

Price volatility and return on pig fattening under different price-quantity contract regimes

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Abstract

The goal of this study is to estimate how different price or quantity fixing contracts affect the value of pig space unit in pig fattening. The value of pig space unit is estimated with a stochastic dynamic programming algorithm. The model maximises the value of pig space unit by using four decision variables. The input-output ratios are endogenous and the option to suspend production temporarily is taken into account in the model. The results suggest that the smooth functioning of markets in Finland can be promoted by ensuring that price changes are transmitted smoothly between input and output markets, and that producers are compensated for giving up the option to suspend production temporarily in the event of an unfavourable market situation. Instead of fixing only the price of output, the contract should aim at reducing the risk associated with gross margin.

Introduction

Risk management and efficient flow scheduling have an increasingly important role in the competitive pork production networks. There are at least two reasons for this. Firstly, individual producers can improve their efficiency in a manner similar to efficient capital markets. While searching for efficiency gains through increasing specialization and size of their production, they also enhance risk management through innovative contract coordination mechanisms and investment portfolios such as diversified ownership structures¹. If the contract coordination is successful, the network can be split into vertically coordinated, highly specialized, efficient and capital intensive firms. In the livestock sector specialization allows to gain economies of scale in production processes even in small or moderate size firms, since the operations are often regulated by environmental regulations which are dependent on firm size. Secondly, the volatility of agricultural commodity market and the pork market has increased in the recent years (e.g. Cooke and Robles 2009). It may increase also in the future as public market interventions are gradually withdrawn and climate change increases the likelihood for adverse supply shocks in the sector (cf. OECD-FAO 2010). Hence, increasing price volatility can further increase producer incentives to enter in risk-reducing and price-fixing coordination contracts.

Coordination contracts which have the power to decrease price volatility and which affect the optimal investment thresholds can help to improve the competitiveness of the pork supply networks particularly through the structural development of the sector. The higher is the price volatility, the larger are the risks and the minimum return on capital required for an investment. As a result, a wider margin between the output and input prices is required for a high risk investment to be profitable as compared to a low risk investment. If a coordination contract is successful in decreasing the risk, it narrows the wedge required between the input and output prices and triggers new investments along the contract-specific production and marketing systems (Pietola and Uusitalo 2001, 2002).

¹ In an efficient capital market individual firms can search for efficiency gains through specialization, since the investors (the owners) can decrease their risk through diversification of assets, i.e. by investing in the shares of more than one firm.

The contract is important also as to ensure the continuous availability of meat to be processed and to increase the rate of use of production capacity. Various combinations of procurement arrangements have been found to improve short-term processor plant performance relative to the situations in which the plant uses only cash/spot markets to purchase all of its slaughter pigs (Vukina et al. 2009).

The use of contracts can depend on the producer's (market) position and risk preferences, which can vary a lot (e.g. Pennings and Wansink 2004). Zheng et al. (2008) found that producers using production contracts were more risk averse than those using the spot markets or marketing contracts. Moreover, Dubois and Vukina (2009) found that producers with higher risk aversion had lower outside opportunities and hence lower reservation utilities, which increases their willingness to enter in low risk contractual arrangements at a given level of expected returns.

When designing the contract, it is important to understand how the price or quantity-fixing contracts affect the farm business. Widely adopted approach to account for uncertainty in agricultural investment problems is to augment the standard net present value models by real options (Dixit and Pindyck 1994). The real options can be used to investigate the value of investment when producer has the option to adjust his/her decisions according to information that is available each moment as compared to waiting for more market information that arrives with the passage of time (e.g. McDonald and Siegel 1986). The producer can have several options that link to each other. Examples of these options are an option to defer the investment; to invest and then temporarily suspend production if found optimal, and restart production when revenues increase again. S/he also has an option to abandon the investment, for instance, by renting out or selling the facility already before the invested good has been exhausted (Trigeorgis 1996). Odening et al. (2005) conclude that the investment trigger, taking into account the value of waiting in an uncertain environment, can be considerably higher compared to classical investment criteria such as the net present value, which may contribute to the reluctance to invest in pig production. Hinrichs et al. (2005) found that uncertainty and flexibility widen the range of returns where inaction is the optimal choice for the producer; i.e., a higher return is required to invest in new production capacity and a lower return is required to disinvest than would be required in the absence of flexibility.

Livestock markets are often criticized for price rigidity and that changes in input prices are transmitted only sluggishly to meat prices. As livestock production process takes time, it can be costly for producers to suspend production unless the fattening pig stock is ready to be marketed. One implication of this is that if producers are faced by a strong negative price shock in the meat market while input prices remain unchanged, they may suffer large losses (cf. Niemi and Lehtonen 2010). Hence, it is important to consider also how the correlation between input and output prices can impact the value of contract.

Carrying out an irreversible investment reduces individual producers' options to adjust in price shocks. However, if the marketing contract is loose enough, then an individual farm specialized in pig fattening may have an option to suspend production if its revenues fall below the variable costs and, restart production again once revenues have recovered.

Retaining such an option may be valuable for an individual fattening unit but costly for the whole pork production chain (Pietola and Wang 2000). The costs are increased because the suspension option requires excess capacity elsewhere in fattening stage, or causes severe distortions in the flow scheduling of piglets. Interruptions at fattening stage imply problems for piglet producers in finding a buyer for their animals and may require maintaining over-due piglets on the farm. The problem is further exacerbated if the stocking rates increase to the extent that animal welfare is compromised.

If the chain involves significant amount of interruptions in the flow scheduling, the efficiency of the network could be improved with a contract where fattening farms are committed to purchase certain, predetermined amount of piglets to maximize the returns for the whole supply chain. Producers who give away the option to suspend production and commit to produce at full capacity, even if meat prices plunge, should demand a compensation for the commitment. Earlier study of Pietola and Wang (2004) suggests that the option to suspend production temporarily has substantial value for an individual fattening farm. Hence, an optimal contract that is fixing the quantity flow at full capacity through the supply chain accounts for this value.

Pietola and Wang (2004) approach was based on fixed input-output enterprise budgets and did not quite correctly account for the fact that the growers can adjust their production systems also through feeding and the timing of slaughtering rather than suspending their production. The goal and contribution of this study is to estimate how different price or quantity fixing contracts affect the value of pig space unit in a more realistic decision setting framework. We relax the assumption of exogenously fixed input-output ratios when estimating the value for option to suspend fattening unit. The value of fattening pig space is maximized by optimising feeding, the timing of slaughter, and production breaks. This stochastic decision problem with four decision variables does not have a closed form solution and it is therefore solved numerically with a stochastic dynamic programming algorithm.

We also estimate the underlying pigmeat price process so that the volatility estimates underlying the optimization routine reflect the revealed price data. Our results, therefore, provide valuable practical information on designing the contract coordination mechanisms in which also the producers at the fattening stage are committed to maximize the value of the supply chain when the pigmeat market exhibit significant volatility.

Model

Objective function and variable definitions

The dynamic programming (DP) model maximises return on fattening pig space for an all-in-all-out production system. The optimal solution is based on the Bellman equation (Bellman, 1957) of the form:

$$(1) \quad V_t(\mathbf{x}_t) = \max_{\mathbf{u}_t} \{R_t(\mathbf{x}_t, \mathbf{u}_t) + \beta E(V_{t+1}(\mathbf{x}_{t+1}))\} \text{ for } t = 1, \dots, T$$

$$\begin{aligned}
\text{subject to:} \quad & \mathbf{x}_{t+1} = g(\mathbf{x}_t, \mathbf{u}_t, \boldsymbol{\varepsilon}) && \text{(transition equations)} \\
& \mathbf{x}_1 \text{ given} && \text{(initial state given)} \\
& V_{T+1}(\mathbf{x}_{T+1}) \text{ given} && \text{(the terminal value),}
\end{aligned}$$

where $V_t(\cdot)$ is the value function for period t ; t is the time index (week); \mathbf{x}_t is the state vector; \mathbf{u}_t is the control vector; $R_t(\cdot)$ is the one-period cash flow (revenues minus expenses); β is the discount factor; $E(\cdot)$ is the expectations operator; $V_{t+1}(\mathbf{x}_{t+1})$ is the next-period value function; $g(\cdot)$ is the vector of transition equations (see sections ‘The pig growth model’ and ‘The volatility and movement of market prices’ below); $\boldsymbol{\varepsilon}$ refers to the variation in the pigs’ carcass composition and growth and to uncertainty about prices obtained in the subsequent period; T is the terminal period (the duration of studied contract period), and \mathbf{x}_1 is the state at the beginning of the planning horizon. T is set 250 weeks. The discount factor (β) is 0.9989, which corresponds to a 6 % annual interest rate. The production is run on a weekly basis, which is a common practice in Finland. It is also consistent with the pattern that pigmeat prices are typically updated once a week.

The control vector includes four decisions: 1) The producer can sell fattening pigs currently held at the farm to the slaughterhouse. 2) After having sold the pigs to the slaughterhouse, s/he can either purchase a new group of piglets and start fattening them or to pause production and buy new piglets after having decided to end the production break. While the producer is raising the pigs, s/he chooses the amount of 3) energy and 4) protein fed to the pigs during the week. The state vector contains the current prices of pigmeat, piglets, and feeds. It also characterizes the weight and genetic performance of a heterogeneous group of pigs so that individual pigs are distributed around the average pig in the group.

One-period returns

Cash-flows in the model are characterised by $R_t(\mathbf{x}_t, \mathbf{u}_t)$. Cash flows associated with the production process are 1) income from marketing the pig for slaughter (salvage value), 2) the expenditure from purchasing a new piglet, 3) the cost of feeding the animal plus other variable costs. Quality-adjusted value of marketed pigmeat is determined by using a linearized pricing system based on a pricing grid used by a slaughterhouse. The feed costs are based on analysis of well-defined diets.

The volatility and movement of market prices

The movement of the price of pigmeat from week t to week $t+1$ is simulated with equation:

$$\begin{aligned}
(2) \quad & \mathbf{x}_{t+1}^{\text{price}} = \mathbf{x}_t^{\text{price}} + \boldsymbol{\varepsilon}_t^{\text{price}} \\
\text{subject to:} \quad & x^{\text{minimum}} \leq x_{t+1}^{\text{price}} \leq x^{\text{maximum}},
\end{aligned}$$

where $\mathbf{x}_{t+1}^{\text{price}}$ is the vector of prices which may realize in week $t+1$, x_t^{price} is the price of pigmeat in week t , $\varepsilon_t^{\text{price}}$ is the distribution of weekly price changes, x^{minimum} and x^{maximum} are the smallest and the largest price that can be realized, and x_{t+1}^{price} is an individual price realization. The smallest and largest price is based on historical data (TIKE 2010).

The error term $\varepsilon_t^{\text{price}}$ includes unpredictable (random) part of price movement. The random part is assumed to be white noise. The distribution is simulated by using a previously estimated ARCH (AR(1)) model (Liu, unpublished) for the Finnish pigmeat market. For methodological issues, see e.g. Hayashi (2000). The simulation model assumes that prices vary like random walk and that the direction and the magnitude of weekly price change is unknown *a priori*. Hence, forecast weekly price changes are not correlated with the current price level and the movement of individual weekly price changes in the model cannot be explained by historical prices in Finnish or other markets.

Pig growth model

The growth of pigs is modelled by using a biologically explicit growth model first illustrated by Niemi (2006), and here adapted from Niemi et al. (2010). The model simulates the growth and quality-adjusted carcass value of pigs explicitly with information on nutrients fed to the pigs. The model simulates how lipid and protein mass in the pig's body responds to the amounts of energy and protein provided to it in feed. It takes into account that individual pigs can have different growth rates and weights.

Data and scenarios

Eight scenarios are examined (see Table 1). The price of pigmeat is considered either deterministic (scenarios D1 and D2) or stochastic (S1 to S6). In the event of stochastic prices, the weekly change in the price of pigmeat is simulated by following distribution presented in Figure 2. Scenarios S5 and S6 however consider cases where the pigmeat price volatility is 1.4-fold when compared to Figure 2. In six out of eight scenarios the producer has the option to suspend production temporarily. In the event of deterministic pigmeat price, the role of the option to suspend production is discussed based on the current results, and hence, it is not modelled in this paper. In further scenarios the price of feed and piglets are or are not correlated with the price of pigmeat. The correlation between the price of piglets and pigmeat is such that one cent increase in pigmeat price is associated with €0.47 increase in piglet price, and that one cent increase in pigmeat price is associated with 0.24% increase in feed price (which is determined by the price of barley). The correlation coefficients were obtained by analysing the Finnish meat markets in 1995 to 2010. The simulated price of pigmeat is allowed to vary within the range where weekly prices were observed to vary during the period from 1995 to 2010 (see Figure 1). Biological data used in the analysis is adapted from Niemi et al. (2010).

Table 1. The characteristic of scenarios examined in this study.

Scenario	Option to suspend production	The precense of price uncertainty	Input price correlated with output price
D1	Yes	Deterministic price	No
D2	Yes	Deterministic price	Yes
S1	Yes	Standard volatility	No
S2	Yes	Standard volatility	Yes
S3	No	Standard volatility	No
S4	No	Standard volatility	Yes
S5	Yes	1.4×Standard volatility	No
S6	Yes	1.4×Standard volatility	Yes

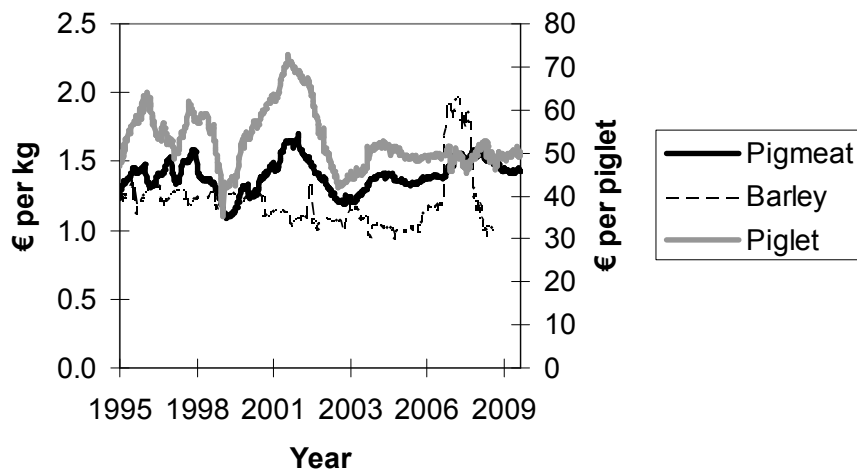


Figure 1. Weekly observed prices for pigmeat, piglets and barley in Finland.

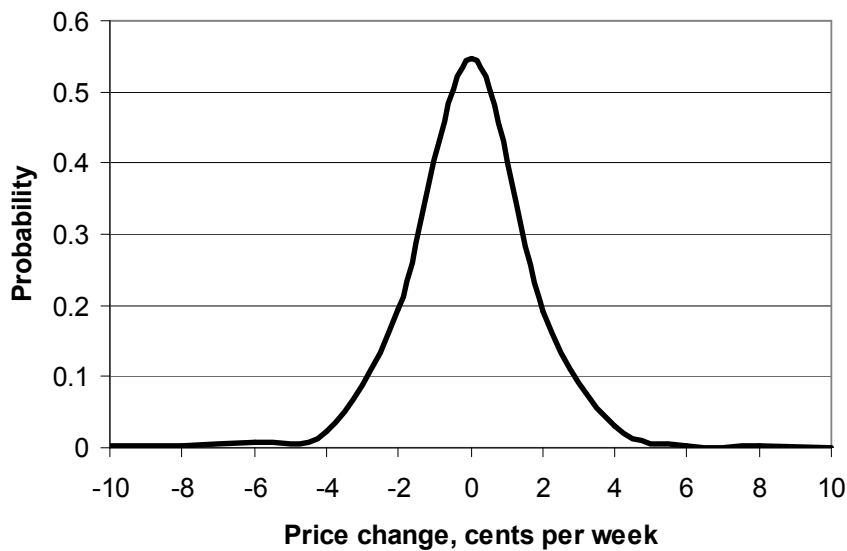


Figure 2. The distribution of weekly change of pigmeat price used in the standard price volatility simulation.

Results

The role of price volatility

The results suggest that the value of the pig space unit significantly increases with increasing pigmeat price, but the slope and the shape of this relationship differs substantially between the above described contract terms and market volatility scenarios. Among the simulated scenarios, the value of pig space unit increases the most rapidly with pigmeat price in scenario D1 where the price of pigmeat is deterministic and separated from input prices. When the prices are deterministic, the value function is bounded from below at zero for low pigmeat prices, since at these points the producer is using the option to suspend production (Figure 3).

When price uncertainty is introduced into the model the value curves become smoothed. In scenario S1, which differs from the scenario D1 only in that S1 has stochastic prices, the value of pig space unit responds less strongly to increases in pigmeat price than it does in the deterministic D1 scenario. At low price levels, scenario S1 results in a higher value than the deterministic price scenario D1, whereas at high deterministic pigmeat price is able to yield higher returns than stochastic price. In scenario S1 the value of pig space unit is bounded from below at zero since the producer is using the option to suspend production temporarily. At high pigmeat prices, the value can decrease because price volatility implies that price development in the future can be also unfavourable, and in the extreme case because there is an upper limit for the price. When an elevated price volatility (+40% from scenario S1 (or S2)) is considered in scenario S5 (or S6), the slope of value function is even less steep than in scenario S1 (or S2) (Figure 5).

When the piglet and feed prices are allowed to vary jointly with pigmeat price, the value of pig space unit is less dependent on changes in the pigmeat price than in other scenarios examined here. This can be observed in Figures 3 to 5 by comparing scenario D1 to D2; S1 to S2; S3 to S4; or S5 to S6. In scenarios D1, S1, S3 and S5 the price of pigmeat is separated from the prices of piglets and feed, whereas in scenarios D2, S2, S4 and S6 the prices are correlated with each others. In particular, the volatility of revenues decreases as the correlation between input and output prices increases the value of pig space unit when the price of pigmeat is currently low, and decreases it when the price of pigmeat is currently high. The impact of the correlation between input and output prices is mainly due to the correlation between piglet and pigmeat price, because the correlation between pigmeat and feed price was found relatively small.

The value of option to suspend production

When the option to suspend production temporarily in the event of stochastic pigmeat price is taken away by the flow scheduling contract, the value of pig space unit decreases (S1 vs. S3). The difference between the scenarios S1 and S3 is negligible when the price is high. In contrast to this, the option to suspend production is the most valuable when the prices are unfavourable as then it can help the producer in avoiding large economic

losses. The value of option to suspend production is considerably smaller when input and output prices are correlated than when they are not correlated, and the difference between S2 and S4 is negligible (Figure 4). The result is because of the correlation between input and output prices, which rules out most situations where revenues are unable to cover variable costs of production. In scenarios S1 and S5, the option to suspend production temporarily is exercised when pigmeat price falls below €1.23 per kg. However, when input prices are correlated with the price of pigmeat, the option is usually not exercised as falling revenues are followed by falling production costs as well.

When the option to pause production is taken away by the flow scheduling contract in the event of deterministic price of pigmeat, the value of pig space unit is below deterministic baseline scenario S1 at low pigmeat prices. The result is not shown but it would be almost linear extrapolation of curve S1 below zero in Figure 3. Hence, when the prices are fixed and they fall below the level where revenues are not covering the variable costs, the producer may find it optimal to exit the industry. In our deterministic scenario D1, the option to exit the industry is exercised when pigmeat price falls below €1.21 per kg.

The optimal feeding pattern and slaughter timing also varies by market situation. When pigmeat price is low, producer can decrease market losses by restricting feeding, paying more attention to carcass leanness and increasing the interval between successive slaughters. The optimal management contributes to the value of pig space unit also when the price volatility increases. The optimal daily amount of energy to be fed to the pigs increases with the price of pigmeat (and with the value of pig space unit). Therefore, the higher is the pigmeat price, the more meat is being produced per pig space unit per year.

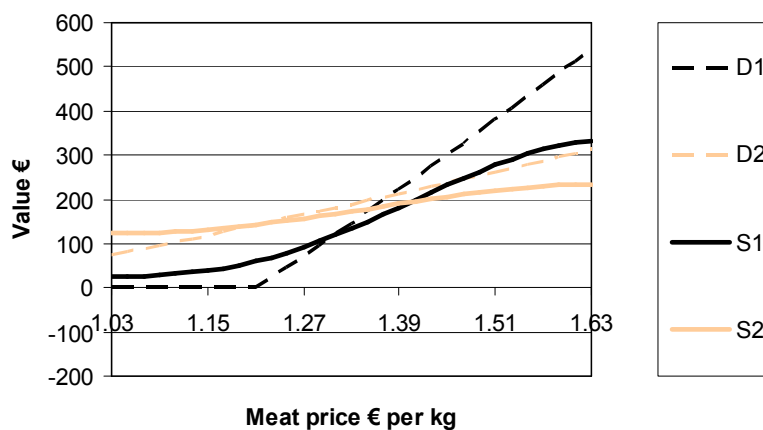


Figure 3. The value of pig space unit as a function of current pigmeat price when prices are either deterministic (D1, D2) or stochastic, and (S1, S2), and input prices are either correlated (D2, S2) or not correlated (D1, S1) with pigmeat price.

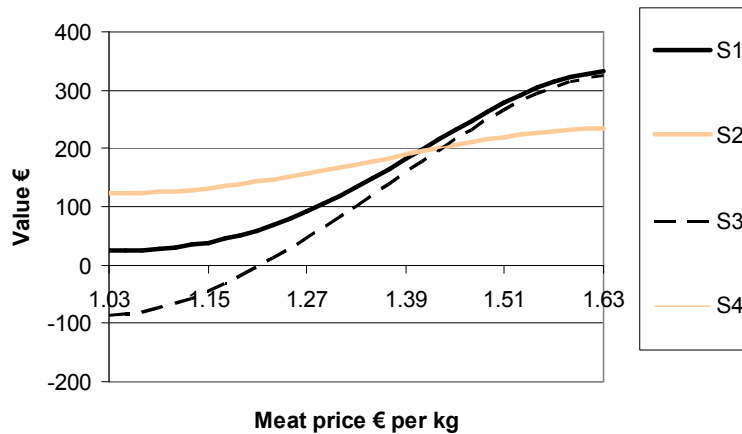


Figure 4. The value of pig space unit as a function of current pigmeat price when input prices are either correlated (S2, S4, curves which are (almost) overlapping) or not correlated (S1, S3) with stochastic pigmeat price, and the producer has (S1, S2) or doesn't (S3, S4) have the option to suspend production temporarily.

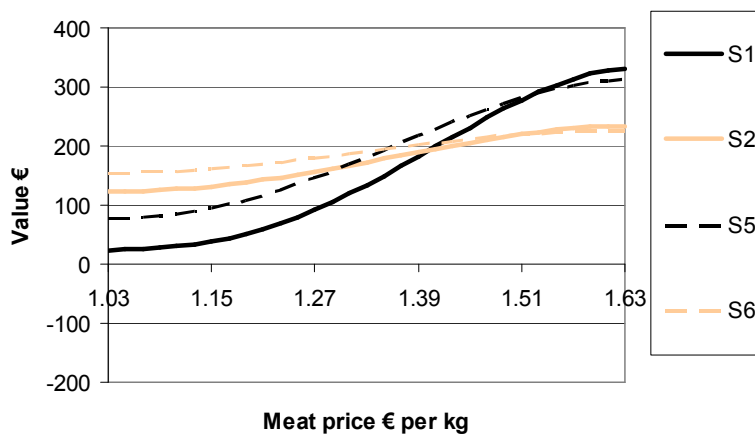


Figure 5. The value of pig space unit as a function of current pigmeat price when input prices are either correlated (S2, S6) or not correlated (S1, S5) with stochastic pigmeat price, and the price volatility is either standard (S1, S2) or 1.4-fold (S5, S6) compared to the standard.

Discussion and conclusion

Results lead to several important conclusions about the importance of price volatility in the performance of coordination contracts. Producer can profit from stable and high pigmeat prices. A rationally behaving producer can adjust input use according to the market situation and obtain a further compensation for risk and capital invested in production. If pigmeat price is low relative to input prices, producer may find it optimal to suspend production to limit his/her losses. The threshold price below which this option is exercised, depends on how much variable costs can be saved by suspending production. On the other hand, if the price of pigmeat increases, the producer can profit from increasing the growth rate of pigs by adjusting feeding pattern.

Besides being a cost item, price volatility also creates opportunities to benefit, and these opportunities can become more frequent in a volatile market. Another implication of price uncertainty is related to relative prices of inputs and output. If input and output prices vary simultaneously to the same direction, it can decrease the volatility of profit margin or the volatility of return on investment significantly, i.e. an increase in feed or piglet price would be associated with an increase in pigmeat price. Unbiased estimation of the value of pig space unit should therefore take into account both price uncertainty and correlation between input and output prices.

Results illustrate that the lack of appropriate contracts and inelasticity of piglet prices can result in distortions in the piglet market. Economic agents (e.g. slaughterhouses, piglet producers) who coordinate piglet trade could ensure their markets by contacting the production so that piglet prices and piglet deliveries are fixed and pigmeat producer is compensated for his/her commitment to purchase piglets also when pigmeat prices are low. Such a contract can increase the return on fattening pig space. Whether the volatility of returns is affected, depends on how input prices are linked to the price of pigmeat.

What kind of contract would a fattening farm then prefer? The preference depends on the relative prices and current status of the market. The producer benefits from having the option to suspend production. Giving up this option requires compensation. Results suggest that compensation that attracts fattening farms to sign the contract is the higher the lower current pigmeat price is. Alternatively, farrowing farms could secure their piglet sales by allowing piglet price to follow changes in the price of pigmeat. For instance, any fall in pigmeat price should be transmitted to piglet prices which would also fall. In such a transparent market fattening farms might not have an incentive to pause production. In both cases, it is relatively expensive for an agent selling the piglets to have the fattening farm fixing the flow of production when market situation is unfavourable.

If the price of pigmeat is low compared to input prices, the producers may prefer choosing a contract which is offering high price volatility (hence, a higher price risk) because that type of contract is also offering a chance for increased revenues in the future, or which is fixing the price of pigmeat relative to input prices at a more favourable level. When the price of pigmeat is high compared to input price, the producer would prefer a contract fixing the price (ratios) at that level and offering low price volatility. In that case, the compensation required for the option to suspend production would be relatively small.

Previous studies have estimated that price volatility of agricultural goods is likely to increase in the coming years. During the past years, Finnish piglet markets have momentarily suffered from the oversupply of piglets. Our conclusion is that the functioning of such a market could be improved by providing fattening farms with contracts where they are committed to purchase certain amount of piglets at a certain price and on certain time and by deeper integration of pigmeat, piglet and grain markets, and that the contracts should be negotiated based on when the market situation is not an extreme.

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