euronext Amsterdam Commodity Exchange fulfills a price discovery role (see Kuiper et al., 2002).

For the empirical analysis, Statistics Netherlands provided us with annual data over the period 1971 – 2003, for the following variables: the farm, export (i.e., wholesale) and retail prices (Euro/kg) of ware potatoes, all deflated by the consumer price index (1990 = 1.00) to obtain p_{pt}, p_{wt} and p_t, respectively, area planted (1000 ha), yield per hectare (100 kg/ha), and rent price of land (Euro/ha), deflated by the consumer price index. Furthermore, we obtained the futures price of potato and the volume of potato futures contras traded at Euronext Amsterdam Commodity Exchange over the period 1971-2003. We used the futures price (Euro/kg) for delivery in April of year t quoted as the closing price of the first trading day of April in year $t − 1$ to represent $F_{t,t}$; to represent $F_{t,t−1}$, we used the futures price (Euro/kg) for delivery in April of year $t + 1$ quoted as the closing price of the first trading day of November (when most potatoes are sold by the farmers) in year t. Both $F_{t,t−1}$ and $F_{t,t}$ are also deflated by the consumer price index. From these time series, we obtain the following variables of interest. First, all prices, spot and futures, are deflated by the consumer price index. The output quantity q_t (million tons) in year t is computed as the yield per hectare times the area planted. Then, using the deflated prices, we construct $x_t = p_t q_t$, $W_{wt} = p_{wt} q_t$ and $W_{wt} = p_{pt} q_t$. We compute the conditional expectation of p_t by the fit of a regression of p_t on a constant and $F_{t,t−1}$ and denote it as $\hat{E}(p_t|I_{t−1})$, assuming that the information set $I_{t−1}$ is common to all MCMs. Using data on yield per hectare and the number of hectares planted, the estimate of the expected output $E(q_t|I_{t−1})$, denoted as $\hat{E}(q_t|I_{t−1})$, is obtained by the product of area planted and expected yield per hectare, where the expected yield per hectare is assumed to follow an autonomous positive linear time trend. Next, we turn to the estimation of $E(p_t q_t|I_{t−1})$. For this, note that $p_t q_t = E(p_t|I_{t−1})E(q_t|I_{t−1}) + E(p_t|I_{t−1})\varepsilon_{qt} + \varepsilon_{pt}E(q_t|I_{t−1}) + \varepsilon_{pt}\varepsilon_{qt}$, where $\varepsilon_{pt} = p_t − E(p_t|I_{t−1})$ and $\varepsilon_{qt} = q_t − E(q_t|I_{t−1})$ are the unexpected components of p_t and q_t, respectively, and $\varepsilon_{pt}\varepsilon_{qt}$ represents the covariance of p_t and q_t, which we may expect to be negative. Consequently, $E(p_t q_t|I_{t−1}) = E(p_t|I_{t−1})E(q_t|I_{t−1}) + E(\varepsilon_{pt}\varepsilon_{qt}|I_{t−1})$. Now, to estimate $E(p_t q_t|I_{t−1})$ we simply regress $p_t q_t$ on a constant and $\hat{E}(p_t|I_{t−1})\hat{E}(q_t|I_{t−1})$. In this way, $\hat{E}(p_t|I_{t−1})\hat{E}(q_t|I_{t−1})$ extracts all the information of interest out of $\varepsilon_{pt}\varepsilon_{qt}$ since the regression residuals are orthogonal to $\hat{E}(p_t|I_{t−1})\hat{E}(q_t|I_{t−1})$.

Hence, the fit of the regression is denoted as $\hat{E}(p_t q_t | I_{t-1}) = \hat{e}_t$, the expected output value at retail level. Next, the estimate of ε_t denoted as $\hat{\varepsilon}_t$ is obtained by subtracting $\hat{e}_t$ from $p_t q_t$. The estimate of σ_ε^2 (i.e. the variance of the random output value at retail level) denoted as $\hat{\sigma}_\varepsilon^2$ is simply computed as the fit of a regression of ε_t^2 on a constant. The rent price of land times the area planted (divided by 10^6) is used as a proxy for $\overline{W}_{pt}$ (the producer's reservation wage). Lastly, we set $\overline{W}_{wt}$ (the wholesaler's reservation wage) equal to zero and used linear models with a constant and linear trend to estimate d_w and d_p.

Note that many variables become time varying during the estimation process, as we use time-series data. Hence the subscript t is imposed on the variables. The only constant parameters left to be estimated are c_p, c_w, d_p, d_w, and α_p. In order to estimate these parameters, we derive the estimation equations as follows. First, we consider the linear contract for the producers $W_p = \alpha_p \alpha_w x + \beta_p$ and substitute $c_p e$ for $\alpha_p \alpha_w$ as obtained from the incentive constraint and substitute for β_p its participation constraint solution. Some rewriting then gives

$$W_{pt} - \overline{W}_{pt} = d_p + c_p \hat{e}_t x_t - 0.5 c_p \hat{e}_t^2 + c_p \hat{e}_t \hat{\mu}_F \hat{\sigma}_{\varepsilon F} / \hat{\sigma}_F^2 - 0.5 \hat{\mu}_F^2 / \hat{\sigma}_F^2 \hat{\rho}_{pt} + 0.5 c_p^2 \hat{e}_t^2 \hat{\rho}_{pt} \hat{S} \quad (1)$$

Similarly, after substituting $c_p e / \alpha_p$ for α_w in $W_w = \alpha_w x + \beta_w$ and then substituting for β_w its participation constraint solution, we obtain

$$W_{wt} - \overline{W}_{wt} - \overline{W}_{pt} = d_p + d_w + c_p \hat{e}_t x_t / \alpha_p - c_p \hat{e}_t^2 / \alpha_p + 0.5(c_p + c_w)\hat{e}_t^2 - 0.5 \hat{\mu}_F^2 / \hat{\sigma}_F^2 \hat{\rho}_{pt}$$
$$+ 0.5 c_p^2 \hat{e}_t^2 \hat{\rho}_{pt} \hat{S} + \hat{\mu}_F \hat{\sigma}_{\varepsilon F} c_p \hat{e}_t / \hat{\sigma}_F^2 \alpha_p - 0.5 \hat{\mu}_F^2 / \hat{\sigma}_F^2 \hat{\rho}_{wt} + 0.5[(1 - \alpha_p)/\alpha_p]^2 c_p^2 \hat{e}_t^2 \hat{\rho}_{wt} \hat{S} \quad (2)$$

After inserting the solutions of ρ_p and ρ_w and modeling the deterministic terms d_p and d_w as linear trends, giving $d_{pt} = d_{p0} + d_{p1}t$ and $d_{wt} = d_{w0} + d_{w1}t$, we can estimate the unknown parameters α_p, c_p, c_w, d_{p0}, d_{p1}, d_{w0}, and d_{w1} in the two-equation system, by using Full Information Maximum Likelihood (FIML). The FIML estimates of the unknown parameters α_p, c_p, c_w, d_{p0}, d_{p1}, d_{w0}, and d_{w1} in Eq. (1) and Eq. (2) are 0.581, 0.261, 0.485, 0.276, –0.007, –0.107, 0.000 respectively. The estimate for α_p is significant and fits nicely within the expected constraints $0 < \hat{\alpha}_p < 1$. The estimates of the marginal cost terms c_p and c_w are positive and significant as well. For the producers we obtain a significantly negative slope of the trend term in the cost function, indicating technological advances in agricultural

production. Also the estimates of α_{wt} obtained by $\hat{c}_p \hat{e}_t / \hat{\alpha}_p$ lie within the (0,1) interval and increase from 0.4 in 1971 to 0.6 in 2000. Consequently, producers and wholesalers face increasing incentive intensities as given by $\hat{\alpha}_p \hat{\alpha}_{wt}$ and $\hat{\alpha}_{wt}$. In contrast, their fixed compensations $\hat{\beta}_{pt}$ and $\hat{\beta}_{wt}$ are decreasing. Given the constant variance of the output value $(\hat{\sigma}_\varepsilon^2)$ this together implies that producers and wholesalers are getting confronted with an increasing coefficient of variation (CV) regarding their profits. Is this because they are better able to manage their risk by extending their position in the futures market relative to their position in the spot market, or do they rather become less risk averse (e.g. because they want to become more market-oriented) or both? It appears that the risk-aversion parameters $\hat{\rho}_{pt}$ and $\hat{\rho}_{wt}$ sharply decreased whereas Figures 1 and 2 show that the optimal hedge ratios have been decreasing as well, from 12% and 38% in 1982 to 10% and 18% in 2003 for the wholesalers and producers, respectively. Consequently, these results give rise to the conclusion that the risk-averse MCMs in the Dutch ware potato marketing channel are more inclined to receiving incentives (which lower the coordination costs in the marketing channel as full incentives would imply the MCMs to be risk neutral leading to the first-best Pareto optimal solution for the channel as a whole) not because they relatively hedge more but rather because they have become considerably less risk averse. This conclusion can be seen as a probable explanation of the decreases in the volume of futures contracts traded over the years in Amsterdam.
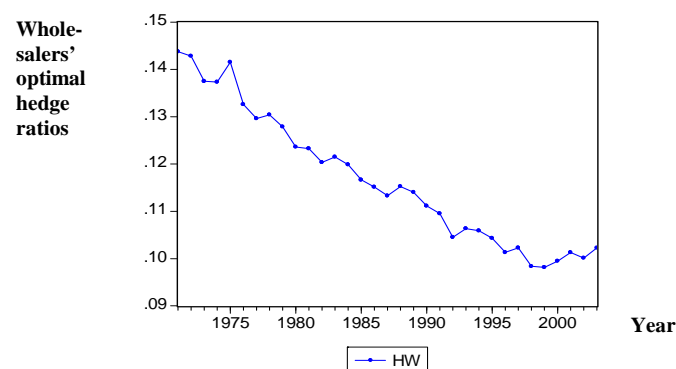

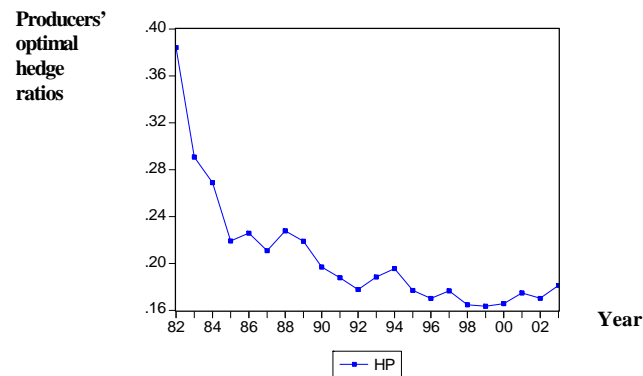**Figure 1.** Wholesalers' optimal dynamic hedge ratio (HW)

Figure 2. Producers' optimal dynamic hedge ratio (HP)

4. Conclusion and Discussion

In this paper, we extend the widely-known two-stage, principal-agent model to a three-stage model involving producers, wholesalers, retailers, and a futures markets to assess risk, and risk-management strategies in an agricultural marketing channel. The model allows risk-averse producers and wholesalers to trade in the futures market, in combination with their respective contract relationships in the spot markets. We derive an expression for their optimal hedge ratios.

The empirical application to the Dutch potato marketing channel shows that as a consequence of decreases in the producers' and wholesalers' degree of risk aversion during 1971-2003, the optimal dynamic hedge ratio for wholesalers decreased from 14% in 1971 to 10% in 2003, whereas that of producers decreased from 38% in 1982 to 18% in 2002. To validate the model's results, we compared the hedge ratios estimated by the model and the actual volume of futures contracts traded in Amsterdam over time. And indeed, the decrease in the hedge ratios of both producers and wholesalers is consistent with reality, as the volume of futures contracts traded at Amsterdam Commodity Futures Exchange also decreased over the years. We conjecture that the hedge ratio estimates in this paper are more consistent with channel members' decision framework than previous estimates, as they account for contract relationships within the marketing channel as well as the production horizons.

Our displayed hedge ratio for the producers (see Figure 2) in 1995 and 1996 of around 0.17 is clearly lower than the ratio reported in Pennings and Meulenberg (1997), who used weekly observations on the basis of which they estimated an optimal hedge ratio in a mean-variance framework for Dutch potato growers of 0.47 for 1995 and 1996. This difference complies with the fact that their mean-variance model dealt only with price risk. And indeed, futures markets more often offer the opportunity to hedge against price risk rather than against output value risk, yet − as is captured by the agency model that we propose − it is the latter risk that the producers must deal with as well.

Finally, note that our analysis has been performed on the basis of the implicit assumption of representative MCMs. Nevertheless, there may be large differences in the performance among

producers as well as among wholesalers and hence in their individual optimal hedge ratios. There is therefore a clear need for further research on panel data of individual producers and wholesalers.

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