Do Livestock Producers Use Selection Indices?: Evidence from US Dairy Bull Prices

PRELIMINARY DRAFT: DO NOT CITE OR CIRCULATE

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May 2023

Abstract

I use a hedonic model to estimate how US dairy producers valued the value production, health, and physical traits of over 24,000 dairy bulls sold between 2000 and 2010. To guide producers toward more sustainable cattle, both governments and breed associations suggest incorporating new traits into selection indices. To understand the influence of selection indices on how producers value traits, I compare the valuations derived from a hedonic model to the valuations assumed in the dairy bull selection index Net Merit. In a selection index constructed from the hedonic analysis, I find that physical traits independent of production and health are nearly 50% of the index. In the USDA's selection index, these physical traits make up less than 20%. While the size of the cow factors negatively into the USDA index, body size factors positively into the hedonic index. Since body size is strongly correlated to methane emissions, these findings have significant implications for how breeding decisions may contribute to climate change and whether changing selection indices will meaningfully impact breeding decisions.

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1. Introduction

Dairy farming is an important sector for food security with an unfortunate externality: greenhouse gas emissions. One source of greenhouse gas emissions in dairy farms is “enteric emissions” which is methane that is released when cattle digest food. To curb enteric emissions in dairy, animal scientists have been studying the relationship between genetics and methane emissions. Recent research shows that methane emissions are positively correlated to a cow’s body size, as larger cows are less efficient with feed and produce more emissions per pound of milk (López-Paredes et al. 2020; Moraes et al. 2014). This implies that dairy producers can mitigate their own emissions by breeding for smaller cows which are more efficient at converting feed to milk.

How, from a policy perspective, could we guide the independent breeding decisions of thousands of dairy producers at once? Animal scientists and dairy industry experts often suggest guiding breeding decisions by incorporating emissions into a selection index (González-Recio et al. 2020). A selection index is a weighted average of genetic traits where each weight reflects the importance of the trait in the breeding program (Hazel 1943). The upside of this approach is that dairy farmers only need to pay attention to one number when choosing bulls. In the United States, the USDA introduced the Net Merit selection index which weighs each genetic trait by the amount of profit expected from increasing that trait in the offspring by one unit (VanRaden 2004). The Net Merit weights are updated every 3-4 years to reflect changes in milk and feed prices and updates on research quantifying the costs of diseases and infertility. By including an emission measure into the selection index with a negative weight, the USDA could theoretically guide producers away from choosing less efficient dairy cows.

Whether this is an effective policy depends on the answer to one key question: do selection indices influence how producers value genetic traits? If producers use selection indices to choose bulls, then changing selection indices will change how dairy farmers breed. If producers ignore selection indices, then incorporating new measures into selection indices is an ineffective way to influence producers. To answer this question, I take advantage of the fact that a hedonic model of dairy bull prices can be used to produce a selection index that, like Net Merit, is based on the perceived profitability of different genetic traits. The Ladd and Martin (1976) model shows that in the case of inputs, the relationship between price and the characteristics of that input can tell us about the expected profit of those traits from the firm’s perspective. The upshot of this is that the weights identified from a hedonic model can be directly compared to Net Merit weights because they both measure profitability. While Net Merit weights reflect the estimates of the USDA, hedonic weights reflect what producers perceive as profitable. If a “hedonic selection index” derived from bull prices weighs traits the same way that Net Merit does, this is evidence that Net Merit is an important source of information for dairy farmers.

Using data from 24,000 dairy bulls sold between 2000 and 2010, I find evidence that producers value genetic traits very differently than Net Merit. According to my hedonic model, US dairy producers value physical traits much more than the USDA. In particular, dairy bull prices imply that body size is positively correlated to profits while the Net Merit index assumes the opposite. Physical traits make up less than 20% of Net Merit but are nearly 50% of the index made from the hedonic model. Dairy farmers also weighed health traits less than the USDA's index even as Net Merit increased weights for health traits between 2000 and 2010

The policy implications of these results are that dairy producers prefer larger cows despite the fact that Net Merit assumes larger cows are bad for profits. This divergence in opinions may be explained by dairy farmers interpreting body size as a proxy for production even when production is already directly measured in other genetic traits. Regardless of why this divergence existed from 2000 to 2010, the divergence suggests the simply incorporating new traits into popular selection indices is not an effective strategy for changing how dairy farmers choose genetics. Given producers appear to value larger cows more independent of their milk production ability, it may be especially challenging to encourage US dairy producers to breed for smaller cattle to control methane emissions.

This paper contributes to the literature using hedonic analysis to analyze input markets and to a smaller literature examining the specific case of cattle markets. The first application of the hedonic model to input markets was Ladd and Martin (1976) who called their model the "Input Characteristics Model" (ICM). This model is built off of the linear characteristics model of Lancaster (1966) and Gorman (1980) which models the demand side of the market. The first order condition of the linear characteristic models implies that the price of a good is a linear function of all of its characteristics. The ICM's innovation is recognizing that, when the good is an input for a firm, the weight of each characteristic in that function represents marginal profit instead of marginal utility. Hedonic input models have primarily been applied to agricultural goods such as wheat (Espinosa and Goodwin 1991; Roberts et al. 2022) and beef cattle (Schroeder et al. 1988; Garber et al. 2022) due to their dual roles as both outputs and inputs depending on the place in the supply chain. A smaller literature has used the ICM to analyze dairy bull markets. Richards and Jeffrey (1996) and Schroeder, Espinosa and Goodwin (1992) both use cross-sections of dairy bull prices from Canada and the US to estimate hedonic models using the genetic traits of dairy bulls. Richards and Jeffrey (1996) use their hedonic model to calculate their own selection index and find that it predicts prices better than Canada's most popular selection index, the Lifetime Profit Index.

My approach builds on this literature in two important ways. First, this is one of the few hedonic analyses to use panel data instead of cross-section. Multiple time periods are especially important for this analysis since we would like to see whether changes in Net Merit weights impact how producers value genetic traits. Having multiple years of data over the same products also allows us to distinguish between shifts in preferences over products and shifts in the types of products offered (Banzhaf 2021). Second, my approach is novel in the literature on hedonic pricing in cattle markets because it recognizes the value in comparing hedonic weights to selection indices. While Richards and Jeffrey (1996) recognizes the similarities between hedonic analysis and selection indices, it only focuses on comparing the prediction ability of hedonic analysis to selection indices. In this analysis, I create an alternative selection index using the hedonic model in order to compare how selection indices differ from producers' actual valuations.

2. Theoretical Framework

This theory model is a sketch of the linear characteristics model of Gorman (1980) and Lancaster (1966) combined with the insights of the Input Characteristics Model of Ladd and Martin (1976). The linear characteristics model for an input market assumes that there is a firm that needs k inputs and has a stock of each input z_k. To increase the stock of each input, the firm can only buy bundles of characteristics in the form of B_i. The "linear" in "linear characteristics model" derives from an assumption about how each bundle B_i increases the input stock z_k. The assumption says that z_k is equal to a linear function of the B_i that the firm has purchased:

$$z_k = \sum_{i=1}^{N} x_{ik} B_j \tag{1}$$

where x_{ik} is the amount of characteristic k that B_i delivers. The amount of z_k that the firm has depends on which bundles the firm buys (B_i) and how much of each k the bundle gives (x_{ik}). This assumption rules out the possibility that buying two bundles together somehow delivers more or less than the total k available in each B_i.

The objective of the firm is to maximize profits by buying bundles B_i which each have a price p_i:

$$max_B \quad \pi(z_1, ..., z_k) - \sum_{i=1}^{N} p_i B_i \quad \text{s.t.} \quad z_k = \sum_{i=1}^{N} x_{ik} B_i \quad \forall \quad k. \tag{2}$$

Schroeder, Espinosa and Goodwin (1992) and Richards and Jeffrey (1996) both point out that, in the case of a dairy herd, π is not only the current period's profits but actually the net present value of the future profits of the dairy herd. Regardless of the interpretation of π, the first order conditions for this model are:

$$p_i = \sum_{k=1}^{K} w_k x_{ik} \quad \forall \quad i. \tag{3}$$

$$\text{s.t.} \quad w_k = \frac{\partial \pi}{\partial z_k} \tag{4}$$

Because of the linear form of Equation 1, each bundle's price p_i is a linear function of the amount of each input it delivers (x_{ik}) weighted by w_k, its marginal contribution to the firm's profits ($\frac{\partial \pi}{\partial z_k}$). Dairy farms buy bundles of genetic traits in the form of breeding with bulls that will produce offspring. That offspring will produce milk and impact profits for the duration of its lifetime, so firms choose each bull to maximize the profits of that offspring's lifetime. This model tells us that a bull's price can be described as a linear function of its genetic traits where each weight is that trait's contribution to the lifetime profit of each offspring.

In the United States, one of the most popular selection indices for dairy bulls is Net Merit. Net Merit is maintained and updated by the USDA and selects weights for genetic traits that represent lifetime profit (VanRaden 2004). Calling these weights ω_k, we can represent the Net Merit index this way:

$$NM_i = \sum_{k=1}^{K} \omega_k x_{ik}. \tag{5}$$

Both w_k and ω_k represent the lifetime profit of increasing that trait. Using Equation 3 as a regression model, we can use the prices of dairy bulls on the market and their genetic traits to estimate w_k. The hypothesis we would like to test is essentially whether $w_k = \omega_k$, or whether dairy producers value genetics the same way that Net Merit does. If the weights are close to equal, this is evidence that Net Merit informs how producers value genetic traits. If Net Merit truly changes breeding decisions, we should also see changes in ω_k be followed by changes in w_k.

Another way to examine the relationship between Net Merit and dairy bull prices is using estimates of w_k from prices to construct an alternative selection index (Richards and Jeffrey 1996). Having calculated estimates $\hat{w}_k$, we can construct an alternative Net Merit index, call it "Hedonic Net Merit":

$$HNM_i = \sum_{k=1}^{K} \hat{w}_k x_{ik}. \tag{6}$$

Just like NM_i is used to rank bulls by profitability, we can also use HNM_i to rank bulls using the results of the hedonic model. If HNM_i ranks bulls in a similar way as NM_i over time, this is further evidence that

TABLE 1. Net Merit Index Relative Weights (%)

Category Trait	Net Merit Revisions 2000	 2003	 2006
Production	**61.91**	**55.48**	**46.00**
Milk Volume (lbs)	4.58	0.0	0.0
Fat (lbs)	20.94	22.38	23.42
Protein (lbs)	36.39	33.1	22.58
Health	**23.12**	**30.70**	**40.57**
Productive Life (months)	13.70	10.74	17.61
Somatic Cell Score	-9.42	-9.14	-8.67
Daughter Pregnancy Rate	-	6.55	8.5
Conception Difficulty (male)	-	-2.34	-
Conception Difficulty (female)	-	-1.93	-
Calving Ability	-	-	5.78
Type (Physical)	**14.98**	**13.83**	**13.43**
Udder Composite	6.92	7.09	6.32
Feet and Legs Composite	4.04	3.63	3.31
Body Size Composite	-4.02	-3.11	-3.81

changes to the Net Merit index impact how producer's value traits. The literature on selection indices often uses one of two methods to quantify how much reranking occurs when selection indices change. First, many papers compare the "relative weights" across indices, meaning the percentage emphasis on each trait compared to the whole index (Cunningham and Tauebert 2009). Second, many papers calculate the correlation between the old index and the new index (Bryant et al. 2007; Gonzalez-Recio et al. 2014). The higher the correlation is, the less reranking has occured as a result of the change.

3. Data and Methodology

The National Association of Animal Breeders (NAAB), a trade organization representing all of the major livestock genetics companies selling bulls in the United States, publishes the posted price and genetic traits of all of the bulls being sold by their members. Traits and prices are posted three times a year at the same time that each bull's predicted genetic traits are calculated and posted publicly by the Council on Dairy Cattle Breeding. My data is from the NAAB's published lists from the years 2000 to 2010 and represents over 24,000 dairy bulls, both foreign and domestic, sold during this period.

The Net Merit index was updated in August of three different years during this period: 2000, 2003, and 2006. Table 1 shows how the relative weights of each category of traits has changed in the three updates. The traits in Net Merit can be broadly categorized as production (traits having to do with milk production), health (traits having to do with longevity, sickness, and fertility), and type (traits having to do with the physical characteristics of the animal). At the beginning of this sample, Net Merit put about 60% of its emphasis on production traits versus about 23% on health traits. After the 2006 revision, production was only 46% of the index and health was about 40%. The decline in production is mainly explained by a decline in the weight on protein and milk volume. The increase is health is explained by a greater emphasis on productive life (lifespan) and the inclusion of several fertility traits (daughter pregnancy rate, calving ability, etc.).[1] Physical traits were reduced slightly in the index from 15% and 13%.

The body size composite trait represents the size of the cow and receives a negative weight, meaning it contributes negatively to profit according to the USDA. According to the 2000 revision, "Research studies ... that were funded by Holstein Association USA at the Universities of Wisconsin and Minnesota concluded that cow size should have negative value in an index because milk income already was accounted for but feed costs were not."[2] Though bigger animals produce more milk, an animal with a higher body size composite and the same amount of milk producing ability would cost more feed for the same amount of milk. Since the milk producing ability of larger cattle is already captured by the production traits in Net Merit, the body composite score is negatively correlated to profit. In contrast, both the udder composite and feet and legs composite correspond to more healthy and resilient cattle and therefore have a positive correlation to profit.

Table 2 shows the average trait values during three periods where Net Merit had the same weights.[3] From 2000 to 2009, all production traits increased between 15 and 25%. Productive life has increased 61% and somatic cell score and conception difficulty all decreased (meaning health has improved). Daughter pregnancy rate, a measure of fertility, also improved during this period. All three of they type traits increased over this period, with udder composite having one of the highest growth rate of all the indices: 75%. Despite having a negative weight in Net Merit, the body size index grew 20% from 2000 to 2009.

Figure 1 shows the average bull price in each evaluation period from August 2008 to December 2009. Reflecting the increase in traits, bull prices increased from $16.5 to about $19 (a 15% increase). The Net Merit

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[1] In the 2003 revision, Net Merit included traits which measure calving *difficulty* and have a negative weight in the index. The 2006 revision released calving ability, an index which combines measures of calving *ease* instead of difficulty, and so calving ability has a positive weight in the index.

[2] See the 2000 Net Merit Revision for more details on this calculation.

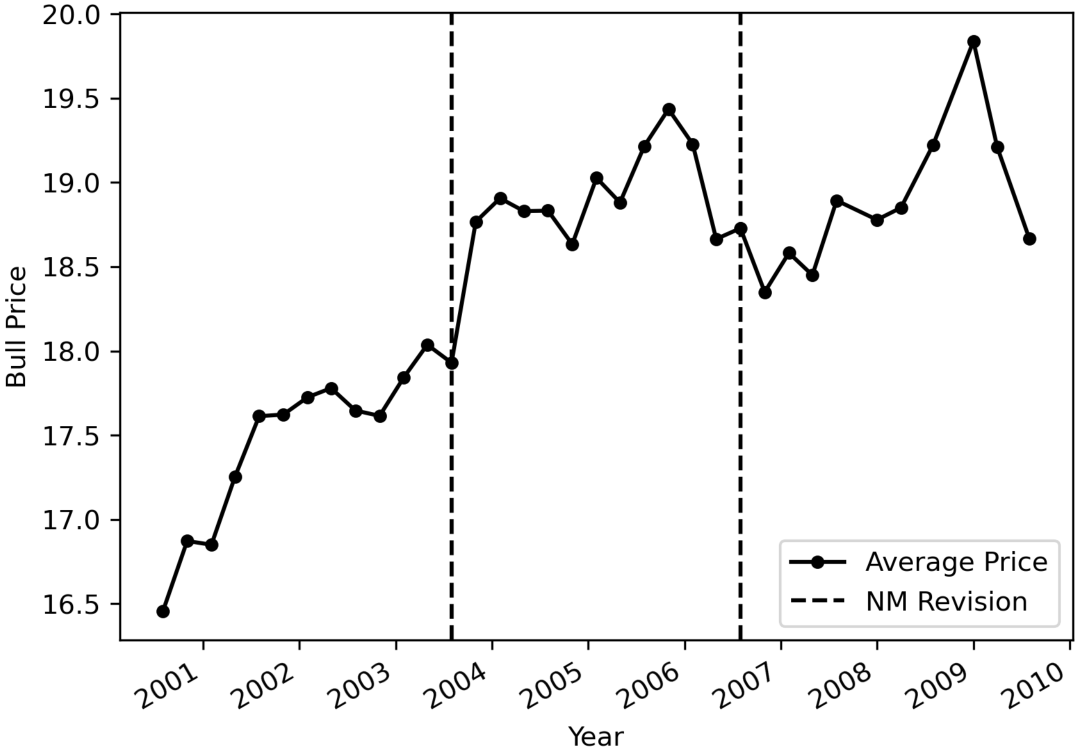
[3] Genetic traits in dairy are by default "base-adjusted," meaning every three or so years the average value is subtracted from every bull's trait value. If a trait is above zero, this means it has more of the trait than that period's average (+50 fat pounds means 50 more pounds than the average bull). If a trait is negative, this means it has less of the trait than the average bull. In order to see genetic improvement in the data, I have undone the base adjustments from 2000 to 2010 so that every trait is relative to the average bull in 2000.

TABLE 2. Net Merit Traits Over Time

Category Trait	Average, 2000-2003	Average, 2003-2006	Average, 2006-2009	% Change, 2000 to 2009
Production				
Milk (lbs)	1,792.72	1,963.03	2,109.09	17.65
Fat (lbs)	57.44	64.97	72.43	26.09
Protein (lbs)	57.54	63.53	67.24	16.85
Health				
Productive Life (months)	1.24	1.37	1.99	61.21
Somatic Cell Score	3.21	3.19	3.15	-1.65
Daughter Pregnancy Rate	-0.2	0.02	-0.04	+
Conception Difficulty (male)	9.22	8.89	9.01	-2.24
Conception Difficulty (female)	7.4	6.55	5.45	-26.32
Calving Ability	-	-	6.04	-
Type (Production)				
Udder Composite	0.91	1.18	1.60	75.54
Feet and Legs Composite	0.89	0.87	1.15	29.92
Body Size Composite	0.74	0.65	0.88	19.51

Note: all trait values are relative to the 2000 average.

FIGURE 1. Bull Price over Time



Note: adjusted to 2000 CPI index.

revisions occurred on August 2003 and August 2006. From the first period in the data until the 2003 revision, the average price climbed from \$16.5 to about \$18. After the 2003 revision, price increased another dollar but then stayed around \$19 for the remainder of the period.

The first order condition of the linear characteristics model, Equation 3, implies that we can use data on prices p_{it} and genetic traits x_{ikt} of each bull i in time t to estimate w_k. My regression model takes the form:

$$p_{it} = \sum_{k=1}^{K} w_k x_{ikt} + \beta Z_{it} + \epsilon_{it}. \tag{7}$$

In order to compare the weights from this model to those of Net Merit, the set of K genetic traits is identical to those used in Net Merit. Comparing hedonic weights w_k to Net Merit weights ω_k is easier if the weights are relative weights that are independent of the units of each trait (interpreted as percentage of emphasis on each trait). Net Merit "relative weights" are calculated by dividing each weight by the standard deviation of the trait (making it in units of standard deviation), taking the absolute value of each trait, and dividing each trait by the sum of those absolute values.[4] To convert w_k weights into relative weights, each trait x_{ikt} is standardized by subtracting the sample mean and dividing by the sample standard deviation. The resulting weights w_k can then be compared even when each trait has a different unit. To get the relative weights, each w_k is divided by the sum of the absolute value of the traits (just as Net Merit does).

In the case that there are omitted variables that correlate to both x_{ikt} and p_{it}, I include a vector of control variables Z_{it} within this regression model. One potential source of endogeneity is the bull's popularity or fame. To control for these impacts, I include the bull's age, the number of daughters in its evaluation (which reflects the amount of farms purchasing that bull), a fixed effect for the stud code (the company that sells the bull), and a fixed effect for the name of the stud farm that the bull comes from.[5] I also include fixed effects for each evaluation period and each bull's birth year.

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[4] See the 2000 Net Merit Revision for more details on this calculation.

[5] In the dairy industry, stud farms are responsible for making crosses of different genetic lines to produce bulls whose semen can be sold on the market. The stud farm's name is almost always contained in the first part of the bull's name. For example, the bull "Braedale Goldwyn" is from Braedale farms and goes by the short name "Goldwyn." Using each bull's full name, we extracted the name of the stud farm. Once a stud farm produces a bull, the farm may sell the rights of distribution to a company that is a member of the NAAB (e.g. ABS, Select Sires, Genex). The name of the company selling the bull's semen is represented by the stud code.

4. Results

I first present the coefficients of the hedonic model (Equation 7) which uses the logarithm of price as an outcome to lessen the influence of any outliers. Each trait is standardized by subtracting the mean and dividing by the standard deviation. Since all the traits are standardized, the relative weights can be obtained by dividing each one by the sum of the absolute value of all of the traits. I estimate the model using three different time periods based on the three Net Merit revisions: 2000-2003, 2003-2006, and 2006-2009. For each of these periods, I compare the relative weights of the hedonic model to the Net Merit weights in each of those revisions. I finish this section by examining the correlations between the Hedonic Net Merit index and the Net Merit index.

Table 3 shows the results of the hedonic model using the logarithm of price as the outcome. Milk production independent of fat and protein, the first variable, is not a significant determinant of price. Fat and protein, however, are positively related to price since this is the metric that most farmers are paid on. Over time, the fat coefficient dips in 2003 but then returns to around its 2000 level. In contrast, the protein coefficient declines from 0.129 in 2000 to 0.07 in 2006. Somatic cell score becomes more negative over time, meaning this health measure is becoming more important to farmers over time. Daughter pregnancy rate and the calving traits were not significant in the first period they were introduced but do become significant in 2006. All three physical traits, udder, feet, and body size, positively impact price. The positive impact of body size is striking because the body size composite receives a negative weight in the Net Merit index for this whole period.

Table 4 shows the relative weights of the Hedonic Net Merit (HNM) and the Net Merit (NM) index in each time period. In 2000, fat and protein were 14 and 22% of the HNM index and 20 and 36% of the NM index. By 2006, fat was still 14% but protein went down to 11% in the HNM. This mirrors protein's shift from 36% to 23% in the NM, indicating that changes in NM may have had an influence on price. While health traits are significant determinants of price, they have a much smaller weight in the HNM index than in NM. Type traits receive the highest weight in the HNM. The udder index is about 27% of the HNM but only about 6% of the NM. Similarly, the feet and legs index is between 11% and 16% of the HNM but only between 3-4% in the NM. Body size receives a positive weight in the HNM and is between 8% and 10% of the index.

Figure 2 shows the shift in emphasis over time visually. In both indices, health traits (represented by the red bar) grow in influence over time. This shift appears to be driven primarily by including more traits in the index around health. HNM has a less than 10% emphasis on health in 2000 but grows to about 20% in 2003 thanks to the inclusion of more traits. Between 2003 and 2006, the HNM index does not weight more towards health even though NM increased its emphasis on health. Physical traits take up close to 50% of the

TABLE 3. Hedonic Model Results

	log(Price)			
	Pooled	2000-2003	2003-2006	2006-2011
Production				
Milk (lbs)	−0.040	0.031	−0.005	0.042
	(0.049)	(0.061)	(0.082)	(0.067)
Fat (lbs)	0.060^{***}	0.084^{***}	0.047	0.098^{***}
	(0.017)	(0.022)	(0.030)	(0.024)
Protein (lbs)	0.102^{***}	0.129^{***}	0.116^{***}	0.077^{***}
	(0.019)	(0.020)	(0.030)	(0.020)
Health				
Productive Life (months)	0.066^{***}	0.045^{***}	0.066^{***}	0.059^{***}
	(0.009)	(0.010)	(0.013)	(0.012)
Somatic Cell Score	-0.017^{***}	−0.004	-0.021^{***}	-0.027^{***}
	(0.005)	(0.008)	(0.005)	(0.005)
Daughter Pregnancy Rate			−0.014	0.019^{**}
			(0.009)	(0.009)
Calving Ability				0.027^{**}
				(0.011)
Conception Difficulty (male)			0.010	
			(0.021)	
Conception Difficulty (female)			−0.009	
			(0.010)	
Type				
Udder Composite	0.110^{***}	0.164^{***}	0.159^{**}	0.188^{***}
	(0.040)	(0.054)	(0.063)	(0.059)
Feet and Legs Composite	0.087^{***}	0.082^{***}	0.099^{***}	0.081^{***}
	(0.008)	(0.010)	(0.012)	(0.009)
Body Size Composite	0.034^{*}	0.045^{*}	0.048^{*}	0.076^{**}
	(0.020)	(0.025)	(0.028)	(0.030)
Observations	24,052	7,723	7,569	7,140
Adjusted R^2	0.596	0.656	0.622	0.643

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

TABLE 4. Relative Weights, Hedonic and Net Merit

	2000-2003		2003-2006		2006-2009	
	Hedonic	Net Merit	Hedonic	Net Merit	Hedonic	Net Merit
Production						
Milk (lbs)	5.365	4.579	-0.877	0.0	6.07	0.0
Fat (lbs)	14.329***	20.94	7.868	22.376	14.115***	23.421
Protein (lbs)	22.07***	36.387	19.549***	33.104	11.178***	22.583
Health						
Productive Life (months)	7.647***	13.699	11.108***	10.736	8.449***	17.609
Somatic Cell Score	-0.702	-9.418	-3.513***	-9.14	-3.884***	-8.675
Daughter Pregnancy Rate			-2.429	6.552	2.692**	8.501
Calving Ability					3.847**	5.783
Conception Difficulty (male)			1.713	-2.34		
Conception Difficulty (female)			-1.56	-1.927		
Type						
Udder Composite	28.01***	6.917	26.614**	7.086	27.111***	6.315
Feet and Legs Composite	14.12***	4.036	16.692***	3.634	11.712***	3.308
Body Size Composite	7.758*	-4.024	8.077*	-3.105	10.942**	-3.805

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

FIGURE 2. Trait Emphasis by Year

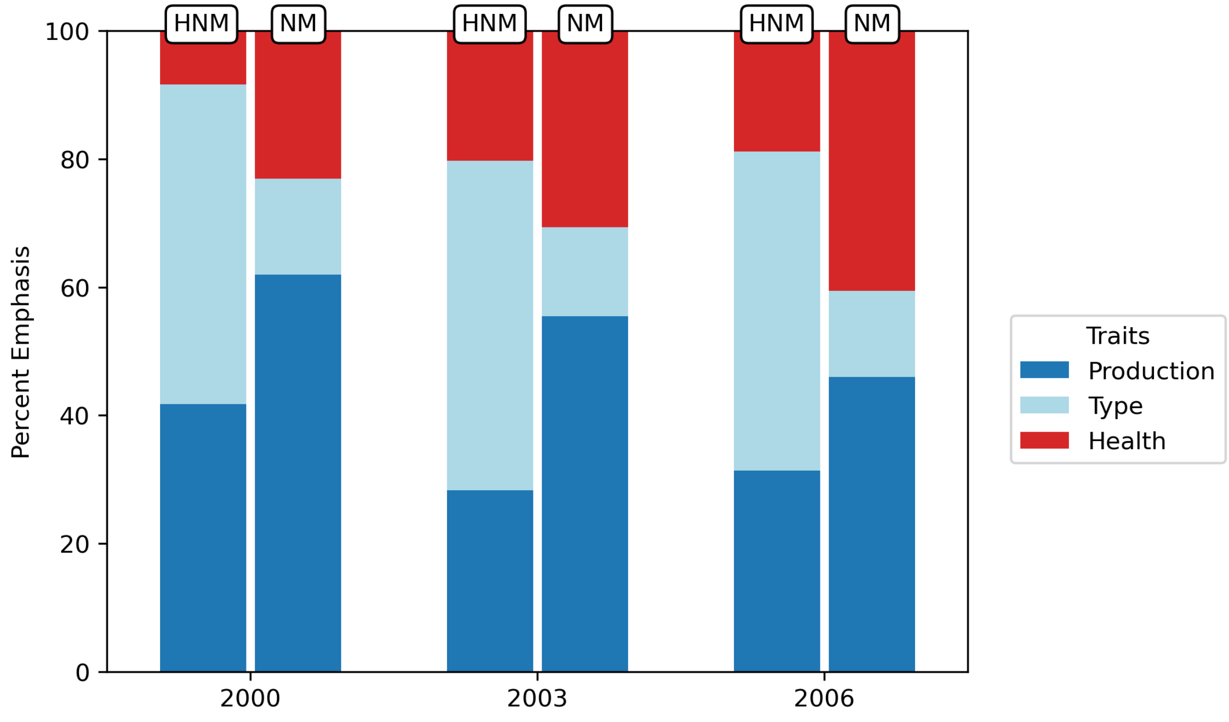
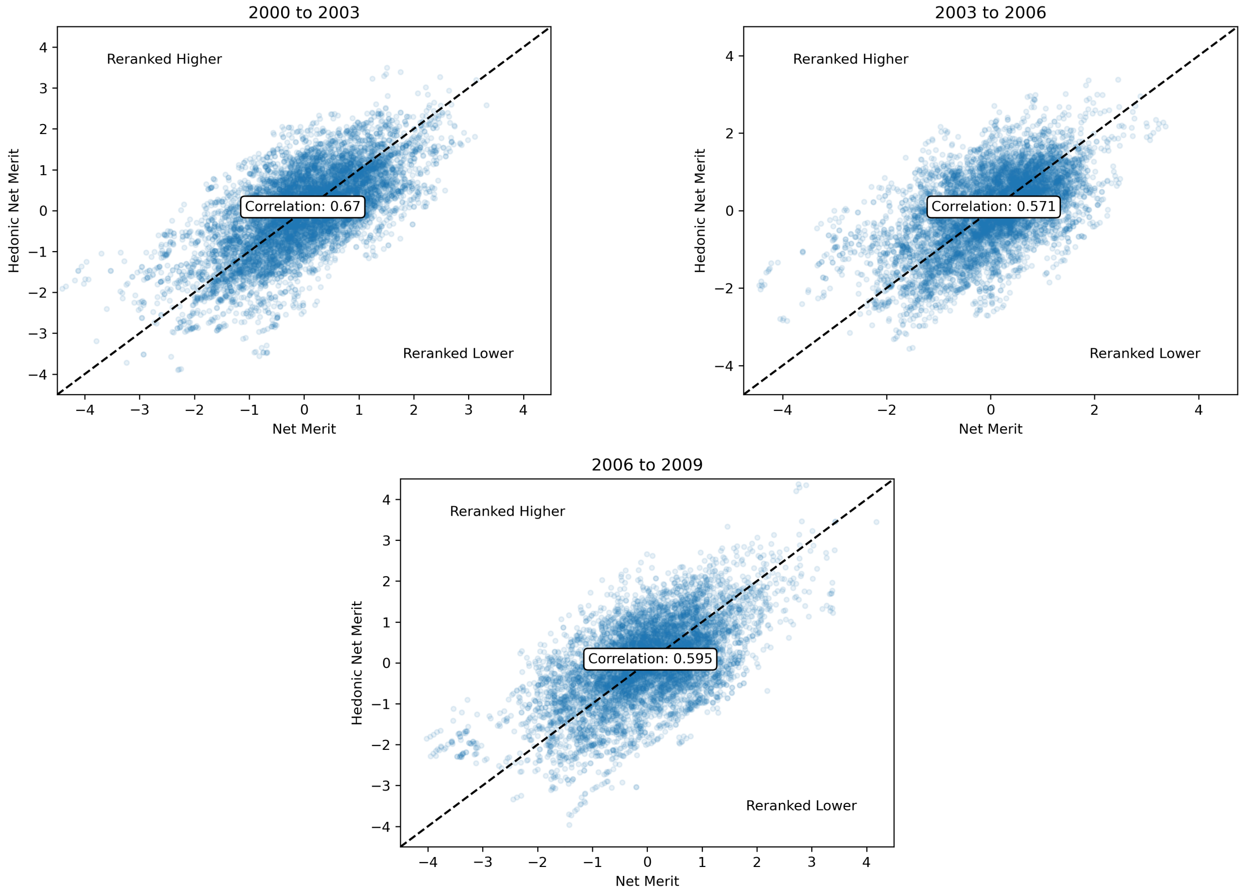


FIGURE 3. Rerankings in Three Periods


2000 to 2003

2003 to 2006

2006 to 2009

HNM but are less than 25% of the NM. As health traits are included into NM, production traits receive less emphasis but type traits go unchanged.

The NM index is used to rank bulls by profitability. How might those rankings change if we used the HNM index instead? One metric for determining the impact of an index on ranking is the correlation between the old index and the new index (Bryant et al. 2007; Schmitt, VanRaden and De Vries 2019). The higher the correlation, the less reranking has occured. Figure 3 shows scatter plots for each time period where the HNM index is on the y-axis and the NM index is on the x-axis. Dots that are the furthest from the dotted line are bulls that experienced the largest changes in their ranking. For all three time periods, the correlation is relatively low: 0.67 from 2000-2003 and around 0.58 for the other periods. As a point of comparison, other reranking studies find the the lowest correlation to be 0.9 (Bryant et al. 2007; Schmitt, VanRaden and De Vries 2019). One driver of these low correlations is the lowest end of the NM index distribution. Many bulls that have a low NM index would be reranked higher under the HNM index. There is still significant dispersion in the middle of the distribution, yet there are a larger number of bulls here that are close to the middle of both indices.

5. Conclusion

The objective of this study was to determine how producer valuation of genetic traits in dairy cattle compares to the Net Merit index. To guide the breeding decisions of dairy producers, a common suggestion is to amend popular selection indices. During this period of study, more health traits were added into Net Merit which took emphasis away from production. Type traits stayed constant. Using a hedonic model, I examined how an alternative index made from the hedonic weights, which I called Hedonic Net Merit, compared to the Net Merit index during this period. I used this comparison to test for how influential Net Merit is in shaping how producers value genetic traits.

I find that dairy farmers appear to value type traits, that is physical traits, much higher than the Net Merit index does. Physical traits are less than 15% of the Net Merit index but are about half of the Hedonic Net Merit index. Despite the fact that body size composite receives a negative weight in Net Merit, it receives a positive weight in HNM. This implies that producers view body size as a profitable genetic trait even for the same level of milk production. There is some evidence that changes in Net Merit are followed by changes in the hedonic coefficients. As more health traits were introduced, they became significant predictors of price (implying that farmers began to value them). As the emphasis on protein decreased, so did the emphasis in the hedonic model.

Since body size composite is correlated with methane emissions, these results have significant policy implications (López-Paredes et al. 2020; Moraes et al. 2014). If producers continue to value body size independent of milk production even when the Net Merit index says otherwise, it is unlikely that introducing more penalties to body size in a revised index will change breeding decisions. This significantly limits the extent to which changes in selection indices will change farmer behavior to mitigate the externalities from dairy.

Why, then, are physical traits so highly valued by farmers even independent of production? One potential explanation could be that farmers trust physical traits as stronger indicators of production and health than production and health traits by themselves. Udder traits are significantly correlated to health outcomes in dairy cattle, as are feet traits. Dairy producers may believe that these traits predict health outcomes better than traits like somatic cell score and productive life. Body size is associated with higher milk production and producers may believe that body size is a better predictor of milk production than the genetic traits for fat and protein yield.

Selection indices are potentially an important tool for changing producer behavior. By updating the weights of selection indices, scientists can help inform producers about the latest research on the benefits and costs of different genetic traits. Yet, our understanding of how livestock producers use these selection indices is still lacking. Most of the work understanding farmer preference for genetic traits in dairy is stated preference work (Martin-Collado et al. 2015). This study complements this work by using bull prices to reveal producer preferences over traits. More revealed preference studies of farmer-adoption of genetics would be an important step in understanding how innovations in genetics can be used to make dairy more sustainable over the long term.

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