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Development of a breeding objective for Estonian Holstein cattle

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Economic weights for milk carrier (water plus lactose), fat and protein yields, calving interval, age at first service, interval between the first service and conception of heifers and length of productive life of Estonian Holsteins were estimated under assumed milk production quota and for non-quota conditions. A bio-economic model of an integrated production system of a closed herd was used. Economic values of milk carrier yield and length of productive life differed between quota and non-quota conditions, but there were only minor differences between those marketing systems in economic values for functional traits. The standardised economic values of the most important traits varied in magnitude between18 to 81% of the economic value for milk yield. Discounting had a substantial impact on the economic value of length of productive life. When defining the breeding objective for Estonian Holstein, the interval between the first service and conception of heifers, and the length of productive life should be included in the breeding goal along with the traits with the highest economic value, milk, fat and protein yield. In the optimum breeding objective, relative weights of production vs. functional traits were 79 and 21%, respectively.

Key-words: economic weights, production traits, functional traits

Introduction

In order to establish a total merit index using Hazel (1943), the relative economic weights of each trait contributing to the aggregate genotype (breeding objective) must be known. Hazel (1943) defined the economic value of a trait as the improvement in profitability resulting from one unit of genetic improvement in that trait, genetic merit of all others remaining constant. Index selection is the optimal

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method to improve complex breeding objectives including several traits (Hazel 1943). Aspects and methods for the derivation of economic values are reviewed by Groen et al. (1997) and Goddard (1998).

In index selection, the breeding objective (also known as total merit or the aggregate genotype) is defined by a linear function of economically important traits. According to Thaller (1998) traits included in the breeding objective must meet at least the following conditions:

(i) They must be economically important.

(ii) They must be heritable.

(iii) They must have genetic variance.

Recordability of a trait is not required as long as a correlated trait or traits exist that can be used as indicators of genetic merit for the traits in the index. Traits included in the selection index should meet the following basic conditions:

(i) They should be easily measurable and recordable.

(ii) They must be heritable with sufficient genetic variance.

(iii) They can be identical with the traits in the breeding goal or must be genetically correlated to one or more traits in the breeding goal.

In many countries, the breeding goal for dairy cattle has been revised to include not only high product yield but also longevity and functional traits that reduce the cost of production. Among such functional traits many countries include at least one measure of daughter fertility, because poor reproductive performance has a significant economic impact at the farm level (Van Doormaal et al. 2004). Selection has dramatically increased milk production per cow, and disease resistance has deteriorated concurrently (Weigel et al. 2004). Incidence rates for many diseases also seem to have increased during times of negative energy balance (Collard et al. 2000). To avoid such consequences, breeding organisations have changed their breeding goal, paying less attention to production and increasing the emphasis on functional traits.

After Estonia's accession to the EU in 2004, the impact of milk yield quotas on economic weights had to be considered. According to Groen et al. (1997), under quota conditions and decreasing milk prices, functional traits, which increase efficiency not by higher product output but by reduced input costs, might have greater impact on farm profit and should therefore, be included in breeding programmes. There also are non-economic reasons for including functional traits in a breeding programme, for example ethical considerations, consumer concern, the need to simplify management and improved farmer satisfaction/reduction of frustration, which are becoming increasingly important (Dempfle 1992, Groen et al. 1997, Olesen et al. 2000). Inclusion of functional traits in breeding programmes is expected to have a major impact on selection response of such traits and cause only moderate reduction in selection response for production (Fewson and Niebel 1986).

Economic values of milk, fat and protein production were first calculated for the Estonian cattle population in 1997 (Pärna and Saveli 1997, Pärna and Saveli 1998), and some functional traits were added in 2002 (Pärna and Saveli 2002). Annual genetic responses in milk, fat and protein yield were estimated to be 57.4 kg, 1.98 kg and 1.67 kg, respectively (Pärna and Meier 2001). Re-evaluating economic values is needed because economic conditions have since changed. Dairy farmers in Estonia are facing structural changes and changes in the market for which they produce. If economic values are uncertain, selection response will be lower than when economic values are known without error (Smith 1983).

This investigation describes the derivation of economic values for milk production and selected functional traits for the Estonian Holstein (EHF) population, and quantifies their relative importance in the aggregate genotype. Absolute and relative economic value of traits will be estimated with a herd model, under an assumed quota on milk production with defined fat and protein content and separately under non-quota conditions. The following traits are considered: milk yield, fat yield, protein yield, calving interval, age at first service, interval between the first service and conception of heifers and length of productive life. Discounted economic values for these traits also were calculated to investigate time delay effects.

Materials and methods

Performance of Estonian cattle populations

In Estonia, 87.9% of cows are enrolled in an official milk recording programme (Results of Animal Recording in Estonia 2005, Figure 1). Distribution by breeds is in favour of EHF (Figure 2). Since 1995, average milk yield in Estonia has risen about 2400 kg (39%, Figure 3), and population size has decreased by 22%. Between 1998 and 2005, the number of inseminations per pregnancy increased from 1.7 to 2.1 for cows and from 1.4 to 1.6 for heifers (Table 1, Results of Animal Recording in Estonia 1999, 2005, 2006). Calving interval for EHF increased from 407 days in 1998 to 421 days in 2004 (Table 2). Furthermore, 23.5% of cows leaving the herd were culled for fertility problems, 24.6% for udder diseases and 10.7% for metabolic diseases, while only 4.2% of cows were culled due to low productivity. This decline in non-yield traits increases the importance of their consideration in aggregate genotype and index selection so as to avoid further deterioration and/or correct the deterioration that has already occurred.

Currently, estimated breeding values (EBV) for production, conformation and udder health traits for bulls and cows in Estonia are computed by the Animal Recording Centre four times per year (Pentjärv and Uba 2004). Breeding value estimation is carried out separately for the EHF and the Estonian Red breed (ER), using the best linear unbiased predictor (BLUP) test day animal model for production and udder health traits and the BLUP animal model for conformation traits. The EBV for each production trait – milk (kg), fat (kg) and protein (kg) – is an average breeding value of the first, second and third lactations, adjusted by the aver-

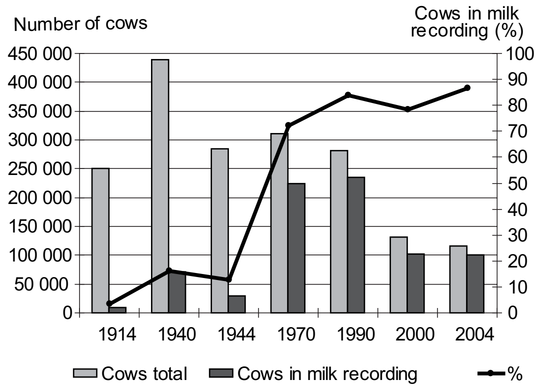

Figure 1. Number of cows in milk recording.

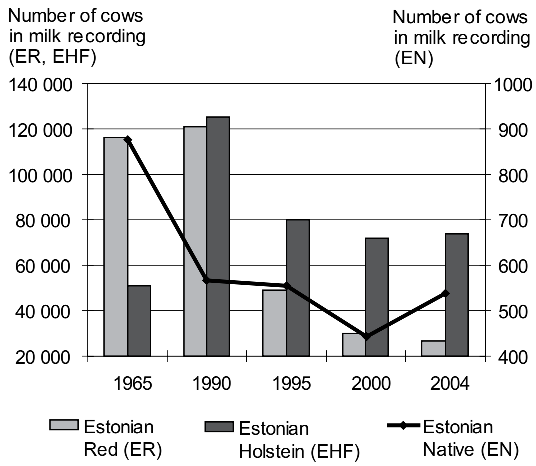

Figure 2. Number of cows in milk recording by breeds.

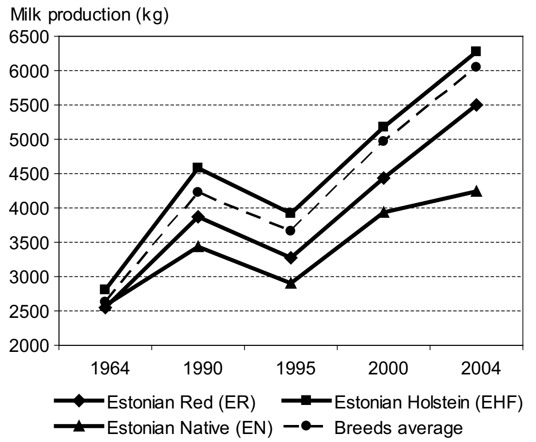

Figure 3. Annual milk yield per cow by breeds.

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Table 1. Artificial insemination and non-return rate of Estonian Holstein cattle (per pregnant cow and heifer).

	Non-return rate 90 days, %				No of inseminations per female			
	1998	1999	2004	2005	1998	1999	2004	2005
Cows	53.0	54.0	51.7	52.2	1.7	1.9	2.1	2.1
Heifers	68.1	68.8	69.4	68.2	1.4	1.5	1.6	1.6
Total	56.3	57.1	56.0	56.1	1.6	1.8	1.9	2.0

Table 2. Distribution of cows by calving interval (days).

	1998	1999	2000	2001	2002	2003	2004	2005
Estonian Holstein	407	407	410	410	411	413	421	420
Estonian Red	401	405	404	402	404	404	410	405
Estonian Native	394	410	408	418	416	400	413	405

age breeding value of the cows born in a defined base year (currently, 1995). Milk production index (SPAV) is expressed as relative breeding value (RBV) with mean of 100 and standard deviation of 12 points for base animals, combining breeding values for milk, fat and protein yield weighted by relative economic values of 0:1:4 for EHF and 0:1:6 for ER (Pentjärv and Uba 2004).

The information source for breeding value estimation of udder health traits is somatic cell count (SCC) in one millilitre of milk, transformed into the somatic cell score (SCS) using the internationally accepted formula SCS = $\log_2$ (SCC/ 100000) + 3 (Pentjärv and Uba 2004).

Udder health index (SSAV) is calculated as the sum of EBVs of the first, second and third lactations with index weights 0.26, 0.37 and 0.37, respectively, and is expressed as RBV (Pentjärv and Uba 2004). For genetic evaluation of conformation traits, data from first lactation cows are used to compute RBVs for 16 linear traits for EHF and 14 linear traits for ER as well as for three general traits. Conformation index (SVAV is expressed as RBV, combining relative breeding values for type, udder and feet by relative economic weights of 0.3:0.5:0.2 for ER and 0.3:0.4:0.3 for EHF (Pentjärv and Uba 2004).

Description of the method

A bio-economic model characterizing the integrated production system of a closed dairy herd was used (Wolfová et al. 2001) for the derivation of trait economic values. The total discounted profit for the herd was calculated as the difference between all revenues and all costs that occurred during the whole life of animals born in the herd in one year, discounted to the birth year of those animals:

$$Z_T^0 = Z^0 S_{StFU}$$

$$Z^0 = \sum_{k \in \Omega} N_k (R_k q_{R_k} - C_k q_{C_k})$$

with Ω={BCa, CCa, FBu, BHei, CHei, CCo1, CCo2+}

where

Z_T^0 - total discounted profit in the population of the given breed (closed herd)

S_{StFU} - number of standard female units (StFU = one cow place occupied during an entire year)

Z^0 - discounted profit per StFU

N_k - average number of animals in category k per StFU

R_k,C_k - average revenues and costs, respectively, per animal of category k

$q_{Rk,}$ q_{Ck} - discounting coefficients for revenues and costs, respectively, in category k

The discounting coefficients for the revenues were calculated by the following formula:

$$q_{R_k} = (1+u)^{-\Delta t_{R_k}}$$

where

Δt_{R_k} - average time interval between the birth of animals of category k and collection time of revenues

u - discount rate (expressed as a fraction).

The discounting coefficients for costs were calculated in the same way and with the same discount rate.

The categories (k) of animals were the following:

BCa - male and female breeding calves during the rearing period from birth to 6 months of age

CCa - calves culled prior to 6 months of age (only calves not suitable for breeding)

FBu - fattening bulls, from 6 months of age to slaughter

BHei - breeding heifers (used for replacement of the cow herd) from the age of 6 months to first calving

CHei - heifers culled before calving (not suitable for breeding or not pregnant)

CCo1 - cows culled during the first lactation

CCo2+ - cows culled in the second and later lactations.

The undiscounted profit (i.e., the average profit per year in the entire balanced system) was calculated by setting u=0 so that all coefficients q took the value of 1.

The discounted economic weight of a given trait i was defined as the partial derivative of the total profit function for the closed herd with respect to the given trait, when all other traits were assumed to take their mean values:

$$a_i = \left\{ \partial Z_T^0 / \partial x_i \big|_{\mathbf{x}=\boldsymbol{\mu}} \right\} / S_{StFU}$$

where

x_i - value of the trait i under consideration

x - vector of the values of all traits (dimension of x = number of traits)

μ - vector of the means of all traits.

Detailed definitions of all evaluated traits and complete description of the method and of indi-

Table 3. Economic analysis of milk and beef production of the Estonian Holstein population.

Derived parameters	
Average length for productive life, days	1640
Age at first calving, days	929
Slaughter age of cows culled in the first lactation, days	1109
Live weight of heifers at first breeding, kg	424
Live weight of heifers at first calving, kg	579
Number of calves born per StFU [1]	0.96
Number of culled calves per StFU	0.13
Number of calves surviving to the end of rearing period per StFU	0.74
Number of fattened bulls per StFU	0.37
Number of heifers with first calving per StFU	0.29
Number of cows culled in 2nd and later lactations per StFU	0.22
Average milk production of cows culled in 1st lactation, kg	4044
Average annual milk production of one cow, kg	5833
Revenues, EEK [2]	
from one culled calf	655
from one fattened bull	3155
from one culled heifer	2645
from one cow culled in 1st lactation	5249
from one cow culled in 2nd or later lactations	6061
from culled calves per StFU	85
from fattened bulls per StFU	1349
from culled heifers per StFU	195
from cows culled in 1st lactation per StFU	377
from annual milk production of cows	18337
Total costs, EEK [2]	
for culled calves per StFU	98
for breeding calves per StFU	1760
for heifers for culling per StFU	396
for calf for culling, EEK per day	12.6
for breeding calf	13.3
per heifer from first breeding to calving	5671
per heifer from ERPC to calving per StFU	3655
for fattened bulls per StFU	1266
for cows culled in 1st lactation per StFU	543
for cows culled in 2nd/later lactation per StFU	13451
of feed for gain per day per cow culled in 2nd or later lactation	0.37
insemination costs per day per cow culled in 2nd or later lactation	1.46
additional feed costs per day for pregnancy in cows	0.24
feed costs for milk of cows culled in 2nd/later lactation per StFU	2598
variable labour costs for cows culled in 2nd/later lactation per StFU	2343
Total profit per StFU, EEK	1245

[1] StFU = Standard Female Unit = one cow place occupied during an entire year

[2] EEK = Estonian Krone

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Table 4. Economic and biological parameters to derive economic values[1].

Economic parameters		Biological parameters	
Price of milk carrier (EEK per kg)	1.75	305-day milk production in 1st lactation (kg)	5539
Price for 1% protein content		Milk protein content (%)	3.24
in milk (EEK)	0.3	Milk fat content (%)	4.09
Price for 1% fat content		Average number of lactations	4
in milk (EEK)	0.1	Maximum number of lactations	10
Price of one insemination (EEK)	300	Age of heifers at 1st service (days)	624
Discounting rate (% per year)	10	Length of pregnancy (days)	278
		Calving interval (days)	410
		Number of inseminations per pregnancy in cows	2.0
		Interval between calving and 1st service in cows (days)	83.3

[1] 1 € = 15.65 EEK.

vidual models used for the calculation of economic weights can be found in Wolfová and Wolf (1996). A computer program developed by those authors was used for the calculations of economic values of the various traits. Scenarios with and without milk quota were investigated.

Farm revenues came from milk production and from production of beef from bull calves and culled cows. Costs were divided into variable costs per cow, fixed costs per cow, and fixed costs per farm. Production and economic data for the Estonian Holstein population, as shown in Table 3, were provided by the joint stock companies. Phenotypic means in Table 4 were taken from the Results of Animal Recording in Estonia (2000).

Definition of functional traits

To simplify derivation of economic values, definition of functional traits and categories of animals are in accordance with the program (Wolfova and Wolf 1996).

Calving interval is the interval in days between successive parturitions. It is assumed that the interval between calving and the ensuing first service and that length of pregnancy are constant. Variation in calving interval is therefore dependent upon variation in the interval between the first service and the service resulting in conception. Thus, calving interval reflects the ability of the cows to conceive and/or the ability of insemination to impregnate.

Age at first service (in days) is defined as the average age of heifers at first insemination. It is assumed that any change in the age at first service will result in the same change in the age at first calving.

Interval between the first and last service of heifers characterises the ability of the heifers to become pregnant and/or the ability of insemination to result in conception. Any change in this interval is expected to yield the same change in the age of heifers at first calving.

Length of productive life is defined as the average number of lactations per cow in the herd. Productive life is understood as functional productive life. That is, cows culled for low milk production are not included in the calculation of the average length of productive life. Such cows form a special category of animals. For simplicity, it is assumed that culling and selection based upon production occur only in the first lactation. When calculating the economic weight for length of productive life, it is assumed that changes in its length result from improvement in the health conditions of cows.

Under constant herd size, increased productive life implies that fewer heifers are needed as replacements. This was accounted for in calculating economic weights by assuming that as productive life increased, more heifers could be culled on milk yield during early first lactation. The resultant increase in selection gain was then taken into account in the calculations.

Results and discussion

Costs, revenues, total profit and phenotypic parameters for EHF and economic and biological parameters used to derive economic values are presented in Tables 3 and 4, respectively. The economic weights for milk, fat yield, protein yield, calving interval, age at first service, interval between the first service and conception of heifers, and length of productive life under the different economic scenarios are shown in Table 5. The economic weights for milk production traits and functional traits were expressed per unit change of each trait and also per standard female unit (one cow place occupied during an entire year). Situations with and without quota and with and without discounting were considered. With no discounting, milk quota influenced the economic weights of milk yield and length of productive life of cows by decreasing both values. There were, however, only minor differences in economic values of interval between first service and conception in heifers, calving interval, and age at first breeding in quota vs. no quota scenarios.

Discounted economic values can be lower or higher than economic values calculated without discounting. If changes in the performance of the given trait influence only revenues or only costs, then the discounted economic values are lower. If, however, a change in performance influences revenues, costs and the discounting coefficient (through changing the time interval (Δt) in the equation for calculating the discounting coefficient), then the discounted economic values will be higher. Differences between discounted and non-discounted economic values are especially large for length of productive life of cows. The differences in economic values increased along with the time interval between birth of improved animals and impact of improved traits on revenues or costs. Ignoring cumulative discounted expressions will lead to bias in assigning relative selection emphasis to traits, resulting in lower than optimal genetic response (Groen et al 1997). Extended productive life of a cow increases profit at farm level by reducing the annual cost of replacements per cow in the herd and by increasing the average herd yield through an increase in the proportion of cows in the higher producing age classes. Extending average productive life of cows reduces the number of replacement heifers to be reared, therefore allowing an increase in the size of the milking herd for a given acreage. Increased productive life of cows might also increase profit due to changes in voluntary culling performed by the farmer (Groen et al. 1997).

Table 5. Economic values for milk and functional traits for the Estonian Holstein population.

Trait	Unit	Economic value (in EEK per unit of given trait and per StFU)			
		without milk quota		with milk quota	
		u = 0	u = 0.10	u = 0	u = 0.10
Milk carrier yield	kg	1.2	0.7	0.9	0.8
Fat yield	kg	–4.8	–2.9	–4.8	–2.9
Protein yield	kg	25.0	15.2	25.0	15.2
Age at first service	days	–0.5	–2.7	–0.6	–2.7
Interval between 1st service and conception in heifers	days	–7.1	–7.3	–7.1	–7.2
Calving interval	days	0.2	–1.8	–0.1	–1.6
Length of productive life	lactations	254.9	51.7	210.0	75.9

StFU = Standard Female Unit = one cow place occupied during an entire year

u = discounting rate per year

Milk quota is an important factor determining the economic value of milk yield. Usually quota on milk yield is adjusted for fat content and the system size is fixed output, meaning that with a change in genetic merit for milk yield, the farmer needs to either reduce the number of cows (Groen et al. 1997) or buy additional quota (Veerkamp et al. 2002). The general approach when deriving economic values for milk production traits in a quota situation has been to reduce the number of cows at the farm (Gibson 1989, Groen 1989, Vargas et al 2002). With milk quota, the economic values for milk production traits (carrier, fat and protein) are decreased as shown by Groen (1989), Gibson (1989) and Veerkamp et al. (2002). Veerkamp et al (2002) derived separate economic values for situations in which milk quota was managed through a reduction in the number of cows (fixed output) or by purchasing additional quota (fixed number of cows). The economic value for fat production was negative in the situation with quota as fixed output whereas the economic value was positive in the situation with purchase of quota. Consequently, the economic value for fat was highly dependent on the cost of purchasing or leasing quota.

To more easily compare the relative economic importance of diverse traits, economic weights often are expressed in terms of each trait's genetic standard deviation. In Table 6, the relative economic weights per genetic standard deviation and additionally the relative economic weights in relation to the most important trait, milk yield, and relative emphasis of milk and functional traits in the aggregate genotype are given. Genetic standard deviations for milk production traits were taken from Pärna and Saveli (1998) and for functional traits from Miesenberger et al. (1998) and Wolfová et al. (2001). The standardised economic weights of fat yield represented 18% and of protein yield 81% of the economic weight for milk yield (Table 6). Economic weights for the interval between the first service and conception of heifers and for length of productive life represented 22 and 28% of the economic weight of milk yield, respectively.

Because cost components depend on other traits in the model and the level of the production system considered, it can only give an idea of costs associated with the derivation of economic values for different traits (Nielsen 2004).

Dairy cattle breeders have developed increasingly accurate indexes to select for profit. According to VanRaden (2002) selection indexes from 11 countries (Germany, France, New Zealand, Netherlands, Canada, Great Britain, Australia, Italy, Denmark, Sweden and Spain) emphasise protein yield over fat yield and nearly all select against milk volume or for increased concentration. Most countries now select for longevity, health, and conformation traits. The derivation of a selection index involves decisions regarding which traits are economically important, calculation of marginal economic gains resulting from improvement for

Table 6. Relative economic values of traits in the Estonian Holstein population, assuming a milk marketing quota and a discount rate of 0.10.

Trait	Unit	Genetic standard deviation	Economic value		
			(in EEK) per genetic standard deviation	relative to milk yield	Relative emphasis (%) in the aggregate genotype
Milk carrier yield	kg	365	328.5	1.00	40
Fat yield	kg	12.6	–60.5	–0.18	–7
Protein yield	kg	10.6	265	0.81	32
Interval between 1st service and conception in heifers	days	10	–71.0	–0.22	–9
Calving interval	days	10	–1.0	0	0
Length of productive life	days	180	92.2	0.28	12

those traits, decisions about traits to be recorded, calculation of phenotypic and genetic parameters related to the complete set of traits, and derivation of index weights based on all this information. Although the method was developed more than 60 years ago, it is still considered superior to all other approaches of multiple trait selection (Sölkner and Fuerst 2002).

Depending on the number of functional traits included in a breeding scheme, the relative importance of production versus functional traits varies from 70:30 to 30:70 (VanRaden 2002), sometimes even more. For the EHF population, the relative weighting for traits representing production vs. traits representing functionality was 79:21. In all of the scenarios examined, selection response in financial terms will come largely from production traits, because genetic parameters favour selection response for fat and protein yields (high heritability, high positive genetic correlation). Model calculations by Sölkner and Fuerst (2002) have shown that without inclusion of functional traits in an index, most of them will deteriorate whereas small positive responses may be expected under selection when they are included in an index.

Conclusions

Although the imposition of a milk quota influenced relative economic values of milk carrier yield and length of productive life of EHF, there were only minor differences in the economic values of functional traits between quota and non-quota scenarios. In our investigation, the most important trait after milk volume was protein yield, reaching 81% of the standardised economic value of milk. Among functional traits that were investigated, length of productive life of cows was most important (28% of the value for milk volume). Discounting had the greatest impact on the economic value of length of productive life. When defining the breeding objective for EHF, the interval between the first service and conception of heifers, and the length of productive life should be included in the breeding goal along with the traits with the highest economic value, milk, fat and protein yield. Relative weightings for production vs. functional traits in aggregate genotype were 79 and 21%, respectively.

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