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Abstract. This paper estimates risk related farmer incentives to enter in vertically coordinated and specialized beef production systems. The conditional mean processes for the asset returns under alternative production and coordination systems are estimated in time series econometric models. Conditional volatility of asset returns are estimated econometrically and incentives to invest in the production facilities are estimated as optimal investment thresholds using the quasi options approach. The results suggest that there is both large profit and production potential to design coordination mechanisms which significantly decrease price risks within the beef production chain.

Index words: beef sector, vertical integration, production systems, risk, asset return, Finland

JEL Classification Numbers: C12, C22, L11, L22, Q12

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1. Introduction

The beef sector is undergoing a rapid structural change in the Northern Europe and is gradually developing towards similar production and marketing systems as, for example, those in Canada. Over the recent years, beef producers have been investing into larger and more specialized production systems because increased size and specialization improve production efficiency and decrease costs of beef production. Specialization decreases demand for labor and opens new options to improve animal growth and feed conversation ratios.

When specialization and the size of production units are increased, the ownership and coordination mechanisms between the individual firms and production sites can be revised to take advantage of increased optimal size of operation, capacity utilization in production and investment in new production technologies. The tendency is to move from traditional open spot market coordination towards vertically coordinated systems, in which animal flows and rent distribution between the individual units are optimized to improve the performance not only in individual units but also in the beef production chain as a whole. Thus, in the vertical coordination systems of production, the focus is shifted from fully exploited within-unit to the unutilized between-units production potential.

It is characteristics for the new production and coordination systems that they mitigate efficient capital market so that efficiency is gained from scale and specialization. Risks are shared through structuring the production, ownership and marketing within the coordinated system rather than diversifying the production within single production units. Ownership and marketing can be structured, for example, by linking individual firms to each other either loosely through strategic alliances or more rigorously through vertical coordination mechanisms, such as franchising (Kliebenstein and Lawrence 1995; Das and Teng 1996; Karantininis et al. 1997; Cozzarin and Westgren 2000; Bogetoft and Olesen 2004).

The returns volatility and risks play a dominant role in triggering irreversible investments in site specific and production line specific production facilities (Dixit and Pindyck 1994). Thus, efficiency of vertical coordination mechanisms is becoming more important in determining incentives to invest in highly specialized production units. They can be used either to decrease and share risks among the sites in the production chain, or even concentrate risks to certain parts of the chain. The sunk cost nature of investment in specialized production technology at the firm level is less of a deterring factor in investment decisions when production coordination mechanism is possible.

The goal of this article is to estimate risk related incentives to invest in specialized and vertically coordinated beef production facilities within a three stage beef production systems. The empirical analysis is based on Finnish beef production data. More specifically, the goal is to estimate the potential value that certain models of vertical coordination or shared ownership (integration) have in decreasing returns volatility and risks of investments in the new production facilities. The value of the coordination mechanisms is estimated using the quasi options approach. Similar approach has previously been used, for example by Grenadier (1995), and Pietola and Wang (2000). Estimating the value of alternative coordination mechanisms is important, because their risk management characteristics significantly steer investments in new production facilities and, more broadly, structural development in the sector.

The subsequent section describes the contract design. The third section explains the econometric model. The fourth section presents the data and enterprise budgets to compute the asset returns. Then, the article moves on to the results and to the concluding remarks.

2. Contract design

The benchmark in the analysis is the traditional two stages system, in which the calves born on the dairy farm are transferred directly to a finishing feedlot at the age of two months. The new and more specialized three stages system with possibilities for coordination of production stages located at different units is to separate a new production stage between the existing dairy farm's "cow-calf" -stage and the specialized "finishing feedlot". Here the new stage is referred to as the "middle feeder".[1] Thus the three stage beef production system involves:

[A]: *Cow-calf operation*

[B]: *Middle feeder*

[C]: *Finishing feedlot*

In the three-stage feeding, the calves born on dairy farms ***[A]*** are transferred to the middle feeder at the age of two weeks. The middle feeder ***[B]*** feeds the calves from the liquid feeding period to the ruminant phase. Then, at the age of 4-6 months, the cattle are transferred to a feedlot for finishing. The finishing feedlot ***[C]*** feeds the cattle to be slaughtered at the age of 14-20 months.

Our analysis focuses on the coordination between the middle feeder ***[B]*** and the finishing feedlot ***[C]*** using the integrated feedlot ***[B+C]*** as the benchmark.[2] The cow-calf –operation ***[A]*** is ruled out from the analysis, since calves represent only a minor share of the output on

[1] In the Canadian context, Karantinis et al. (1997) calls a production stage similar to the "middle feeder" as the "backgrounding" –operation.

[2] The benchmark has a subtle difference to the feedlot of the traditional two stage system. The calves entering the new middle feeder stage [B] and, thus, also the corresponding integrated feedlot [B+C] are younger (2 weeks) than the calves entering the traditional feedlot at the age of 2 months.

dairy farms with little influence on investment decisions. Investment thresholds on dairy farms are, for the most part, determined by other factors, such as returns to milk production, than the pricing and coordination of the trade for calves.

In addition to the integrated model ***[B+C]***, two vertical coordination mechanisms are simulated. These differ from the integrated model by the way the animal input is priced and by the franchising contract between the last two stages of production. The first is the traditional open spot market coordination, in which the pricing centers to the animals moved from the middle feeder ***[OB]*** into the finishing feedlot ***[OC]*** and the pricing scheme is the observed market price. The market price is quoted by the largest slaughter houses, and these slaughter houses also intervene in the market as third party dealers.

The second coordination mechanism follows a certain (naïve) franchising type contract, in which the finishing feedlot ***[FC]*** owns the animals, supplies the feeds, and pays a fixed price from labor and capital to the middle feeder ***[FB]***. The existing finishing feedlot units have high incentives to self insure their operations by entering in vertically integrated and coordinated systems. The finishing feedlot units also have potential to profit by offering very attractive, low risk franchising contracts to production stage coordination partners without increasing their own risks. Thus, the finishing feedlot is the franchisor and the middle feeder is the franchisee. The coordination results in an expanded production capacity for the franchisor and a better capacity utilization for the franchisee. However, the overall production capacity may remain unchanged under the franchising coordination mechanism.

In all simulated models, the weaned calves (sold by the cow-calf units) and the ready to slaughter animals (sold by the finishing feedlot) are traded on the open spot market, as is the standard in the Finnish beef supply chain. Similar franchising type contracts have been analyzed previously in the hog sector (Cozzarin and Westgren 2000; Uusitalo and Pietola

2002). In the context of beef sector, vertical coordination has been previously analyzed by Karantininis et al. (1997).

The asset return is defined as the total return to the capital invested in a capacity unit of one bovine bull. It is computed by enterprise budgets using fixed, time invariant input and output quantities but time variant prices for inputs and outputs. Time invariant input-output-ratios imply that contracting does not significantly decrease effort once irreversible investment has been made. Changes in these ratios and production capacity are ex ante possible when decisions on investment in new technologies are made. This assumption has been the standard in a large number of empirical studies and is justified by keeping the empirical analysis compact (e.g., Karantininis et al. 1997; Purcell and Hudson 2003). Furthermore, the effects of contracts to the effort of individual agents can be ambiguous. It is often conjectured that contracts, which decrease returns volatility and independence of individual agents, result in decreased effort. Nevertheless, Key and McBride (2003) found evidence that contracts increase performance of individual agents.

3. Econometric model

The conditional mean and conditional volatility processes for the asset returns in period t (R_t) are estimated in an autoregressive, AR(k), model for returns with k denoting the number of lagged returns in the model. The asset return refers to the total return to the capital invested in a capacity unit of one bovine bull. The standard AR-equation is augmented by seasonal effects *S(t).* The model in the general form is written as:

$$R_{t+1} = \phi_0 + \sum_{i=0}^{k} \phi_{1+i} R_{t-i} + S(t) + \varepsilon_{t+1} \tag{1}$$

where ϕ's are unknown parameters to be estimated, and ε_{t+1} is an error. The seasonal variation is controlled for by including a polynomial $S(t)=\xi_1 t_s+\xi_2 t_s^2+\xi_3 t_s^3$, in the return equation (1). Here t_s =1,…,52 denotes periods measured as weeks within a year, and ξ's are unknown parameters to be estimated. Here the time trend captures the within year trend in the asset return. The within year variations in returns are restricted to be the same across years. The between year variations can be captured by year dummies, although, overflowed here when using changes in the variables, or alternatively at the expense of an overparametrization of the model by allowing the ξ's to vary across years. The square and cubic terms allow for a flexible form of the temporal variations in asset returns allowing for shifts and switches between positive and negative changes in returns.

The issue of stationarity of variables is central in time series analysis. Stationarity of the price process is tested for by the Augmented Dickey-Fuller (ADF) tests, using non-stationary unit root process as the null-hypothesis (Dickey and Fuller 1979). For obtaining the ADF-test statistics, the conditional mean process was re-parametrisized and estimated in the form:

$$R_{t+1}=\phi_0+\rho R_t+\sum_{i=0}^{k}\mu_{1+i}\Delta R_{t-i}+S(t)+\varepsilon_{t+1} \qquad (2)$$

where $\mu_{1+i}=\left(\sum_{i=0}^{k}\phi_{1+i}\right)-1$ and ρ is a parameter.

The purpose of the test is to give signals on statistical grounds whether shocks in returns will persist in the future returns (i.e. returns are non-stationary) or whether they will gradually dampen such that returns tend to move back towards their steady state after a shock (stationary returns). Stationarity of the conditional mean process plays a crucial role in computing the optimal investment thresholds to attain optimal production capacity.

If the error ε_t turns out non-stationary having a unit root in (1) and (2), then the unit root is imposed and the model is estimated in a difference form:

$$\Delta R_{t+1} = \phi_0 + \sum_{i=0}^{k} \mu_{1+i} \Delta R_{t-i} + S(t) + \varepsilon_{t+1} \quad (3)$$

where $\Delta R_t = R_t - R_{t-1}$ and the error ε_t is stationary. If the error term turns out to be non-stationary and the model is estimated without imposing a unit root in level form, the parameter estimates become spurious.

4. Data and asset returns

Asset returns

The asset returns data (R_t) are production stage specific (either ***[B]*** *or* ***[C]***) and coordination specific (either ***[OB], [OC], [FB], [FC]*** *or* ***[B+C]***) asset returns to the capital invested in a capacity unit when it is used to grow one bovine bull. In total we have five different returns series corresponding to the two stages and three coordinations listed above.

The asset returns are computed by enterprise budgets that have a similar structure, for example, to the standardized gross margins used in the Eurostat. The enterprise budgets are computed conditional on fixed, time invariant input and output quantities. The quantities, as well as subsidy rates, which depend on farm location, represent the quantities and subsidy rates of a farm located in the Central Finland, coded as C2-area in the subsidy classification system of the Common Agricultural Policy (CAP). Most of the beef supplied in Finland originates from this area.

The weekly price data, at which the enterprise budgets are evaluated, span the period of January 1995 to December 2002. The prices represent the whole country and have no systematic variation by production areas. Though, it is found to be a good representation of the prices of the C2-area. The data start at 1995, because at that time Finland joined the European Union (EU) and the agricultural market regime was changed. Thus, inferences made are on the post EU-membership period. A comparison with the pre-membership condition is not possible due to market regime changes[3] and lack of data.

During the years 1995-2000 the purchase price of the 50 kg baby calf was 5/8 times the market price for traditionally traded older calves (weight at transfer approximately 80 kilos). From the year 2001 onwards the price of baby calves is based on the statistics collected by Food and Farm Facts Ltd (2001). The selling price of ready-to-slaughter animals follows the observed market price schemes.

Evaluating the annual enterprise budgets at weekly prices is consistent and does not result in any losses of generality in the volatility estimates. Rescaling the data and the underlying enterprise budgets does not alter the results. The chosen approach is also consistent with actual marketing decisions, particularly, when the animals are traded in the open spot market. Even if it has taken, say, 15 months to rear a mature bull, it is sold at the current price quotation. Nevertheless, the weekly data were the highest frequency price data accessible in this study. The total number of observations in each asset returns series is 392.[4]

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[3] If data on the pre-membership period had have been available one could use switching regression methods to pool data and despite major market regime changes to be able to distinguish the return patterns over time. Such analysis would have made possible to isolate the membership effects on asset returns.

[4] The number of observations is less than 8 years x 52 weeks = 416 observations due to the lags and leads used in the study.

Below we describe, in more details, the production process, prices and returns corresponding to the two stages of production and three coordination alternatives mentioned previously.

Middle Feeder ***[B]***

Calves are transferred to the middle feeder at the age of 15 days and at the weight of 50 kg. Young cattle are transferred from the middle feeder to the finishing feedlot at the age of 148 days (i.e. about 5 months), at which point they will have reached a live weight of 183 kg. The calves stay in the middle feeding 133 days (about 4,5 months). The growth rate is approximately 1100 grams per day. It was assumed, that there is a 13 days idle period between the calf lots. Each year 2.5 calves are raised in a capacity unit of the middle feeder's barn.

Feed is the main variable cost. It consists of food produced at the farm and externally purchased feed. The consumption of feed in this study is based on Agrifood Research Finland's (MTT) feeding experiment. Indexes were used to determine the market price changes of feed bought outside the cattle farm. The price of silage was determined by the production costs (so called HILA-calculation). The maintenance and overhead costs were not, as usual, included in the variable costs. These latter costs are proportional to the number of calve units.

Finishing Feedlot ***[C]***

The finishing period is assumed to be 329 days (i.e. about 11 months). The slaughtering age is thus estimated to be 477 days (about 1 year and 4 months). The live weight at slaughter is 555 kg, of which about 294 kg is meat. The average daily growth was 1100 grams. Feed intake, daily growth rates, final weights, and feeding period lengths are based on production conditions in the central Finland.

The consumption of feeds is from the MTT feeding experiments and prices are from the HILA accounts as described above.

Open Spot Market Coordination

Under open spot market coordination, the middle feeder and the finishing feedlot are both owned and operated by independent agents. The coordination and rent sharing between the sites is conducted through trading the animals.

The selling price of the middle fed cattle was tied to the meat price. The price of the middle fed cattle was the producer price of bull (minus 0,34 euros/kg) per live weight kilogram. The difference is aimed at covering trading costs. This pricing scheme is followed by most slaughter houses in Finland. As standard in the industry, a fixed transfer commission (25 euros) was added to the corresponding purchase price paid by the finishing feedlot in order to account for the trading costs.

The development of asset returns during 1995 to 2002 measured in euro per unit at the middle feeder ***[OB]*** and at the finishing feedlot ***[OC]*** under open spot market coordination are highlighted in Figure 1. The two series vary greatly over time and differ in patterns. The fluctuations are mainly caused by the changes in subsidies, meat price and price of calves affecting the assets returns of the two production stages differently.

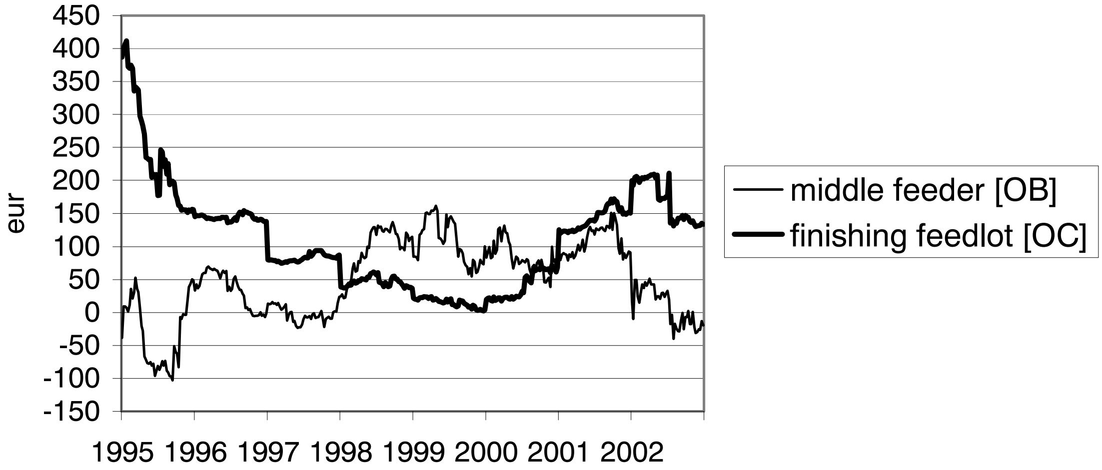

Figure 1. Annual asset return (euro/unit) at the middle feeder ***[OB]*** and at the finishing feedlot ***[OC]*** under open spot market coordination in 1995-2002.

Table 1 shows descriptive statistics on the annual asset return at the middle feeder ***[OB]*** under open spot market coordination. The typical annual asset return range is between 47 and 156 euros. Profitability was highest in 1998 to 2001. The mean values range in the interval -32 to 107. The negative returns are observed because of reductions in price and subsidy rates. Another factor for negative returns to middle feeder in 1995 and 1997 is the fixed pricing structure used in study.

Table 1. Descriptive statistics on the annual asset return at the middle feeder under open spot market coordination ***[OB]***.

Year	Mean	Std. Dev.	Minimum	Maximum	Range
1995	-32.29	51.31	-103.15	52.57	155.72
1996	34.79	26.85	-7.01	69.86	76.88
1997	-2.15	11.88	-23.40	23.88	47.28
1998	95.72	34.23	21.94	136.66	114.72
1999	107.61	32.84	54.70	161.41	106.71
2000	83.23	22.09	38.73	131.13	92.39
2001	107.44	20.60	78.71	150.61	71.91
2002	8.35	27.95	-40.10	51.37	91.47

Table 2 shows descriptive statistics on the annual asset return at the finishing feedlot ***[OC]*** under open spot market coordination. The typical asset return range is between 18 and 260 euros, which is more than at the middle feeder. At the finishing feedlot asset returns are always positive. The wide range in year 1995 is caused by the changes in subsidies aimed at helping farmers to adjust to EU-membership. However, the subsidy decreased gradually over time.

Table 2. Descriptive statistics on the annual asset return at the finishing feedlot under open spot market coordination ***[OC]***.

Year	Mean	Std. Dev.	Minimum	Maximum	Range
1995	243.47	82.86	151.05	411.52	260.47
1996	143.65	4.53	135.56	153.95	18.39
1997	82.72	5.77	74.72	94.20	19.48
1998	46.36	7.24	36.62	61.31	24.69
1999	14.95	6.73	2.24	24.19	21.94
2000	41.15	20.91	17.39	71.57	54.18
2001	141.96	16.25	120.36	171.99	51.63
2002	168.50	31.31	130.10	210.94	80.84

Franchising

In the simulated franchising contract, the finishing feedlot was defined as the franchisor, who takes most of the economic responsibilities and receives his returns as a residual, after all franchisee's costs have been subtracted from the total returns. In other words, most risks are concentrated to the franchisor that receives a residual claimant status (Cozzarin and Westgren 2000). The annual asset returns for the franchisor are computed as the asset returns to the integrated system ***[B+C]*** minus the fixed payment to middle feeder (Figure 2). In the beginning of the period and in recent years the observed discrepancy in the observed positive returns is in the favor of open spot market coordination production stage. However, franchising contract turns out to gain from finishing feedlot in the 1998-2001 but the return is low or negative.

The feedlot operator ***[FC]*** buys baby calves, owns the animals until they are sold to be slaughtered. He/she buys all feeds and receives all returns from the slaughtered animals and buys the middle feeding service from the franchisee ***[FB]***. The franchisee receives a fixed cost based payment in turn to providing the facilities and the service to middle feed the cattle. The annual asset returns for the franchisee are a pre-determined constant by our definition of the contract. The returns are 200 euros/year. The amount consists of 65 euros returns to capital and 135 euros for labor per capacity unit.

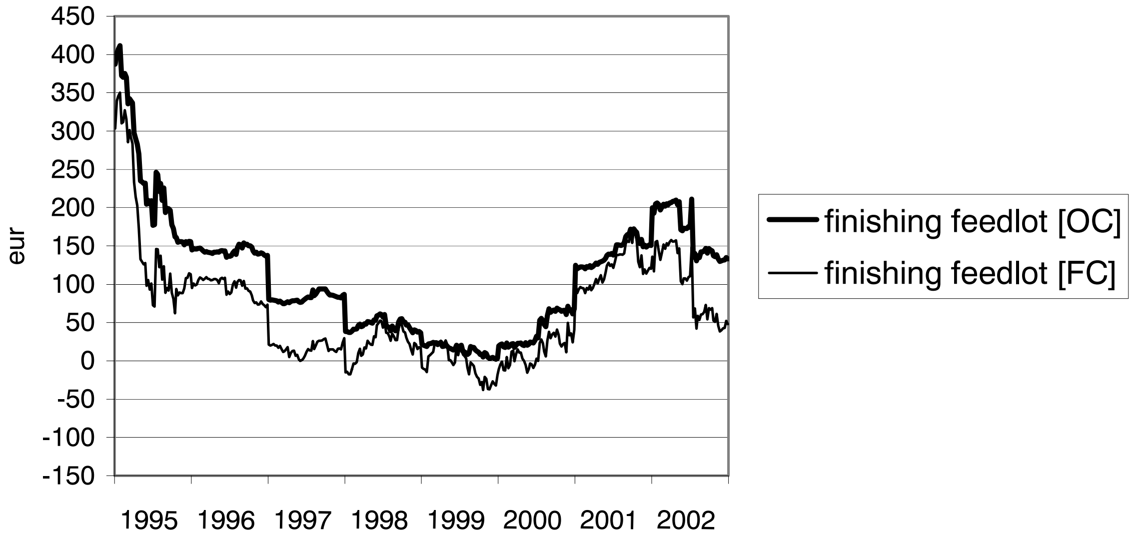

Figure 2. Annual asset return (euro/unit) at the finishing feedlot under open spot market coordination ***[OC]*** and the franchising contract ***[FC]*** in 1995–2002.

Table 3 shows descriptive statistics on the annual asset return at the finishing feedlot ***[FC]*** that is a franchisor. The typical asset return range is between 30 and 288 euros. Again we observe large variations over time in franchising contract. Only in 1999 the mean value is negative with relatively large dispersion.

Table 3. Descriptive table on the annual asset return at the finishing feedlot that is a franchisor ***[FC]***.

Year	Mean	Std. Dev.	Minimum	Maximum	Range
1995	164.02	92.98	62.16	350.27	288.10
1996	95.78	12.57	70.08	109.63	39.55
1997	16.05	7.43	-0.01	29.67	29.68
1998	22.57	19.30	-17.74	52.81	70.56
1999	-3.67	19.89	-37.92	26.68	64.60
2000	12.64	17.55	-15.43	49.54	64.98
2001	121.52	23.23	88.55	171.20	82.65
2002	98.34	44.02	38.44	157.34	118.90

Integrated ***[B+C]***

In the integrated unit the asset returns are simply the sum of the returns to the middle feeder ***[B]*** and finishing feedlot ***[C]*** (Figure 3 below). The difference between the franchising and integrated systems is the constant asset return paid to the franchisee, i.e. a neutral shift in the return. In Figure 3 the observed values of annual asset returns (euro/unit) in integrated feedlot ***[B+C]*** in 1995–2002 is presented together with the corresponding predicted values. The predicted values are obtained using parameter estimates based on Equation 2.

Table 4 shows descriptive statistics on the annual asset return in integrated feedlot ***[B+C]***. The typical asset return range is between 21 and 210 euros with small dispersion in the middle periods. Again the wide range of 1995 is caused by the adjustment in subsidies at the time of accession to the EU. As in finishing feedlot in the integrated feedlot asset returns always are positive with small dispersion. The finishing feedlot ***[C]*** seems to be more profitable compared to the middle feeder ***[B]*** production stage. This might be due to longevity of stay at this stage of production and optimization of slaughtering time.

Table 4. Descriptive table on the annual asset return in integrated feedlot ***[B+C]***.

Year	Mean	Std. Dev.	Minimum	Maximum	Range
1995	168.68	67.93	93.61	303.93	210.32
1996	117.14	9.02	98.81	127.12	28.31
1997	59.51	5.21	48.32	69.23	20.90
1998	63.32	13.98	34.04	84.91	50.87
1999	43.45	14.24	18.83	65.00	46.17
2000	54.42	12.33	34.78	80.67	45.89
2001	132.63	16.63	108.84	167.97	59.13
2002	117.79	30.45	76.01	158.75	82.74

The Finnish FADN–data shows similar development for profitability in beef farms during 1998-2002 as reported in Table 3 and 4. The Agenda 2000 reform increased the subsidy levels of beef production which caused this positive development.

5. Results

The conditional mean and conditional volatility processes in the AR-model of equations (2) and (3) are estimated by ordinary least squares method. The parameter estimates of the conditional mean process are reported in Table 5.

Based on the results in Table 5 the first order parameter measuring seasonal effects confirm that returns increase linearly with time over the year in the case of middle feeder in open spot market coordination ***[OB]***. The statistically significant second order term suggests that returns increase at a decreasing rate. The insignificant third order term parameter is indication of absent of switches in returns within a year. None of the time-specific effects in the remaining models ***[OC, B+C and FC]*** are statistically significant.

Table 5. Parameter estimates of the conditional mean process (Equation 2). Standard Errors are in parenthesis.

Model variable (parameter in parentheses)	Open market coordination			Franchising
	Middle feeder ***[OB]***	Finishing feedlot ***[OC]***	Integrated ***[B+C]***	Finishing Feedlot ***[FC]***
Intercept (ϕ_0)	-6.8831*	-2.5894	-4.1487	-2.2792
	(3.01384)	(1.9912)	(2.1810)	(2.08869)
Lagged returns (ρ)	0.9765**	1.01746**	1.01288**	1.01156**
	(0.01159)	(0.005638)	(0.00921)	(0.009542)
Lagged returns difference (μ_1)	-0.1820**	-0.2156**	-0.2182**	-0.2140**
	(0.05114)	(0.05108)	(0.05183)	(0.05182)
Within season time trend (ξ_1)	1.2549*	0.3295	0.5771	0.1851
	(0.5089)	(0.3157)	(0.3282)	(0.1449)
Within season time squared (ξ_2)	-0.04840*	-0.01677	-0.02411	-0.475exp(-5)
	(0.02352)	(0.01459)	(0.01516)	(0.436exp(-5))
Within season time cubic (ξ_3)	0.000541	0.000233	0.000295	0.166exp(-8)
	(0.000309)	(0.000192)	(0.000199)	(0.159exp(-8))

Based on the Equation (2) the ADF-test statistics was obtained. These are reported in Table 6. ADF-test statistics are greater than the critical values at 5% level of significance. The null hypothesis of non-stationary unit root process is not, therefore, rejected at a reasonably low 5% risk level. The test results indicate that asset returns are non-stationary implying that shocks in asset returns will persist in the future returns. Non-stationarity of mean process has important implications to producers' income because a shock in the returns will not gradually dampen down with a passage of time. It can be assumed that if, for example, BSE-shock decreases returns, they are expected to stay below the steady state equilibrium (adjusted by the return shifters such as seasonal effects). The first Finnish BSE-case was detected in December 7, 2001.

Table 6. ADF test statistics estimated in Equation 2.

	Open market coordination			Franchising
	Middle feeder ***[OB]***	Finishing feedlot ***[OC]***	Integrated ***[B+C]***	Finishing Feedlot ***[FC]***
ADF-test value	-7.7796*	5.6306*	4.1460*	3.7328*

ADF test is Augmented Dickey-Fuller test. Critical values at 5 % risk are for ADF with intercept – 13.7.

The parameter estimates of the conditional mean process, when the unit root is imposed (Equation 3), are reported in Table 7. The significance of the lagged return differences indicate that the conditional mean process has a memory of two time periods. Note that the lagged return difference includes twice lagged return level. Thus the result supports the view that market information included in the current returns and current returns lagged by one period cannot be increased by past returns. In other words, the conditional mean process is dynamically complete when it is conditioned on current and once lagged returns. Again the μ is similar across the four models.

Table 7. Parameter estimates of the conditional mean process. The unit root is imposed (Equation 3). Standard Errors are in parenthesis.

Model variable (parameter in parentheses)	Open market coordination: Middle Feeder ***[OB]***	Open market coordination: Finishing feedlot ***[OC]***	Integrated ***[B+C]***	Franchising: Finishing Feedlot ***[FC]***
Intercept (ϕ_0)	-7.9950**	-0.2214	-1.2369	-1.2227
	(2.9752)	(1.8588)	(1.3866)	(1.8990)
Lagged return difference (μ_1)	-0.1926**	-0.1790**	-0.2033**	-0.2000**
	(0.05108)	(0.05024)	(0.05074)	(0.05055)
Within season time trend (ξ_1)	1.1788*	0.2786	0.07866	0.1699
	(0.5095)	(0.3188)	(0.08039)	(0.1444)
Within season time squared (ξ_2)	-0.04395	-0.0150	0.0000483	-0.462exp(-5)
	(0.02351)	(0.01474)	(0.0000366)	(0.436exp(-5))
Within season time cubic (ξ_3)	0.000481	0.000211	-0.000021	0.162exp(-8)
	(0.000309)	(0.000194)	(0.0000326)	(0.159exp(-8))

In order to show the performance of the models, Figure 3 presents the observed and predicted values of annual asset returns (euro/unit) in integrated feedlot ***[B+C].*** The model explains well the variations in the returns data. The good fit of the model despite some insignificant parameters is a reflection of use of high frequency (i.e. weekly) data.

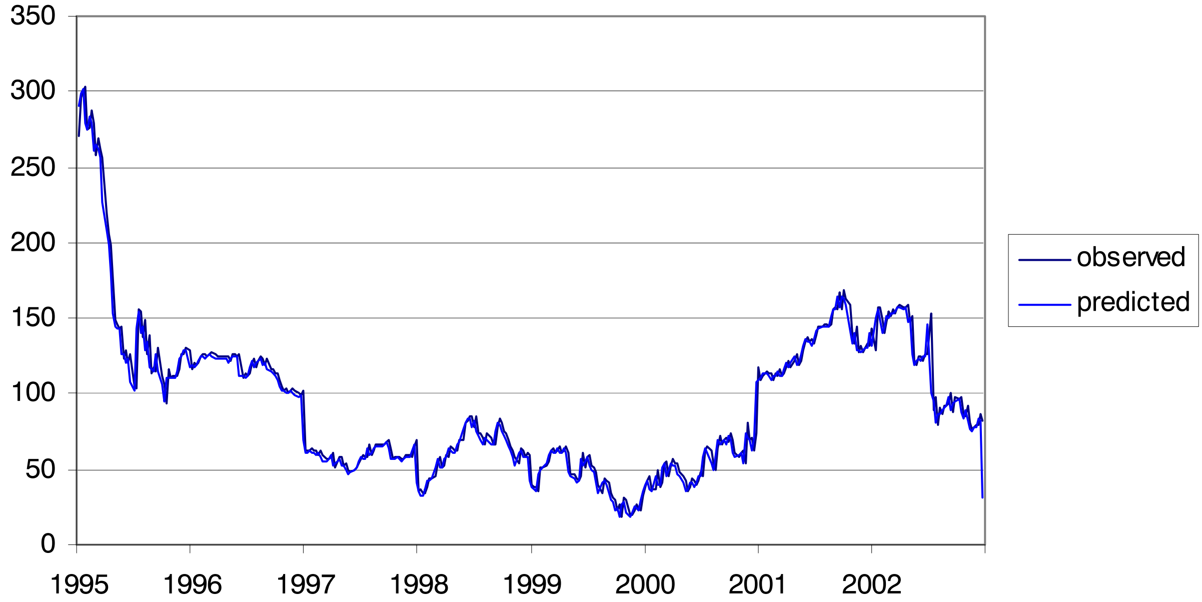

Figure 3. The observed and predicted values of annual asset returns (euro/unit) in integrated feedlot ***[B+C]*** in 1995–2002.

We find significant heterogeneity in volatility across production technologies. The volatility of asset returns, measured as standard deviation, was estimated for the middle feeder under open spot market coordination ***[OB]*** at 26.7% of the average returns (Table 8).[5] In the

[5] The estimated standard errors are 'year ahead' predictions of the returns. The 'year ahead' prediction is obtained by multiplying the 'week ahead' prediction by the square root of 52, because the standard error of the Wiener process increases linearly in the square root of time.

finishing feedlot under open spot market coordination ***[OC]***, the corresponding volatility was estimated at only 7.7%, which is less than one third of that in the middle feeder ***[OB]***. These volatility estimates imply that the threshold returns to capital required for investments in new production facilities, when evaluated at 15% capital cost, are estimated at 24.3% and 17.3%. In the integrated production ***[B+C]*** the standard deviation was estimated at 9.2% of the average returns and the corresponding threshold returns to capital is 17.7%. If the finishing feedlot ***[FC]*** and the middle feeder ***[FB]*** operations are coordinated by a franchising contract, the returns volatility of the middle feeder (franchisee) is zero by our definition. The returns volatility of the franchisor is estimated at 18.7%, which is twice the volatility of the integrated unit. When compared to the open spot market coordination, the franchisor's returns volatility is between the returns volatility of middle feeder and finishing feedlot. The threshold returns to capital of investing in the franchisor finishing feedlot is 21.1%.

Table 8. Volatility of asset returns (σ) and optimal investment threshold returns to capital at 15% capital cost. [a)]

	Open market coordination			Franchising	
	Middle feeder ***[OB]***	Finishing feedlot ***[OC]***	Integrated ***[B+C]***	Middle feeder ***[FB]***	Finishing feedlot ***[FC]***
Standard deviation (σ), % of the mean returns	26.7	7.7	9.2	0	18.7
Threshold returns to capital at 15% capital cost [b)]	24.3	17.3	17.7	15	21.1

Number of observations is 392.

[a)] The 15 % capital cost can be, for example, a sum of 5 % interest rate and 10 % depreciation.

[b)] The threshold returns to capital are computed using the quasi options approach (Dixit and Pindyck 1994, Chapter 5).

Figure 4 summarizes the volatility estimates and the corresponding investment thresholds for the simulated contracting alternatives. The simulations results are presented in Table 8. The assumed capital cost of 15 % is shown by the dashed line. When the returns to investment exceed the capital cost the standard Net Present Value -rule (NPV) recommends investing. The solid upward sloping curve is investment threshold under the options approach. It is the sum of capital cost and the option value driven up by the returns volatility. If returns to capital are above the solid line, also the option rule recommends investing, otherwise postponing the investment is recommended.

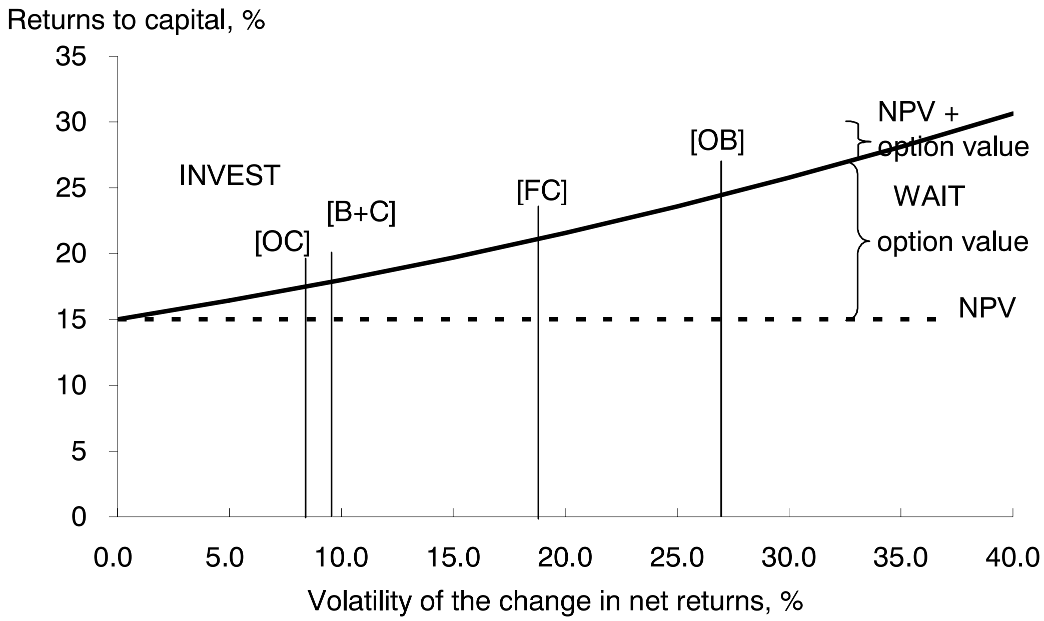

Figure 4. Volatility estimates and investment thresholds for integrated feedlot ***[B+C]***, for middle feeder and finishing feedlot under open market coordination, ***[OB]*** and ***[OC]***, and for finishing feedlot under franchising contract ***[FC]***.

6. Concluding remarks

This paper estimates risk related farmer incentives to invest in specialized and vertically coordinated beef production facilities in Finland. The total asset returns to the capital invested in beef production facilities are computed in fixed input fixed output enterprise budgets that are evaluated at weekly prices for inputs and outputs during 1995 to 2002. The volatility of the asset returns were then estimated in the standard conditional mean and conditional volatility autoregressive time series models for different single stages and vertically integrated production stages.

The results suggest that returns volatility and, thus, also the threshold returns to capital required in investments are, particularly, high in the middle feeder operation under open spot market coordination, compared to other coordination alternatives in that production stage and compared to the other production stages. The result is consistent with the observed industry phenomenon that, in spite of the efficiency gains of increased specialization, new investments in the middle feeder operations did not emerge until either the existing finishing operations started to share the market risks of these investments or they invested in ownership of the new middle feeder operations.

When the ownership of the middle feeder and finishing feedlot are integrated into single firm, the resulting integrated system exhibits returns volatility (standard deviation) of 9.2% from the mean returns, which is only one third of the volatility in the independent middle feeder (26.7%) and only slightly larger than in the independent finishing feedlot (7.7%). An integration of ownership of the two stages into single form reduces returns risk affecting positively investment decisions.

The finishing feedlots also have potential to offer attractive, low risk franchising contracts to the middle feeders while increasing their own risks only reasonably, compared to the volatility decrease in the middle feeder operation. When an independent finishing feedlot enters a franchising contract as a franchisor its returns volatility is increased from 7.7% to 18.7%, while the returns volatility in the middle feeder is decreased from 26.7% to zero.

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