ADJUSTMENTS TO CHANGING ECONOMIC CONDITIONS IN NORWEGIAN DAIRY FARMING

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ABSTRACT
LP models of Norwegian dairy farms are designed to evaluate the impact of changes in prices and subsidies on production systems and on profitability at the farm level. At 1999-prices, producing a fixed milk quota with low to moderate yielding cows (6000 to 6600 kg milk annually) is most profitable. Silage offered ad libitum is profitable. A three cut harvesting system is more profitable than two cuts. Changes in the milk price have no effects on production. If forage crops is the only possible land use, increased area payments have no effects on production. If non-forage crops are also grown, increased area payments for forage crops result in a higher proportion of the land being used for temporary grass (ley) and in cheaper forage, making higher silage intake per cow profitable. Higher intake of silage achieved through supplementing less concentrates, results in lower milk yield per cow. By increasing headage payments, milk yield falls, as it is optimal to have more cows to produce the same quota output. Reduced product and concentrate prices combined with higher area and headage payments result in more cows and lower yields. Silage offered in a fixed ration is the most profitable option and the level of concentrates per cow is high. More land is then used for permanent pastures and less for non-forage crops.

Introduction

During the past 15-20 years, the economic conditions for Norwegian dairy farmers have changed considerably. In 1983 milk quotas were introduced. Many farms have the resources to increase milk production, but are limited by restrictive quotas, which actually have been reduced on many farms since 1983. Farm gate prices have dropped during the past 10-12 years, whereas area and headage payments have increased.

Annual milk yields peaked in 1993 at 6350 kg energy corrected milk (ECM) per cow. By 1999, milk yields were down to 6125 kg ECM/cow. In the same period, the annual use of concentrates remained stable at 1700-1750 feed unit milk (FUm) per cow. (One

FUm is defined as 6900 kJ net energy for lactation, which equals one kg barley.) Even though this development seems somewhat unbalanced to some, it can be partially explained as an economically rational adjustment to changes in the economic conditions.

New agricultural policy goals were decided upon in 2000. Prices, especially for grain, are to be further reduced, thus leading to cheaper concentrates and enabling price reductions for meat and dairy products. The ensuing income losses are to be (partially) compensated for by changes in public support programmes and a deduction in taxable farm income. The maximum income compensation (before tax) of the deduction is NOK 14,000 (€1 ≈ NOK 8.10).

This paper thus discusses how the use of inputs, outputs and economic results on Norwegian dairy farms are effected by changes in prices and public subsidy schemes. The farms' milk quotas are given. Factors that are assessed include grassland fertilisation, harvesting regimes, pasture management, feeding regimes and the roughage/-concentrate ratio. In addition, it is considered to what degree dairy production ought to be combined with other farm enterprises.

The farm models

Farm models to analyse adjustments in Norwegian dairy farming have been designed. A full description of the models is given in Flaten (2001). The models are constructed as single year linear programming models, aimed at finding the farm plan that has the largest possible total gross margin, but which do not violate any of the constraints.

The model's technical coefficients relating to crop and livestock production were partly obtained from various scientific studies. But little of the published research is suitable for incorporation into modelling studies. Therefore, subjective assessments were necessary to fill in many of the gaps.

Farmland can be used as meadow land (and harvested two or three times per season), pasture and for growing barley. Separate models have been designed for each of the two harvesting regimes. Grain cannot be grown on certain farms. Models for farms without grain production has thus also been analysed, and in total there are four models. In the models with (without) barley, the farmland is 22.5 (19.0) hectare (ha). Farmland can neither be rented nor leased. Winter forage (grass) is direct-cut and conserved as silage. Temporary grass is either sown without a cover crop or with barley as cover crop.

The two harvesting regimes are: 1) three cuts; the first just after heading starts around June 10th, the others on July 25th and September 20th, and 2) two cuts, both in relatively late developmental stages, on June 25th and September 1st. Fewer cuts result in higher dry matter (DM) yields. However, digestibility is reduced and the difference in net energy yield between the two regimes is thus diminished. In Table 1, net yields and protein contents in the two harvesting regimes and with increasing nitrogen (N) fertilization rates are shown. Protein contents are expressed as AAT (amino acids absorbed in the small intestine) and PBV (protein balance in rumen), according to the Nordic protein evaluation system.

Table 1 Net grass yields and protein contents

	Kg DM/ha	FUm/ha	AAT, g/kg DM	PBV, g/kg DM
Two cuts:				
50 kg N/ha	4740	3410	70	-44
100 kg N/ha	5500	3960	70	-27
150 kg N/ha	5890	4240	70	-17
200 kg N/ha	6080	4380	70	-9
250 kg N/ha	6110	4400	70	-3
Three cuts:				
100 kg N/ha	3840	3230	73	-10
150 kg N/ha	4610	3870	73	10
200 kg N/ha	5120	4300	73	25
250 kg N/ha	5380	4520	73	36
300 kg N/ha	5440	4570	73	46

Increasing the number of cuts leads to reduced winter survival and a thinner sward. The model for two (three) cuts is based on 4 (3) year grass leys duration (the sowing year excluded).

Pasture yields should be high enough to cover the animals' forage requirements during the entire grazing period, which lasts from May 20th to September 10th. Pasture can be temporary (re-established every 6th year) or permanent. Fertilizer application rates on temporary pastures are 150 kg N/ha, 200 kg N/ha or 250 kg/ha. Pasture yields are lower than silage yields. On permanent pasture, fertilization is low (50 kg N/ha) and so is also yields.

Barley is grown according to regional standards, and expected yields are 3.75 t/ha. Feed grain cannot be ground on-farm, and the entire barley crop is thus sold. Straw may be ammoniated and fed to the young cattle.

Forage can not be sold or purchased, but concentrates are purchased. Feed mixtures (for dairy cows), prices and energy and protein contents are shown in Table 2.

Table 2 Concentrate mixtures for dairy cows

	Price-1999	Energy content	Protein contents	
	NOK/kg feed	FUm/kg feed	AAT, g/FUm	PBV, g/FUm
Ruminant feed 97 low (RF97L)	2.54	0.95	97	-15
Ruminant feed 97 high (RF97H)	2.77	0.95	97	20
Ruminant feed 200 (RF200)	4.21	0.93	200	100
Ruminant feed – pasture (RFP)	2.59	0.95	97	-30

Farm livestock includes dairy cows, followers and steers. The calving period is October. The annual culling rate for dairy cows is 40%. Each cow produces 1.00 calves per annum. Male calves can either be sold or retained for beef production. However, no male calves can be purchased. Housing capacity limits the herd size to a maximum of 18 dairy cows and ten followers over eight months. Steers can either use space allocated to dairy followers or empty cow stalls. The annual milk quota is 90,000 litres.

Milk yields during the winter period depend on the feed level, whereas the AAT/PBV system ensures the protein requirement. Silage can be offered *ad libitum* or in fixed (restricted) rations. Table 3 presents daily concentrate supplementation and silage intake (ad lib feeding) during lactation in the winter period at different performance levels and the two harvesting regimes. Higher supplementation of concentrates increases milk yield, but at a diminishing rate. The addition of concentrates depresses silage intake but increases total DM-intake. Given the same amount of concentrates, DM-intake is highest for late-cut silage, but milk yields are highest for earlier-cut silage. Higher concentrate supplementation increases body weight at turnout, but these differences is assumed to disappear during the pasture period.

Table 3 Milk yield, supplementation of concentrates and intake of silage in the winter period. Silage offered ad libitum.

	Milk yield, kg/cow[1]				
	5500	6000	6500	7000	>7000[2]
Two cuts:					
Concentrate suppl., kg DM/day	3.20	4.90	7.00	9.90	11.70
Silage intake, kg DM/day	13.40	12.47	11.50	9.80	8.57
Three cuts:					
Concentrate suppl., kg DM/day	2.50	4.00	6,00	8.60	12.20
Silage intake, kg DM/day	12.75	12.02	11.01	9.63	7.63

[1] Milk yield for entire lactation period. Milk yields during winter feeding (235 days) are determined by subtracting milk yield on pasture (980 kg), independent of yield level.
[2] 7250 kg for two cuts and 7500 kg for three cuts.

Silage can also be rationed, but a minimum amount is necessary in order to maintain normal rumen functions. For each milk performance level, a scenario with minimal silage intake is also included. Within the upper and lower limits for silage intake one FUm silage replaces one FUm concentrate and vice versa.

During the grazing period all cows receive the same amount of concentrate. It is assumed that the remaining feed requirement is covered by pasture grass.

Feed plans for young livestock is fixed. For heifers and steers one can choose between one feeding regime with, and one without ammoniated straw. However, the use of straw requires access to own farm-grown barley straw. Late-harvested silage gives lower daily weight gains of steers. At two (three) cuts, the steers are ready for slaughter at an age of 550 (450) days and a carcass weight of 300 (285) kg.

The maximum farm-labour input by the farm family is 3500 hours per annum. Fixed labour input (2000 hours) is not explicitly priced in the models. The remaining 1500 hours are variable, and are the limiting factor for own labour input. Additional labour can be hired. The opportunity cost of the family's variable labour input is NOK 75 per hour. The same rate is used for hired labour.

Subsidy levels and prices from 1999 are used in the basic models (NAERI, 1999). Area payments for grain (incl. sward establishment with barley as cover crop) are 3720 NOK/ha. Area payments rates for forage crops are 5050 and 2170 NOK/ha for areas of 0-10 and 10-25 ha, respectively. Annual headage payments for dairy cows in the intervals 1-8, 9-16 and 17-25 cows are 3,974, 2,300 and 1,650 NOK/cow, respectively. For other cattle, the annual rates are 715 and 565 NOK for 1-25 and 26-140 head of cattle, respectively. Structural income support in dairy production is NOK 2.00 per litre for the first 30,000 litres delivered. Important prices are; Milk 3.53 NOK/litre, beef 36.05 NOK/kg, cow beef 30.55 NOK/kg, barley 1.92 NOK/kg and concentrates (see Table 2).

The farm economic result (later called profit) in the models is revenues (included subsidies) minus variable costs (included variable family labour). The family's fixed labour input, interest and depreciation costs for fixed assets (except breeding cattle), maintenance of buildings, insurance, electricity, administration, etc is not included.

Results and discussion

Basic models

The results for the basic models (1999-conditions) are shown in Table 4.

Table 4 Results for the basic models

	Model[1]			
	3C-GB	2C-GB	3C-G	2C-G
Economic indicators:				
Profit (NOK)	331,472	318,616	300,218	288,936
Area payments (NOK)	88,302	88,823	70,030	70,030
Headage payments (NOK)	62,170	62,361	62,170	63,428
Crop management				
Silage (ha)	9.3	8.8	9.0	8.9
Pasture (ha)	6.3	6.5	5.8	6.6
Permanent pasture (ha)	0	0	0	0
Sward establishment without cover crop (ha)	0	0	4.2	3.5
Sward establishment with cover crop (ha)	4.4	3.5	-	-
Barley (ha)	2.5	3.7	-	-
Fertilizer, silage (kg N/ha)	200	155	200	194
Fertilizer, pasture (kg N/ha)	150	150	195	200
Livestock management				
Cows (number)	14.70	14.93	14.70	16.00
Of this *ad libitum* access to silage (number)	14.70	14.93	14.70	16.00
Heifers (annual)	5.88	5.97	5.88	6.40
Beef bulls (fat stock/year)	7.35	5.56	7.35	3.73
Sold calves (number/year)	1.47	3.40	1.47	5.87
Yield (kg milk/cow)	6603	6500	6603	6073
Intake of concentrates (kg/cow)	1943	2089	1943	1598
RF97L	1873	0	1873	269
RF7H	0	2022	0	1262
RF200	3	0	3	0
RFP	67	67	67	67
Labour input (hours)	3353	3345	3375	3.367
Shadow prices				
Land (NOK/ha)	4710	4710	4800	4800
Milk quota (NOK/litre)	1.37	0.74	1.19	0.85
Housing, cow places (NOK/place)	0	1572	0	528
Housing, young stock places (NOK/place)	0	1572	0	528

[1] 3C-GB, three cuts, barley; 2C-GB, two cuts, barley; 3C-G, three cuts, no barley; 2C-G, two cuts, no barley

Ad lib silage feeding is most profitable. The dairy herd consists of moderate to low-yielding cows, and milk production is highest at three cuts. In order to ensure a given milk performance level, more concentrates have to be fed at two cuts. Still, lower milk yield at two cuts may reduce supplementation of concentrates per cow. The PBV is lower in late-harvested grass (two cuts), necessitating use of expensive concentrates high in PBV. Three cuts are more profitable than two cuts.

When possible, ammoniated straw is fed to yearlings. At three cuts, all steers are fed to finish in both models, and there is available housing space. At two cuts, all housing space is utilised due to additional cows and replacement heifers, as well as a longer fattening period for the steers. Some male calves are then sold.

Barley is grown when possible. The marginal profit in barley production determines the shadow price of land. Grassland is preferably re-established with barley as cover crop. This is encouraged by the higher marginal area payments for grains, but use of cover crops would still be most profitable even if the area payments were equal. Nitrogen fertilization in grassland is moderate.

Choice of production strategy is affected by farm resources and the possibilities for (and profitability of) alternative enterprises. Other runs of the models show that unprofitable alternatives enable low-performance production systems to be more profitable. Scarcity of fixed resources increases the profitability of high-performance production systems and intensive grassland production.

Reduced milk price and increased subsidies

Table 5 shows the optimal production strategy when the milk price is reduced by NOK 0.25 per litre and the area payment for forage crops increases by NOK 1000 per ha.

Model calculations (not presented here) show that changes in milk price do not affect the use of inputs and milk yield as long as the price drop is less than the shadow price of the milk quota. However, profitability decreases. The farms have the capacity to increase milk production, and the profitability of the alternative enterprises is relatively low. Thus, milk quota shadow prices are high. The milk price must fall significantly before the milk quotas are not fully utilised.

If only forage crops can be grown, the shadow price of land increases correspondingly to the increase of the area payment (Table 5). The internal price of forages does not change, and the choice of production strategy is thus not affected. In the long run, higher shadow prices of land help to keep farmland in operation, or even to stimulate the acquisition or cultivation of new farmland.

Table 5 Results in the case of reduced milk prices (-0.25 NOK/litre) and increased area payments for forage crops (+1000 NOK/ha)

	Model			
	3C-GB	2C-GB	3C-G	2C-G
Economic indicators:				
Profit (NOK)	325,405	312,229	296,718	285,436
Area payments (NOK)	102,858	103,235	89,030	89,030
Headage payments (NOK)	63,586	63,498	62,170	63,428
Crop management				
Silage (ha)	11.0	9.6	9.0	8.9
Pasture (ha)	6.5	7.2	5.8	6.6
Permanent pasture (ha)	0	0	0	0
Sward establishment, no cover crop (ha)	0	0	4.2	3.5
Sward establishment with cover crop (ha)	5.0	3.9	-	-
Barley (ha)	0	1.8	-	-
Fertilizer, silage (kg N/ha)	150	173	200	194
Fertilizer, pasture (kg N/ha)	150	150	195	200
Livestock management				
Cows (number)	15.12	16.20	14.70	16.00
Of this *ad libitum* access to silage (number)	15.12	16.20	14.70	16.00
Heifers (annual)	6.05	6.48	5.88	6.40
Beef bulls (fat stock/year)	7.56	3.39	7.35	3.73
Sold calves (number/year)	1.51	6.33	1.47	5.87
Yield (kg milk/cow)	6419	6000	6603	6073
Intake of concentrates (kg/cow)	1712	1513	1943	1598
RF97L	1598	0	1873	269
RF97H	0	1446	0	1262
RF200	47	0	3	0
RFP	67	67	67	67
Labour input (hours)	3368	3362	3375	3367
Shadow prices				
Land (NOK/ha)	4760	4710	5800	5800
Milk quota (NOK/litre)	1.29	0.50	0.94	0.60
Housing, cow places (NOK/place)	0	1735	0	528
Housing, young stock places (NOK/place)	0	1735	0	528

In models including barley, forage production becomes more profitable when the area payment for forage crops is increased and the barley acreage decreases. At two cuts, barley is still grown, and shadow prices of land remain unchanged. However, at three cuts barley is not grown any more. The shadow price of land increases, but not at the same rate as the area payment. The internal price of forages thus drops at both two and three cuts. Too achieve increased intake of cheaper silage, cows are supplemented less concentrates. Milk yields drop and the number of cows increases to utilize the quota.

Cheaper forage as a result of increased area payments for forage crops leads to lower fertilization rates on grassland for silage in model 3C-GB. At two cuts fertilization increases. Lower-yielding cows have a higher intake of silage low in PBV, while the supply of high-PBV concentrates is reduced. In order to meet the cows' PBV requirements, fertilization have to increase in order to raise PBV contents in the silage.

Theoretical analyses (Flaten, 2000) and model calculations not presented here show that increased marginal headage payment promotes more cows with lower milk yields. This, in turn, results in a greater demand for forage and increased application of N in grassland. Increased headage payment increases the shadow price of the milk quota. In addition, more cows and greater forage demand can also result in higher shadow prices for housing capacity and land.

Significant changes in prices and subsidies

The following scenario, with significant price and support changes, is assessed (Table 6): the price of barley is reduced by 25% (0.48 NOK/kg) to 1.44 NOK/kg. The price of seed grain and concentrates is reduced accordingly. The price drop is partially made up for by raising the area payment for grain by 1280 NOK/ha to NOK 5000 NOK/ha. Milk and beef prices are reduced by 15%. The area payment, after levelling-out its structural profile, is 4500 NOK/ha forage area for the interval 0-25 ha. For dairy cows, headage payment now amounts to 3750 and 2750 NOK/cow for the intervals 1-16 and 17-25 cows, respectively. Payment for young cattle is changed to NOK 900 per head. The changes are greater than actually were implemented in 2000.

Lower concentrate prices result in increased use of concentrates, reduced silage intake, and higher performance production systems. Nevertheless, Table 6 shows a tendency to lower milk yields than in Table 4. This can be explained by, *inter alia*, increased marginal headage payment that makes it profitable to increase the number of cows, but to reduce milk yields per cow. Further, weakened profitability in alternative enterprises (beef and barley) stimulates lower yielding production systems.

In several models lower concentrate prices make silage rationing profitable, especially at three cuts. Farmland is smallest for the models without barley production, and at three cuts the cows are given only the minimal amount of silage.

Table 6 Results in the case of significant changes in prices and subsidies

	Model			
	3C-GB	2C-GB	3C-G	2C-G
Economic indicators:				
Profit (NOK)	307,943	299,000	282,375	275,788
Area payments (NOK)	103,210	102,922	85,500	85,500
Headage payments (NOK)	75,149	76,882	75,149	76,661
Crop management				
Silage (ha)	9.8	9.9	6.6	8.4
Pasture (ha)	3.2	4.4	1.6	7.1
Permanent pasture (ha)	5.6	4.9	8.3	0
Sward establishment, no cover crop (ha)	0	0	2.5	3.5
Sward establishment with cover crop (ha)	3.9	3.3	-	-
Barley (ha)	0	0	-	-
Fertilizer, silage (kg N/ha)	150	173	200	152
Fertilizer, pasture (kg N/ha)	150	150	150	150
Livestock management				
Cows (number)	14.93	16.20	14.93	16.00
Of this *ad libitum* access to silage (number)	10.57	16.20	0	12.79
Heifers (annual)	5.97	6.48	5.97	6.40
Beef bulls (fat stock/year)	7.47	3.39	7.47	3.73
Sold calves (number/year)	1.49	6.33	1.49	5.87
Yield (kg milk/cow)	6500	6000	6500	6073
Intake of concentrates (kg/cow)	2140	1513	2966	1823
RF97L	2073	0	2899	0
RF97H	0	1446	0	1756
RF200	0	0	0	0
RFP	67	67	67	67
Labour input (hours)	3318	3346	3266	3345
Shadow prices				
Land (NOK/ha)	5800	5860	6050	6180
Milk quota (NOK/litre)	1.30	0.77	1.19	0.82
Housing, cow places (NOK/place)	0	763	0	729
Housing, young stock places (NOK/place)	0	763	0	729

Increased area payment partially compensates for lower grain prices, but not enough to make barley production profitable. Growing forage crops is relatively more profitable due to increased marginal area payments. This, in addition to silage rationing, does lead to abundant farmland resources. Land use becomes extensive, and several models include significant use of permanent pasture. Farmland remains in operation, but in a low input-output manner.

Relative to the basic models, profits are reduced by NOK 13,000-23,500. However, the farm income deduction of NOK 14,000 partially compensates for this. Three cuts are still most profitable, but the difference between the harvesting regimes is smaller.

Profits are reduced most in models including barley. Increased marginal area payment for forage crops results in increased shadow prices of land, even though the profits decline. For other fixed resources the shadow prices show no systematic tendencies.

Conclusions

Linear programming models have been designed to examine optimal adjustment on Norwegian dairy farms with a fixed milk quota. The results depend on the economic and (partially uncertain and subjective) agronomic assumptions on which the models have been constructed. The results must be interpreted in this context.

In the basic models (1999 prices), the cows are offered silage *ad libitum*. The cows are medium to low yielding, and yields are highest at three cuts. A three cut harvesting system is more profitable than two cuts. Unprofitable or lacking alternatives enables low-performance production systems to be more profitable. Scarcity of fixed resources increases the profitability of high-performance production systems and intensive grassland production.

Changes in milk price do not affect the use of inputs and production of outputs, given profitable marginal milk production. The shadow price of the milk quota changes according to change in milk price.

What happens when area payments for forage crops increases? No changes occur if only forage crops can be grown. However, if barley can be grown in addition, forage crops then becomes more profitable. Barley area is reduced. In order to increase silage intake, the cows are supplemented less concentrates. This results in reduced milk yields and additional cows. Fertilizer application rates are reduced when cutting three times, but are increased when cutting twice, because in the latter scenario, a lower PBV supply (from concentrates) needs to be compensated for by silage high in PBV.

By increasing headage payments, milk yield falls, as it is optimal to have more cows to produce the same quota output. This, in turn, results in a greater demand for forage and higher input of fertilizers.

What happens when reduced prices (especially grain and concentrates) are to be compensated for by taxable farm income deductions and a levelling-out of the subsidy's structural profile? Lower concentrate prices result in increased milk yields. However, the opposite yield-reducing effects of increased marginal headage and area payments, as well as poorer profitability in alternative enterprises are larger. In several models lower concentrate prices make silage rationing profitable, especially at three cuts, and more concentrates are fed. Whereas the forage area increases, the barley area decreases. Land use is more extensive, and several models include significant use of permanent pasture. The models' profits are reduced, but this can be made up for by measures such as income deductions. Three cuts are still most profitable, but the difference between the harvesting regimes is smaller.

Several decision problems were not considered, e.g., time of calving and culling strategies. The model has a short-term perspective. In the long run, farmers would have to invest in new farm buildings and machinery. Building investments increase the average cost per kg milk, implying that it is profitable to utilize the fixed milk quota with fewer cows. However, one has to also consider the possibility for future expansion when planning building investments. Investments in field machinery etc increase the marginal cost of forage, but technological changes can offset such costs. Thus, there still remain many options for further research in Norwegian dairy farmers' adjustment to changing economic conditions.

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