Incentive Provision and Coordination Costs in Food-Marketing Channels: A Multi-Stage Channel-Agency Theory Perspective

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Food-supply chains have become extensively vertically coordinated through the use of contracts as an organizational response to satisfy the needs of consumers in the saturated food markets of the industrialized countries. The contracts involved must establish an optimal trade-off between incentive provision and risk reduction. Agency theory can be used to model this trade-off. We show how to do this in a three-stage (producer, wholesaler, retailer) principal-agent supply-chain model. Its application to the Dutch supply chain of ware potatoes shows that during the period 1961–2002, retailers have been able to provide more incentives to the wholesalers and producers and as a consequence the costs of coordination in the supply chain decreased.

Food-supply chains are facing a transition from using open-market mechanisms for coordinating the various stages of value-adding (e.g., production, wholesale, retail) to negotiated coordination involving governance forms such as alliances, joint ventures, contracts, franchising agreements, and vertical integration (e.g., Boehlje, Hoffing, and Schroeder 1999). A driving force behind this integration is the need to coordinate the timing and quality of purchases and deliveries along the supply chain. Perishability of products caused early integration, but other factors—relating to economies of scale in the management of information about consumers and their preferences, for example—reinforced the trend (e.g., Johnson and Berdegué 2004).

In particular, the rise of mega-processors and mega-retailers has resulted in very little produce being traded on the open market. Often, the competitiveness of these enterprises is strengthened through strict grades and standards imposed on the producer-suppliers through contracts. Contracts provide the contracting parties a certain level of control and risk sharing and are often used to improve quality and/or performance through incentive structures (e.g. Curtis and McCluskey 2003; Milgrom and Roberts 1992). As such, vertical coordination through contracting can be seen as an organizational response to an increased demand for quality among increasingly discerning consumers (Wolf, Hueth, and Ligon 2001). The resulting market orientation implies adjusting production processes and products to respond to specific consumer demands and to market signals and trends. In contrast, product orientation, based on the principles that good products sell themselves and should be standardized to keep costs down, becomes less suitable now that consumer food markets in industrialized countries have become saturated, international competition is growing, and food companies must concomitantly meet the rising demand for product differentiation and sustainable production. Wholesalers and processors are important economic actors that link producers with the needs and wants of the consumers as articulated by the large, powerful retailers. To become successful, such a link has to solve the problems of information asymmetry and incentive incompatibility between the trading parties. Of these, the producers have more information about their own efforts than those of the wholesalers and the retailers, and if the producers obtain a fixed wage, they want to keep costs down at the expense of quality and/or product differentiation, while the retailers ask for quality and differentiated products to satisfy consumers' needs.

Given its focus on developing contracts that align incentives while at the same time addressing monitoring issues, this paper employs principal-agent theory to address the issues of coordination and risk-aversion in an integrated food-supply-

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chain model consisting of three stages: producers, wholesalers/processors, and retailers. The key idea within agency theory is that principal-agent relationships should reflect efficient information and risk-bearing costs, incentive alignments, and the contract as the unit of analysis (e.g., Cook and Barry 2004). An agency problem arises if the risk-averse agent (e.g., producer and/or wholesaler/processor) is assigned decision (or control) rights (e.g., regarding production, distribution, processing) that affect the principal's (e.g., retailer and consumer) wealth or utility function. The principal cannot fully observe the effort of the agent, and hence is not sure whether or not the agent acts according to the best interest of the principal when the goals of the principal and the agent conflict. Moreover, simply assigning claims to the residual income generated by the asset as an incentive to the agent to act in the interest of the principal does not go without the cost of more risk on the part of the agent who is then asking for a higher risk-premium.

Principal-agent theory applies in all cases where one party has an informational advantage over another that can be exploited to the benefit of the advantaged party at the expense of the advantaged party's trading partner (Salanié 1997). Given agency problems, we cannot expect a supply chain to function as well economically as it would if all information were shared without any cost involved or if the incentives of principal and agent could be cost aligned. This shortfall is called "agency costs" (Cook and Barry 2004). Those costs may include *ex ante* search costs (associated with adverse-selection [hidden-information] problems) and/or *ex post* monitoring and enforcement costs (associated with moral hazard (hidden action) problems) (e.g. Sykuta and Cook 2001; Douma and Schreuder 2002). This paper shows how to estimate these agency costs in a food-supply chain. Its main contribution in this respect is the extension of the widely elaborated two-stage principal-agent model into a three-stage (e.g., producer, wholesaler, retailer) supply-chain framework. After deriving the model, an empirical illustration is provided for the Dutch supply chain of ware potatoes.

Three-Stage Supply-Chain Principal-Agent Model

Consider a product that is produced by producers, processed and distributed by wholesalers, and finally sold to the consumers by retailers. Let x denote the retail value of the product. This value can be decomposed as $x = e + \varepsilon$, where e is the retail value as expected at the time when the producers take their production decision and ε is the unexpected component with mean zero and variance σ^2. The retailers purchase the product from the wholesalers by offering them the linear contract $W_w = \alpha_w x + \beta_w$, where W_w is the retailers' payment to the wholesalers, $0 \leq \alpha_w \leq 1$ is the retail-value sharing rate, and β_w is a fixed payment. In turn, the wholesalers purchase the product from the producers by offering them the linear contract $W_p = \alpha_p \alpha_w x + \beta_p$ with $0 \leq \alpha_p \leq 1$ and fixed payment β_p. The effort of the wholesalers (producers) comes at a cost $C_w = 0.5c_w e^2 + d_w$ ($C_p = 0.5c_p e^2 + d_p$), where $c_w > 0$ ($c_p > 0$) and d_w (d_p) is a deterministic term. Finally, while the retailers, who are carrying a broad assortment of products, are assumed to be risk-neutral, the wholesalers and producers are allowed to be risk-averse.

The profit of the producers is $\Pi_p = W_p - C_p = \alpha_p \alpha_w x + \beta_p - 0.5c_p e^2 - d_p$. Hence the unexpected profit component is $\Pi_w - E(\Pi_w) = \alpha_w \alpha_p \varepsilon$ so that $Var(\Pi_w) = (\alpha_w \alpha_p)^2 \sigma^2$. The objective function for profit maximization can be expressed on the basis of the expected mean-variance (EV) model, and hence the producers maximize the certainty equivalent of their profit $CE_p = E(\Pi_p) - 0.5\rho_p Var(\Pi_p)$ by choosing the optimal level of effort value e, where ρ_p is the risk-aversion coefficient if $\rho_p \geq 0$ (Kahl 1983).[1] The optimal solution is the incentive constraint $e = \alpha_w \alpha_p / c_p$, which clearly shows the incentive mechanism of $\alpha_w \alpha_p$. Nevertheless, the certainty equivalent of the opportunity cost of the producers, denoted by O_p, forces the wholesalers to pay the producers a little more than O_p, which is simply approximated by the participation constraint $CE_p = O_p$. From this condition the wholesalers can derive that they have to pay a fixed compensation to the producers as given by $\beta_p = O_p + d_p - 0.5(\alpha_w \alpha_p)^2/c_p + 0.5\rho_p(\alpha_w \alpha_p)^2 \sigma^2$.

Now the wholesalers can determine α_p by maximizing their certainty equivalent $CE_w = E(\Pi_w) - 0.5\rho_w Var(\Pi_w) = E(W_w - W_p - C_w) - 0.5\rho_w Var(\Pi_w) = \alpha_w(1 - \alpha_p)e + \beta_w - \beta_p - C_w - 0.5\rho_w \alpha_w{}^2(1 - \alpha_p)^2 \sigma^2$ for α_p given the conditions for e and β_p as derived

[1] For the conditions that justify the use of the EV model and the discussion of the EV model and the general expected-utility model, the reader is referred to Bigelow (1993) and Meyer and Rasch (1992).

above. The result is the incentive intensity principle $\alpha_p = (1 + c_p\sigma^2\rho_w)/[1 + c_p\sigma^2(\rho_w + \rho_p) + c_w/c_p]$, which shows that, when neglecting the marginal wholesale cost (i.e., $c_w = 0$), simply giving full incentives to the producers by setting $\alpha_p = 1$ is not optimal if they are risk-averse ($\rho_p > 0$) and cannot be monitored on their precise effort ($\sigma^2 > 0$).

Finally, the retailers can determine α_w by maximizing their expected profit $E(\Pi_r) = e - E(W_w) = (1 - \alpha_w)e - \beta_w$ for α_w given the incentive condition for e as presented above and the condition $\beta_w = O_w + d_w + O_p + d_p - \alpha_w{}^2\alpha_p/c_p + 0.5\rho_p(\alpha_w\alpha_p)^2\sigma^2 + 0.5\rho_w\alpha_w{}^2(1 - \alpha_p)^2\sigma^2$ as can be derived from the participation constraint $CE_w = O_w$, where O_w is the certainty equivalent of the opportunity cost of the wholesalers. The result is the incentive-intensity principle: $\alpha_w = 1/\{1 + c_w/c_p + c_p\sigma^2(\rho_p + [(1 - \alpha_p)/\alpha_p]^2\rho_w)\}\alpha_p$, which will be equal to one if the risk-aversion coefficients ρ_p and ρ_w are zero and/or no unobservability or risk is involved ($\sigma^2 > 0$).

Having time-series data available on x, e, W_w, W_p, O_w and O_p, we can estimate σ^2 by computing $\mathrm{Var}(x - e)$ and estimate α_p, the deterministic components d_p and d_w and the cost function parameters c_w and c_p in the nonlinear-equation system $W_p - O_p = d_p + c_p ex + 0.5\alpha_p e + 0.5(c_p/\alpha_p - 3c_p - c_w)e^2$ and $W_w - O_w - O_p - 0.5e = d_w + d_p + (c_p/\alpha_p)e(x - e)$ as implied by the linear-payment contracts, that is, $W_w = \alpha_w x + \beta_w$ and $W_p = \alpha_w\alpha_p x + \beta_p$, and the incentive, participation, and incentive-compatibility constraints. With these estimates, the incentive constraint and the two participation and incentive-compatibility constraints there are five equations with five unknowns: α_w, β_p, β_w, ρ_p, and ρ_w. Their solutions can be seen as the estimates of the model. The estimate for α_w is $\alpha_w = c_p e/\alpha_p$. Given that e is a time-varying variable and c_p and α_p are constant parameters, α_w will be time-varying as well. The solutions $\beta_p = O_p + d_p + 0.5\alpha_p e + 0.5(c_p/\alpha_p - 3c_p - c_w)e^2$, $\beta_w = O_w + O_p + d_w + d_p + 0.5e - (c_p/\alpha_p)e^2$, $\rho_p = (\alpha_p{}^2 - 2\alpha_p c_p e + c_p e - \alpha_p c_w e)/\alpha_p c_p{}^2\sigma^2 e$, and $\rho_w = \alpha_p(\alpha_p - c_p e)/c_p{}^2\sigma^2 e(1 - \alpha_p)$ also allow for time-varying values.

The validity of the model can be evaluated by comparing the actual payments W_p and W_w over time with their respective estimates $\alpha_w x + \beta_w$ and $\alpha_p\alpha_w x + \beta_p$. If the model performs well, it can be used to estimate the agency costs by setting $\rho_w = \rho_p = 0$ so that $\alpha_p{}^* = 1/(1 + c_w/c_p)$ and $\alpha_w{}^* = 1$, by which $1/(c_w + c_p)$ is found as the estimate of the expected first-best Pareto-optimal retail value e^*. Consequently, the expected first-best Pareto-optimal profits become $E(\Pi_r{}^*) = 0.5/(c_w + c_p) - O_w - O_p - d_w - d_p$, $E(\Pi_w{}^*) = O_w + 3c_p/2(c_w + c_p)^2$ and $E(\Pi_p{}^*) = O_p - 3c_p/2(c_w + c_p)^2$. The differentials $E(\Pi_r{}^*) - E(\Pi_r)$, $E(\Pi_w{}^*) - E(\Pi_w)$ and $E(\Pi_p{}^*) - E(\Pi_p)$ are the estimated agency costs for the retailers, wholesalers, and producers, respectively. Notice that these estimates are maximum levels because they are based on the assumption that the higher e^* could have been realized in the consumer market.

Empirical Application

Every year, some eight million tons of potatoes are produced in the Netherlands, mainly on family farms. About half are ware potatoes, approximately 20 percent are seed potatoes, and the remaining 30 percent are potatoes grown for starch. Most ware potatoes are sold to wholesalers. A negligible amount is sold directly by the producers to the retailers. 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, and hence contractual arrangements to do so have emerged. In turn, growers see contracts as a way to reduce price risk. Spot-market prices tend to fluctuate largely from one year to another due to weather and disease issues, the level of imports, and domestic and export demand. Although retailers (wholesalers) may gain knowledge of wholesalers' (growers') ability through the use of quality measurement, wholesalers' (growers') investments, as well as weather and disease conditions, this is not sufficient to derive, without uncertainty, wholesalers' (growers') actual level of effort from the retailers' turnover. Wholesalers' and growers' interest in hedging on the futures market supports the assertion that they might be risk-averse.

For our empirical analysis, Statistics Netherlands provided us with annual data over the period 1961–2002 for the farm, export (i.e., wholesale), and retail prices (Euro/kg) of ware potatoes, all deflated by the consumer price index (1990 = 1.00); the area planted (1000 ha); the yield per hectare (100 kg/ha); and the rent price of land (Euro/ha), deflated by the consumer price index. From these variables, we obtain seven variables of interest. First, the output quantity q (million tons) is com-

puted as the yield per hectare times the area planted (divided by 10^4). Given the retail price p, the retail value x is obtained as $x = pq$ (billion Euro). Next, to compute the expected retail value e, we observe that the yield per hectare clearly shows a positive linear trend, so we use the fit of the linear trend as a proxy for the expected yield per hectare. Consequently, the expected output *quantity* is derived as the expected yield per hectare times the area planted (divided by 10^4). Then we estimate the expected price as the fit of a univariate AR(3) model for the retail price (Euro/kg). Denoting these expectations as $E(q)$ and $E(p)$, then $x = pq = E(p)E(q) + E(p)\varepsilon_q + \varepsilon_p E(q) + \varepsilon_p\varepsilon_q$, where $\varepsilon_p = p - E(p)$ and $\varepsilon_q = q - E(q)$ are the unexpected components of p and q, respectively, and $\varepsilon_p\varepsilon_q$ represents the covariance of p and q, which we may expect to be negative. Consequently, $e = E(p)E(q) + Cov(p,q)$. To estimate e, we simply regress x on a constant and $E(p)E(q)$, and set e equal to the fit of the regression. In this way, e extracts all the information of interest out of $\varepsilon_p\varepsilon_q$, since the regression residuals are orthogonal to $E(p)E(q)$. Furthermore, W_p (W_w) (billion Euro) is computed as the farm price (export price) times q. The rent price of land times the area planted (divided by 10^6) is used as a proxy for O_p. Lastly, we set O_w equal to zero and use linear models with a constant and linear trend to estimate d_w and d_p.

The variables in the nonlinear-equation system appear to be trend-stationary. Hence the model is simply estimated in levels. The estimates for c_w and c_p are significant and positive: $c_w = 0.57$ (t value = 3.88) and $c_p = 0.24$ (t value = 3.63). The respective equations explain 29% and 74% of the variance in W_p and W_w, respectively, and show a satisfying fit. The estimates of the key-factors in the model are presented in Table 1. They reveal that the incentives to wholesalers and producers have increased over time: α_w ($\alpha_p\alpha_w$) more than doubled from 0.28 (0.16) in the 1960s to 0.63 (0.36) in 2000. This increase complies with the decrease in the risk-aversion coefficients (ρ_p and ρ_w), of which the one for the producers (ρ_p) was negative from 1982 on. Moreover, the fixed payment β_w (β_p) of the retailers (wholesalers) to the wholesalers (producers) as a percentage of retail turnover (x) decreased from 50% (30%) in the 1960s to −16% (−23%) in 2002. These negative percentages come down to a total investment of 0.66 billion Euro by wholesalers and producers in their business relationship with the retailers in 2002.

With increasingly negative fixed-payment levels compensated by higher retail-value sharing rates, wholesalers and producers are being exposed to more risk, since their rewards are contingent upon an increasing portion of the final retail value. But why do retailers let this happen? Transferring risk to upstream stages in the supply chain, which have fewer opportunities to spread risk compared with the large retailers and therefore find it more costly to bear, simply reduces the gains from trade. In contrast, retailers would prefer to bear the risk themselves (the wholesalers and, during the time that they were risk averse, the producers ask for a higher price as a compensation for the risk they bear) and extract the gains from this by lowering the price they pay to the wholesalers. Consequently, if retailers do transfer market-level risk to wholesalers and producers, as shown by the decreasing variance of the retailers' profit compared to the increasing variance of wholesalers' and producers' profits (Table 1), there must be another reason for doing so than mere risk aversion.

"Chain reversal," whereby traditional supply-oriented chains are transformed into demand-oriented chains, offers a possible explanation why retailers wish to transfer risk to upstream stages in the supply chain, in spite of the higher risk-bearing costs. These higher risk-bearing costs might not outweigh the higher profits the supply chain achieves when producers and wholesalers are given more incentives to meet the delivery conditions that enable retailers to increasingly offer high value-added products that better satisfy the needs of the consumer than do the mainstream homogeneous products. And indeed, the required coordination efficiency in the supply of ware potatoes has been greatly improved, as can be seen from the fact that the agency costs (i.e., $C_a = E(\Pi_r^* + \Pi_w^* + \Pi_p^*) - E(\Pi_r + \Pi_w + \Pi_w)$) decreased from 0.11 billion Euro in 1965, which was 16% of the total retail value (i.e., 100% × C_a/x) in 1965, to 0.05 billion Euro in 2002 (3% of the total retail value in 2002) (Table 1).

Conclusions

Food-supply chains have become extensively vertically coordinated through the use of contracts as an organizational response to better satisfy the needs of consumers in the saturated food markets of the industrialized countries. Wholesalers often link producers with consumers' needs as articulated by

Table 1. Values and Estimates of Variables and Parameters in the Three-Stage Supply-Chain Principal-Agent Model.

		1965	1970	1975	1980	1985	1990	1995	2000	2002
x	($\times 10^9$ €)	0.66	1.20	0.79	0.99	0.92	1.12	1.46	1.37	1.70
e	($\times 10^9$ €)	0.73	0.82	0.70	1.13	1.23	1.20	1.37	1.51	1.59
σ^2	($\times 10^9$ €)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
ρ_w		229	190	243	111	94	98	73	58	50
ρ_p		51	22	61	−37	−49	−46	−65	−76	−82
W_w	($\times 10^9$ €)	0.49	0.77	0.54	0.54	0.60	0.67	0.84	0.71	0.70
α_w		0.30	0.35	0.29	0.47	0.52	0.51	0.58	0.63	0.67
β_w	($\times 10^9$ €)	0.37	0.33	0.31	0.16	0.08	0.06	−0.07	−0.19	−0.27
C_w	($\times 10^9$ €)	0.12	0.13	0.04	0.24	0.27	0.22	0.31	0.39	0.45
W_p	($\times 10^9$ €)	0.43	0.28	0.35	0.31	0.16	0.31	0.40	0.11	0.20
α_p		0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
$\alpha_p\alpha_w$		0.18	0.20	0.17	0.27	0.30	0.29	0.33	0.36	0.38
β_p	($\times 10^9$ €)	0.24	0.20	0.25	0.03	−0.04	−0.02	−0.17	−0.29	−0.39
C_p	($\times 10^9$ €)	0.31	0.33	0.30	0.40	0.42	0.42	0.47	0.51	0.54
O_p	($\times 10^9$ €)	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
$\mathrm{Var}(\Pi_r)$	($\times 10^6$ €)	27.0	23.9	27.9	15.4	13.1	13.6	9.97	7.52	6.12
$\mathrm{Var}(\Pi_w)$	($\times 10^6$ €)	0.94	1.20	0.86	2.27	2.69	2.58	3.36	4.04	4.51
$\mathrm{Var}(\Pi_p)$	($\times 10^6$ €)	1.71	2.20	1.57	4.15	4.91	4.72	6.14	7.38	8.24
C_a	($\times 10^9$ €)	0.11	0.07	0.12	0.00	0.00	0.00	0.01	0.03	0.05

the large, powerful retailers. The contracts involved must establish an optimal trade-off between incentive provision and risk reduction. Agency theory can be used to model this trade-off; to do so we specified a three-stage (producer, wholesaler, retailer) principal-agent supply-chain model for estimation and simulation purposes. Its application to the Dutch supply chain of ware potatoes shows that the costs of coordination in the supply chain decreased from 0.11 billion Euro in 1965 to 0.05 billion Euro in 2002, implying a reduction of 55%. This reduction complies with the ongoing process of chain reversal whereby the supply chain becomes more demand-oriented as producers and wholesalers are given more incentives to enable retailers to increasingly carry high value-added products that better satisfy consumers' needs.

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