STØTTET AF
Mælkeafgiftsfonden

Documentation for Single-Step evaluation of the Temperament breeding value in Holstein

What we have done

The mixed-model hasn't changed compared to the classical pedigree-based evaluation. We have fixed-effects for 5-year herd, which country × month × year the measurement is taken, first calving age, which week of the lactation the measurement was taken at and the classifyer taking the measurement. The herd of the animal (which is different from the 5-year herd) is taken as a random/permanent effect.

Systematic problems with the model was identified. The Legarra-Reverter score is consistently low, see the section below for a more detailed discussion. However, as can also be seen below, the Single-step model brings an improvement in accuracy over a pedigree-based model. Since much investigation was done with little-to-no result, the original model was kept. The following variations of the original model was tried:

- Remove older measurements

  This did not improve the performance of the model

- Identify and remove herds with non-normal phenotype distributions

  This did not improve the performance of the model

- Re-estimate the heritability

  We found a lower heritability (4%) for Holstein than the official figure (8%). This did improve the performance of the model, but did not fix the assymetry between the sire and dame contribution.

- Remove dames of sires

  Since these cows might have recieved a higher level of care than the average cow, this could influence specifically the Legarra-Reverter score. This did improve the model by a small amount, but did not fix the assymmetry betwen the sire and dame contribution.

Legarra-Reverter analysis

The Legarra-Reverter score and accuracy of a pedigree-based model is below:

```
cf1 ~ 1 + cr1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	-0.00810277	0.0659611	-0.12	0.9025	-0.138863	0.122657
cr1	0.82147	0.169423	4.85	<1e-05	0.485609	1.15733

```
Accuracy: 0.424
```

and below is the Legarra-Reverter score and accuracy of the Single-step model:

```
f1 ~ 1 + r1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.0320307	0.0408733	0.78	0.4350	-0.0489958	0.113057
r1	0.826847	0.0875154	9.45	<1e-15	0.653358	1.00034

```
Accuracy: 0.674
```

The low Legarra-Reverter score can be explained by an asymmetric influence of the dams and sires breeding value on the predicted breeding value:

```
f1 ~ 1 + sire_r1 + dame_r1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	-0.0178463	0.0617122	-0.29	0.7730	-0.140197	0.104504
sire_r1	0.524525	0.0925805	5.67	<1e-06	0.340975	0.708075
dame_r1	0.423209	0.0960004	4.41	<1e-04	0.232878	0.613539

Interbull test

An Interbull GEBV test was performed. The result is given below:

```
Summary statistics on candidate bulls (CB) and test bulls (TB)
---------------------------------------------------------------
Trait Variable         N      Mean       Std      Min      Max
---------------------------------------------------------------
tem   CB EBV         304   105.476    13.323    66.37   150.35
tem   TB EBV         304   105.476    13.323    66.37   150.35
tem   TB  VAL(y)     304   105.102    16.020    54.65   148.75 Base=Current
tem   TB GEBV(x1)    304   107.295    11.056    61.74   133.80 Base=Old
tem   TB EBVr(x2)    304   106.235     8.767    67.31   135.82 Base=Old
tem   TB GEBV(x1)    304   107.458    11.031    62.00   133.90 Base=Current
tem   TB EBVr(x2)    304   106.401     8.748    67.56   135.92 Base=Current
tem   BB  EBVf(y)   5147    96.060    17.065     6.17   161.82
tem   BB  EBVr(x)   5147    96.055    17.092     5.88   161.71
tem   BB  EBV(wt)   5147    50.791    35.356     0.00    99.00
---------------------------------------------------------------
tem : DGEBV : Base 0.25: Full = 0.40 + 0.998 * Red  b1 1.037 ~> 1.040  b2 0.954 ~> 0.957

Details of GEBVtest calculations
tem i_est = (105.476 - 105.476) / 13.323 = 0.000

After Base adjustments:
tem p=1.000 x= 0.000 i=0.000 k=0.000 R2b=0.529 E(b1)=1.000 b1=1.040
tem b1-E(b1) =  0.040  t =  0.76  bootstrap P(b=Eb) = 45.8  b1_test = Pass
tem R2_1 = 52.9  R2_2 = 28.5   bootstrap P(R2_gain) =100.0  R2_test = Pass
tem   stat_test=Y   pract_test=Y   bio_test=Y   R2_test=Y   overall = PASS

2025-Jan-27 14:32:52 gebvtest_202409.py: finished tem

2025-Jan-27 14:32:52 gebvtest_202409.py: end
```

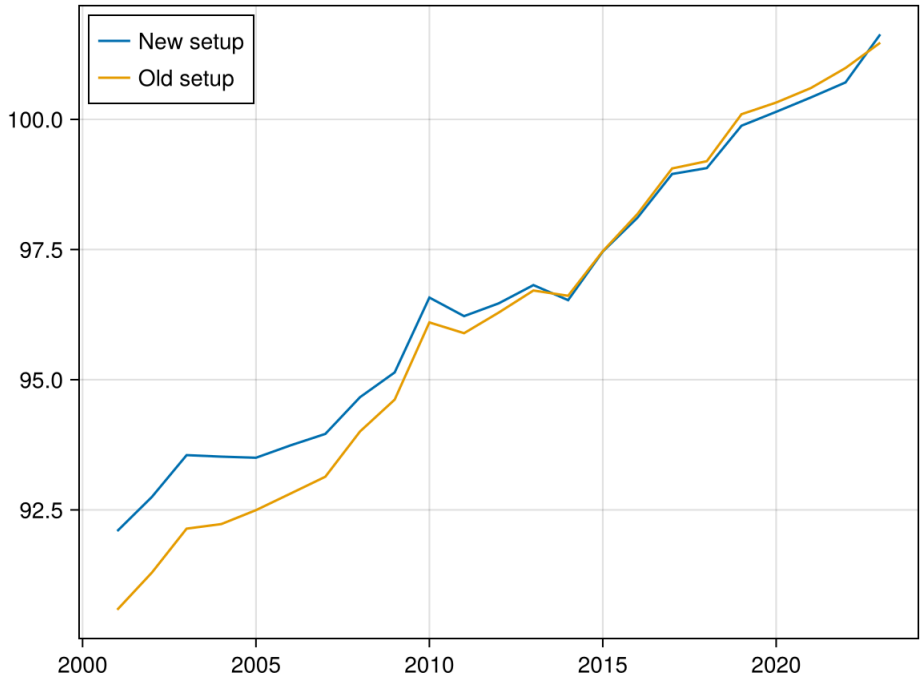
Comparison of old vs new pedigree-based EBV

The existing breeding values are a mix of pedigree-based breeding values for non-genotyped animals and two-step breeding values for genotyped animals. To see if we alter the breeding values imply by moving to a new setup, we compare pedigree-based breeding values computed using the new setup to the old pedigree-based values.

Comparison of old vs new pedigree-based EBV, all animals

23×7 DataFrame

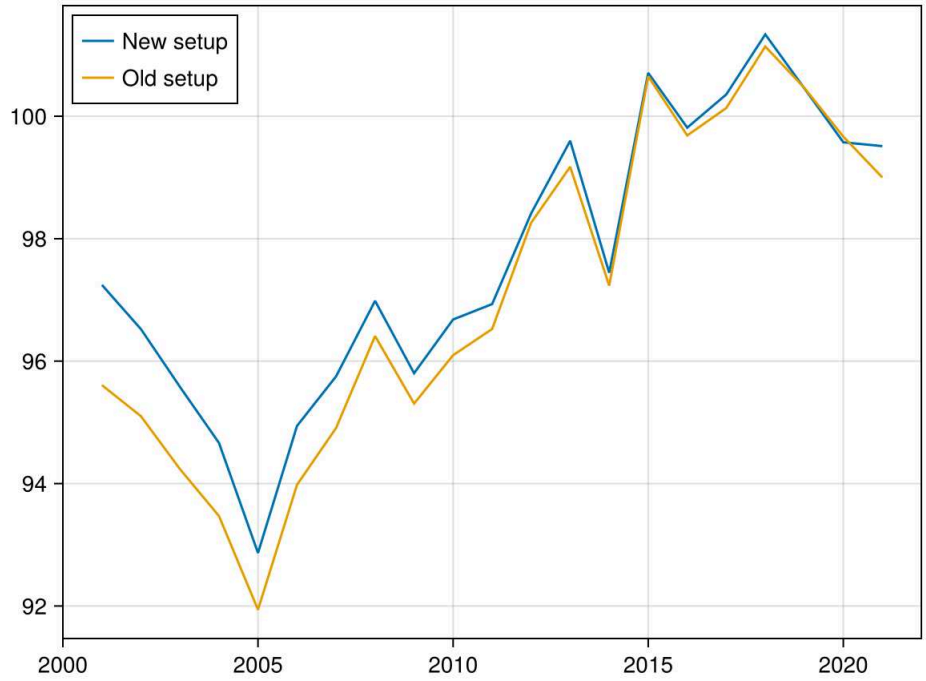
Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	92.0933	90.5825	7.66811	7.5851	0.982071	77175
2	2002	92.7502	91.2971	7.30903	7.24675	0.981651	77165
3	2003	93.5517	92.1401	7.18002	7.13894	0.981149	79523
4	2004	93.5226	92.2279	7.36787	7.31979	0.982106	78529
5	2005	93.5017	92.4955	7.8232	7.66639	0.972198	76301
6	2006	93.7404	92.8153	7.15859	7.06037	0.967474	78916
7	2007	93.9595	93.1371	6.85326	6.79708	0.963051	72775
8	2008	94.6647	94.0064	6.70574	6.70053	0.960952	71601
9	2009	95.1408	94.6185	6.49899	6.4987	0.953722	70053
10	2010	96.5779	96.1004	6.79794	6.8408	0.971163	66900
11	2011	96.2214	95.8937	6.457	6.49551	0.96643	64954
12	2012	96.4672	96.2904	6.18562	6.28899	0.962006	63167
13	2013	96.8174	96.7133	6.07985	6.14412	0.962099	62765
14	2014	96.5281	96.6118	6.24796	6.26556	0.965874	62122
15	2015	97.4615	97.4681	6.44218	6.46328	0.973772	58619
16	2016	98.1114	98.1833	5.70238	5.7524	0.970233	58079
17	2017	98.9513	99.0579	5.39257	5.40658	0.96916	56428
18	2018	99.0647	99.1968	5.87711	5.87823	0.978546	55277
19	2019	99.8783	100.099	5.73829	5.75225	0.97965	51940
20	2020	100.146	100.323	5.67924	5.64879	0.982024	49668
21	2021	100.421	100.602	5.48153	5.46362	0.985667	43891
22	2022	100.71	100.987	5.36143	5.30228	0.98521	26831
23	2023	101.632	101.472	4.37129	4.17808	0.964143	36



Comparison of old vs new pedigree-based EBV, nordic AI bulls

21×7 DataFrame

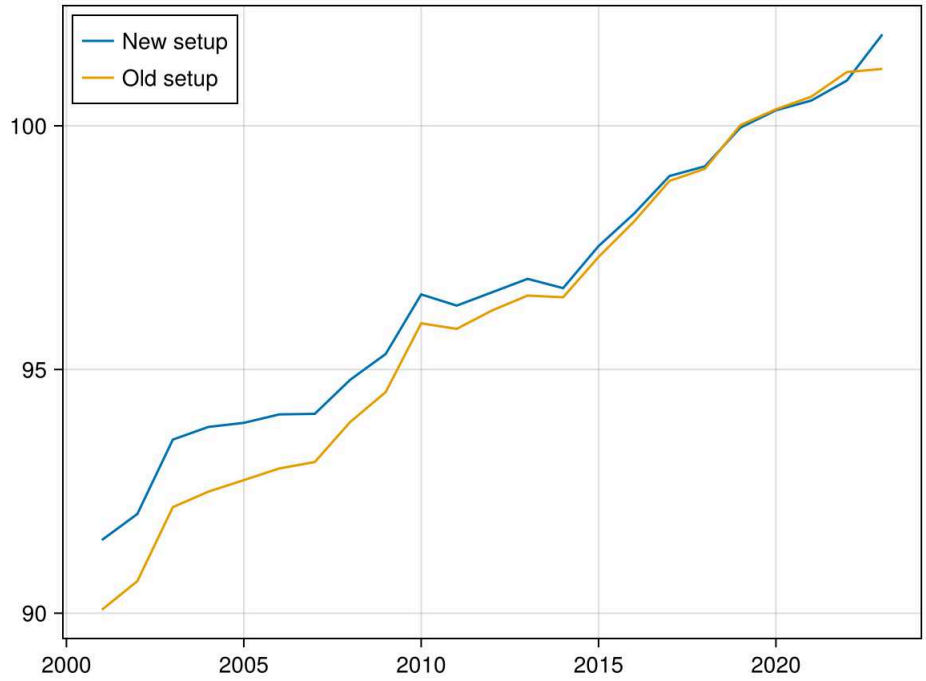
Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	97.2449	95.6076	8.98519	8.84477	0.993182	446
2	2002	96.5224	95.1002	9.3337	9.23401	0.993847	409
3	2003	95.5794	94.2363	9.84009	9.64775	0.996041	364
4	2004	94.6639	93.4701	10.0805	9.95051	0.995196	368
5	2005	92.8665	91.9389	9.63203	9.49251	0.99387	360
6	2006	94.9423	93.98	8.75718	8.77937	0.99424	400
7	2007	95.7502	94.9068	8.86041	8.81719	0.994023	311
8	2008	96.9845	96.4093	8.24909	8.20489	0.990299	259
9	2009	95.8025	95.3064	8.73199	8.67158	0.986524	235
10	2010	96.6804	96.0969	8.38347	8.23039	0.989003	196
11	2011	96.9318	96.525	9.46467	9.22803	0.994621	160
12	2012	98.4135	98.2599	8.33219	8.25105	0.989906	177
13	2013	99.599	99.1742	7.6209	7.66773	0.990122	155
14	2014	97.4439	97.2333	9.03615	9.05607	0.992115	120
15	2015	100.708	100.651	8.3922	8.24445	0.990234	86
16	2016	99.8142	99.6866	10.0036	9.89369	0.993877	67
17	2017	100.356	100.134	8.83551	8.78859	0.991421	67
18	2018	101.337	101.139	8.4927	8.61682	0.990548	79
19	2019	100.457	100.464	8.42595	8.41636	0.993301	56
20	2020	99.5746	99.6667	5.55633	5.38451	0.96198	48
21	2021	99.5117	99.0	NaN	NaN	NaN	1



Comparison of old vs new pedigree-based EBV, nordic cows with phenotype

23×7 DataFrame

Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	91.5007	90.0703	7.88025	7.72584	0.98856	40721
2	2002	92.0364	90.658	7.73049	7.58599	0.989086	41386
3	2003	93.5618	92.1754	7.30091	7.1768	0.989143	45325
4	2004	93.8209	92.4934	7.48045	7.36543	0.990403	46837
5	2005	93.9052	92.73	7.85086	7.7169	0.991031	48294
6	2006	94.0785	92.9693	7.27395	7.18634	0.990218	52203
7	2007	94.0896	93.1014	7.08151	7.00855	0.98997	48435
8	2008	94.7895	93.9234	6.94378	6.92257	0.989739	46891
9	2009	95.3182	94.5365	6.70141	6.70145	0.989417	45432
10	2010	96.54	95.9468	7.06079	7.04085	0.989508	42201
11	2011	96.3102	95.833	6.8369	6.81506	0.989267	39037
12	2012	96.5842	96.2121	6.56014	6.59627	0.987599	35086
13	2013	96.8593	96.5166	6.48896	6.50959	0.987365	34357
14	2014	96.6688	96.4807	6.67392	6.68044	0.98765	32843
15	2015	97.5313	97.3079	6.89975	6.87775	0.988474	30738
16	2016	98.1961	98.0353	6.26145	6.28505	0.98714	30713
17	2017	98.969	98.8689	5.92562	5.91875	0.985411	30407
18	2018	99.1694	99.1182	6.3395	6.33642	0.988533	30277
19	2019	99.9628	100.015	6.24748	6.26646	0.988822	28302
20	2020	100.318	100.338	6.23202	6.2265	0.989142	26349
21	2021	100.519	100.598	6.18747	6.17719	0.991568	19107
22	2022	100.928	101.103	6.2236	6.1674	0.992225	9007
23	2023	101.875	101.167	4.75411	4.38662	0.953148	12



As can be seen, our new setup does not replicate exactly the same breeding values when run without genotypical data. We attribute this mainly to a difference in raw data. The old setup has 1677527 measured phenotypes as of February 2025. Our setup uses only 1120876 of these measurements. The reason is twofold: first, we only accept pure-bred Holstein cows to contribute phenotypes. This was an early descision made for all Single-step models to only allow pure-bred data in the evaluation, as we believe this will increase accuracy. This brings the amount of measurements down to 1134005 measurements. Finally, we remove dames of sires, which brings us down to the final number.

From this point onwards, we will compare the new genomic Single-step breeding values to the old pedigree-based values. The reader should thus keep in mind, that there will be a base-level difference stemming from the different dataset.

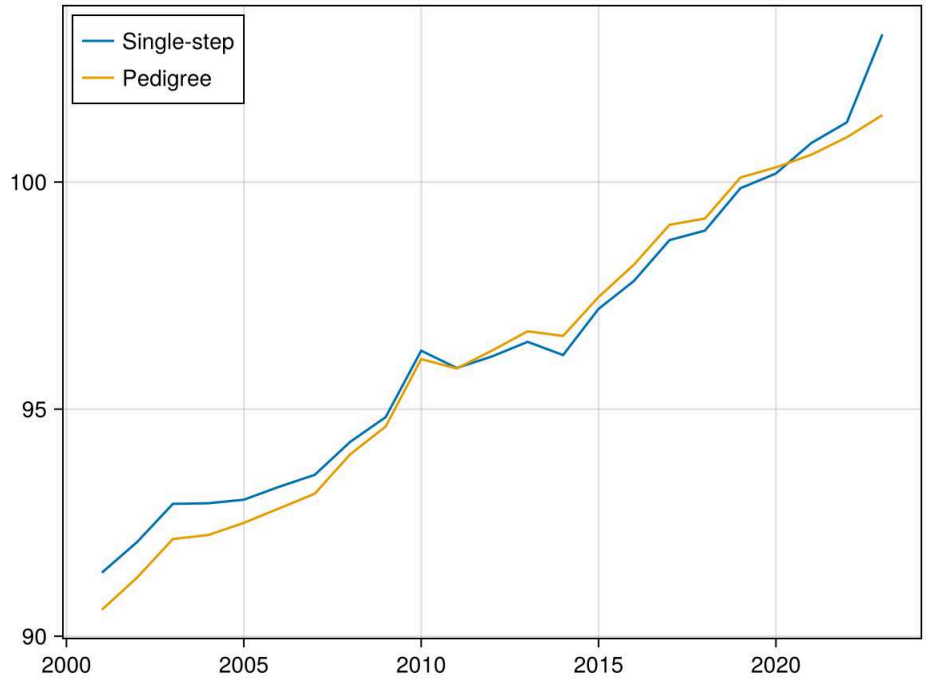
Comparison of genetic Single-step to old breeding values

We now explore how the breeding values copmuted using the full genomic Single-step setup compares to the existing breeding values.

Comparison of genetic Single-step vs old pedigree-based, all animals

23×7 DataFrame

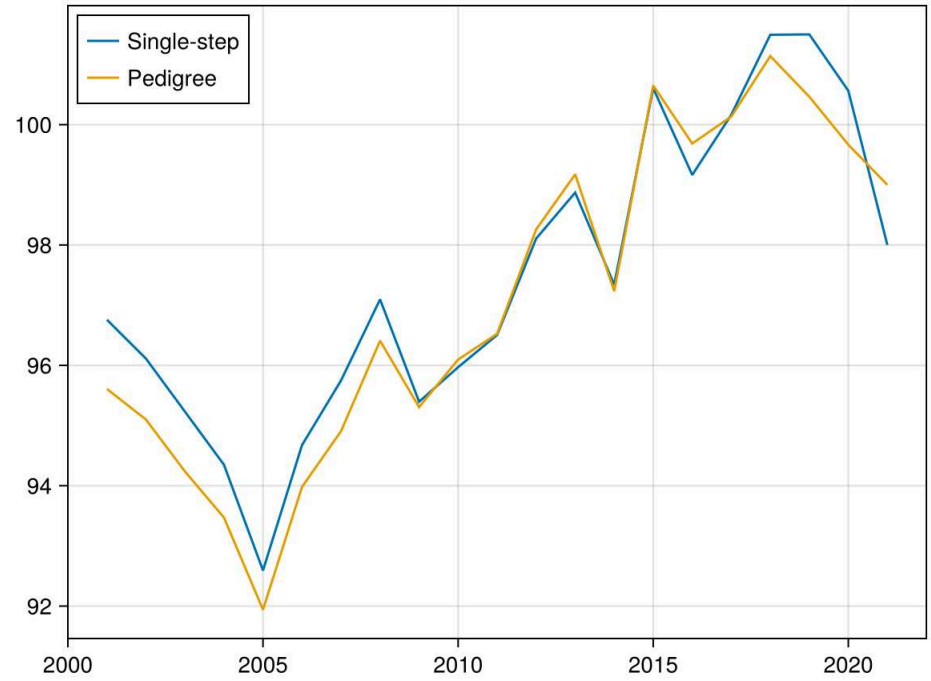
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	91.3987	90.5825	7.56469	7.5851	0.982043	77175
2	2002	92.0792	91.2971	7.20437	7.24675	0.98145	77165
3	2003	92.9137	92.1401	7.0832	7.13894	0.979966	79523
4	2004	92.9272	92.2279	7.26326	7.31979	0.979803	78529
5	2005	93.0053	92.4955	7.65681	7.66639	0.975308	76301
6	2006	93.2911	92.8153	7.01948	7.06037	0.968945	78916
7	2007	93.5534	93.1371	6.72957	6.79708	0.96364	72775
8	2008	94.2796	94.0064	6.59055	6.70053	0.958371	71601
9	2009	94.8241	94.6185	6.42895	6.4987	0.943202	70053
10	2010	96.2863	96.1004	6.83757	6.8408	0.948051	66900
11	2011	95.9055	95.8937	6.55537	6.49551	0.925856	64954
12	2012	96.1608	96.2904	6.41574	6.28899	0.905182	63167
13	2013	96.4809	96.7133	6.41627	6.14412	0.884017	62765
14	2014	96.1899	96.6118	6.65852	6.26556	0.877934	62122
15	2015	97.2065	97.4681	6.91874	6.46328	0.875376	58619
16	2016	97.8232	98.1833	6.38723	5.7524	0.825935	58079
17	2017	98.7206	99.0579	6.33724	5.40658	0.787202	56428
18	2018	98.9309	99.1968	6.8702	5.87823	0.793342	55277
19	2019	99.8637	100.099	6.90827	5.75225	0.773156	51940
20	2020	100.188	100.323	6.96084	5.64879	0.751636	49668
21	2021	100.86	100.602	6.95751	5.46362	0.729833	43891
22	2022	101.315	100.987	6.97318	5.30228	0.697109	26831
23	2023	103.25	101.472	6.06336	4.17808	0.604233	36



Comparison of genetic Single-step vs old pedigree-based, nordic AI bulls

21×7 DataFrame

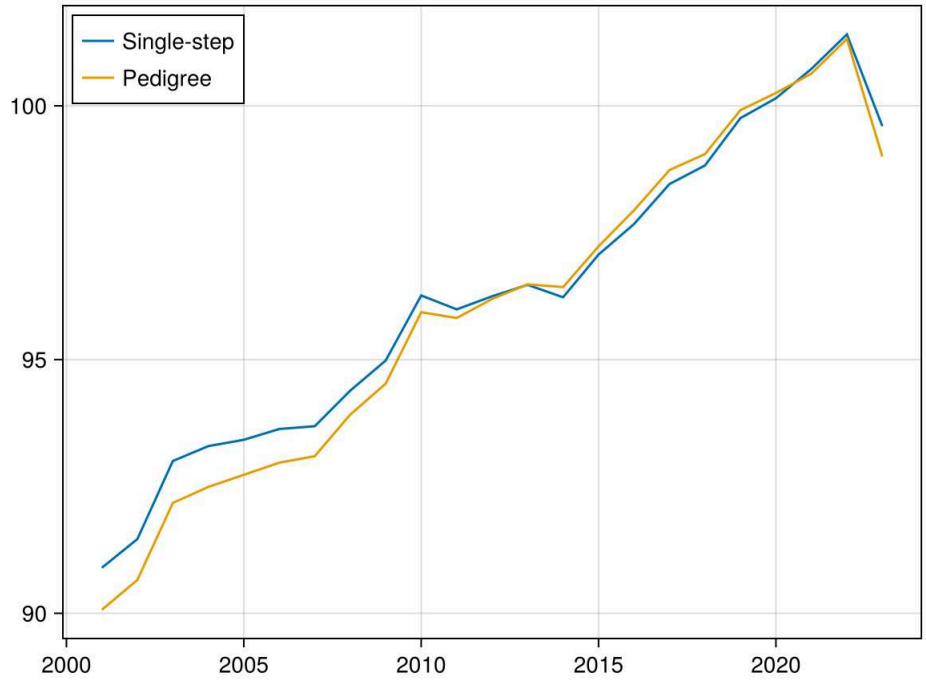
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	96.7578	95.6076	8.83479	8.84477	0.990411	446
2	2002	96.1125	95.1002	9.19303	9.23401	0.991652	409
3	2003	95.2308	94.2363	9.71872	9.64775	0.993093	364
4	2004	94.3478	93.4701	9.89447	9.95051	0.990503	368
5	2005	92.5917	91.9389	9.43486	9.49251	0.987926	360
6	2006	94.675	93.98	8.54499	8.77937	0.983382	400
7	2007	95.7492	94.9068	8.77357	8.81719	0.976092	311
8	2008	97.0965	96.4093	8.42168	8.20489	0.968489	259
9	2009	95.3957	95.3064	9.12267	8.67158	0.895698	235
10	2010	95.9694	96.0969	9.00422	8.23039	0.874645	196
11	2011	96.5062	96.525	9.31422	9.22803	0.91169	160
12	2012	98.1073	98.2599	9.04439	8.25105	0.891043	177
13	2013	98.871	99.1742	7.35528	7.66773	0.898581	155
14	2014	97.3417	97.2333	9.14633	9.05607	0.912719	120
15	2015	100.605	100.651	7.76005	8.24445	0.952385	86
16	2016	99.1642	99.6866	9.8467	9.89369	0.948632	67
17	2017	100.164	100.134	9.41726	8.78859	0.943994	67
18	2018	101.494	101.139	8.98271	8.61682	0.925992	79
19	2019	101.5	100.464	9.04936	8.41636	0.887574	56
20	2020	100.562	99.6667	6.80083	5.38451	0.727442	48
21	2021	98.0	99.0	NaN	NaN	NaN	1



Comparison of genetic Single-step vs old pedigree-based, nordic phenotyped cows without genotypes

23×7 DataFrame

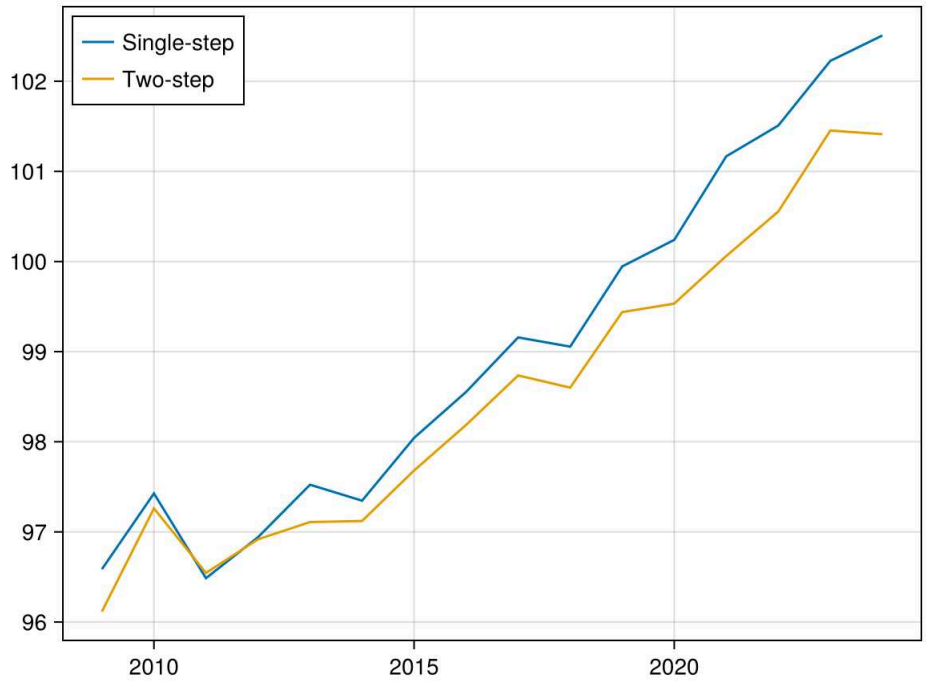
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	90.8979	90.0703	7.75465	7.72584	0.987689	40721
2	2002	91.463	90.6576	7.58998	7.58565	0.988197	41383
3	2003	93.0018	92.175	7.18565	7.177	0.98737	45317
4	2004	93.2949	92.4912	7.34682	7.36457	0.988388	46813
5	2005	93.4195	92.7291	7.71037	7.71649	0.988766	48258
6	2006	93.6324	92.9681	7.1487	7.18608	0.986539	52133
7	2007	93.6868	93.0963	6.95576	7.0056	0.984957	48345
8	2008	94.3882	93.9156	6.82551	6.9197	0.982991	46767
9	2009	94.9814	94.5263	6.59685	6.69645	0.979678	45123
10	2010	96.2629	95.9329	6.99966	7.03851	0.979169	41804
11	2011	95.9896	95.8186	6.76442	6.80185	0.971336	38063
12	2012	96.2471	96.1947	6.54055	6.56622	0.965189	33626
13	2013	96.4724	96.4819	6.41713	6.46117	0.96203	31814
14	2014	96.2277	96.429	6.63251	6.62633	0.956193	29777
15	2015	97.0695	97.2318	6.85755	6.82622	0.955916	26865
16	2016	97.6707	97.9413	6.27876	6.25479	0.944522	24546
17	2017	98.4594	98.7348	6.05225	5.95362	0.94005	21536
18	2018	98.8252	99.0496	6.31482	6.26582	0.94731	18665
19	2019	99.7584	99.9159	6.27533	6.22076	0.94758	16576
20	2020	100.15	100.254	6.20372	6.13287	0.948029	13442
21	2021	100.728	100.636	6.19027	6.22662	0.955147	9732
22	2022	101.408	101.319	6.01486	6.18635	0.945346	4700
23	2023	99.6	99.0	5.41295	5.33854	0.951648	5



Comparison of genetic Single-step vs old two-step, all animals

16×7 DataFrame

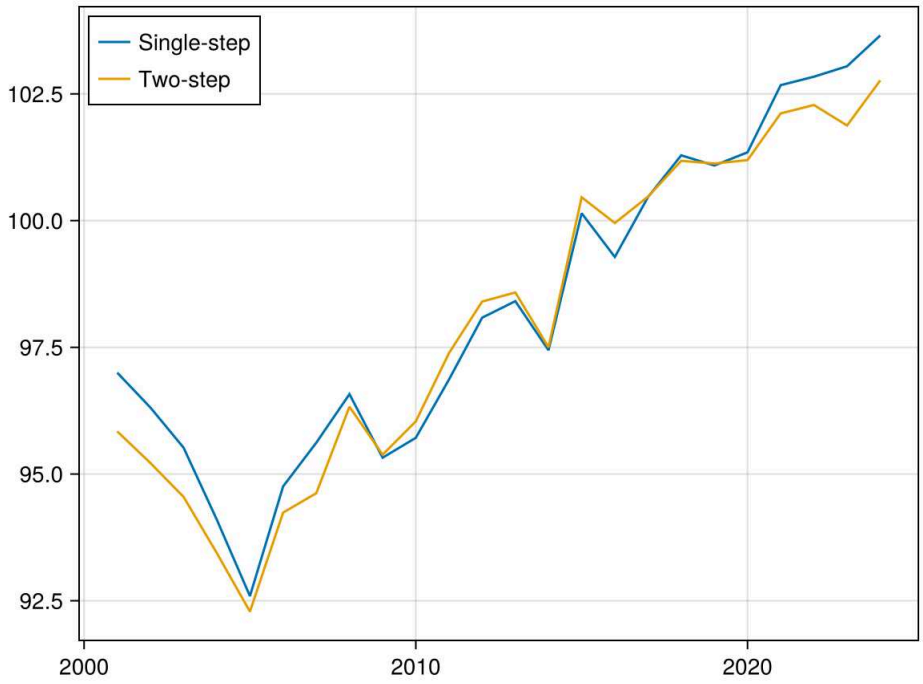
Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	96.5861	96.1154	8.49478	8.13013	0.675056	3223
2	2010	97.4262	97.2608	8.30774	8.22394	0.685685	4092
3	2011	96.4862	96.5448	8.32512	7.94027	0.711023	6394
4	2012	96.941	96.9176	8.2459	7.90429	0.739932	8968
5	2013	97.5231	97.1089	8.03874	7.63832	0.783388	13032
6	2014	97.3463	97.1211	8.25626	7.87711	0.818692	15441
7	2015	98.0429	97.6813	8.19341	7.77005	0.819334	18068
8	2016	98.5533	98.1869	7.64139	7.24658	0.786139	26667
9	2017	99.1575	98.7358	7.29813	6.92373	0.805881	37055
10	2018	99.0552	98.6001	7.64496	7.20927	0.834049	49434
11	2019	99.9455	99.4387	7.51043	7.09117	0.827897	55290
12	2020	100.24	99.5327	7.43911	6.97329	0.827902	65882
13	2021	101.167	100.061	7.32685	6.92081	0.772177	74500
14	2022	101.509	100.554	7.21756	6.99268	0.771289	84094
15	2023	102.226	101.453	7.26534	6.98815	0.802171	84985
16	2024	102.508	101.412	7.01649	6.60451	0.776263	60271



Comparison of genetic Single-step vs old two-step, nordic AI bulls with genotypes

24×7 DataFrame

Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	97.0	95.8413	8.69125	8.35767	0.864563	265
2	2002	96.3113	95.2169	9.24613	8.96135	0.883291	302
3	2003	95.5194	94.5492	9.73229	9.40757	0.910372	258
4	2004	94.1015	93.4431	9.97182	9.55684	0.898882	325
5	2005	92.5925	92.2859	9.50599	9.07031	0.891277	346
6	2006	94.7563	94.2395	8.31728	8.21713	0.846457	394
7	2007	95.6181	94.6223	8.60317	8.85057	0.885312	343
8	2008	96.5757	96.3279	8.35125	8.28628	0.861041	304
9	2009	95.3231	95.3831	8.87038	8.30563	0.921778	294
10	2010	95.7149	96.0394	8.79625	8.53252	0.908981	249
11	2011	96.8646	97.3863	9.12234	8.84476	0.928968	192
12	2012	98.0849	98.4031	9.21787	8.76381	0.935499	212
13	2013	98.4104	98.5825	7.87322	7.26909	0.913909	173
14	2014	97.4427	97.5007	9.16529	9.11575	0.951316	131
15	2015	100.144	100.46	7.86605	7.72444	0.95035	97
16	2016	99.2821	99.9521	9.59694	9.65959	0.960569	78
17	2017	100.465	100.473	9.49862	8.8431	0.947655	71
18	2018	101.287	101.18	8.77879	8.34725	0.944296	94
19	2019	101.087	101.126	9.46004	8.67531	0.952279	69
20	2020	101.347	101.194	6.77643	6.68671	0.915501	72
21	2021	102.672	102.115	8.14429	6.79725	0.896833	58
22	2022	102.839	102.281	7.03433	6.57761	0.840606	62
23	2023	103.045	101.876	8.20934	7.87874	0.884162	44
24	2024	103.652	102.765	6.18362	7.28816	0.794116	23

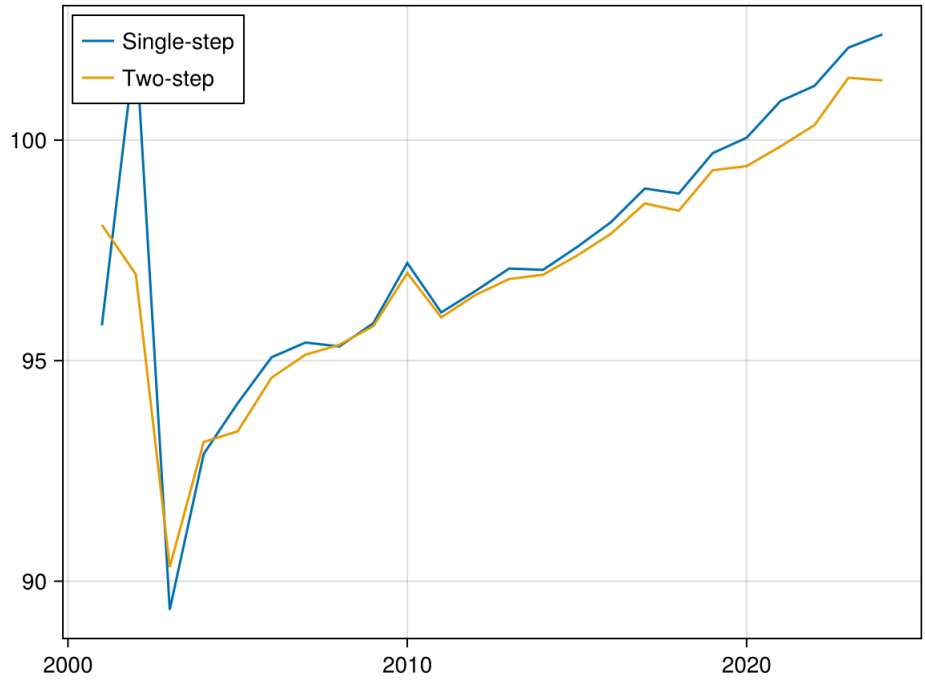


Comparison of genetic Single-step vs old two-step, nordic genotyped cows without phenotypes

24×7 DataFrame

Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	95.8	98.0766	8.16701	9.8332	0.952261	5
2	2002	102.25	96.9583	6.60177	8.80546	0.809693	4
3	2003	89.3529	90.3214	8.75315	9.89154	0.664222	17
4	2004	92.8842	93.157	7.87112	8.96888	0.793593	95
5	2005	94.0335	93.3971	8.70677	9.0192	0.820895	179
6	2006	95.0767	94.6143	7.93562	8.1485	0.724513	300
7	2007	95.4106	95.1352	7.23035	8.1351	0.701678	397
8	2008	95.3224	95.3608	6.511	7.89384	0.693306	735
9	2009	95.8495	95.7835	8.43618	7.86064	0.856081	950
10	2010	97.2145	96.9854	8.22315	7.92508	0.873441	1394
11	2011	96.0929	95.9816	7.99558	7.48968	0.860009	2466
12	2012	96.5758	96.486	8.07276	7.67626	0.851397	3942
13	2013	97.0882	96.8503	7.8255	7.40272	0.858359	6612
14	2014	97.0586	96.9483	8.12599	7.64716	0.871229	7741
15	2015	97.5746	97.3807	8.08327	7.60343	0.867789	9769
16	2016	98.1376	97.8758	7.47804	7.05096	0.848461	14860
17	2017	98.9019	98.5635	7.19219	6.80668	0.84129	22483
18	2018	98.789	98.3993	7.56756	7.12292	0.859744	32120

19	2019	99.7045	99.3166	7.40462	6.98655	0.857222	37503
20	2020	100.054	99.41	7.35488	6.85808	0.85627	46157
21	2021	100.887	99.8582	7.29777	6.81684	0.854014	53673
22	2022	101.23	100.341	7.2434	6.92557	0.852068	66983
23	2023	102.097	101.413	7.29953	7.00803	0.845257	76541
24	2024	102.397	101.353	7.03431	6.61029	0.815055	54743



Single-step genetic trend for all animals by birthyear

All animals:

24×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	91.5272	7.54398	82838
2	2002	92.1308	7.16565	82490
3	2003	92.9587	7.0501	85230
4	2004	92.9741	7.25348	84212
5	2005	93.0944	7.58839	81869
6	2006	93.3875	7.02931	84905
7	2007	93.6984	6.70728	78641
8	2008	94.3984	6.56406	78316
9	2009	94.9113	6.49202	77063
10	2010	96.3629	6.84549	75432
11	2011	95.988	6.63712	75460
12	2012	96.2585	6.49403	75913
13	2013	96.6533	6.5134	78052
14	2014	96.3934	6.76468	81000
15	2015	97.4065	6.97738	80632
16	2016	98.0387	6.50322	86584
17	2017	98.8887	6.43856	88905
18	2018	98.9872	6.92305	93982
19	2019	99.9303	6.92119	94628
20	2020	100.286	6.98459	98550
21	2021	101.191	7.01551	102033
22	2022	101.565	7.04526	99860
23	2023	102.255	7.25223	86950
24	2024	102.52	7.01639	61206

Nordic AI bulls:

24×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	96.7629	8.82552	447
2	2002	96.1359	9.16467	412
3	2003	95.2308	9.71872	364
4	2004	94.3478	9.89447	368
5	2005	92.6288	9.44814	361
6	2006	94.7076	8.51949	407
7	2007	95.5648	8.58438	347
8	2008	96.6287	8.33797	307
9	2009	95.4067	8.87942	300
10	2010	95.7149	8.79625	249
11	2011	96.8497	9.10089	193

12	2012	98.0849	9.21787	212
13	2013	98.4253	7.85288	174
14	2014	97.4427	9.16529	131
15	2015	100.061	7.86853	98
16	2016	99.2821	9.59694	78
17	2017	100.465	9.49862	71
18	2018	101.287	8.77879	94
19	2019	101.087	9.46004	69
20	2020	101.347	6.77643	72
21	2021	102.492	8.19245	59
22	2022	102.839	7.03433	62
23	2023	103.045	8.20934	44
24	2024	103.652	6.18362	23

Nordic cows w/ phenotype:

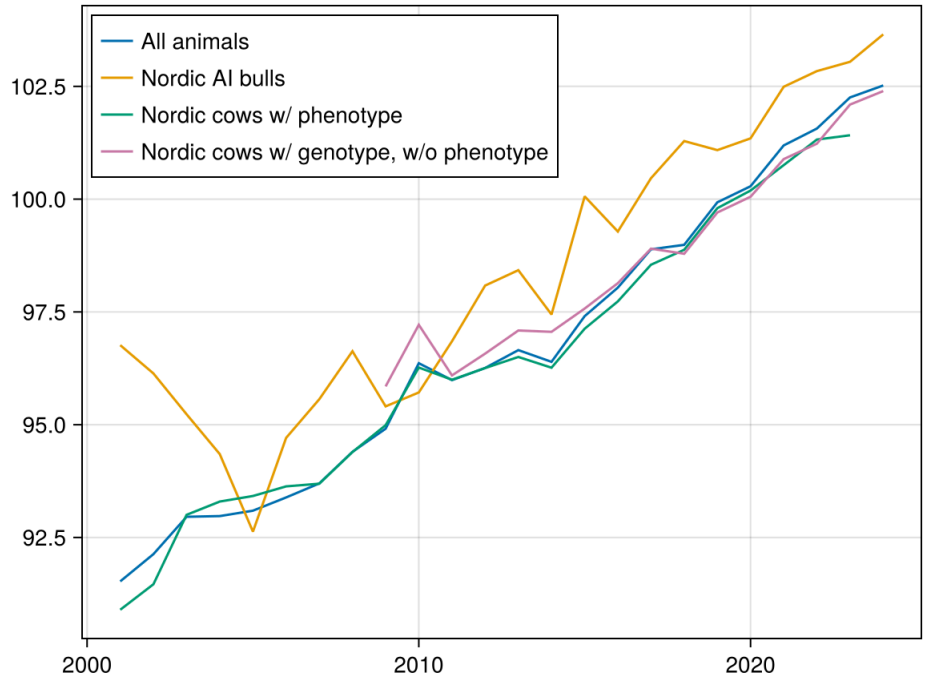
23×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	90.8979	7.75465	40721
2	2002	91.4632	7.59017	41386
3	2003	93.0022	7.18541	45325
4	2004	93.2966	7.34742	46837
5	2005	93.4197	7.71103	48294
6	2006	93.633	7.14911	52203
7	2007	93.6918	6.95814	48435
8	2008	94.394	6.82758	46891
9	2009	94.9897	6.61094	45432
10	2010	96.2668	7.01508	42201
11	2011	95.9971	6.80264	39037
12	2012	96.2556	6.63381	35086
13	2013	96.5016	6.59297	34357
14	2014	96.2638	6.82475	32843
15	2015	97.1278	7.0762	30738
16	2016	97.7334	6.62012	30713
17	2017	98.547	6.46965	30407
18	2018	98.8776	6.95265	30277
19	2019	99.8004	6.96046	28302
20	2020	100.191	7.03431	26349
21	2021	100.754	6.96684	19107
22	2022	101.321	6.83427	9007
23	2023	101.417	4.75697	12

Nordic cows w/ genotype, w/o phenotype:

16×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2009	95.8495	8.43618	950
2	2010	97.2145	8.22315	1394
3	2011	96.0929	7.99558	2466
4	2012	96.5758	8.07276	3942
5	2013	97.0882	7.8255	6612
6	2014	97.0586	8.12599	7741
7	2015	97.5746	8.08327	9769
8	2016	98.1376	7.47804	14860
9	2017	98.9019	7.19219	22483
10	2018	98.789	7.56756	32120
11	2019	99.7045	7.40462	37503
12	2020	100.053	7.35476	46159
13	2021	100.887	7.29777	53673
14	2022	101.23	7.24335	66984
15	2023	102.097	7.29949	76542
16	2024	102.396	7.03441	54746

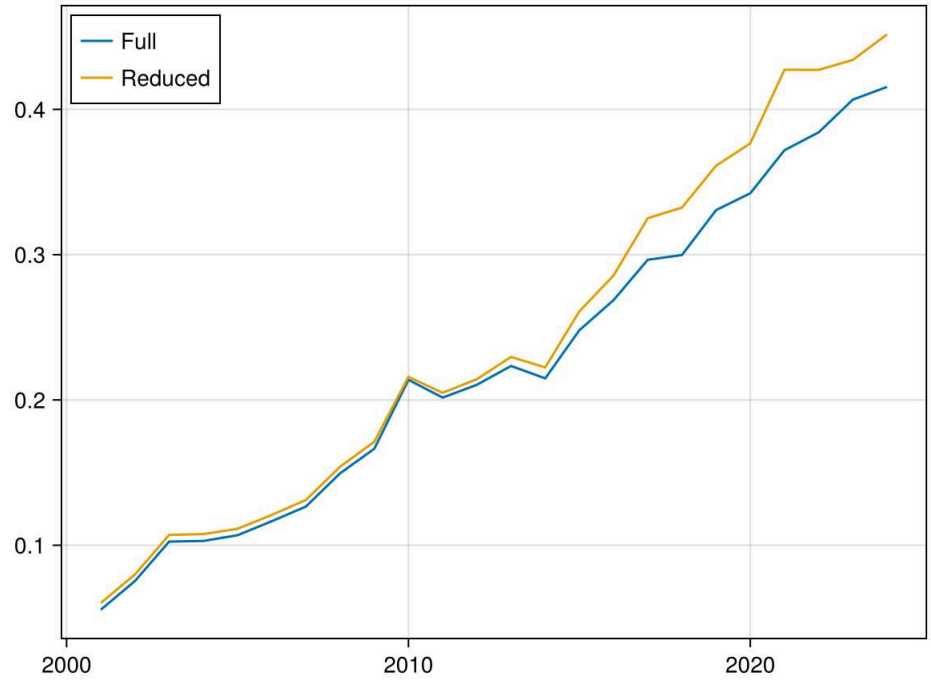


Genetic trend, full vs. reduced evaluation

The Legarra-Reverter test suggests that the breeding value estimated for candidate bulls is higher than their true breeding value. A reduced evaluation was performed, where performances of daughter of bulls born after 2016 were removed from the dataset. Below is an analysis of the difference between the full evaluation and this reduced evaluation.

24×7 DataFrame

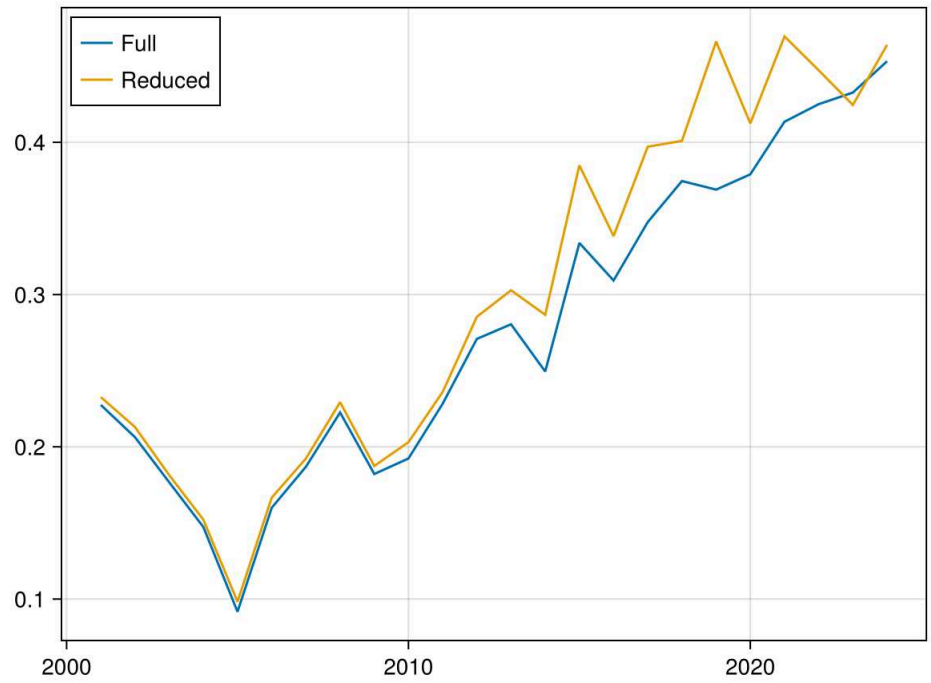
Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	0.0556227	0.0602788	0.246738	0.246692	0.999781	82838
2	2002	0.0754127	0.0799483	0.234339	0.234528	0.999625	82490
3	2003	0.102508	0.107123	0.230504	0.230683	0.999574	85230
4	2004	0.102963	0.107696	0.237224	0.237248	0.999408	84212
5	2005	0.106919	0.111341	0.248177	0.24878	0.99916	81869
6	2006	0.116531	0.120897	0.229889	0.230625	0.998669	84905
7	2007	0.126642	0.131184	0.219321	0.220067	0.998147	78641
8	2008	0.149531	0.154084	0.214634	0.215428	0.997145	78316
9	2009	0.166395	0.17122	0.212285	0.212614	0.993943	77063
10	2010	0.213833	0.215873	0.22385	0.224632	0.990962	75432
11	2011	0.201626	0.204925	0.217017	0.216958	0.987462	75460
12	2012	0.21042	0.214312	0.212282	0.212597	0.983189	75913
13	2013	0.22339	0.229602	0.213009	0.213309	0.979581	78052
14	2014	0.214844	0.222377	0.221216	0.22202	0.97727	81000
15	2015	0.248004	0.260979	0.228197	0.228255	0.974821	80632
16	2016	0.268718	0.285671	0.212603	0.211185	0.962597	86584
17	2017	0.296481	0.325089	0.210578	0.208222	0.952604	88905
18	2018	0.299743	0.332411	0.226442	0.222407	0.950197	93982
19	2019	0.330668	0.361222	0.226359	0.213335	0.883754	94628
20	2020	0.342265	0.376615	0.228434	0.204274	0.823473	98550
21	2021	0.371892	0.42726	0.22943	0.200798	0.813053	102033
22	2022	0.384165	0.427177	0.230452	0.20274	0.833132	99860
23	2023	0.406719	0.434046	0.237216	0.217324	0.871286	86950
24	2024	0.415438	0.451572	0.229518	0.216307	0.880009	61206



Genetic trend, full vs. reduced evaluation, nordic AI bulls

24×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	0.227542	0.232668	0.288502	0.288902	0.999798	447
2	2002	0.206335	0.213007	0.299504	0.299703	0.999717	412
3	2003	0.176751	0.181453	0.31703	0.316783	0.999649	364
4	2004	0.147351	0.152158	0.323814	0.322442	0.999431	368
5	2005	0.09168	0.0982515	0.308768	0.308313	0.998969	361
6	2006	0.159966	0.166598	0.278847	0.279808	0.998335	407
7	2007	0.186892	0.192323	0.280977	0.280612	0.997657	347
8	2008	0.222543	0.229299	0.273119	0.270939	0.9965	307
9	2009	0.182154	0.187428	0.289841	0.29192	0.983844	300
10	2010	0.192345	0.203078	0.287835	0.277387	0.981168	249
11	2011	0.228281	0.235981	0.297752	0.297117	0.983422	193
12	2012	0.270872	0.285377	0.301977	0.302724	0.983248	212
13	2013	0.280492	0.302821	0.257	0.25461	0.977147	174
14	2014	0.249486	0.286714	0.299027	0.308503	0.982597	131
15	2015	0.33388	0.384908	0.257768	0.258289	0.970848	98
16	2016	0.309252	0.338412	0.314086	0.306982	0.909847	78
17	2017	0.347609	0.397116	0.310619	0.262378	0.790522	71
18	2018	0.374558	0.400975	0.28811	0.221284	0.761541	94
19	2019	0.368925	0.466183	0.309829	0.233916	0.832774	69
20	2020	0.378987	0.41245	0.223484	0.191243	0.694078	72
21	2021	0.413528	0.469569	0.269721	0.238233	0.888666	59
22	2022	0.42507	0.447292	0.229687	0.199958	0.867432	62
23	2023	0.432689	0.424545	0.268463	0.247137	0.9194	44
24	2024	0.453236	0.464028	0.203183	0.193803	0.868123	23



Number of above bulls moving by a certain number of index points

32×2 DataFrame

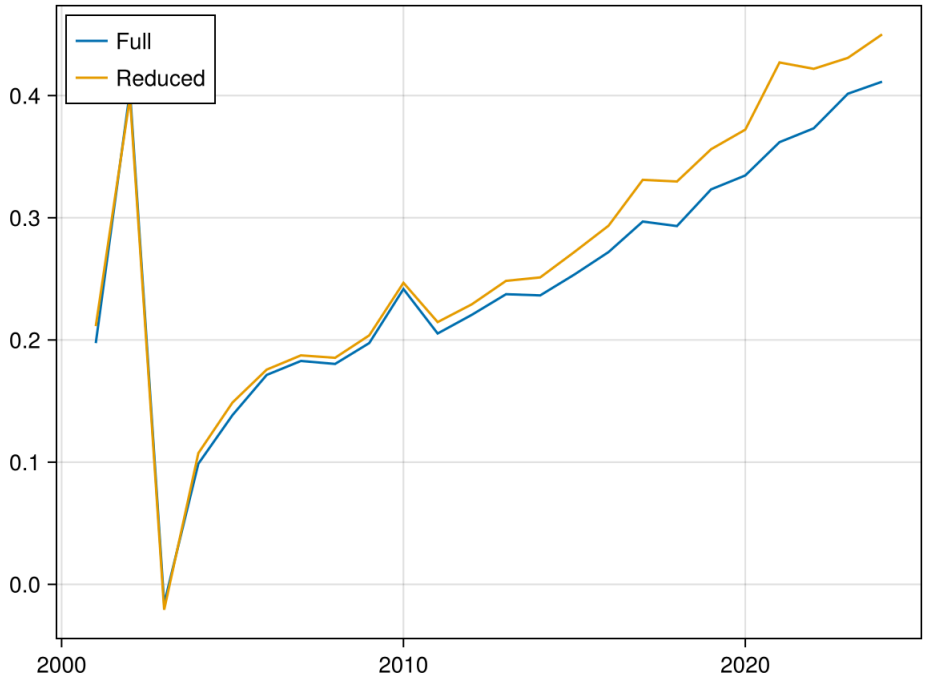
Row	diff	n
	Int64	Int64
1	-21	1
2	-16	2
3	-15	3
4	-14	2
5	-13	1
6	-12	4
7	-11	2
8	-10	5
9	-9	14
10	-8	17
11	-7	10
12	-6	18
13	-5	46
14	-4	47
15	-3	109
16	-2	259
17	-1	491
18	0	2764
19	1	736
20	2	192
21	3	99
22	4	50
23	5	23
24	6	12
25	7	11
26	8	8
27	9	6
28	10	6
29	11	1
30	12	1
31	13	1
32	16	1

Genetic trend, full vs. reduced evaluation, nordic genotyped cows without phenotype

24×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	0.197432	0.211309	0.266156	0.267921	0.996364	5
2	2002	0.403782	0.398707	0.21604	0.206618	0.997363	4
3	2003	-0.0157644	-0.0207706	0.28424	0.282343	0.996027	17
4	2004	0.0987164	0.107362	0.257616	0.250253	0.994003	95
5	2005	0.138543	0.148839	0.283128	0.286482	0.991956	179
6	2006	0.1714	0.175758	0.258951	0.261883	0.992963	300
7	2007	0.182823	0.187391	0.236745	0.237562	0.990604	397
8	2008	0.180395	0.185415	0.212933	0.211078	0.987935	735

9	2009	0.197483	0.203773	0.275785	0.271622	0.968175	950
10	2010	0.241685	0.246764	0.268889	0.265682	0.968668	1394
11	2011	0.205305	0.214644	0.261558	0.258107	0.967749	2466
12	2012	0.220596	0.229196	0.263928	0.26228	0.96592	3942
13	2013	0.23745	0.248372	0.255935	0.252083	0.962275	6612
14	2014	0.236474	0.251197	0.265828	0.262844	0.963164	7741
15	2015	0.253563	0.272009	0.264316	0.259389	0.961011	9769
16	2016	0.271961	0.293535	0.244613	0.23985	0.951775	14860
17	2017	0.296904	0.331043	0.235359	0.231474	0.946226	22483
18	2018	0.293222	0.329682	0.247564	0.242488	0.946968	32120
19	2019	0.32327	0.35613	0.242216	0.230418	0.892147	37503
20	2020	0.334657	0.372141	0.24058	0.219355	0.838997	46159
21	2021	0.361886	0.427093	0.238721	0.212365	0.824457	53673
22	2022	0.373194	0.421901	0.236919	0.209697	0.835703	66984
23	2023	0.401523	0.430854	0.238757	0.218111	0.870453	76542
24	2024	0.411377	0.450064	0.230126	0.217408	0.879859	54746



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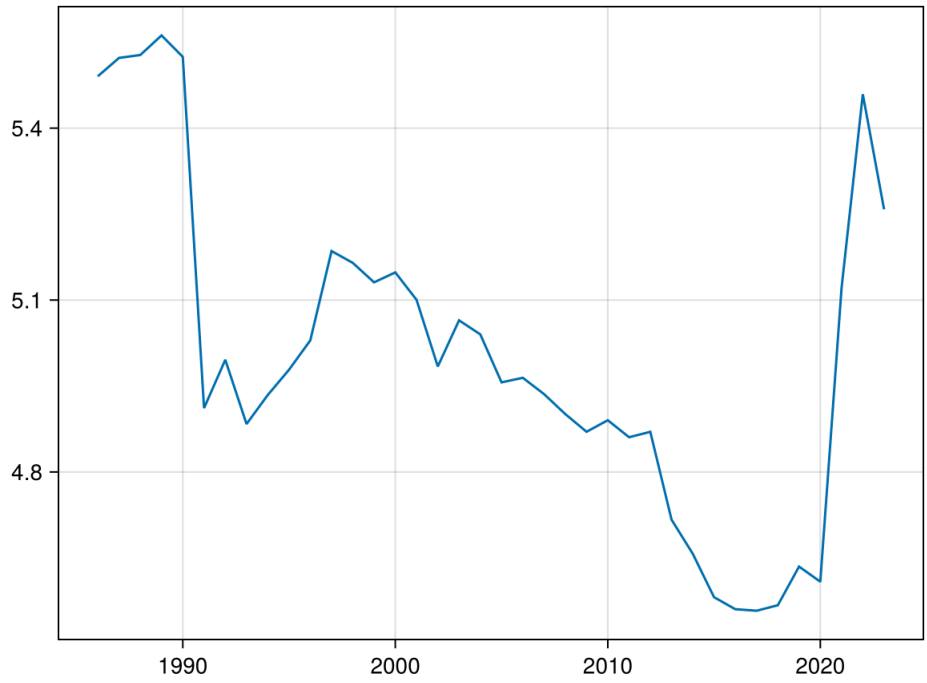
38×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	1986	5.49048	1.29688	21
2	1987	5.52259	1.50265	3550
3	1988	5.52761	1.49932	7910
4	1989	5.56183	1.50898	11203
5	1990	5.52439	1.63674	14113
6	1991	4.91143	1.82815	20682
7	1992	4.99575	1.84819	22487
8	1993	4.88367	1.80999	25141
9	1994	4.93434	1.81511	25265
10	1995	4.97844	1.83143	25109
11	1996	5.0296	1.82214	25436
12	1997	5.18547	1.82149	29447
13	1998	5.16484	1.81779	33862
14	1999	5.13093	1.81399	35320
15	2000	5.14824	1.84992	37348
16	2001	5.10037	1.84298	40723
17	2002	4.98409	1.82531	41394
18	2003	5.06454	1.7932	45326
19	2004	5.04008	1.78547	46838
20	2005	4.95637	1.74753	48297
21	2006	4.96431	1.77107	52204
22	2007	4.93586	1.76864	48436
23	2008	4.90098	1.75059	46892
24	2009	4.87011	1.75243	45433
25	2010	4.89028	1.73795	42201
26	2011	4.86062	1.74381	39037
27	2012	4.87005	1.72764	35086
28	2013	4.7167	1.80121	34357
29	2014	4.65713	1.83754	32843
30	2015	4.58144	1.84225	30740
31	2016	4.56048	1.82764	30713
32	2017	4.5578	1.84655	30408
33	2018	4.56741	1.83592	30277
34	2019	4.63487	1.8649	28302

35	2020	4.60846	1.84843	26349
36	2021	5.12078	1.72616	19107
37	2022	5.45917	1.50783	9007
38	2023	5.25833	1.26811	12



Correlations and levels between pedigree-based and Single-Step reliabilities for nordic insemination bulls with at least 50 offspring by birth year

20×7 DataFrame

Row	BYR	cor	mean_rel1	mean_ebv_rel1	std_rel1	std_ebv_rel1	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	0.996679	75.6909	77.4718	8.001	7.28297	186
2	2002	0.987367	75.8354	77.4572	7.38956	6.56292	154
3	2003	0.993542	72.3286	74.2896	7.37638	6.49819	225
4	2004	0.986355	74.8426	75.8464	9.21336	8.04484	223
5	2005	0.988375	75.0643	75.8788	7.80333	7.09527	152
6	2006	0.9332	77.8817	77.6716	7.91473	6.74603	127
7	2007	0.95819	76.5801	75.6894	7.44466	6.07782	128
8	2008	0.960223	79.1738	77.4494	8.78514	7.68339	112
9	2009	0.992507	82.5728	78.8301	6.77963	8.77424	86
10	2010	0.995939	83.2266	79.4996	8.21662	10.641	81
11	2011	0.993558	82.9327	79.3625	6.25696	8.21686	73
12	2012	0.996306	85.5517	82.6246	6.99942	9.33811	85
13	2013	0.996254	85.4955	82.4362	6.78048	9.16135	82
14	2014	0.995767	88.4174	86.4999	6.5302	8.73946	67
15	2015	0.996316	88.8432	87.0503	7.14576	9.47183	61
16	2016	0.997332	88.3475	86.3437	7.68724	10.0969	45
17	2017	0.995462	89.1385	87.6969	7.25245	9.47256	42
18	2018	0.995965	87.0704	84.906	7.1726	9.69443	44
19	2019	0.995851	84.9762	81.9416	6.48871	8.96754	27
20	2020	0.994998	78.833	74.2267	5.20368	7.78568	6

Correlations and levels between two-step and Single-Step reliabilities for nordic insemination bulls without offspring by birth year

22×7 DataFrame

Row	BYR	cor	mean_rel1	mean_two_rel1	std_rel1	std_two_rel1	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	NaN	28.325	74.0	NaN	NaN	1
2	2002	0.997654	31.5997	76.6667	2.97977	2.3094	3
3	2005	NaN	23.827	69.0	NaN	NaN	1
4	2006	0.0247078	28.35	74.7143	1.46903	1.25357	7
5	2007	0.58855	29.6326	75.2564	2.27103	1.8598	39
6	2008	0.641789	29.8963	74.84	3.84252	2.47733	50
7	2009	0.844256	55.8876	74.25	2.76643	2.04702	68
8	2010	0.788673	56.4788	74.6909	1.98193	1.64286	55
9	2011	0.909209	57.4843	75.2	2.19253	1.25558	35
10	2012	0.801318	57.4502	75.3415	2.30395	1.54288	41

11	2013	0.943643	58.1335	75.2632	3.00688	1.88096	19
12	2014	0.807358	58.347	75.3846	1.74238	0.960769	13
13	2015	0.803227	56.5577	74.7273	2.18648	1.00905	11
14	2016	0.783593	58.0377	75.1818	2.45254	1.60114	11
15	2017	0.851322	58.8413	76.0	0.79045	0.816497	4
16	2018	0.899751	55.7456	74.2941	3.3188	1.49016	17
17	2019	0.871726	57.1573	74.7692	2.33871	1.16575	13
18	2020	0.883442	53.8451	73.3235	3.36909	1.55155	34
19	2021	0.917707	53.8284	73.0175	3.62545	1.76768	57
20	2022	0.91043	50.4133	71.1129	3.68948	2.00904	62
21	2023	0.902368	46.6918	68.4318	2.6591	1.53104	44
22	2024	0.770458	45.0568	67.7826	1.59984	0.902347	23

Tables of differences

Number of nordic AI bulls with at least 50 offspring moving by certain index levels from old breeding values (pedigree-based)

20×4 DataFrame

Row	diff	n	mean_rel	mean_n_daughters
	Int64	Int64	Float64	Float64
1	-10	1	75.325	54.0
2	-9	1	77.4843	63.0
3	-8	1	75.1383	63.0
4	-7	6	79.9315	79.8333
5	-6	9	77.5882	73.7778
6	-5	19	78.5803	79.4737
7	-4	26	81.784	128.269
8	-3	58	80.0911	111.707
9	-2	102	81.7056	164.569
10	-1	208	82.2591	256.567
11	0	435	80.4267	344.354
12	1	547	77.5087	222.037
13	2	333	76.6087	119.102
14	3	144	78.7812	112.035
15	4	62	79.2907	105.242
16	5	32	79.3952	100.812
17	6	11	78.7096	89.3636
18	7	4	79.0308	74.5
19	8	1	80.861	142.0
20	9	2	75.4949	54.0

Number of nordic AI bulls with no offspring moving by certain index levels from old breeding values (two-step)

23×3 DataFrame

Row	diff	n	mean_rel
	Int64	Int64	Float64
1	-11	1	59.6994
2	-10	1	45.4836
3	-9	1	56.4191
4	-8	4	48.4214
5	-7	2	51.6519
6	-6	5	49.6583
7	-5	8	53.0769
8	-4	17	52.4481
9	-3	15	51.3332
10	-2	28	51.4447
11	-1	24	53.7125
12	0	28	51.4826
13	1	29	52.6331
14	2	19	50.1466
15	3	27	50.4799
16	4	22	52.5918
17	5	10	53.0895
18	6	10	48.2229
19	7	5	53.2729
20	8	4	46.1865
21	9	3	54.8174
22	10	1	43.19
23	11	1	44.6484

Documentation for Single-Step evaluation of the Temperament breeding value in Jersey

What we have done

The mixed-model hasn't changed compared to the classical pedigree-based evaluation. We have fixed-effects for 5-year herd, which country × month × year the measurement is taken, first calving age, which week of the lactation the measurement was taken at and the classifyer taking the measurement. The herd of the animal (which is different from the 5-year herd) is taken as a random/permanent effect.

Systematic problems with the model was identified. The Legarra-Reverter score is consistently low, see the section below for a more detailed discussion. However, as can also be seen below, the Single-step model brings an improvement in accuracy over a pedigree-based model. Since much investigation was done with little-to-no result, the original model was kept. The following variations of the original model was tried:

- Remove older measurements

  This did not improve the performance of the model

- Identify and remove herds with non-normal phenotype distributions

  This did not improve the performance of the model

- Re-estimate the heritability

  We found a lower heritability (4%) for Holstein than the official figure (8%). This did improve the performance of the model, but did not fix the assymetry between the sire and dame contribution.

- Remove dames of sires

  Since these cows might have recieved a higher level of care than the average cow, this could influence specifically the Legarra-Reverter score. This did improve the model by a small amount, but did not fix the assymmetry betwen the sire and dame contribution.

Legarra-Reverter analysis

The Legarra-Reverter score and accuracy of a pedigree-based model is below:

```
cf1 ~ 1 + cr1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.0807328	0.048816	1.65	0.1090	-0.0191071	0.180573
cr1	0.734552	0.277346	2.65	0.0129	0.167316	1.30179

```
Accuracy: 0.441
```

and below is the Legarra-Reverter score and accuracy of the Single-step model:

```
f1 ~ 1 + r1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.0677213	0.0436352	1.55	0.1315	-0.0215227	0.156965
r1	0.872048	0.179999	4.84	<1e-04	0.50391	1.24019

```
Accuracy: 0.669
```

The low Legarra-Reverter score can be explained by an asymmetric influence of the dams and sires breeding value on the predicted breeding value:

```
f1 ~ 1 + sire_r1 + dame_r1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.0441566	0.0528456	0.84	0.4105	-0.0640926	0.152406
sire_r1	0.521456	0.152355	3.42	0.0019	0.209371	0.833541
dame_r1	0.321492	0.21644	1.49	0.1486	-0.121865	0.764848

Interbull test

An Interbull GEBV test was performed. The result is given below:

```
Summary statistics on candidate bulls (CB) and test bulls (TB)
---------------------------------------------------------------
Trait Variable         N      Mean       Std      Min      Max
---------------------------------------------------------------
tem   CB EBV          57   103.022    14.093    73.01   147.54
tem   TB EBV          34   103.196    12.787    73.01   127.12
tem   TB  VAL(y)      34   103.569    11.743    76.40   123.44 Base=Current
tem   TB GEBV(x1)     34   103.176     8.578    84.18   116.46 Base=Old
tem   TB EBVr(x2)     34   103.115     7.325    86.04   120.41 Base=Old
tem   TB GEBV(x1)     34   102.707     8.662    83.53   116.12 Base=Current
tem   TB EBVr(x2)     34   102.645     7.397    85.40   120.11 Base=Current
tem   BB  EBVf(y)    291   100.061    15.546    25.92   144.15
tem   BB  EBVr(x)    291   100.459    15.132    29.28   137.72
tem   BB  EBV(wt)    291    58.547    32.393     0.00    98.00
---------------------------------------------------------------
tem : DGEBV : Base 0.25: Full = -1.48 + 1.010 * Red  b1 0.637 ~> 0.631  b2 0.441 ~> 0.437

Details of GEBVtest calculations
tem i_est = (103.196 - 103.022) / 14.093 = 0.012

After Base adjustments:
tem p=0.996 x=-2.637 i=0.012 k=0.033 R2b=0.222 E(b1)=0.974 b1=0.631
tem b1-E(b1) = -0.343  t = -1.31  bootstrap P(b=Eb) = 15.2  b1_test = NS-
tem R2_1 = 21.6  R2_2 =  7.5   bootstrap P(R2_gain) = 90.2  R2_test = NS+
tem   stat_test=Y   pract_test=N   bio_test=N   R2_test=-   overall = hiSE

2025-Feb-06 09:31:26 gebvtest_202409.py: finished tem

2025-Feb-06 09:31:26 gebvtest_202409.py: end
```

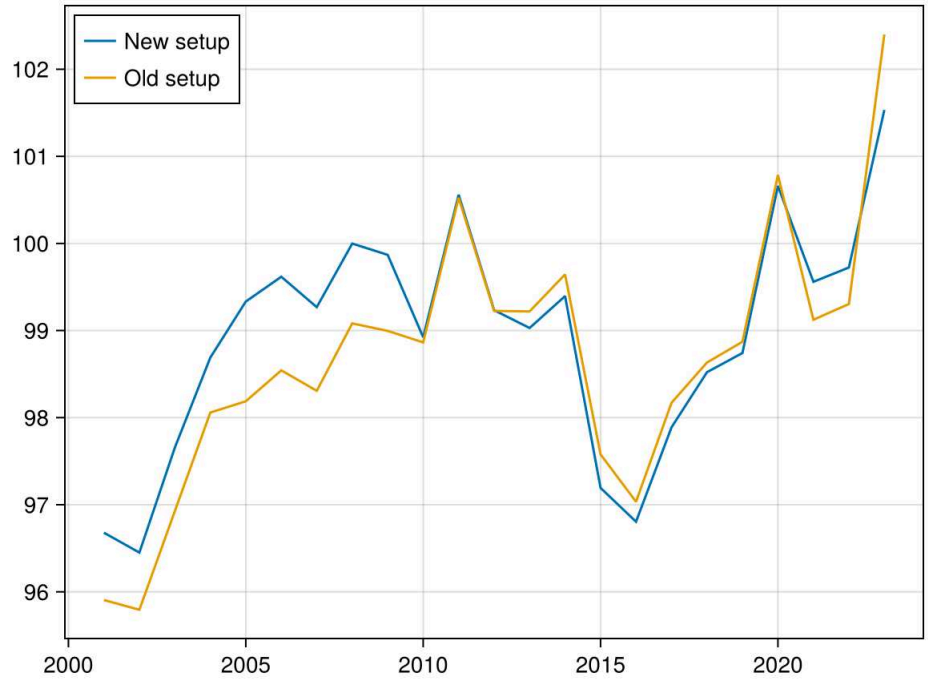
Comparison of old vs new pedigree-based EBV

The existing breeding values are a mix of pedigree-based breeding values for non-genotyped animals and two-step breeding values for genotyped animals. To see if we alter the breeding values imply by moving to a new setup, we compare pedigree-based breeding values computed using the new setup to the old pedigree-based values.

Comparison of old vs new pedigree-based EBV, all animals

23×7 DataFrame

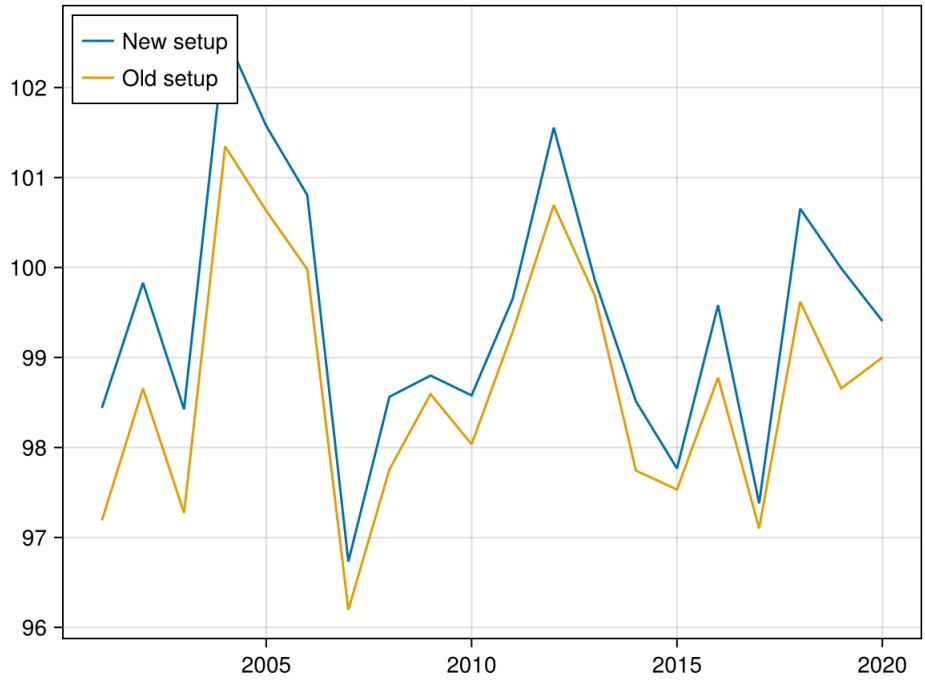
Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	96.6786	95.9057	5.91032	5.76304	0.96588	6181
2	2002	96.4508	95.7944	6.31246	6.08101	0.972362	6205
3	2003	97.6561	96.9266	5.80134	5.67327	0.970707	6821
4	2004	98.6898	98.0588	5.79136	5.71394	0.971616	6842
5	2005	99.333	98.1876	6.16583	5.88149	0.937813	7397
6	2006	99.6177	98.5428	5.76348	5.60327	0.940119	7850
7	2007	99.2684	98.3081	6.11331	5.86639	0.949027	7849
8	2008	99.9983	99.0818	6.14656	6.00803	0.951112	8251
9	2009	99.8688	98.9956	6.24856	6.04247	0.957367	8962
10	2010	98.9228	98.8636	6.32177	6.0795	0.946062	9008
11	2011	100.559	100.524	5.66664	5.36559	0.936039	10073
12	2012	99.2333	99.2254	5.16135	4.92675	0.92601	10033
13	2013	99.0291	99.2195	5.34941	5.10419	0.926748	8682
14	2014	99.3957	99.6441	5.88698	5.51856	0.943723	9042
15	2015	97.193	97.5783	6.85203	6.33881	0.97117	8932
16	2016	96.8051	97.0344	6.75722	6.46333	0.972275	8461
17	2017	97.8886	98.1703	7.76147	7.67024	0.984285	8487
18	2018	98.5218	98.6327	5.67627	5.67101	0.97115	9137
19	2019	98.7422	98.8712	6.25726	6.26354	0.980489	9104
20	2020	100.66	100.786	6.81503	6.61789	0.98185	9362
21	2021	99.5593	99.1241	6.42029	6.53586	0.978638	8664
22	2022	99.724	99.3046	5.95546	6.16095	0.940282	6097
23	2023	101.533	102.4	7.80008	8.89483	0.968675	40



Comparison of old vs new pedigree-based EBV, nordic AI bulls

20×7 DataFrame

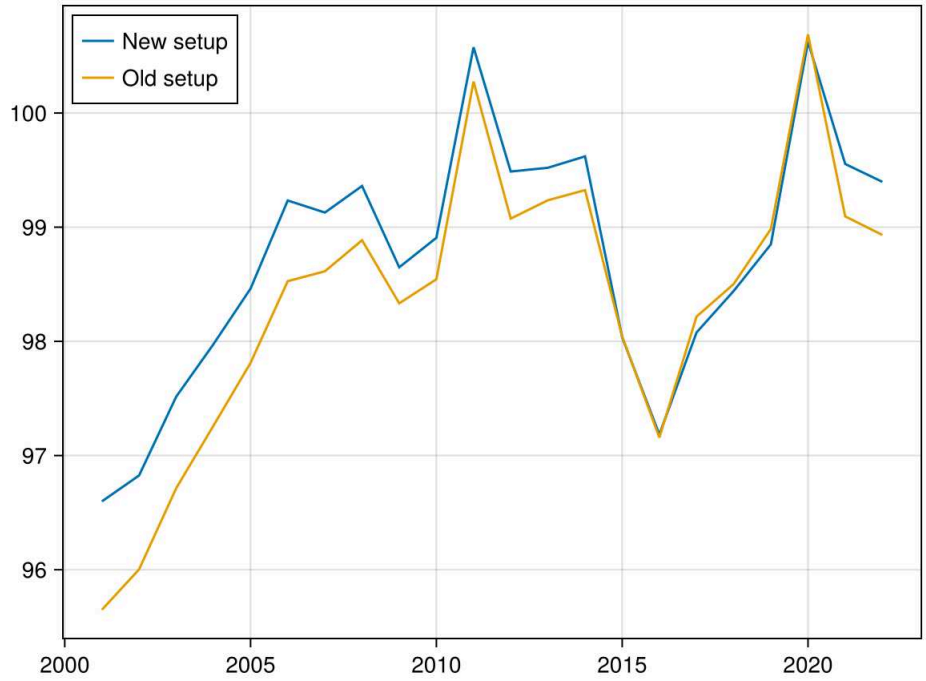
Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	98.4391	97.1887	8.829	8.54863	0.996271	53
2	2002	99.8294	98.6545	9.86041	9.38521	0.997601	55
3	2003	98.4245	97.2727	9.41782	9.12151	0.996758	55
4	2004	102.591	101.347	9.32797	9.05895	0.997319	49
5	2005	101.575	100.63	9.43336	8.98977	0.994815	46
6	2006	100.804	99.9796	10.3263	9.92784	0.997558	49
7	2007	96.732	96.1964	11.3657	11.0674	0.995686	56
8	2008	98.5631	97.7556	8.73944	8.47498	0.993544	45
9	2009	98.7989	98.5926	7.81881	7.58727	0.987992	54
10	2010	98.5782	98.0357	7.9035	7.68934	0.983334	56
11	2011	99.652	99.2857	8.68969	8.38898	0.989326	49
12	2012	101.555	100.694	8.36923	8.34467	0.989972	49
13	2013	99.8626	99.6863	8.76929	8.54749	0.984758	51
14	2014	98.5143	97.7436	11.1257	11.0113	0.992891	39
15	2015	97.7663	97.5312	10.8089	10.4696	0.994977	32
16	2016	99.5814	98.7778	7.2893	7.47989	0.978301	27
17	2017	97.3784	97.1	10.5865	10.0802	0.989012	30
18	2018	100.654	99.619	9.61574	9.96733	0.979241	21
19	2019	99.9908	98.6562	10.4334	10.4961	0.97401	32
20	2020	99.4056	99.0	9.35789	10.9499	0.948262	21



Comparison of old vs new pedigree-based EBV, nordic cows with phenotype

22×7 DataFrame

Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	96.5984	95.6492	6.75304	6.52721	0.991766	2640
2	2002	96.8254	96.0026	6.71629	6.45437	0.992117	2276
3	2003	97.5159	96.7144	6.65678	6.44703	0.991305	2742
4	2004	97.9747	97.2604	6.80896	6.62111	0.99228	2750
5	2005	98.4623	97.8117	6.88365	6.67764	0.992973	3499
6	2006	99.2335	98.5272	6.55274	6.40546	0.991815	3598
7	2007	99.1282	98.6139	6.83457	6.58603	0.992832	3398
8	2008	99.3611	98.8857	6.96589	6.81879	0.993449	3447
9	2009	98.6487	98.3332	6.94996	6.79366	0.994091	3715
10	2010	98.9073	98.5441	7.17379	7.02495	0.993756	3185
11	2011	100.576	100.276	6.5586	6.40019	0.991458	3284
12	2012	99.4876	99.0751	6.08697	6.00357	0.991059	2928
13	2013	99.5205	99.2361	6.12744	6.06378	0.989425	2575
14	2014	99.6203	99.3247	6.72098	6.50547	0.989132	2202
15	2015	98.0352	98.0415	7.47386	7.05379	0.989445	2073
16	2016	97.1833	97.1578	7.63556	7.41955	0.989993	2187
17	2017	98.0776	98.2167	8.44558	8.36786	0.992986	2058
18	2018	98.4416	98.5025	7.01229	6.99896	0.98905	2215
19	2019	98.8497	98.9835	7.12666	7.12358	0.989591	2486
20	2020	100.623	100.689	7.37821	7.2338	0.989701	2505
21	2021	99.5537	99.0944	7.33852	7.46201	0.986858	2373
22	2022	99.3971	98.932	6.85888	6.94429	0.966478	1441



As can be seen, our new setup does not replicate exactly the same breeding values when run without genotypical data. We attribute this mainly to a difference in raw data. The old setup has 1677527 measured phenotypes as of February 2025. Our setup uses only 1120876 of these measurements. The reason is twofold: first, we only accept pure-bred Holstein cows to contribute phenotypes. This was an early descision made for all Single-step models to only allow pure-bred data in the evaluation, as we believe this will increase accuracy. This brings the amount of measurements down to 1134005 measurements. Finally, we remove dames of sires, which brings us down to the final number.

From this point onwards, we will compare the new genomic Single-step breeding values to the old pedigree-based values. The reader should thus keep in mind, that there will be a base-level difference stemming from the different dataset.

Comparison of genetic Single-step to old breeding values

We now explore how the breeding values copmuted using the full genomic Single-step setup compares to the existing breeding values.

Comparison of genetic Single-step vs old pedigree-based, all animals

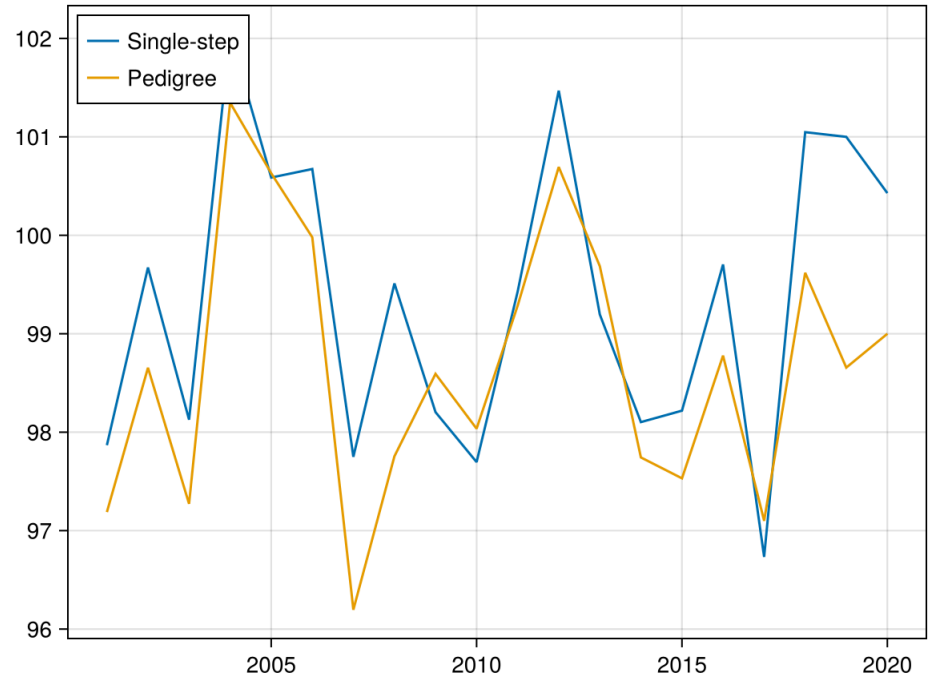
23×7 DataFrame

Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	95.4936	95.9057	6.03744	5.76304	0.945132	6181
2	2002	95.3252	95.7944	6.37089	6.08101	0.951534	6205
3	2003	96.7015	96.9266	5.95154	5.67327	0.942218	6821
4	2004	97.5077	98.0588	5.90256	5.71394	0.935561	6842
5	2005	97.5627	98.1876	6.16931	5.88149	0.922249	7397
6	2006	97.7136	98.5428	5.97398	5.60327	0.90821	7850
7	2007	97.41	98.3081	6.35621	5.86639	0.906181	7849
8	2008	98.1959	99.0818	6.40386	6.00803	0.896613	8251
9	2009	98.3085	98.9956	6.48436	6.04247	0.885221	8962
10	2010	98.1776	98.8636	7.01188	6.0795	0.824323	9008
11	2011	99.6254	100.524	6.77842	5.36559	0.767056	10073
12	2012	98.5208	99.2254	6.40038	4.92675	0.710272	10033
13	2013	98.488	99.2195	6.55897	5.10419	0.73627	8682
14	2014	98.9206	99.6441	7.10025	5.51856	0.754628	9042
15	2015	97.039	97.5783	8.1193	6.33881	0.825597	8932
16	2016	96.4478	97.0344	7.99193	6.46333	0.792166	8461
17	2017	97.7997	98.1703	8.75954	7.67024	0.824232	8487
18	2018	98.8871	98.6327	7.224	5.67101	0.735092	9137
19	2019	98.5416	98.8712	7.78146	6.26354	0.772046	9104
20	2020	100.578	100.786	8.28384	6.61789	0.782074	9362
21	2021	99.4558	99.1241	7.82072	6.53586	0.749978	8664
22	2022	100.247	99.3046	7.7937	6.16095	0.697856	6097
23	2023	101.775	102.4	9.75991	8.89483	0.740646	40

Comparison of genetic Single-step vs old pedigree-based, nordic AI bulls

20×7 DataFrame

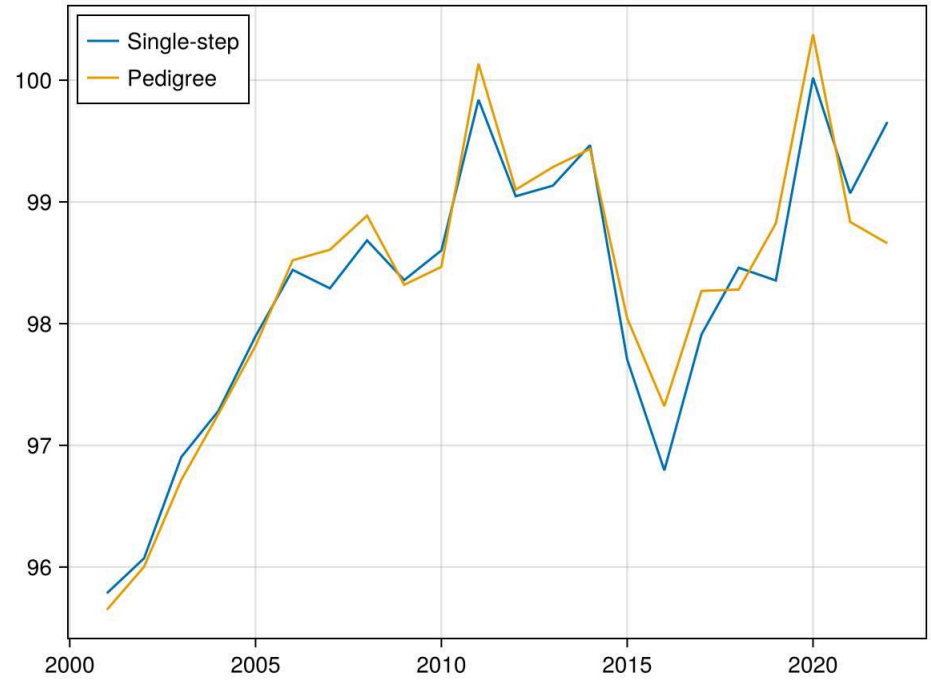
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	97.8679	97.1887	8.88828	8.54863	0.988668	53
2	2002	99.6727	98.6545	9.745	9.38521	0.985422	55
3	2003	98.1273	97.2727	9.55695	9.12151	0.981455	55
4	2004	102.041	101.347	9.42063	9.05895	0.980699	49
5	2005	100.587	100.63	9.56051	8.98977	0.962347	46
6	2006	100.673	99.9796	9.61637	9.92784	0.977769	49
7	2007	97.75	96.1964	11.3061	11.0674	0.96711	56
8	2008	99.5111	97.7556	8.41433	8.47498	0.915838	45
9	2009	98.2037	98.5926	8.84964	7.58727	0.842585	54
10	2010	97.6964	98.0357	8.62748	7.68934	0.851433	56
11	2011	99.4286	99.2857	10.1468	8.38898	0.84438	49
12	2012	101.469	100.694	8.93052	8.34467	0.869997	49
13	2013	99.1961	99.6863	9.64162	8.54749	0.856951	51
14	2014	98.1026	97.7436	12.3412	11.0113	0.868727	39
15	2015	98.2188	97.5312	10.9064	10.4696	0.915113	32
16	2016	99.7037	98.7778	7.90723	7.47989	0.877386	27
17	2017	96.7333	97.1	11.1012	10.0802	0.927163	30
18	2018	101.048	99.619	9.85635	9.96733	0.86999	21
19	2019	101.0	98.6562	11.6176	10.4961	0.916639	32
20	2020	100.429	99.0	10.3854	10.9499	0.870125	21



Comparison of genetic Single-step vs old pedigree-based, nordic phenotyped cows without genotypes

22×7 DataFrame

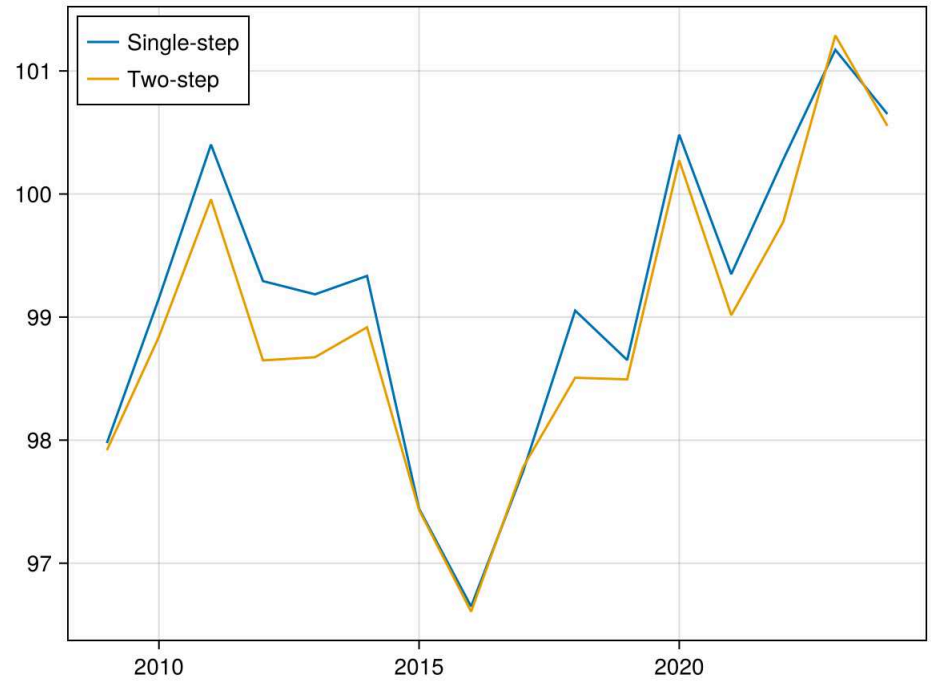
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	95.7848	95.6492	6.78958	6.52721	0.985867	2640
2	2002	96.0721	96.0026	6.66123	6.45437	0.986312	2276
3	2003	96.903	96.7144	6.66015	6.44703	0.983555	2742
4	2004	97.2826	97.2567	6.78187	6.62451	0.983453	2746
5	2005	97.897	97.8181	6.91913	6.67604	0.979021	3496
6	2006	98.4409	98.5209	6.71796	6.40893	0.973217	3590
7	2007	98.2898	98.6073	6.90164	6.58129	0.968386	3382
8	2008	98.6838	98.8873	7.0287	6.82601	0.967826	3435
9	2009	98.3579	98.3194	6.94004	6.80441	0.961497	3685
10	2010	98.6015	98.4664	7.1624	6.98018	0.96553	2723
11	2011	99.8395	100.135	6.60044	6.27057	0.95862	2511
12	2012	99.0467	99.1009	6.03124	5.89631	0.941575	2289
13	2013	99.1335	99.2861	6.2627	5.88501	0.926138	1978
14	2014	99.4664	99.435	6.68362	6.2321	0.9288	1623
15	2015	97.7038	98.0435	7.70223	7.0096	0.944152	1401
16	2016	96.7944	97.322	7.62476	7.03512	0.926161	1211
17	2017	97.9119	98.269	7.97638	7.78823	0.950974	1067
18	2018	98.4597	98.2798	6.97256	6.64382	0.937095	1240
19	2019	98.3542	98.8237	6.91868	6.7362	0.952139	1265
20	2020	100.02	100.376	6.90637	6.75338	0.951768	1188
21	2021	99.0709	98.835	7.14252	7.23792	0.961497	1115
22	2022	99.6561	98.6599	6.87117	6.6356	0.944246	538



Comparison of genetic Single-step vs old two-step, all animals

16×7 DataFrame

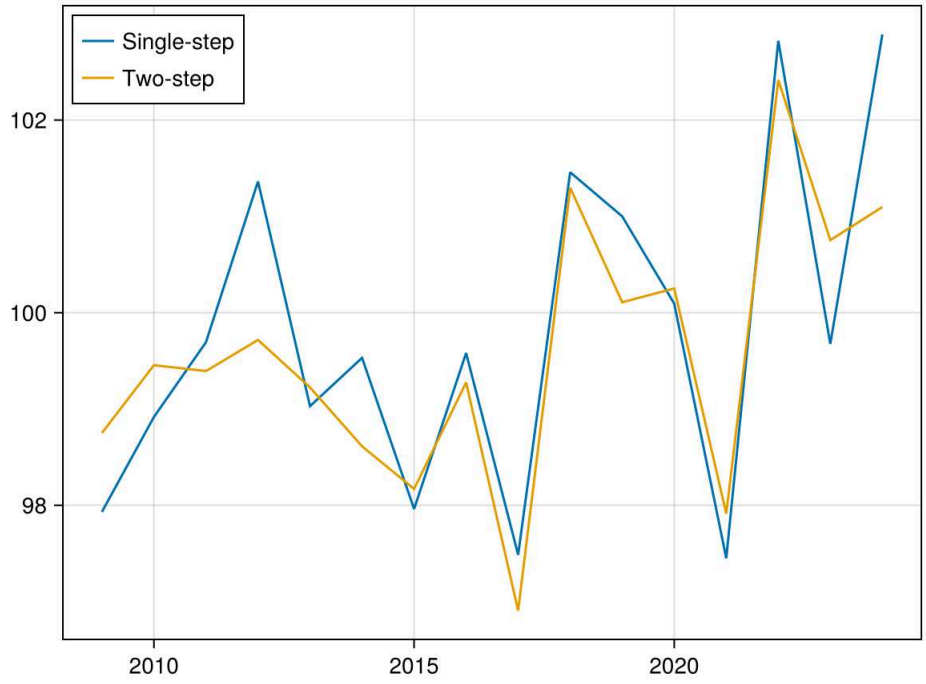
Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	97.976	97.9182	7.48553	6.74978	0.858869	416
2	2010	99.1528	98.8406	7.87231	7.05253	0.871414	2624
3	2011	100.402	99.9566	7.55721	6.65441	0.861155	4795
4	2012	99.2922	98.6482	7.30056	6.46907	0.848295	5444
5	2013	99.1849	98.6738	7.49711	6.7225	0.860938	4430
6	2014	99.3345	98.917	8.09514	6.90636	0.875189	5480
7	2015	97.443	97.433	8.84137	7.20239	0.883569	6573
8	2016	96.6483	96.6067	8.8331	7.42109	0.896515	7731
9	2017	97.7467	97.7812	9.21895	8.00139	0.903829	9858
10	2018	99.0526	98.5069	7.94284	7.0187	0.870521	12060
11	2019	98.6508	98.4938	8.28568	7.38521	0.887034	14956
12	2020	100.482	100.274	8.78614	7.72768	0.89675	18493
13	2021	99.3488	99.0151	8.30555	7.56604	0.887003	18306
14	2022	100.281	99.7736	8.0878	7.3243	0.883694	19772
15	2023	101.172	101.288	8.06115	7.40604	0.878219	19257
16	2024	100.65	100.554	7.82905	7.07546	0.871046	13734



Comparison of genetic Single-step vs old two-step, nordic AI bulls with genotypes

16×7 DataFrame

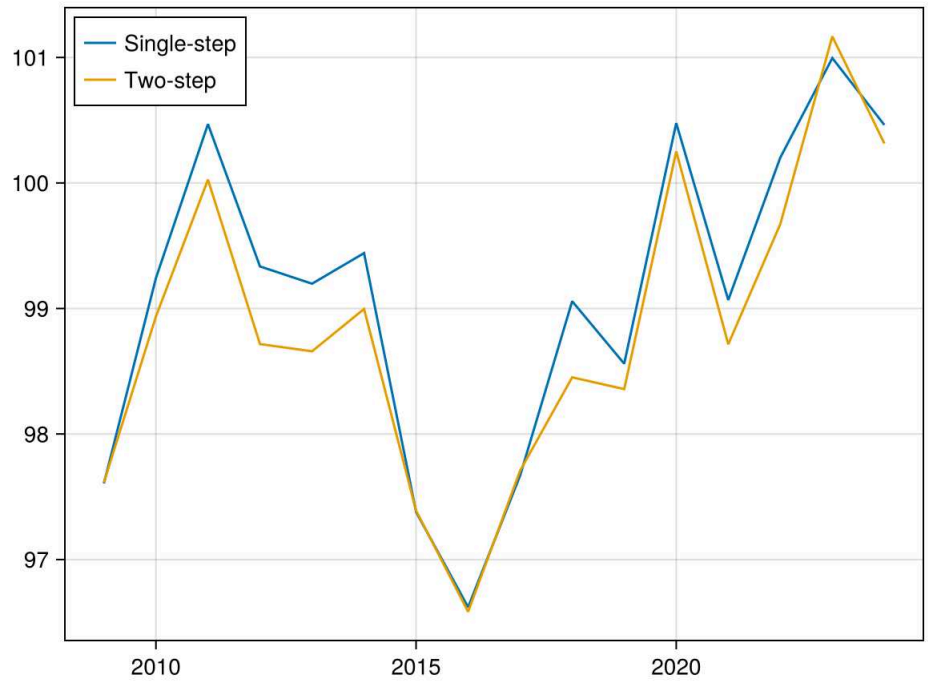
Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	97.931	98.7509	8.79765	7.71133	0.889524	58
2	2010	98.9178	99.4548	8.64541	7.7524	0.875258	73
3	2011	99.6933	99.394	9.36349	8.22413	0.90581	75
4	2012	101.362	99.7172	8.4681	7.22583	0.905041	58
5	2013	99.0299	99.2236	8.94592	7.21134	0.910729	67
6	2014	99.5312	98.6127	10.9108	9.01279	0.962857	64
7	2015	97.9623	98.1702	9.99223	8.63992	0.94265	53
8	2016	99.5806	99.2752	8.1477	7.9535	0.909449	31
9	2017	97.4865	96.9066	10.2106	9.85904	0.957096	37
10	2018	101.458	101.298	9.38073	8.14614	0.932319	24
11	2019	101.0	100.109	10.7033	10.1545	0.934765	51
12	2020	100.094	100.252	9.48805	10.2332	0.904821	32
13	2021	97.45	97.9142	8.05733	7.25393	0.874993	40
14	2022	102.824	102.416	8.95602	8.39459	0.909704	34
15	2023	99.6765	100.754	8.0518	7.20536	0.853027	34
16	2024	102.889	101.098	7.76924	6.73075	0.97577	9



Comparison of genetic Single-step vs old two-step, nordic genotyped cows without phenotypes

16×7 DataFrame

Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	97.6062	97.6142	7.36619	6.69226	0.847036	193
2	2010	99.2425	98.9366	7.592	6.75209	0.857382	1897
3	2011	100.469	100.027	7.30638	6.3813	0.845497	3602
4	2012	99.3349	98.7164	7.11095	6.31049	0.837039	4353
5	2013	99.1974	98.6588	7.23155	6.49177	0.852443	3333
6	2014	99.4413	98.996	7.90542	6.78325	0.868442	4346
7	2015	97.3785	97.3897	8.76951	7.12383	0.880264	5208
8	2016	96.6204	96.584	8.69631	7.31403	0.89236	6062
9	2017	97.6697	97.7083	9.11326	7.91486	0.904661	7753
10	2018	99.0577	98.4515	7.75662	6.90185	0.870527	9785
11	2019	98.5602	98.3576	8.1519	7.24695	0.886323	11966
12	2020	100.477	100.252	8.62597	7.59467	0.895571	14768
13	2021	99.0677	98.715	8.09797	7.39544	0.884854	14425
14	2022	100.202	99.6724	7.96942	7.2507	0.8824	15581
15	2023	100.995	101.168	8.04958	7.40485	0.880609	15745
16	2024	100.462	100.314	7.70086	6.94278	0.870141	11855



Single-step genetic trend for all animals by birthyear

All animals:

24×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	95.495	6.00937	6549
2	2002	95.3047	6.34485	6550
3	2003	96.6181	5.92778	7245
4	2004	97.3607	5.89173	7297
5	2005	97.497	6.10819	7926
6	2006	97.6597	5.90989	8459
7	2007	97.3062	6.29723	8490
8	2008	98.0827	6.33182	9037
9	2009	98.1842	6.45344	9992
10	2010	98.0393	6.95389	10407
11	2011	99.4716	6.78238	12214
12	2012	98.4874	6.46366	13114
13	2013	98.4906	6.5837	12131
14	2014	98.8326	7.05003	13475
15	2015	97.0719	8.0997	14602
16	2016	96.5062	8.13289	15388
17	2017	97.5922	8.73258	17409
18	2018	98.9044	7.54156	19135
19	2019	98.6453	7.96609	20843
20	2020	100.382	8.52233	23461
21	2021	99.3465	8.16766	22437
22	2022	100.186	7.97597	22086
23	2023	101.174	8.06334	19663
24	2024	100.671	7.82238	14007

Nordic AI bulls:

24×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	97.8679	8.88828	53
2	2002	99.6727	9.745	55
3	2003	98.1273	9.55695	55
4	2004	102.041	9.42063	49
5	2005	100.745	9.51765	47
6	2006	100.86	9.60869	50
7	2007	97.75	11.3061	56
8	2008	99.2292	8.24683	48
9	2009	97.931	8.79765	58
10	2010	98.9178	8.64541	73
11	2011	99.6933	9.36349	75
12	2012	101.362	8.4681	58
13	2013	99.0299	8.94592	67
14	2014	99.5312	10.9108	64
15	2015	97.9623	9.99223	53
16	2016	99.4062	8.07569	32
17	2017	97.1842	10.2426	38

18	2018	101.458	9.38073	24
19	2019	101.0	10.7033	51
20	2020	100.094	9.48805	32
21	2021	97.45	8.05733	40
22	2022	102.824	8.95602	34
23	2023	99.6765	8.0518	34
24	2024	102.889	7.76924	9

Nordic cows w/ phenotype:

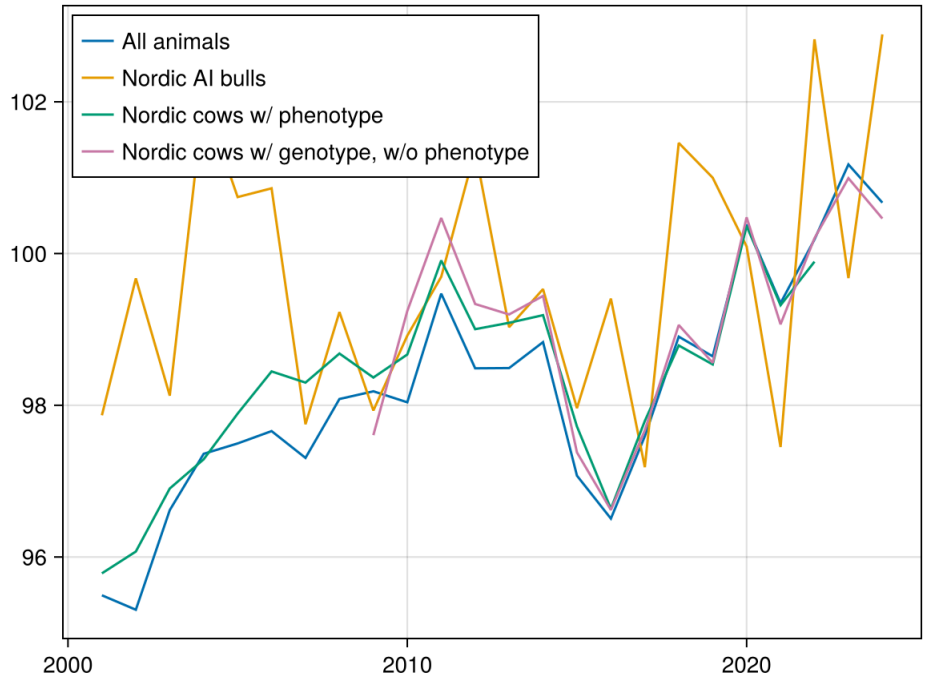
22×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	95.7848	6.78958	2640
2	2002	96.0721	6.66123	2276
3	2003	96.903	6.66015	2742
4	2004	97.2884	6.77976	2750
5	2005	97.89	6.92107	3499
6	2006	98.4461	6.71405	3598
7	2007	98.299	6.90514	3398
8	2008	98.682	7.02102	3447
9	2009	98.3658	6.94609	3715
10	2010	98.6694	7.42172	3185
11	2011	99.909	7.09141	3284
12	2012	99.0034	6.58476	2928
13	2013	99.0874	6.85025	2575
14	2014	99.188	7.33511	2202
15	2015	97.7202	8.25328	2073
16	2016	96.6365	8.4473	2187
17	2017	97.793	9.03991	2058
18	2018	98.7883	7.75755	2215
19	2019	98.5382	7.88794	2486
20	2020	100.363	8.11403	2505
21	2021	99.3189	7.86114	2374
22	2022	99.8931	7.91393	1441

Nordic cows w/ genotype, w/o phenotype:

16×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2009	97.6062	7.36619	193
2	2010	99.2425	7.592	1897
3	2011	100.469	7.30638	3602
4	2012	99.3349	7.11095	4353
5	2013	99.1974	7.23155	3333
6	2014	99.4413	7.90542	4346
7	2015	97.3785	8.76951	5208
8	2016	96.6204	8.69631	6062
9	2017	97.6697	9.11326	7753
10	2018	99.0577	7.75662	9785
11	2019	98.5602	8.1519	11966
12	2020	100.477	8.62597	14768
13	2021	99.0677	8.09797	14425
14	2022	100.202	7.96942	15581
15	2023	100.994	8.05175	15747
16	2024	100.462	7.70086	11855



Genetic trend, full vs. reduced evaluation

The Legarra-Reverter test suggests that the breeding value estimated for candidate bulls is higher than their true breeding value. A reduced evaluation was performed, where performances of daughter of bulls born after 2016 were removed from the dataset. Below is an analysis of the difference between the full evaluation and this reduced evaluation.

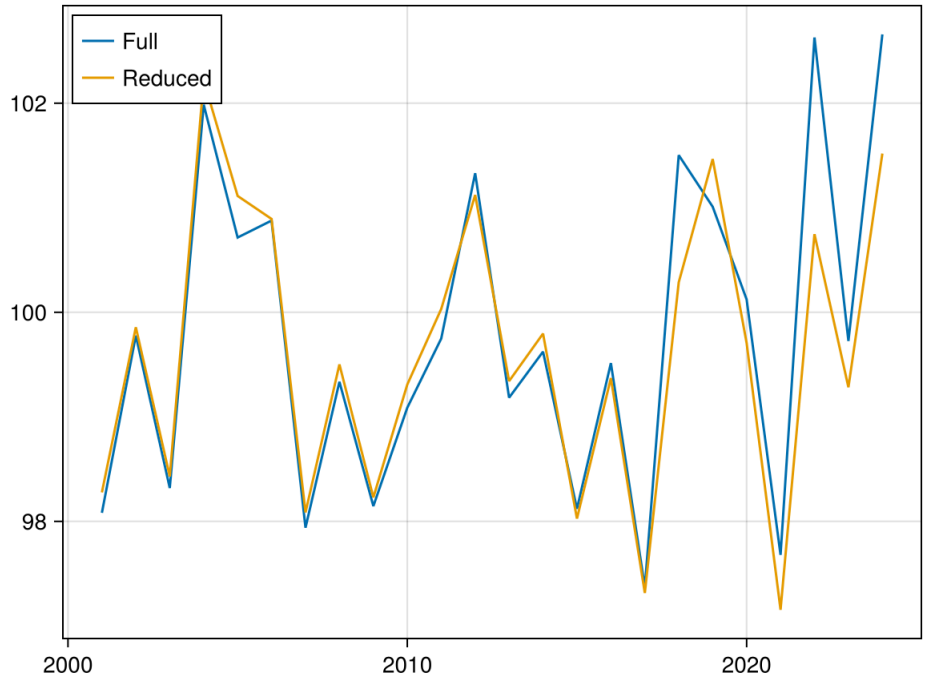
24×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	95.8881	95.9818	5.55944	5.54583	0.997238	6549
2	2002	95.7104	95.7812	5.8743	5.88402	0.996516	6550
3	2003	96.9257	96.9679	5.48711	5.479	0.995083	7245
4	2004	97.6198	97.7898	5.44959	5.44216	0.993858	7297
5	2005	97.7377	98.0151	5.6486	5.63976	0.989504	7926
6	2006	97.8997	98.1963	5.46422	5.45899	0.98702	8459
7	2007	97.5597	97.9344	5.82355	5.78232	0.984462	8490
8	2008	98.2838	98.6876	5.85819	5.7429	0.981302	9037
9	2009	98.377	98.7326	5.9701	5.85253	0.977759	9992
10	2010	98.2438	98.2095	6.43341	6.4974	0.965242	10407
11	2011	99.5701	99.566	6.27618	6.32789	0.953828	12214
12	2012	98.6573	98.5063	5.97905	5.99654	0.943356	13114
13	2013	98.6591	98.5104	6.08917	6.11471	0.943997	12131
14	2014	98.9764	98.8873	6.52847	6.58455	0.947792	13475
15	2015	97.3457	96.9931	7.49699	7.40731	0.941579	14602
16	2016	96.8243	96.9423	7.52668	7.34701	0.942922	15388
17	2017	97.8311	98.0585	8.08468	7.85514	0.937444	17409
18	2018	99.0437	98.3797	6.98042	6.64907	0.915196	19135
19	2019	98.8024	99.0538	7.37306	6.63589	0.794624	20843
20	2020	100.411	99.3115	7.89118	6.71901	0.766558	23461
21	2021	99.4553	99.3849	7.55922	6.04716	0.676006	22437
22	2022	100.231	99.7895	7.38116	5.97156	0.747691	22086
23	2023	101.147	100.134	7.46601	5.97746	0.789182	19663
24	2024	100.679	99.6021	7.23892	6.0135	0.811656	14007

Genetic trend, full vs. reduced evaluation, nordic AI bulls

24×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	98.0823	98.2775	8.23593	8.12798	0.998109	53
2	2002	99.7775	99.8572	9.04123	8.99996	0.997827	55
3	2003	98.3196	98.4304	8.86284	8.93683	0.994709	55
4	2004	101.986	102.22	8.74974	8.86618	0.995257	49
5	2005	100.716	101.113	8.86283	8.87288	0.992357	47
6	2006	100.878	100.893	8.82674	8.91896	0.99399	50
7	2007	97.9399	98.086	10.4272	10.5236	0.99102	56
8	2008	99.3352	99.5015	7.61502	7.56724	0.985979	48
9	2009	98.1463	98.2296	8.16667	7.92221	0.969203	58
10	2010	99.0879	99.3094	8.02397	7.83606	0.966511	73
11	2011	99.749	100.032	8.64194	8.06772	0.953014	75
12	2012	101.33	101.122	7.76524	7.93654	0.952538	58
13	2013	99.1837	99.3422	8.27507	8.08022	0.950472	67
14	2014	99.6235	99.7962	10.1045	9.79155	0.948668	64
15	2015	98.1206	98.027	9.21637	8.68146	0.928234	53
16	2016	99.5143	99.3708	7.44829	6.95581	0.834947	32
17	2017	97.3698	97.3158	9.54602	8.27585	0.649516	38
18	2018	101.503	100.288	8.70043	5.90525	0.520626	24
19	2019	101.01	101.466	9.84879	6.91181	0.596262	51
20	2020	100.123	99.7071	8.76982	6.90578	0.776122	32
21	2021	97.68	97.1551	7.4838	5.58721	0.72705	40
22	2022	102.629	100.747	8.22271	6.58889	0.770362	34
23	2023	99.7257	99.2832	7.51948	6.07214	0.909624	34
24	2024	102.658	101.518	7.17728	5.09663	0.914544	9



Number of nordic AI bulls born after 2016 (data-cut year) moving by a certain number of index points between the full and reduced

35×2 DataFrame

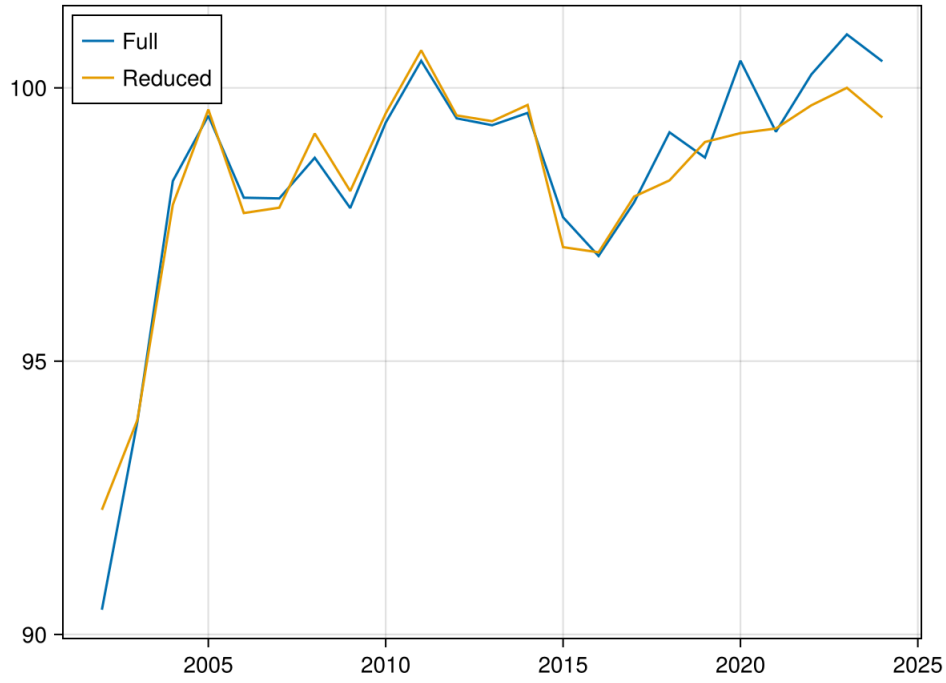
Row	diff	n
	Int64	Int64
1	-24	1
2	-23	1
3	-21	1
4	-16	1
5	-15	1
6	-13	1
7	-12	5
8	-11	2
9	-10	3
10	-9	5
11	-8	7
12	-7	8
13	-6	16
14	-5	15
15	-4	28
16	-3	70
17	-2	79
18	-1	205
19	0	283
20	1	173
21	2	94
22	3	48
23	4	29
24	5	20
25	6	16
26	7	14
27	8	9
28	9	4
29	10	1
30	11	2
31	12	4
32	14	5
33	15	2
34	16	1
35	17	1

Genetic trend, full vs. reduced evaluation, nordic genotyped cows without phenotype

23×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2002	90.4524	92.2801	2.89634	1.16049	1.0	2
2	2003	93.8942	93.9229	5.50352	6.26299	0.961317	8
3	2004	98.2972	97.8637	5.49247	5.27938	0.963651	20
4	2005	99.4906	99.6041	4.75447	4.42473	0.966778	27

5	2006	97.9906	97.7101	4.90679	4.37429	0.932086	42
6	2007	97.9777	97.8081	6.3288	5.95466	0.964218	72
7	2008	98.7216	99.1652	5.62517	5.4657	0.963192	126
8	2009	97.8011	98.1123	6.83857	6.42408	0.920388	193
9	2010	99.3644	99.533	7.02461	6.70574	0.937719	1897
10	2011	100.495	100.687	6.76401	6.54755	0.930775	3602
11	2012	99.4426	99.4957	6.57967	6.21912	0.921061	4353
12	2013	99.3168	99.3901	6.69248	6.46095	0.921251	3333
13	2014	99.5421	99.6876	7.32567	7.15197	0.934425	4346
14	2015	97.6317	97.0856	8.1143	7.86666	0.936528	5208
15	2016	96.9247	96.9911	8.04862	7.698	0.937708	6062
16	2017	97.9035	98.0106	8.43622	8.10712	0.933636	7753
17	2018	99.1866	98.3075	7.176	6.72544	0.911253	9785
18	2019	98.7248	99.0103	7.54434	6.75586	0.786356	11966
19	2020	100.497	99.1717	7.98408	6.84688	0.76765	14768
20	2021	99.1974	99.2573	7.49104	6.08346	0.661714	14425
21	2022	100.247	99.6818	7.37628	6.0101	0.753972	15581
22	2023	100.978	100.001	7.45611	5.93846	0.791801	15747
23	2024	100.485	99.458	7.1252	5.97752	0.811916	11855



Correlations and levels between pedigree-based and Single-Step reliabilities for nordic insemination bulls with at least 50 offspring by birth year

20×7 DataFrame

Row	BYR	cor	mean_rel1	mean_ebv_rel1	std_rel1	std_ebv_rel1	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	0.910428	88.7948	76.8478	12.5913	18.3677	6
2	2002	0.891606	94.3653	80.656	4.3246	10.2459	4
3	2003	0.978046	91.5018	82.3364	13.8463	15.6476	5
4	2004	0.884413	83.0564	69.2552	12.6995	15.2866	16
5	2005	0.879028	84.1439	68.9489	11.9978	13.7039	11
6	2006	0.810192	82.7776	65.0449	12.3618	12.9399	8
7	2007	0.765377	91.1197	68.283	7.20249	11.7183	14
8	2008	0.945235	95.5684	75.0579	3.3627	10.8208	11
9	2009	0.999139	86.1192	79.4663	10.7245	15.5232	6
10	2010	0.94892	78.8991	70.3257	5.0854	7.8847	9
11	2011	0.805139	78.8308	63.575	6.69227	12.6408	4
12	2012	0.97666	86.973	81.8723	5.51362	8.10699	7
13	2013	0.961259	81.1466	70.2244	7.73984	15.5757	7
14	2014	0.851324	81.9988	72.0136	7.29079	14.6331	11
15	2015	0.910802	86.2328	79.51	5.4426	11.206	17
16	2016	0.869915	82.2521	68.1577	7.92249	15.4972	13
17	2017	0.877689	84.4668	76.9846	7.09576	10.5828	21
18	2018	0.971385	84.6771	78.9617	5.50153	11.5462	7
19	2019	0.882057	80.7652	71.7894	5.72706	11.956	17
20	2020	0.9311	71.1895	57.4033	3.37472	5.031	3

Correlations and levels between two-step and Single-Step reliabilities for nordic insemination bulls without offspring by birth year

15×7 DataFrame

Row	BYR	cor	mean_rel1	mean_two_rel1	std_rel1	std_two_rel1	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2010	0.946465	43.4604	58.4444	2.77792	2.91492	18
2	2011	0.955967	43.172	58.4286	3.10798	2.82093	28
3	2012	0.950702	42.6712	58.4545	3.03774	3.26691	11
4	2013	0.958955	42.4179	58.2941	2.66539	2.22948	17
5	2014	0.932716	41.6071	57.1481	3.26634	2.83798	27
6	2015	0.951324	42.1557	57.6957	3.20105	2.68726	23
7	2016	0.909426	40.2762	56.0	3.57787	2.96648	6
8	2017	0.945141	43.6757	59.0	3.45022	2.50713	8
9	2018	0.999938	35.7367	51.3333	4.58511	4.93288	3
10	2019	0.88451	42.9277	58.6667	3.46551	3.10376	21
11	2020	0.892808	41.9953	58.0	2.57509	2.58957	18
12	2021	0.965298	38.0094	54.825	4.82037	3.74773	40
13	2022	0.948485	35.1423	53.4412	3.95607	3.37721	34
14	2023	0.874279	31.1066	48.8824	2.29464	2.26655	34
15	2024	0.810997	30.6058	49.0	1.92691	1.32288	9

Tables of differences

Number of nordic AI bulls born after 2010 with at least 50 offspring moving by certain index levels from old breeding values (pedigree-based)

17×4 DataFrame

Row	diff	n	mean_rel	mean_n_daughters
	Int64	Int64	Float64	Float64
1	-8	1	70.2521	53.0
2	-6	1	72.1143	55.0
3	-5	2	81.389	129.0
4	-4	3	86.913	195.0
5	-3	7	79.6919	122.143
6	-2	8	77.3106	99.5
7	-1	10	83.5323	209.0
8	0	17	85.4522	239.059
9	1	19	85.443	188.211
10	2	16	85.0979	166.562
11	3	10	81.3008	164.1
12	4	4	81.8434	124.75
13	5	3	81.5262	128.333
14	6	2	78.907	129.0
15	7	2	83.8041	153.0
16	8	1	75.3068	66.0
17	10	1	81.6087	85.0

Number of nordic AI bulls born after 2020 with no offspring moving by certain index levels from old breeding values (two-step)

20×3 DataFrame

Row	diff	n	mean_rel
	Int64	Int64	Float64
1	-10	1	32.8598
2	-9	1	41.9929
3	-8	2	31.3239
4	-7	3	33.6352
5	-6	6	31.9796
6	-5	2	39.4554
7	-4	7	33.1534
8	-3	10	36.1457
9	-2	10	35.6245
10	-1	12	35.4551
11	0	7	34.8549
12	1	16	35.6092
13	2	14	34.313
14	3	12	33.4704
15	4	4	33.0434
16	5	2	33.734
17	6	2	30.4266
18	7	2	37.0768
19	8	3	34.1744
20	11	1	30.9296

Mendelian sampling analysis

All:

18×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2005	-0.0629164	2.63325	6604
2	2006	-0.028063	2.55104	7109
3	2007	-0.0157333	2.6488	7214
4	2008	0.011143	2.59792	7673
5	2009	0.0133693	2.72291	8527
6	2010	0.0103834	3.25091	8764
7	2011	0.00747823	3.50911	10564
8	2012	0.052718	3.60799	11571
9	2013	0.0692301	3.56927	10754
10	2014	0.00194327	3.66209	12093
11	2015	0.108637	3.84611	13315
12	2016	0.151505	3.95955	14257
13	2017	0.0920521	4.17569	16344
14	2018	0.112739	4.22686	18188
15	2019	0.106075	4.28817	20099
16	2020	0.0953766	4.41374	22862
17	2021	0.0648911	4.40902	21983
18	2022	0.0262381	4.55496	21686

Nordic cows:

18×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2005	-0.0742386	2.62541	6304
2	2006	-0.048115	2.51354	6817
3	2007	-0.0351839	2.60236	6935
4	2008	-0.00128953	2.59829	7367
5	2009	0.0180175	2.66137	8131
6	2010	0.00316109	3.20185	8225
7	2011	-0.000408873	3.48083	9783
8	2012	0.0473545	3.60617	10622
9	2013	0.069833	3.5657	9580
10	2014	-0.0110239	3.66672	10704
11	2015	0.101014	3.87608	11642
12	2016	0.16525	3.98831	12118
13	2017	0.0910805	4.17873	12994
14	2018	0.0978398	4.26459	15091
15	2019	0.0887734	4.35216	16835
16	2020	0.0652072	4.44035	19231
17	2021	0.0640817	4.41731	18414
18	2022	0.0212448	4.56086	18075

Nordic cows w/ phenotype, w/o genotype:

18×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2005	-0.0853553	3.12425	3462
2	2006	-0.0124895	2.97178	3563
3	2007	-0.0227882	3.06189	3357
4	2008	0.00559647	3.0315	3395
5	2009	-0.0441217	3.00424	3649
6	2010	-0.0113341	3.04699	2691
7	2011	0.0159338	2.94005	2479
8	2012	-0.0437859	2.98567	2261
9	2013	0.0304192	2.80486	1956
10	2014	-0.00498753	2.97399	1604
11	2015	-0.0455872	3.09336	1371
12	2016	0.0021097	3.28326	1185
13	2017	0.00912584	3.08629	1041
14	2018	0.0483347	3.30648	1231
15	2019	-0.0783373	2.93323	1251
16	2020	-0.0177815	2.75483	1181
17	2021	0.0169104	2.87151	1094
18	2022	0.025	2.95867	520

Nordic cows w/o phenotype, w genotype:

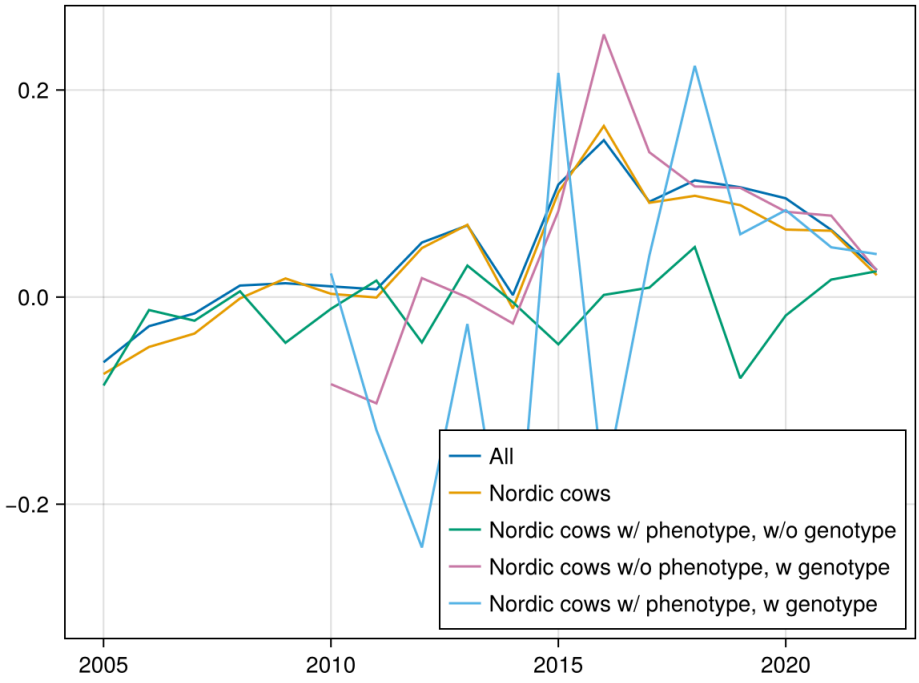
13×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2010	-0.0840403	4.23985	1886
2	2011	-0.102593	4.28231	3587
3	2012	0.0183222	4.43524	4339
4	2013	-0.000300571	4.55777	3327
5	2014	-0.0254784	4.55858	4337
6	2015	0.0829804	4.70666	5194
7	2016	0.253681	4.64785	6045
8	2017	0.139899	4.70006	7727
9	2018	0.106839	4.72542	9767
10	2019	0.105503	4.68715	11938
11	2020	0.082428	4.69351	14728
12	2021	0.0786458	4.64763	14400
13	2022	0.0257003	4.68042	15564

Nordic cows w/ phenotype, w genotype:

13×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2010	0.0228758	4.85162	459
2	2011	-0.128405	4.66853	771
3	2012	-0.241758	4.90151	637
4	2013	-0.0259631	5.28259	597
5	2014	-0.301903	5.32197	578
6	2015	0.216518	5.54238	672
7	2016	-0.186023	5.12973	973
8	2017	0.039899	5.35354	990
9	2018	0.223306	5.19454	974
10	2019	0.0607055	5.21594	1219
11	2020	0.0839666	5.1997	1316
12	2021	0.0480922	4.94873	1258
13	2022	0.0415282	5.31801	903

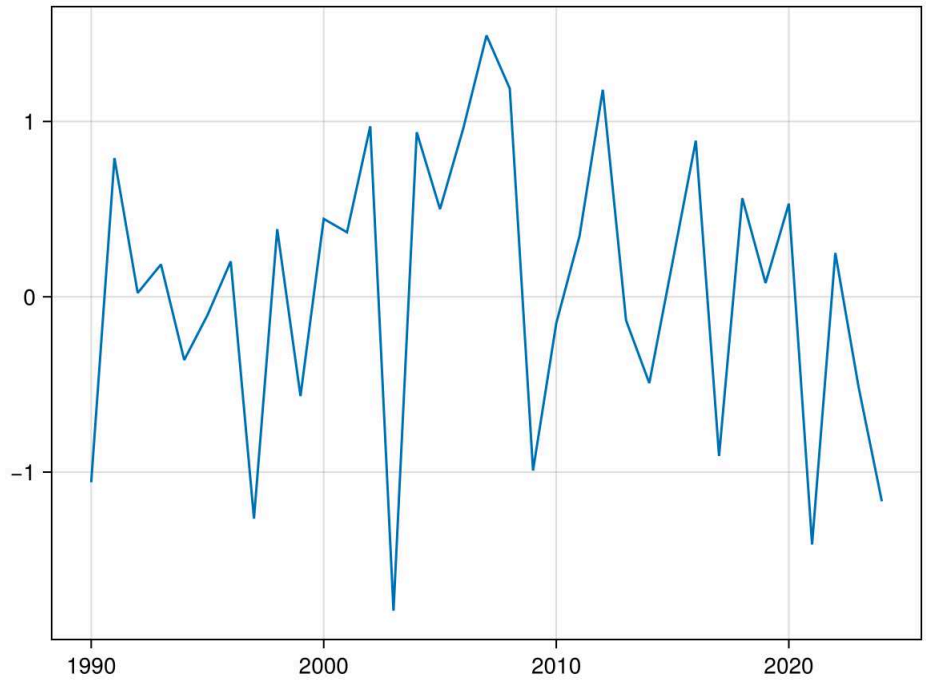


Nordic AI bulls:

35×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	1990	-1.05797	6.21522	69
2	1991	0.791209	5.90013	91
3	1992	0.021978	5.88166	91
4	1993	0.184524	5.59301	84
5	1994	-0.360577	5.47521	104
6	1995	-0.104651	6.59194	86
7	1996	0.202128	6.15015	94
8	1997	-1.26515	6.69168	66
9	1998	0.385714	6.19208	70
10	1999	-0.566176	5.91728	68
11	2000	0.444444	5.34681	72
12	2001	0.367925	5.77224	53
13	2002	0.972727	6.0265	55
14	2003	-1.79091	6.40218	55
15	2004	0.938776	6.50931	49
16	2005	0.5	6.09793	47
17	2006	0.96	6.88228	50
18	2007	1.49107	7.16589	56
19	2008	1.1875	5.3759	48
20	2009	-0.991379	5.58859	58
21	2010	-0.150685	5.84326	73
22	2011	0.346667	5.94341	75
23	2012	1.18103	5.528	58
24	2013	-0.134328	5.27758	67
25	2014	-0.492188	6.34053	64
26	2015	0.198113	5.88213	53
27	2016	0.890625	6.40783	32
28	2017	-0.907895	6.3998	38
29	2018	0.5625	5.73	24
30	2019	0.0784314	6.73452	51
31	2020	0.53125	5.04326	32

32	2021	-1.4125	4.28158	40
33	2022	0.25	4.79938	34
34	2023	-0.514706	4.95049	34
35	2024	-1.16667	4.96865	9



Documentation for Single-Step evaluation of the Temperament breeding value in RDC

What we have done

The mixed-model hasn't changed compared to the classical pedigree-based evaluation. We have fixed-effects for 5-year herd, which country $\times$ month $\times$ year the measurement is taken, first calving age, which week of the lactation the measurement was taken at and the classifyer taking the measurement. The herd of the animal (which is different from the 5-year herd) is taken as a random/permanent effect.

Systematic problems with the model was identified. The Legarra-Reverter score is consistently low, see the section below for a more detailed discussion. However, as can also be seen below, the Single-step model brings an improvement in accuracy over a pedigree-based model. Since much investigation was done with little-to-no result, the original model was kept. The following variations of the original model was tried:

- Remove older measurements

  This did not improve the performance of the model

- Identify and remove herds with non-normal phenotype distributions

  This did not improve the performance of the model

- Remove dams of sires

  Since these cows might have recieved a higher level of care than the average cow, this could influence specifically the Legarra-Reverter score. This did improve the model by a small amount, but did not fix the assymmetry betwen the sire and dam contribution.

- Remove Finnish data

  Due to small herd sizes and regularization within herds in our data-import step, Finnish data might be skewed relative to their true value. Removing Finnish data did improve the model by a small amount, but did not fix the asymmetry between the sire and dam contribution.

Of these measures, we kept the removal of dams of sires in the final model.

Legarra-Reverter analysis

The Legarra-Reverter score and accuracy of a pedigree-based model is below:

```
cf1 ~ 1 + cr1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.1325	0.0385288	3.44	0.0008	0.0561372	0.208863
cr1	0.747941	0.154944	4.83	<1e-05	0.440846	1.05504

```
Accuracy: 0.42
```

and below is the Legarra-Reverter score and accuracy of the Single-step model:

```
f1 ~ 1 + r1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.0387676	0.0286975	1.35	0.1795	-0.0181099	0.0956451
r1	0.914953	0.0924735	9.89	<1e-16	0.731673	1.09823

```
Accuracy: 0.688
```

The low Legarra-Reverter score can be explained by an asymmetric influence of the dams and sires breeding value on the predicted breeding value:

```
f1 ~ 1 + sire_r1 + dame_r1
Coefficients:
```

	Coef.	Std. Error	t	Pr(>|t|)	Lower 95%	Upper 95%
(Intercept)	0.0602002	0.0402292	1.50	0.1375	-0.019541	0.139941
sire_r1	0.485714	0.0843635	5.76	<1e-07	0.318491	0.652937
dame_r1	0.328666	0.102706	3.20	0.0018	0.125086	0.532246

Interbull test

An Interbull GEBV test was performed. The result is given below:

```
Summary statistics on candidate bulls (CB) and test bulls (TB)
---------------------------------------------------------------
Trait Variable         N      Mean       Std      Min      Max
---------------------------------------------------------------
tem   CB EBV         129   102.123    14.912    58.42   130.26
tem   TB EBV         129   102.123    14.912    58.42   130.26
tem   TB  VAL(y)     129   101.383    14.651    58.01   129.96 Base=Current
tem   TB GEBV(x1)    129    99.740    10.714    69.59   134.00 Base=Old
tem   TB EBVr(x2)    129   100.313     9.080    80.24   136.27 Base=Old
tem   TB GEBV(x1)    129    99.764    10.568    70.03   133.56 Base=Current
tem   TB EBVr(x2)    129   100.329     8.956    80.53   135.79 Base=Current
tem   BB  EBVf(y)    857    97.063    17.248    33.55   158.05
tem   BB  EBVr(x)    857    97.003    17.389    32.71   159.32
tem   BB  EBV(wt)    857    78.798    23.907     1.08    99.00
---------------------------------------------------------------
tem : DGEBV : Base 0.25: Full = 1.39 + 0.986 * Red  b1 0.781 ~> 0.792  b2 0.764 ~> 0.774

Details of GEBVtest calculations
tem i_est = (102.123 - 102.123) / 14.912 = 0.000

After Base adjustments:
tem p=1.000 x= 0.000 i=0.000 k=0.000 R2b=0.328 E(b1)=1.000 b1=0.792
tem b1-E(b1) = -0.208  t = -2.19  bootstrap P(b=Eb) =  2.8  b1_test = Fail
tem R2_1 = 32.8  R2_2 = 22.6   bootstrap P(R2_gain) = 99.0  R2_test = Pass
tem   stat_test=N   pract_test=N   bio_test=N   R2_test=Y   overall = FAIL

2025-Feb-11 07:39:07 gebvtest_202409.py: finished tem

2025-Feb-11 07:39:07 gebvtest_202409.py: end
```

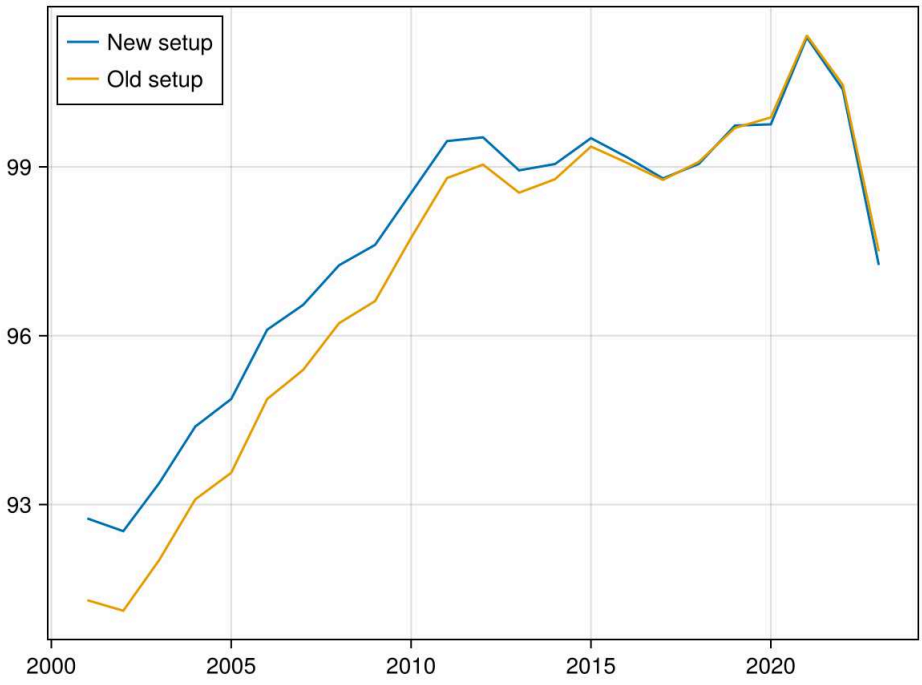
Comparison of old vs new pedigree-based EBV

The existing breeding values are a mix of pedigree-based breeding values for non-genotyped animals and two-step breeding values for genotyped animals. To see if we alter the breeding values imply by moving to a new setup, we compare pedigree-based breeding values computed using the new setup to the old pedigree-based values.

Comparison of old vs new pedigree-based EBV, all animals

23×7 DataFrame

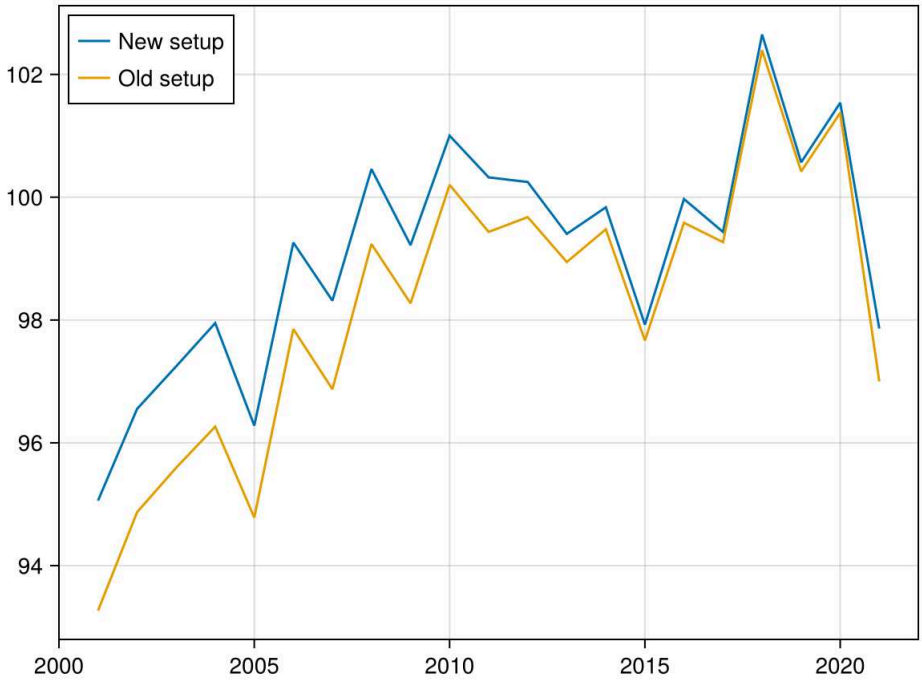
Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	92.7528	91.3002	6.92251	6.84572	0.987767	67853
2	2002	92.527	91.1132	7.07562	7.02151	0.988899	65265
3	2003	93.383	92.0156	6.7256	6.71371	0.9875	63792
4	2004	94.3854	93.0915	6.67932	6.65856	0.987619	61108
5	2005	94.8753	93.5644	6.64371	6.65657	0.98706	58018
6	2006	96.1066	94.8744	6.70072	6.72102	0.987333	56416
7	2007	96.5487	95.393	6.47215	6.505	0.986395	53241
8	2008	97.2528	96.2238	6.65846	6.67978	0.986938	51950
9	2009	97.6141	96.6156	6.6757	6.77795	0.985112	50005
10	2010	98.5361	97.7393	6.76544	6.84963	0.983209	46246
11	2011	99.4581	98.8014	6.4819	6.51476	0.981079	44316
12	2012	99.5245	99.0398	6.72807	6.76062	0.979904	39063
13	2013	98.9381	98.5414	6.44486	6.44284	0.979257	38166
14	2014	99.0501	98.78	5.86358	5.91137	0.975698	35716
15	2015	99.51	99.3609	6.15467	6.09664	0.964249	32813
16	2016	99.1716	99.0724	5.6457	5.66276	0.963852	30879
17	2017	98.7947	98.7683	5.52139	5.56892	0.963492	27996
18	2018	99.0536	99.0896	5.54717	5.56221	0.96226	26027
19	2019	99.7337	99.6907	5.88943	5.9067	0.970326	23083
20	2020	99.7556	99.8788	5.23361	5.28124	0.971029	22312
21	2021	101.3	101.336	5.49979	5.50682	0.980919	17592
22	2022	100.374	100.458	5.23131	5.27272	0.979246	8517
23	2023	97.2563	97.5	2.65326	2.12132	1.0	2



Comparison of old vs new pedigree-based EBV, nordic AI bulls

21×7 DataFrame

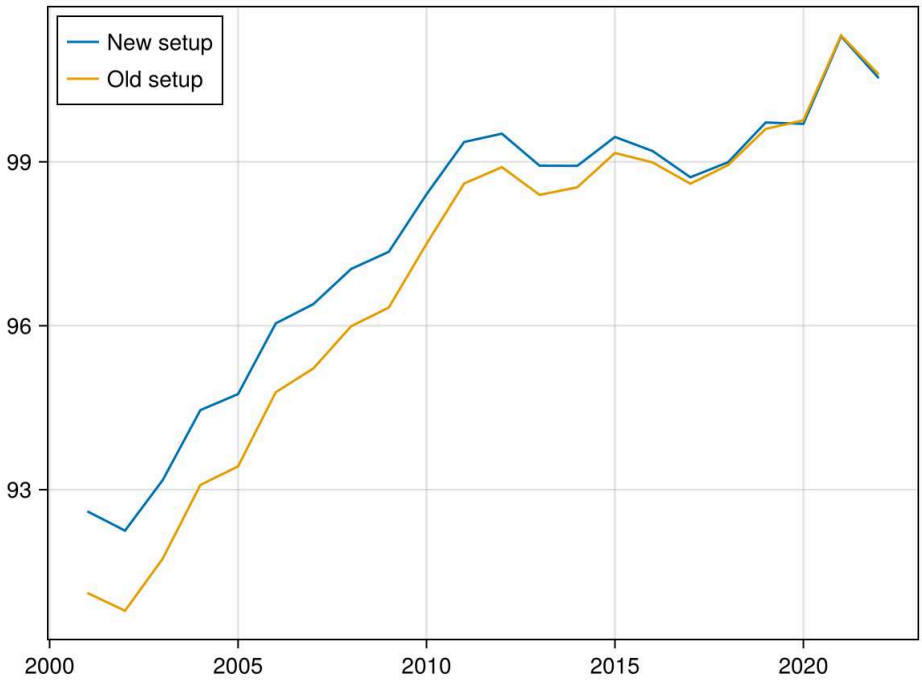
Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	95.0588	93.2669	9.55373	9.52376	0.995603	266
2	2002	96.553	94.8707	9.41751	9.23295	0.99519	232
3	2003	97.2453	95.5943	9.12946	8.98486	0.994657	244
4	2004	97.9501	96.2629	9.36675	9.36026	0.994567	232
5	2005	96.2797	94.7828	9.01934	9.0397	0.993665	221
6	2006	99.2609	97.8527	8.73795	8.61382	0.993188	224
7	2007	98.315	96.8727	8.94035	8.87108	0.993666	220
8	2008	100.458	99.2376	8.47226	8.41007	0.991502	202
9	2009	99.2204	98.2716	9.16357	9.12305	0.990832	162
10	2010	101.002	100.201	9.6219	9.6822	0.989583	169
11	2011	100.323	99.4345	8.30138	8.23141	0.987499	168
12	2012	100.247	99.6763	8.56056	8.49209	0.98971	173
13	2013	99.403	98.9449	8.43537	8.33267	0.984361	127
14	2014	99.8363	99.4778	8.27793	8.25197	0.985645	90
15	2015	97.9242	97.6667	7.00612	7.0946	0.986752	75
16	2016	99.9701	99.5833	7.29641	7.21842	0.982277	72
17	2017	99.4337	99.2676	8.14046	7.98741	0.979615	71
18	2018	102.65	102.393	7.53239	7.75694	0.974712	56
19	2019	100.568	100.42	7.75414	7.91044	0.984457	50
20	2020	101.538	101.375	6.34077	6.85294	0.974741	48
21	2021	97.8607	97.0	NaN	NaN	NaN	1



Comparison of old vs new pedigree-based EBV, nordic cows with phenotype

22×7 DataFrame

Row	BYR	mean_cf1	mean_kebv	std_cf1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	92.6025	91.1097	7.16338	7.06248	0.992541	43226
2	2002	92.2497	90.7831	7.38718	7.30919	0.993336	43141
3	2003	93.1738	91.7357	7.02671	6.9892	0.992339	43098
4	2004	94.4555	93.0861	7.01027	6.95946	0.992342	41016
5	2005	94.7495	93.426	6.88114	6.85728	0.992153	40079
6	2006	96.0436	94.7831	6.83053	6.83272	0.99209	39186
7	2007	96.3971	95.2202	6.68467	6.7032	0.991341	37300
8	2008	97.0396	95.9908	6.75403	6.7337	0.991982	36568
9	2009	97.3538	96.3334	6.73208	6.78484	0.991639	35823
10	2010	98.4062	97.5	6.85991	6.89889	0.992283	32855
11	2011	99.3638	98.6038	6.67842	6.67551	0.991121	29717
12	2012	99.5157	98.9024	6.96045	6.96055	0.99122	25167
13	2013	98.9294	98.3952	6.66449	6.64084	0.991087	25868
14	2014	98.9271	98.5342	6.09964	6.11419	0.988846	24685
15	2015	99.4554	99.1618	6.37409	6.3249	0.989376	22878
16	2016	99.1973	98.9891	5.87322	5.87269	0.986726	22206
17	2017	98.7181	98.5999	5.74371	5.77332	0.985378	20368
18	2018	98.9924	98.9399	5.73728	5.73968	0.986338	18898
19	2019	99.7204	99.6029	6.09191	6.1007	0.987503	17063
20	2020	99.6959	99.7608	5.52031	5.54109	0.985405	16331
21	2021	101.298	101.315	5.92822	5.91561	0.989529	10412
22	2022	100.532	100.598	5.90131	5.92343	0.988301	3722



As can be seen, our new setup does not replicate exactly the same breeding values when run without genotypical data. We attribute this mainly to a difference in raw data. The old setup has 1265183 measured phenotypes as of February 2025. Our setup uses only 948601 of these measurements. The reason is twofold: first, we only accept pure-bred red dairy cows to contribute phenotypes. This was an early descision made for all Single-step models to only allow pure-bred data in the evaluation, as we believe this will increase accuracy. This brings the amount of measurements down to 966072 measurements. Finally, we remove dams of sires, which brings us down to the final number. Furthermore, there is a difference in the way phantom parent groups are computed between the two evaluations. We attribute the difference in trend to this effect.

From this point onwards, we will compare the new genomic Single-step breeding values to the old pedigree-based values. The reader should thus keep in mind, that there will be a base-level difference stemming from the different dataset.

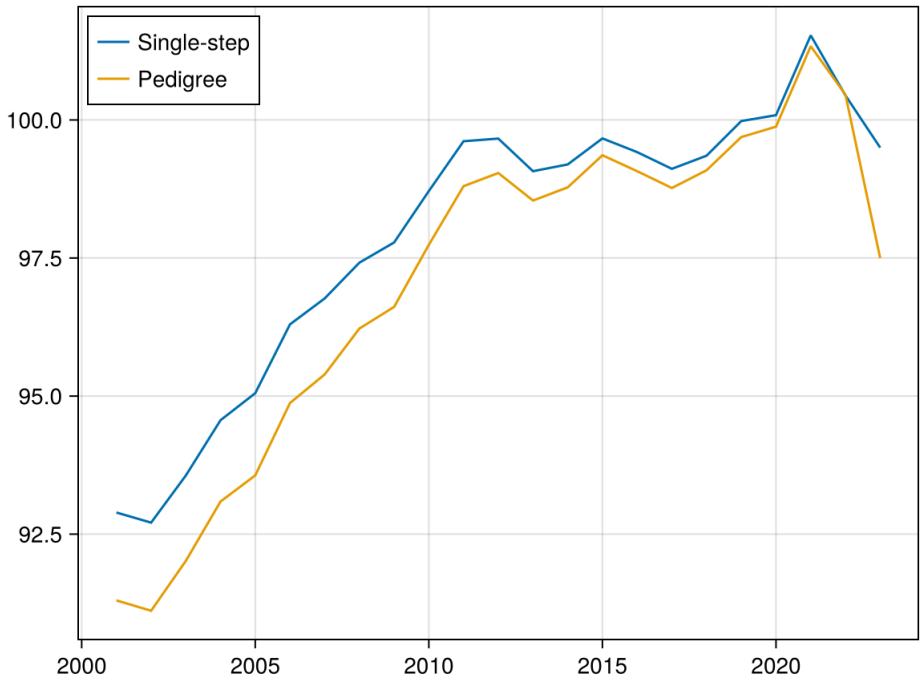
Comparison of genetic Single-step to old breeding values

We now explore how the breeding values copmuted using the full genomic Single-step setup compares to the existing breeding values.

Comparison of genetic Single-step vs old pedigree-based, all animals

23×7 DataFrame

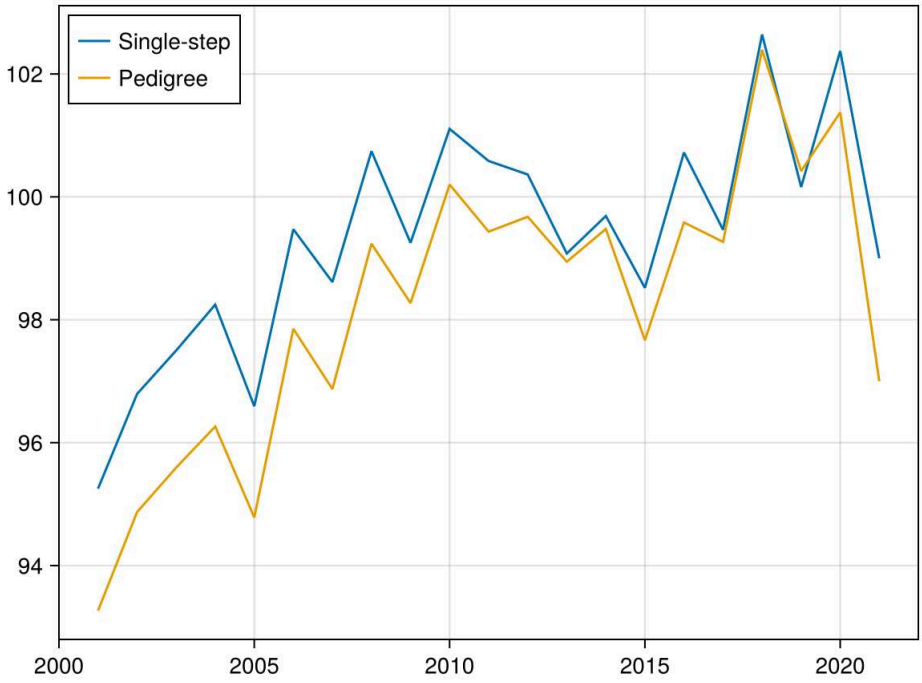
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	92.8918	91.3002	6.82229	6.84572	0.985451	67853
2	2002	92.7087	91.1132	6.97115	7.02151	0.986395	65265
3	2003	93.5621	92.0156	6.62657	6.71371	0.984443	63792
4	2004	94.5638	93.0915	6.60121	6.65856	0.983678	61108
5	2005	95.0531	93.5644	6.56836	6.65657	0.982897	58018
6	2006	96.2987	94.8744	6.62003	6.72102	0.981338	56416
7	2007	96.7689	95.393	6.40671	6.505	0.977564	53241
8	2008	97.4165	96.2238	6.60059	6.67978	0.975326	51950
9	2009	97.7826	96.6156	6.63499	6.77795	0.968656	50005
10	2010	98.7132	97.7393	6.82798	6.84963	0.952452	46246
11	2011	99.6152	98.8014	6.66816	6.51476	0.932637	44316
12	2012	99.6633	99.0398	6.96162	6.76062	0.925383	39063
13	2013	99.0724	98.5414	6.72466	6.44284	0.914117	38166
14	2014	99.1951	98.78	6.22575	5.91137	0.88916	35716
15	2015	99.6659	99.3609	6.56425	6.09664	0.875789	32813
16	2016	99.4179	99.0724	6.26862	5.66276	0.837536	30879
17	2017	99.1151	98.7683	6.27254	5.56892	0.812523	27996
18	2018	99.3536	99.0896	6.33739	5.56221	0.795767	26027
19	2019	99.9806	99.6907	6.71561	5.9067	0.804075	23083
20	2020	100.087	99.8788	6.38651	5.28124	0.753899	22312
21	2021	101.531	101.336	6.6577	5.50682	0.755647	17592
22	2022	100.445	100.458	6.63299	5.27272	0.70744	8517
23	2023	99.5	97.5	3.53553	2.12132	1.0	2



Comparison of genetic Single-step vs old pedigree-based, nordic AI bulls

21×7 DataFrame

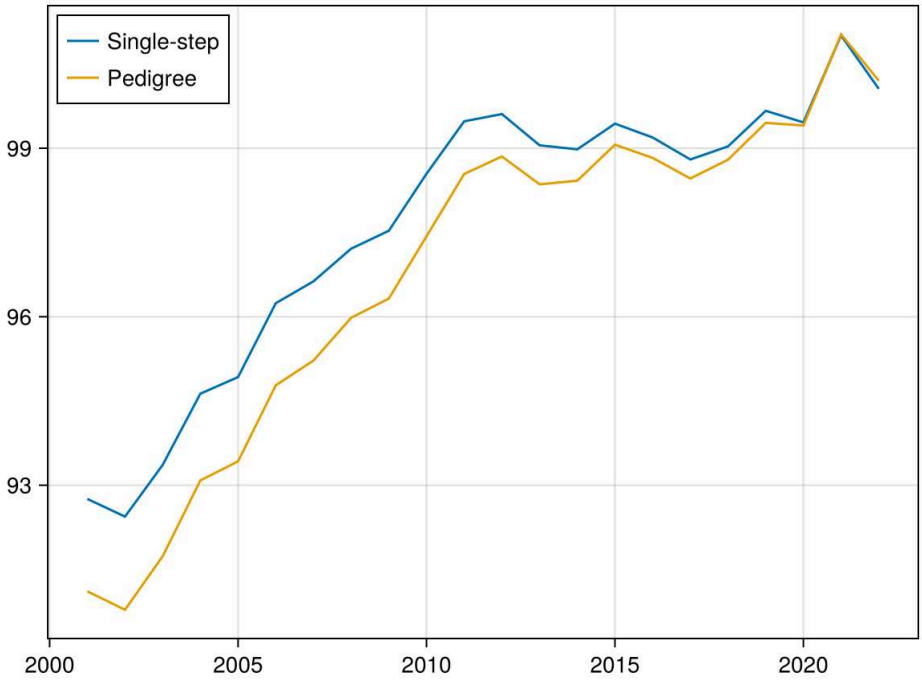
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	95.2519	93.2669	9.3885	9.52376	0.993646	266
2	2002	96.7931	94.8707	9.2867	9.23295	0.992832	232
3	2003	97.5	95.5943	9.06969	8.98486	0.992953	244
4	2004	98.2457	96.2629	9.16444	9.36026	0.991545	232
5	2005	96.5928	94.7828	8.94919	9.0397	0.989318	221
6	2006	99.4732	97.8527	8.54895	8.61382	0.985026	224
7	2007	98.6136	96.8727	8.8411	8.87108	0.986084	220
8	2008	100.743	99.2376	8.39468	8.41007	0.977716	202
9	2009	99.2531	98.2716	9.11371	9.12305	0.950885	162
10	2010	101.107	100.201	9.66464	9.6822	0.946426	169
11	2011	100.583	99.4345	8.12729	8.23141	0.923047	168
12	2012	100.364	99.6763	8.85873	8.49209	0.916379	173
13	2013	99.0787	98.9449	8.85116	8.33267	0.917419	127
14	2014	99.6889	99.4778	8.57832	8.25197	0.944167	90
15	2015	98.52	97.6667	7.65181	7.0946	0.936721	75
16	2016	100.722	99.5833	7.38331	7.21842	0.915344	72
17	2017	99.4648	99.2676	8.10437	7.98741	0.923832	71
18	2018	102.643	102.393	8.56298	7.75694	0.9019	56
19	2019	100.16	100.42	7.92403	7.91044	0.924854	50
20	2020	102.375	101.375	7.56989	6.85294	0.695706	48
21	2021	99.0	97.0	NaN	NaN	NaN	1



Comparison of genetic Single-step vs old pedigree-based, nordic phenotyped cows without genotypes

22×7 DataFrame

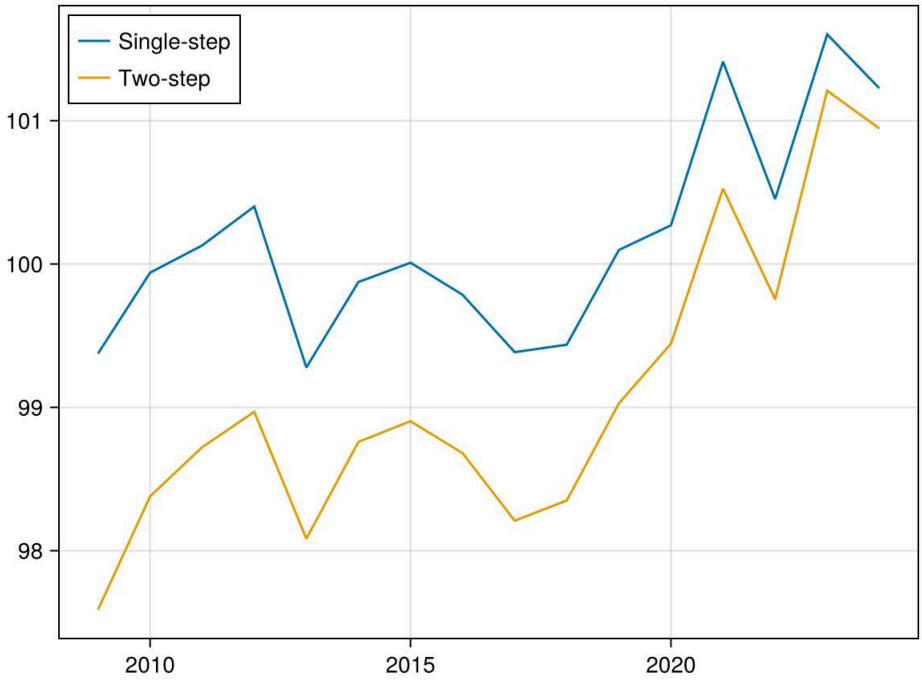
Row	BYR	mean_SS1	mean_kebv	std_SS1	std_kebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	92.7563	91.1097	7.07513	7.06248	0.990874	43226
2	2002	92.4412	90.7831	7.28613	7.30919	0.991571	43141
3	2003	93.362	91.736	6.92492	6.98901	0.990271	43097
4	2004	94.6302	93.086	6.92712	6.95948	0.989707	41011
5	2005	94.9257	93.4254	6.80565	6.85669	0.98856	40062
6	2006	96.2405	94.7796	6.74847	6.83252	0.987295	39155
7	2007	96.6296	95.219	6.61564	6.70221	0.984965	37254
8	2008	97.2117	95.9822	6.69825	6.73299	0.983662	36483
9	2009	97.5306	96.3235	6.65585	6.77928	0.981934	35591
10	2010	98.5453	97.432	6.78202	6.88578	0.982906	30653
11	2011	99.4794	98.5413	6.61863	6.63936	0.977598	26120
12	2012	99.6083	98.8532	6.91962	6.93072	0.975047	21749
13	2013	99.0516	98.3571	6.63106	6.61237	0.96861	22386
14	2014	98.9798	98.422	6.11338	6.11418	0.956455	21046
15	2015	99.4373	99.0622	6.39815	6.2967	0.957387	18144
16	2016	99.191	98.8273	5.99483	5.89483	0.951089	15299
17	2017	98.7998	98.4615	5.80343	5.7446	0.946959	12829
18	2018	99.0324	98.7958	5.76975	5.71187	0.948461	10646
19	2019	99.666	99.4509	6.08413	6.05018	0.953706	8772
20	2020	99.4598	99.4043	5.64822	5.60104	0.94785	7134
21	2021	101.007	101.026	5.98793	6.02784	0.960546	4251
22	2022	100.058	100.202	5.83604	5.88832	0.944492	1245



Comparison of genetic Single-step vs old two-step, all animals

16×7 DataFrame

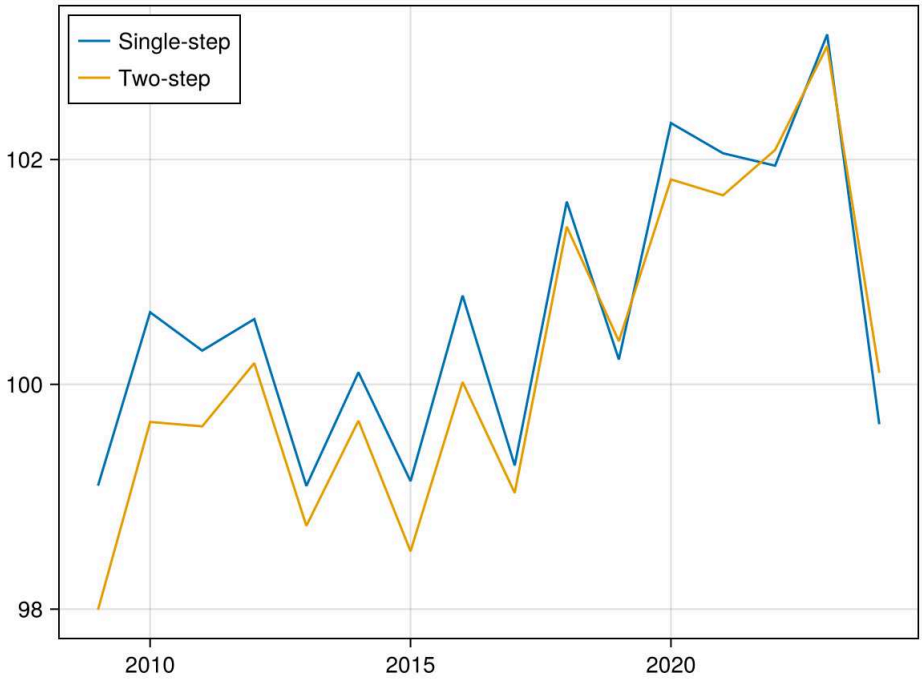
Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	99.3756	97.5881	8.03773	8.36208	0.829527	1286
2	2010	99.9399	98.3792	7.9675	7.7008	0.898106	4842
3	2011	100.13	98.722	7.78661	7.40727	0.897167	8463
4	2012	100.401	98.9689	8.07759	7.72011	0.90385	9851
5	2013	99.2785	98.0839	7.75909	7.25212	0.906955	10291
6	2014	99.8748	98.7592	7.17213	6.77811	0.904173	11109
7	2015	100.009	98.9031	7.46327	6.9686	0.908156	13878
8	2016	99.7851	98.6802	7.04689	6.643	0.897198	18208
9	2017	99.3853	98.2092	6.98298	6.51546	0.8945	21566
10	2018	99.4375	98.3502	6.94059	6.46453	0.891747	23976
11	2019	100.098	99.0277	7.25839	6.85368	0.902081	24289
12	2020	100.27	99.4442	6.78273	6.33192	0.890381	27004
13	2021	101.412	100.526	6.9152	6.42794	0.885052	27551
14	2022	100.454	99.7539	6.85135	6.42392	0.881537	28304
15	2023	101.602	101.209	6.54899	6.30143	0.862956	26014
16	2024	101.227	100.946	6.32128	5.98107	0.847237	18299



Comparison of genetic Single-step vs old two-step, nordic AI bulls with genotypes

16×7 DataFrame

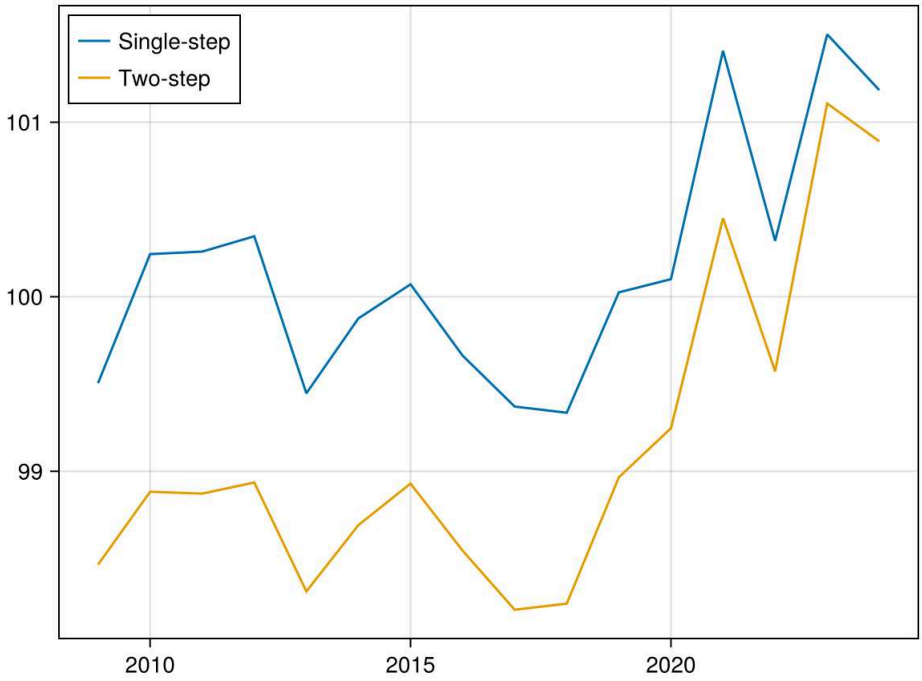
Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	99.0984	97.9946	8.45994	8.43201	0.946831	244
2	2010	100.641	99.6654	9.25638	8.8731	0.960812	259
3	2011	100.3	99.6262	7.9128	7.62721	0.937087	260
4	2012	100.58	100.189	8.97161	8.53553	0.959538	205
5	2013	99.0957	98.7409	8.62848	7.98991	0.959635	188
6	2014	100.106	99.6764	8.12817	8.14407	0.956167	141
7	2015	99.1386	98.5145	7.78721	7.22986	0.960412	101
8	2016	100.789	100.02	7.42751	7.5215	0.956549	95
9	2017	99.2784	99.034	7.99445	7.74716	0.950282	97
10	2018	101.625	101.403	7.73158	7.61417	0.952092	88
11	2019	100.221	100.384	7.51949	7.64605	0.931781	77
12	2020	102.324	101.823	6.93435	6.74948	0.925599	74
13	2021	102.056	101.682	6.75505	6.18263	0.91045	72
14	2022	101.945	102.085	6.64975	6.0463	0.874071	73
15	2023	103.113	103.009	6.03407	5.84637	0.845781	53
16	2024	99.6452	100.102	4.80658	5.26142	0.783512	31



Comparison of genetic Single-step vs old two-step, nordic genotyped cows without phenotypes

16×7 DataFrame

Row	BYR	mean_SS1	mean_two_ebv	std_SS1	std_two_ebv	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2009	99.5048	98.4652	8.39081	7.89231	0.915904	311
2	2010	100.244	98.8827	7.65564	7.22848	0.903953	1510
3	2011	100.259	98.8722	7.85495	7.3277	0.910936	2906
4	2012	100.347	98.9358	8.04006	7.57788	0.918205	3933
5	2013	99.4469	98.3117	7.64303	7.11335	0.911371	4328
6	2014	99.8763	98.6921	7.13169	6.70089	0.901233	5085
7	2015	100.071	98.9296	7.45357	6.92671	0.908918	6693
8	2016	99.6627	98.5453	6.97687	6.52728	0.896386	8849
9	2017	99.3708	98.2067	6.94949	6.41816	0.89579	11286
10	2018	99.3355	98.2418	6.90694	6.38358	0.893847	12961
11	2019	100.025	98.9658	7.21766	6.75035	0.908248	13298
12	2020	100.101	99.2467	6.74184	6.24254	0.894067	14683
13	2021	101.409	100.45	6.90292	6.37498	0.900409	18023
14	2022	100.321	99.573	6.87288	6.40311	0.895875	22658
15	2023	101.503	101.108	6.57039	6.29955	0.884435	23069
16	2024	101.184	100.89	6.33914	5.98831	0.872617	15969



Single-step genetic trend for all animals by birthyear

All animals:

24×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	92.9174	6.81181	68923
2	2002	92.7439	6.94982	66478
3	2003	93.582	6.60549	65004
4	2004	94.5723	6.5724	62431
5	2005	95.0765	6.54784	59359
6	2006	96.3098	6.59316	57953
7	2007	96.7932	6.3803	54819
8	2008	97.4374	6.56992	53959
9	2009	97.824	6.62359	52594
10	2010	98.7426	6.82899	49678
11	2011	99.5989	6.69665	49765
12	2012	99.6774	7.00781	46023
13	2013	99.0119	6.77149	45560
14	2014	99.1946	6.27718	44187
15	2015	99.6175	6.61264	42612
16	2016	99.412	6.34951	42261
17	2017	99.1296	6.36295	41113
18	2018	99.3042	6.44477	40636
19	2019	99.9595	6.84481	37480
20	2020	100.059	6.45777	37563
21	2021	101.33	6.72313	34247
22	2022	100.413	6.75616	31024
23	2023	101.598	6.54407	26332
24	2024	101.216	6.30564	18721

Nordic AI bulls:

24×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	95.2519	9.3885	266
2	2002	96.7931	9.2867	232
3	2003	97.5	9.06969	244
4	2004	98.3205	9.16116	234
5	2005	96.5928	8.94919	221
6	2006	99.4732	8.54895	224
7	2007	98.5792	8.83584	221
8	2008	100.228	7.99456	259
9	2009	99.1143	8.44626	245
10	2010	100.641	9.25638	259
11	2011	100.3	7.9128	260
12	2012	100.58	8.97161	205
13	2013	99.0688	8.61348	189
14	2014	100.106	8.12817	141
15	2015	99.1386	7.78721	101
16	2016	100.802	7.38935	96
17	2017	99.2784	7.99445	97
18	2018	101.625	7.73158	88
19	2019	100.221	7.51949	77
20	2020	102.324	6.93435	74
21	2021	102.056	6.75505	72
22	2022	101.945	6.64975	73
23	2023	103.113	6.03407	53
24	2024	99.6452	4.80658	31

Nordic cows w/ phenotype:

22×4 DataFrame

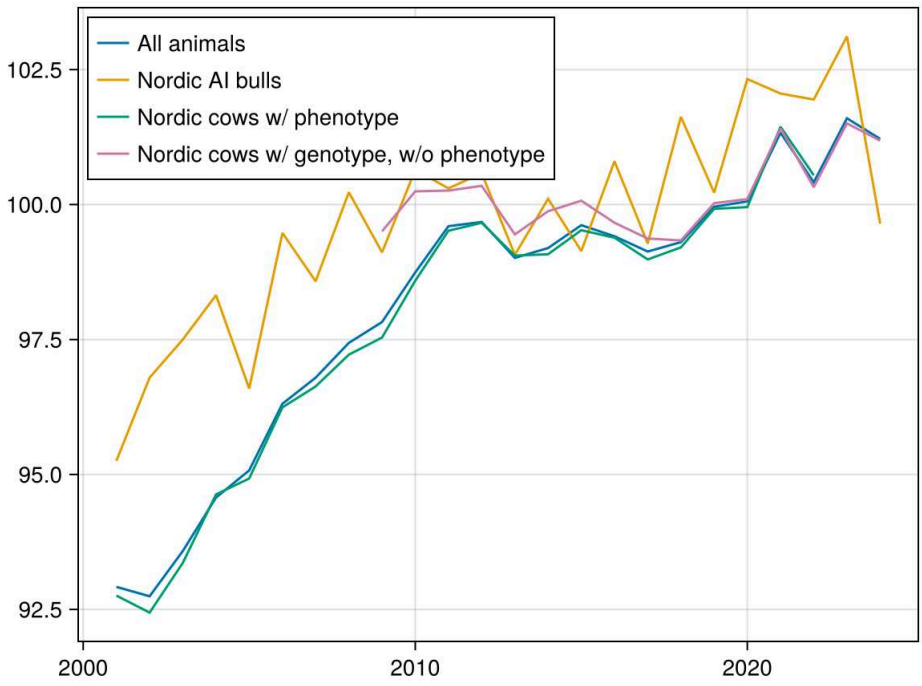
Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2001	92.7563	7.07513	43226
2	2002	92.4412	7.28613	43141
3	2003	93.3618	6.92509	43098
4	2004	94.6303	6.92693	41016
5	2005	94.9261	6.80594	40079
6	2006	96.2434	6.74861	39186
7	2007	96.6307	6.61697	37300
8	2008	97.2191	6.698	36568
9	2009	97.5368	6.66822	35823
10	2010	98.589	6.87953	32855
11	2011	99.5152	6.79265	29717
12	2012	99.6616	7.10024	25167
13	2013	99.0536	6.83002	25868
14	2014	99.0794	6.31675	24685

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
15	2015	99.5247	6.6736	22878
16	2016	99.386	6.38817	22206
17	2017	98.9829	6.33387	20368
18	2018	99.2069	6.36568	18898
19	2019	99.9205	6.75313	17063
20	2020	99.9526	6.39004	16331
21	2021	101.441	6.65986	10412
22	2022	100.543	6.62814	3722

Nordic cows w/ genotype, w/o phenotype:

16×4 DataFrame

Row	BYR	mean	std	n
	Int64	Float64	Float64	Int64
1	2009	99.5048	8.39081	311
2	2010	100.244	7.65564	1510
3	2011	100.259	7.85495	2906
4	2012	100.347	8.04006	3933
5	2013	99.4469	7.64303	4328
6	2014	99.8763	7.13169	5085
7	2015	100.071	7.45357	6693
8	2016	99.6627	6.97687	8849
9	2017	99.3708	6.94949	11286
10	2018	99.3355	6.90694	12961
11	2019	100.025	7.21766	13298
12	2020	100.101	6.74184	14683
13	2021	101.409	6.90292	18023
14	2022	100.321	6.87273	22659
15	2023	101.503	6.57039	23069
16	2024	101.184	6.33888	15971

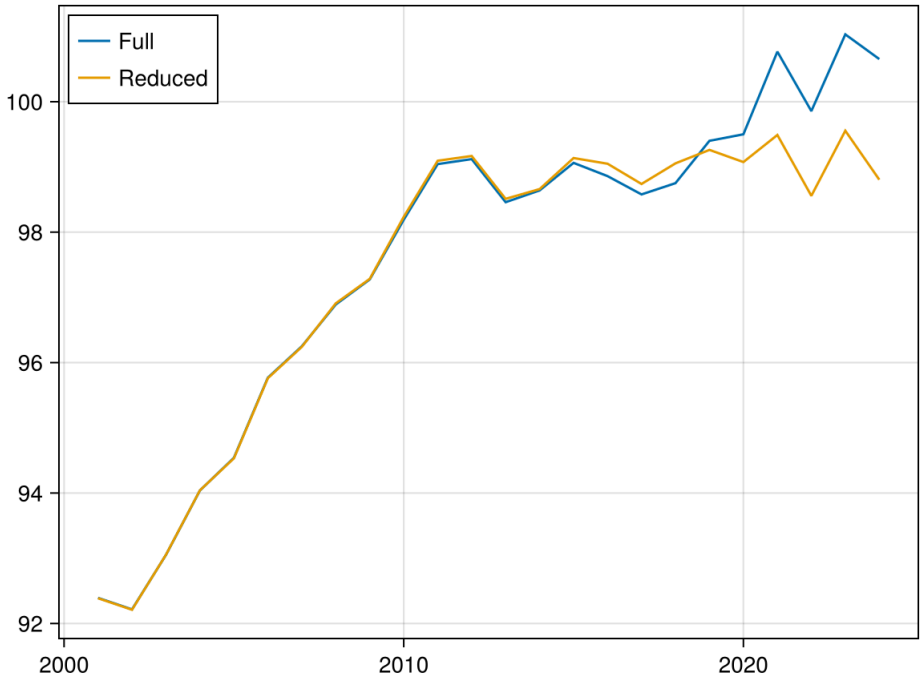


Genetic trend, full vs. reduced evaluation

The Legarra-Reverter test suggests that the breeding value estimated for candidate bulls is higher than their true breeding value. A reduced evaluation was performed, where performances of daughter of bulls born after 2016 were removed from the dataset. Below is an analysis of the difference between the full evaluation and this reduced evaluation.

24×7 DataFrame

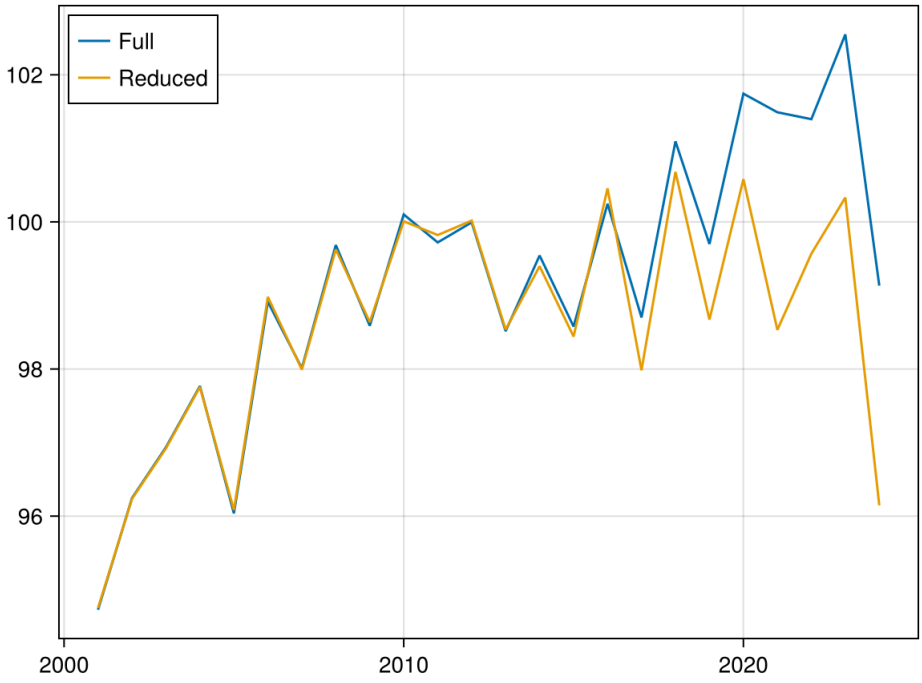
Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	92.3926	92.3873	6.77664	6.78413	0.999838	68923
2	2002	92.2161	92.2108	6.91216	6.91713	0.999785	66478
3	2003	93.0517	93.0543	6.57126	6.57437	0.999627	65004
4	2004	94.0395	94.0418	6.53829	6.54418	0.99949	62431
5	2005	94.5406	94.5329	6.5114	6.51392	0.999095	59359
6	2006	95.7692	95.7613	6.55804	6.56325	0.998792	57953
7	2007	96.2502	96.242	6.34697	6.34497	0.998289	54819
8	2008	96.8912	96.9092	6.53469	6.55235	0.997754	53959
9	2009	97.2755	97.2845	6.58887	6.60881	0.99671	52594
10	2010	98.19	98.2342	6.79179	6.76577	0.992814	49678
11	2011	99.0437	99.095	6.66149	6.62834	0.989485	49765
12	2012	99.1203	99.1679	6.972	6.91872	0.987732	46023
13	2013	98.4599	98.5108	6.73855	6.6789	0.985261	45560
14	2014	98.64	98.6605	6.24495	6.16694	0.97963	44187
15	2015	99.0623	99.1363	6.57667	6.47775	0.977087	42612
16	2016	98.8592	99.0492	6.31513	6.23284	0.968376	42261
17	2017	98.5787	98.7388	6.329	6.2078	0.960586	41113
18	2018	98.7515	99.055	6.40904	6.28502	0.946674	40636
19	2019	99.4005	99.2611	6.80846	5.99299	0.821928	37480
20	2020	99.5007	99.0751	6.42222	5.75324	0.845223	37563
21	2021	100.767	99.4899	6.6877	5.72276	0.771365	34247
22	2022	99.8561	98.5573	6.71846	6.04133	0.8074	31024
23	2023	101.032	99.5551	6.5092	6.01542	0.870247	26332
24	2024	100.654	98.8048	6.27355	5.93003	0.882267	18721



Genetic trend, full vs. reduced evaluation, nordic AI bulls

24×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	94.727	94.751	9.36048	9.36469	0.999805	266
2	2002	96.2454	96.2346	9.26573	9.27911	0.999766	232
3	2003	96.9366	96.9213	9.009	9.03644	0.999605	244
4	2004	97.7681	97.7558	9.10773	9.13247	0.999402	234
5	2005	96.0374	96.0841	8.94045	8.92029	0.999305	221
6	2006	98.9142	98.9799	8.49283	8.52246	0.998934	224
7	2007	98.0108	97.9916	8.78469	8.78547	0.998415	221
8	2008	99.6854	99.626	7.94641	8.01059	0.996749	259
9	2009	98.5883	98.6384	8.40449	8.44808	0.989554	245
10	2010	100.101	100.008	9.19968	9.25299	0.986589	259
11	2011	99.721	99.8213	7.88115	7.92128	0.982188	260
12	2012	99.994	100.017	8.91835	8.76363	0.986927	205
13	2013	98.515	98.5366	8.52845	8.43633	0.985456	189
14	2014	99.5429	99.3969	8.10137	8.11128	0.977837	141
15	2015	98.5777	98.4413	7.70877	7.56982	0.974207	101
16	2016	100.246	100.455	7.37064	6.63186	0.862645	96
17	2017	98.7009	97.9829	7.90558	6.67572	0.726918	97
18	2018	101.095	100.68	7.69927	5.91902	0.806021	88
19	2019	99.6993	98.6724	7.48743	5.91969	0.630488	77
20	2020	101.743	100.581	6.86524	5.77557	0.773942	74
21	2021	101.49	98.5322	6.74857	5.96132	0.794455	72
22	2022	101.397	99.5674	6.53155	6.06507	0.855842	73
23	2023	102.549	100.331	5.92853	5.89885	0.888127	53
24	2024	99.1335	96.147	4.85024	4.64173	0.738902	31



Number of nordic AI bulls born after 2016 (data-cut year) moving by a certain number of index points between the full and reduced

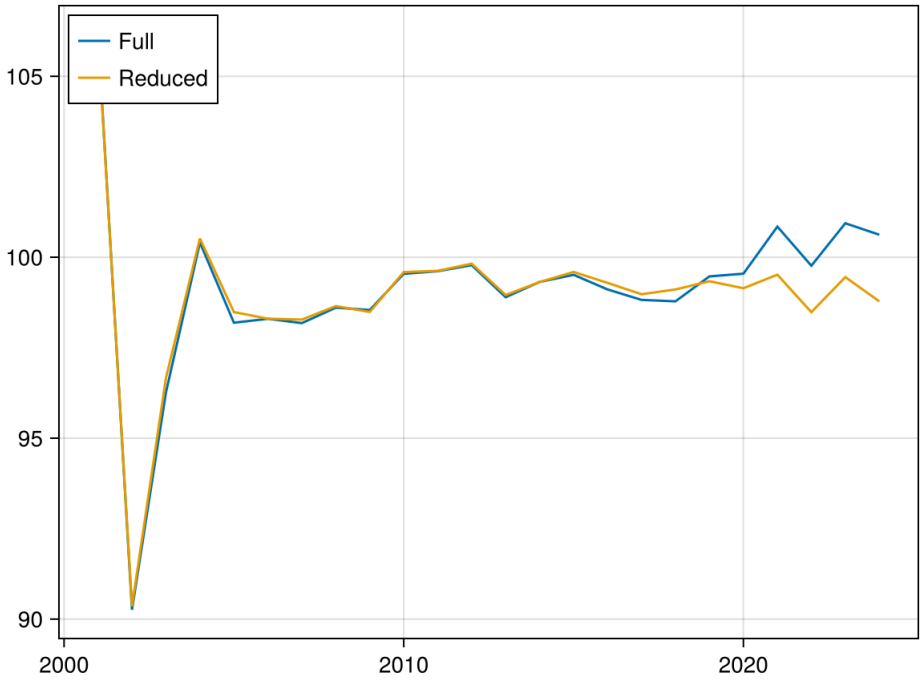
31×2 DataFrame

Row	diff	n
	Int64	Int64
1	-15	1
2	-14	1
3	-12	1
4	-11	5
5	-10	4
6	-9	2
7	-8	9
8	-7	12
9	-6	11
10	-5	20
11	-4	49
12	-3	60
13	-2	177
14	-1	480
15	0	2115
16	1	509
17	2	194
18	3	101
19	4	74
20	5	39
21	6	27
22	7	22
23	8	15
24	9	11
25	10	5
26	11	8
27	12	4
28	13	2
29	14	1
30	16	2
31	21	1

Genetic trend, full vs. reduced evaluation, nordic genotyped cows without phenotype

24×7 DataFrame

Row	BYR	mean_f1	mean_r1	std_f1	std_r1	cor	n
	Int64?	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	106.158	106.076	NaN	NaN	NaN	1
2	2002	90.2587	90.354	5.29708	5.04387	0.999674	3
3	2003	96.2647	96.6641	6.91156	7.1332	1.0	2
4	2004	100.406	100.518	8.71682	8.64637	0.993785	12
5	2005	98.1911	98.4848	7.41149	7.4734	0.989927	35
6	2006	98.2982	98.302	6.74632	6.34323	0.989985	60
7	2007	98.1794	98.2768	7.0942	7.08381	0.991317	113
8	2008	98.6069	98.6493	7.76616	7.78815	0.990905	211
9	2009	98.5424	98.4878	8.47597	8.39876	0.97993	323
10	2010	99.5413	99.5897	7.67636	7.63063	0.974063	1526
11	2011	99.6143	99.6247	7.8644	7.78658	0.975683	2928
12	2012	99.7805	99.8223	8.00851	7.93602	0.974276	3937
13	2013	98.8951	98.9558	7.60867	7.45923	0.97038	4328
14	2014	99.3174	99.3154	7.09583	6.94632	0.965074	5085
15	2015	99.5143	99.5925	7.41529	7.2061	0.964568	6693
16	2016	99.1096	99.2916	6.94053	6.82703	0.958409	8849
17	2017	98.8208	98.9779	6.91111	6.73358	0.953958	11286
18	2018	98.7817	99.1103	6.86738	6.7514	0.94501	12961
19	2019	99.4709	99.3365	7.17741	6.48174	0.850488	13298
20	2020	99.545	99.143	6.70767	6.20524	0.880862	14683
21	2021	100.846	99.5176	6.86707	6.02085	0.799844	18023
22	2022	99.765	98.4817	6.83639	6.18943	0.821964	22659
23	2023	100.938	99.4504	6.53546	6.03539	0.86976	23069
24	2024	100.622	98.7815	6.30666	5.93993	0.882149	15971



Correlations and levels between pedigree-based and Single-Step reliabilities for nordic insemination bulls with at least 50 offspring by birth year

20×7 DataFrame

Row	BYR	cor	mean_rel1	mean_ebv_rel1	std_rel1	std_ebv_rel1	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2001	0.998553	81.2367	82.4431	5.85175	5.37757	218
2	2002	0.998713	80.7916	82.0467	5.53217	5.08646	182
3	2003	0.998631	79.9372	81.2455	5.95259	5.49022	206
4	2004	0.998085	78.5255	80.0296	6.25196	5.75428	197
5	2005	0.998428	80.1663	81.4363	5.41238	4.99344	197
6	2006	0.998585	79.5019	80.8617	5.69689	5.21843	196
7	2007	0.997963	76.5645	78.2145	6.39621	5.80887	171
8	2008	0.998717	78.4727	79.9049	5.64528	5.1436	152
9	2009	0.986402	81.6609	78.781	4.37079	5.68077	113
10	2010	0.993993	81.0781	77.3011	6.19036	7.88759	84
11	2011	0.992803	82.2512	79.2841	6.19836	7.74531	102
12	2012	0.996111	83.2776	80.5402	6.94453	8.78801	93
13	2013	0.996007	84.9918	82.5471	7.50305	9.63394	74
14	2014	0.996521	86.8815	85.0197	7.60251	9.65127	62
15	2015	0.996672	87.9937	86.6555	6.97985	8.76886	56
16	2016	0.996047	88.0717	86.8297	6.79125	8.35402	48
17	2017	0.996558	89.0851	88.106	6.88101	8.56306	43
18	2018	0.997533	87.9745	86.7533	7.23842	8.86949	30
19	2019	0.996168	84.4002	82.5432	6.24237	7.98955	26
20	2020	0.994635	81.4253	78.618	4.60424	6.81207	3

Correlations and levels between two-step and Single-Step reliabilities for nordic insemination bulls without offspring by birth year

15×7 DataFrame

Row	BYR	cor	mean_rel1	mean_two_rel1	std_rel1	std_two_rel1	n
	Int64	Float64	Float64	Float64	Float64	Float64	Int64
1	2010	0.890819	57.0898	72.4176	2.17	1.70663	91
2	2011	0.915958	56.4098	71.9022	2.5402	2.1384	92
3	2012	0.925767	55.3465	70.2059	3.17809	2.60279	34
4	2013	0.956783	55.1554	70.5806	3.48628	2.91153	62
5	2014	0.940163	56.4052	71.2308	2.3896	1.82161	52
6	2015	0.96818	55.5265	70.2222	3.20152	2.48586	27
7	2016	0.875365	55.9012	70.76	2.01951	1.33167	25
8	2017	0.985508	53.756	69.1154	4.69659	4.17925	26
9	2018	0.917671	54.0492	69.6667	2.27079	1.67083	33
10	2019	0.944221	53.8642	69.4444	2.6666	1.69464	27
11	2020	0.949776	53.4082	69.0	3.0353	2.03101	33
12	2021	0.937177	52.2446	68.3472	2.78418	1.81667	72
13	2022	0.950986	47.9123	65.4247	3.22483	2.43765	73
14	2023	0.943871	44.9316	63.0755	2.12863	1.67388	53
15	2024	0.955156	43.2961	61.8387	1.74404	1.24088	31

Tables of differences

Number of nordic AI bulls born after 2010 with at least 50 offspring moving by certain index levels from old breeding values (pedigree-based)

18×4 DataFrame

Row	diff	n	mean_rel	mean_n_daughters
	Int64	Int64	Float64	Float64
1	-9	2	77.0297	52.5
2	-6	1	81.1082	88.0
3	-5	9	79.0877	72.4444
4	-4	19	80.0324	82.1053
5	-3	11	81.942	105.364
6	-2	42	83.1007	181.167
7	-1	71	85.4267	203.056
8	0	122	89.0528	426.746
9	1	104	88.2499	362.221
10	2	63	85.5919	233.746
11	3	50	81.3239	106.9
12	4	25	81.0066	90.76
13	5	7	79.5458	76.0
14	6	4	79.9221	67.5
15	7	3	78.2681	60.0
16	8	2	78.3407	65.5
17	9	1	78.2004	60.0
18	10	1	77.4113	56.0

Number of nordic AI bulls born after 2020 with no offspring moving by certain index levels from old breeding values (two-step)

18×3 DataFrame

Row	diff	n	mean_rel
	Int64	Int64	Float64
1	-9	1	43.3346
2	-8	1	49.5338
3	-7	3	45.0599
4	-6	5	45.2342
5	-5	8	47.7191
6	-4	14	46.7231
7	-3	8	50.0861
8	-2	27	47.9466
9	-1	34	47.765
10	0	28	48.4794
11	1	25	48.6188
12	2	29	48.8773
13	3	18	48.2869
14	4	9	45.6999
15	5	8	46.7327
16	6	6	47.2642
17	7	3	47.8887
18	8	2	50.7483

Mendelian sampling analysis

All:

18×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2005	-0.0289816	2.27818	55863
2	2006	-0.0126214	2.2865	54471
3	2007	-0.0205676	2.30136	51586
4	2008	-0.00370232	2.30407	50779
5	2009	0.0190224	2.40554	49652
6	2010	0.0151718	2.58383	46995
7	2011	-0.0295396	2.71397	46920
8	2012	-0.0118693	2.85077	43347
9	2013	0.00816156	2.92864	43129
10	2014	0.0296093	3.04563	42132
11	2015	0.0667181	3.20358	40836
12	2016	0.0446977	3.40186	40897
13	2017	0.0984246	3.5438	40117
14	2018	0.0526356	3.66819	39650
15	2019	0.113407	3.75596	36801
16	2020	0.14247	3.87819	37264
17	2021	0.222309	3.97588	33856
18	2022	0.151945	4.14125	30590

Nordic cows:

18×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2005	-0.0307466	2.26443	55128
2	2006	-0.0119586	2.26949	53727
3	2007	-0.022884	2.2837	50887
4	2008	-0.00687	2.29197	50000
5	2009	0.0207943	2.37181	48595
6	2010	0.0158174	2.53979	45551
7	2011	-0.0288487	2.64037	44664
8	2012	-0.0149752	2.75194	40567
9	2013	0.00557593	2.83864	40352
10	2014	0.0361297	2.96065	39372
11	2015	0.059961	3.12657	37958
12	2016	0.0435315	3.34602	37984
13	2017	0.0960839	3.50148	36822
14	2018	0.0526664	3.62142	36304
15	2019	0.104946	3.73762	33479
16	2020	0.153041	3.85371	33687
17	2021	0.228095	3.96143	30165
18	2022	0.143714	4.1545	27165

Nordic cows w/ phenotype, w/o genotype:

18×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2005	-0.0353955	2.51556	39991
2	2006	-0.0115125	2.50563	39001
3	2007	-0.025261	2.50727	37073
4	2008	-0.0122448	2.50187	36301
5	2009	0.0146673	2.53241	35453
6	2010	0.0154093	2.54023	30501
7	2011	-0.0221418	2.53835	25969
8	2012	-0.0192575	2.56769	21550
9	2013	0.00735493	2.59688	22162
10	2014	0.0201238	2.63866	20846
11	2015	0.0387748	2.65298	17924
12	2016	-0.00793284	2.66224	15127
13	2017	0.0548204	2.64286	12696
14	2018	0.0340855	2.58112	10503
15	2019	0.0336144	2.52171	8657
16	2020	-0.00184659	2.49894	7040
17	2021	0.105029	2.46179	4156
18	2022	0.00743802	2.42428	1210

Nordic cows w/o phenotype, w genotype:

13×4 DataFrame

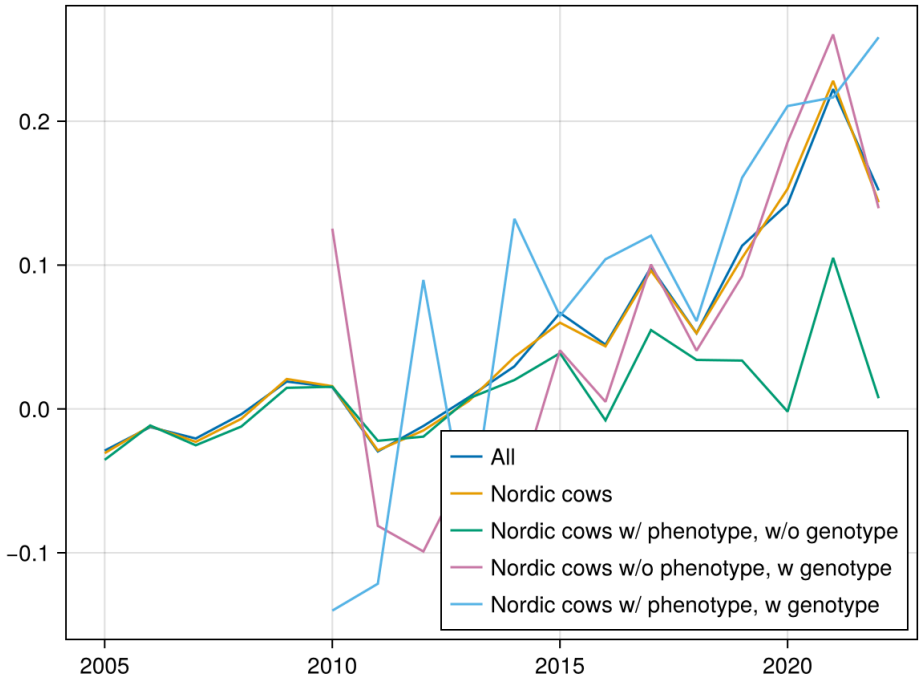
Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2010	0.12533	3.93668	1516
2	2011	-0.0812757	3.95019	2916

3	2012	-0.0991071	3.98749	3920
4	2013	-0.0363213	4.07549	4295
5	2014	-0.0637604	4.20513	5058
6	2015	0.040743	4.15638	6676
7	2016	0.00498245	4.11666	8831
8	2017	0.100417	4.15424	11278
9	2018	0.040527	4.17747	12942
10	2019	0.092248	4.19266	13274
11	2020	0.185522	4.24226	14664
12	2021	0.260318	4.19481	18003
13	2022	0.139542	4.25293	22642

Nordic cows w/ phenotype, w genotype:

13×4 DataFrame

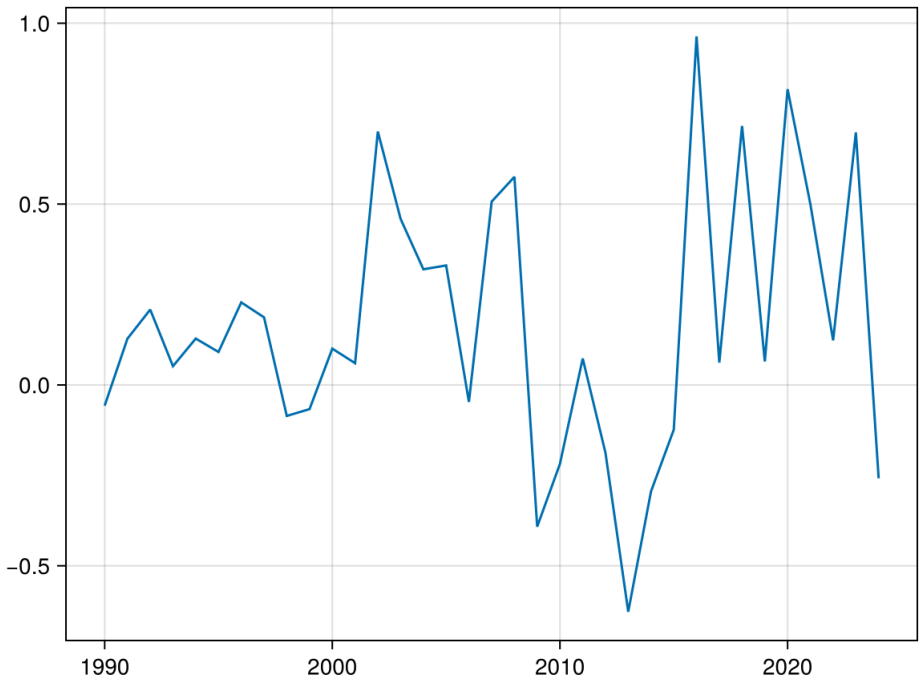
Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	2010	-0.14021	4.36125	2186
2	2011	-0.121504	4.19757	3576
3	2012	0.0896683	4.37693	3407
4	2013	-0.0858993	4.4257	3475
5	2014	0.132166	4.51004	3628
6	2015	0.0647109	4.53469	4721
7	2016	0.104058	4.50919	6900
8	2017	0.120456	4.43093	7538
9	2018	0.0610983	4.43343	8249
10	2019	0.160714	4.48114	8288
11	2020	0.210572	4.43296	9194
12	2021	0.216583	4.49145	6157
13	2022	0.258384	4.46162	2475



Nordic AI bulls:

35×4 DataFrame

Row	BYR	mean_diff	std_diff	n
	Int64	Float64	Float64	Int64
1	1990	-0.0572755	4.95467	323
2	1991	0.127907	5.06255	344
3	1992	0.208333	4.57668	384
4	1993	0.0518732	5.11022	347
5	1994	0.128165	5.25963	316
6	1995	0.0911854	5.23306	329
7	1996	0.228188	5.42797	298
8	1997	0.186916	5.58228	321
9	1998	-0.0856164	4.91766	292
10	1999	-0.0667939	5.35362	262
11	2000	0.100346	5.53511	289
12	2001	0.0601504	5.88604	266
13	2002	0.700431	5.85186	232
14	2003	0.459016	5.69622	244
15	2004	0.319742	5.63813	233
16	2005	0.330317	5.28006	221
17	2006	-0.046875	5.5311	224
18	2007	0.506787	5.4434	221
19	2008	0.57529	4.69631	259
20	2009	-0.391837	4.81135	245
21	2010	-0.218147	4.75339	259
22	2011	0.0730769	5.17255	260
23	2012	-0.187805	5.03883	205
24	2013	-0.626984	5.08986	189
25	2014	-0.294326	5.56169	141
26	2015	-0.123762	5.37792	101
27	2016	0.963542	5.66812	96
28	2017	0.0618557	5.511	97
29	2018	0.715909	5.21701	88
30	2019	0.0649351	4.8043	77
31	2020	0.817568	5.02771	74
32	2021	0.5	3.71332	72
33	2022	0.123288	4.30986	73
34	2023	0.698113	3.57117	53
35	2024	-0.258065	3.87916	31



HOL summery stastistics for SS and previous breeding value for nordic AI bulls with minimum 15 offspring, by birth year

Obs	BYR	name	no	mean_noff	std_noff	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2010	bv1	184	169	480	95.5	95.6	8.8	8.9	-0.1	0.9	1.00
2	2011	bv1	150	103	192	96.1	96.2	9.5	9.5	-0.1	0.8	1.00
3	2012	bv1	152	150	239	97.9	98.0	9.2	9.2	-0.1	0.7	1.00
4	2013	bv1	135	160	280	98.6	98.7	7.5	7.5	-0.2	1.0	0.99
5	2014	bv1	97	228	259	96.8	96.9	9.6	9.7	-0.1	1.0	0.99
6	2015	bv1	81	330	414	101.1	101.1	7.7	7.8	0.0	0.8	0.99
7	2016	bv1	62	332	441	99.6	99.6	10.1	10.1	0.0	1.0	0.99
8	2017	bv1	58	350	442	100.2	100.0	9.6	9.7	0.2	1.2	0.99
9	2018	bv1	62	307	416	102.2	102.3	9.7	9.3	-0.1	1.6	0.99
10	2019	bv1	42	284	371	103.6	103.4	9.2	9.2	0.2	3.3	0.93
11	2020	bv1	13	167	148	100.9	100.8	8.4	7.2	0.2	4.2	0.87

HOL summery stastistics for SS and previous breeding value for nordic AI bulls with minimum 15 offspring, by birth year

Obs	diff	d_milksp	p_milksp
1	-10	1	0
2	-9	1	0
3	-6	1	0
4	-5	1	0
5	-4	4	0
6	-3	9	1
7	-2	45	4
8	-1	247	24
9	0	482	47
10	1	187	18
11	2	38	4
12	3	10	1
13	4	5	0
14	5	2	0
15	6	1	0
16	8	1	0
17	10	1	0

HOL summery stastistics for SS and prev SS breeding value for nordic AI bulls with no offspring, by birth year

Obs	BYR	name	no	mean_noff	std_noff	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2019	bv1	13	0	0	100.5	100.8	10.4	11.0	-0.2	1.5	0.99
2	2020	bv1	23	0	0	103.3	103.3	6.5	6.4	-0.1	1.7	0.96
3	2021	bv1	54	0	0	103.7	103.7	8.0	7.9	0.0	2.0	0.97
4	2022	bv1	62	0	0	104.2	103.9	7.1	7.1	0.3	2.7	0.93
5	2023	bv1	44	0	0	103.2	103.9	8.6	8.2	-0.7	2.2	0.97
6	2024	bv1	38	0	0	105.3	104.8	5.9	5.9	0.5	2.0	0.94

HOL summery stastistics for SS and prev SS breeding value for nordic AI bulls with no offspring, by birth year

Obs	diff	d_milksp	p_milksp
1	-9	1	0
2	-6	1	0
3	-5	4	2
4	-4	4	2
5	-3	14	6
6	-2	27	12
7	-1	43	18
8	0	49	21
9	1	42	18
10	2	25	11
11	3	10	4
12	4	6	3
13	5	5	2
14	7	3	1

sum sta for SS and prev SS breeding value for genotyped females without phenotype, by birth year

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2019	bv1	37019	99.4	99.5	7.5	7.5	-0.1	1.3	0.98
2	2020	bv1	45555	99.9	100.0	7.5	7.4	-0.1	1.4	0.98
3	2021	bv1	48716	100.8	101.0	7.5	7.3	-0.2	1.6	0.98
4	2022	bv1	59553	101.4	101.6	7.3	7.3	-0.2	2.3	0.95
5	2023	bv1	77003	102.1	102.5	7.3	7.3	-0.4	2.6	0.94
6	2024	bv1	70162	103.0	102.9	7.2	7.0	0.0	2.1	0.96
7	2025	bv1	471	103.8	103.2	7.0	6.9	0.6	2.0	0.96

sum sta for SS and prev SS breeding value for genotyped females without phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-12	1	0
2	-11	14	0
3	-10	93	0
4	-9	435	0
5	-8	1121	0
6	-7	1630	0
7	-6	2118	1
8	-5	3375	1
9	-4	7444	2
10	-3	17952	5
11	-2	39338	12
12	-1	66282	20
13	0	76376	23
14	1	60176	18
15	2	34731	10
16	3	16785	5
17	4	7106	2
18	5	2502	1
19	6	782	0
20	7	180	0
21	8	30	0
22	9	3	0
23	10	3	0
24	11	1	0
25	13	1	0

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2015	bv1	4199	96.9	97.0	8.6	8.6	-0.2	1.2	0.99
2	2016	bv1	6579	97.5	97.6	7.9	7.9	-0.1	1.3	0.99
3	2017	bv1	9319	98.2	98.3	7.5	7.5	-0.1	1.3	0.99
4	2018	bv1	12023	98.6	98.7	8.0	7.9	-0.1	1.3	0.99
5	2019	bv1	12227	99.7	99.8	8.0	7.9	-0.1	1.3	0.99
6	2020	bv1	13373	100.2	100.2	7.9	7.8	0.0	1.4	0.98
7	2021	bv1	9667	100.8	100.9	7.9	7.7	-0.2	1.6	0.98
8	2022	bv1	4412	101.3	101.6	7.7	7.7	-0.3	2.1	0.96
9	2023	bv1	7	.	.	.	.	.	.	0.91

sum sta for SS and previous breeding value for genotyped females with phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-9	2	0
2	-8	6	0
3	-7	11	0
4	-6	32	0
5	-5	102	0
6	-4	457	1
7	-3	2200	3
8	-2	7859	11
9	-1	16902	24
10	0	21261	30
11	1	14848	21
12	2	6057	8
13	3	1548	2
14	4	365	1
15	5	114	0
16	6	31	0
17	7	6	0
18	8	4	0
19	17	1	0

HOL summery stastistics for SS and previous breeding value for nongenotyped females with phenotype, by birth year

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2015	bv1	27071	96.2	96.4	6.9	6.9	-0.2	0.6	1.00
2	2016	bv1	24778	97.0	97.1	6.3	6.3	-0.1	0.7	0.99
3	2017	bv1	21769	97.9	98.0	6.1	6.1	-0.1	0.7	0.99
4	2018	bv1	18756	98.4	98.5	6.4	6.3	-0.1	0.7	0.99
5	2019	bv1	16692	99.5	99.6	6.3	6.3	-0.1	0.8	0.99
6	2020	bv1	13509	100.0	100.1	6.3	6.2	0.0	0.9	0.99
7	2021	bv1	9775	100.6	100.8	6.3	6.2	-0.1	1.1	0.99
8	2022	bv1	4690	101.5	101.7	6.0	6.0	-0.1	1.5	0.97
9	2023	bv1	5	.	.	.	.	.	.	1.00

HOL summery stastistics for SS and previous breeding value for nongenotyped females with phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-18	1	0
2	-10	2	0
3	-9	1	0
4	-7	9	0
5	-6	16	0
6	-5	57	0
7	-4	152	0
8	-3	496	0
9	-2	3127	2
10	-1	30284	22
11	0	82993	61
12	1	17139	13
13	2	2120	2
14	3	424	0
15	4	147	0
16	5	65	0
17	6	8	0
18	7	2	0
19	8	1	0
20	9	1	0

RDC summery stastistics for SS and previous breeding value for nordic AI bulls with minimum 15 offspring, by birth year

Obs	BYR	name	no	mean_noff	std_noff	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2010	bv1	155	101	219	100.8	100.5	9.6	9.7	0.3	0.8	1.00
2	2011	bv1	151	127	245	100.5	100.1	8.0	8.2	0.4	0.8	1.00
3	2012	bv1	146	125	198	100.2	100.0	8.8	8.7	0.2	0.7	1.00
4	2013	bv1	107	173	271	99.6	99.3	8.6	8.7	0.3	0.7	1.00
5	2014	bv1	81	246	345	100.1	100.1	8.8	8.8	0.0	0.9	0.99
6	2015	bv1	71	260	323	98.3	98.4	7.4	7.3	-0.1	0.8	0.99
7	2016	bv1	66	266	365	100.4	100.5	7.4	7.4	-0.1	0.9	0.99
8	2017	bv1	62	301	414	99.5	99.7	8.1	8.2	-0.2	1.1	0.99
9	2018	bv1	49	312	460	103.2	103.5	8.4	8.8	-0.3	1.9	0.98
10	2019	bv1	39	266	253	100.1	100.4	9.2	8.6	-0.4	2.7	0.96
11	2020	bv1	13	162	125	103.3	103.5	7.9	9.1	-0.2	3.3	0.93

RDC summery stastistics for SS and previous breeding value for nordic AI bulls with minimum 15 offspring, by birth year

Obs	diff	d_sdg	p_sdg
1	-6	2	0
2	-5	3	0
3	-4	4	0
4	-3	9	1
5	-2	26	3
6	-1	165	18
7	0	407	43
8	1	275	29
9	2	31	3
10	3	11	1
11	4	4	0
12	5	2	0
13	6	1	0

RDC summery stastistics for SS and prev SS breeding value for nordic AI bulls with no offspring, by birth year

Obs	BYR	name	no	mean_noff	std_noff	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2019	bv1	27	0	0	101.1	101.3	6.9	6.6	-0.2	1.4	0.98
2	2020	bv1	22	0	0	101.4	101.8	5.5	5.8	-0.4	1.4	0.97
3	2021	bv1	70	0	0	102.1	102.6	7.0	6.8	-0.6	1.9	0.96
4	2022	bv1	73	0	0	102.3	102.4	6.8	6.6	-0.1	2.2	0.95
5	2023	bv1	53	0	0	102.6	103.9	5.9	5.7	-1.3	1.9	0.95
6	2024	bv1	41	0	0	101.3	100.8	5.1	5.3	0.5	2.1	0.92

RDC summery stastistics for SS and prev SS breeding value for nordic AI bulls with no offspring, by birth year

Obs	diff	d_milksp	p_milksp
1	-6	1	0
2	-5	6	2
3	-4	9	3
4	-3	25	9
5	-2	47	16
6	-1	44	15
7	0	55	19
8	1	51	18
9	2	26	9
10	3	16	6
11	4	6	2

sum sta for SS and prev SS breeding value for genotyped females without phenotype, by birth year

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2019	bv1	12447	100.1	100.2	7.1	7.1	-0.1	1.2	0.99
2	2020	bv1	13714	100.1	100.2	6.8	6.8	-0.1	1.3	0.98
3	2021	bv1	14428	101.2	101.6	6.9	6.9	-0.4	1.5	0.98
4	2022	bv1	17549	100.3	100.5	6.9	6.9	-0.2	1.8	0.96
5	2023	bv1	22817	101.4	101.8	6.4	6.5	-0.3	1.8	0.96
6	2024	bv1	20369	101.2	101.5	6.4	6.3	-0.3	1.7	0.96
7	2025	bv1	109	101.7	101.5	7.0	6.9	0.2	1.4	0.98
8	2027	bv1	2	.	.	.	.	.	.	1.00

sum sta for SS and prev SS breeding value for genotyped females without phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-9	2	0
2	-8	1	0
3	-7	8	0
4	-6	108	0
5	-5	519	1
6	-4	1883	2
7	-3	5420	5
8	-2	12767	13
9	-1	22405	22
10	0	26140	26
11	1	18833	19
12	2	9337	9
13	3	3040	3
14	4	785	1
15	5	148	0
16	6	31	0
17	7	8	0

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2015	bv1	5236	100.0	99.7	7.5	7.6	0.3	1.1	0.99
2	2016	bv1	7462	99.8	99.6	7.1	7.2	0.2	1.2	0.99
3	2017	bv1	8108	99.3	99.2	7.1	7.1	0.1	1.2	0.99
4	2018	bv1	8946	99.5	99.5	7.0	7.1	0.0	1.2	0.99
5	2019	bv1	8950	100.0	100.1	7.4	7.4	-0.1	1.2	0.99
6	2020	bv1	9910	100.3	100.4	6.9	6.9	-0.1	1.3	0.98
7	2021	bv1	6473	101.4	101.8	7.1	7.1	-0.4	1.4	0.98
8	2022	bv1	2602	100.8	100.9	7.1	7.0	-0.2	1.7	0.97

sum sta for SS and previous breeding value for genotyped females with phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-7	2	0
2	-6	3	0
3	-5	24	0
4	-4	180	0
5	-3	1126	2
6	-2	5017	9
7	-1	13283	23
8	0	18818	33
9	1	13303	23
10	2	4848	8
11	3	920	2
12	4	136	0
13	5	22	0
14	6	3	0
15	7	1	0
16	10	1	0

RDC summery stastistics for SS and previous breeding value for nongenotyped females with phenotype, by birth year

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2015	bv1	18615	99.4	99.1	6.3	6.3	0.3	0.6	1.00
2	2016	bv1	15732	99.1	98.9	5.9	6.0	0.3	0.7	0.99
3	2017	bv1	13065	98.8	98.6	5.8	5.8	0.2	0.7	0.99
4	2018	bv1	10924	99.0	99.0	5.8	5.8	0.1	0.7	0.99
5	2019	bv1	8937	99.6	99.6	6.1	6.1	0.0	0.8	0.99
6	2020	bv1	7337	99.5	99.5	5.6	5.6	0.0	0.9	0.99
7	2021	bv1	4327	100.8	101.0	5.9	6.0	-0.3	1.0	0.99
8	2022	bv1	1247	99.9	100.1	5.8	5.8	-0.2	1.2	0.98

RDC summery stastistics for SS and previous breeding value for nongenotyped females with phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-8	2	0
2	-7	3	0
3	-6	3	0
4	-5	9	0
5	-4	42	0
6	-3	189	0
7	-2	1147	1
8	-1	9661	12
9	0	47080	59
10	1	20186	25
11	2	1542	2
12	3	243	0
13	4	61	0
14	5	12	0
15	6	4	0

JER summery stastistics for SS and previous breeding value for nordic AI bulls with minimum 15 offspring, by birth year

Obs	BYR	name	no	mean_noff	std_noff	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2010	bv1	42	40	37	99.5	99.2	7.8	7.9	0.3	0.6	1.00
2	2011	bv1	27	36	40	99.9	99.9	9.4	9.5	0.1	0.8	1.00
3	2012	bv1	20	90	123	102.1	102.1	9.6	9.6	0.1	0.6	1.00
4	2013	bv1	15	80	100	96.7	96.5	9.1	9.2	0.1	0.7	1.00
5	2014	bv1	15	115	88	92.1	91.9	14.8	14.7	0.1	0.6	1.00
6	2015	bv1	22	182	161	98.7	98.6	11.5	11.5	0.1	0.9	1.00
7	2016	bv1	15	121	80	101.2	101.1	6.6	6.8	0.1	0.8	0.99
8	2017	bv1	24	177	134	97.5	97.6	12.2	11.7	0.0	1.2	1.00
9	2019	bv1	22	157	105	100.7	101.0	11.2	11.6	-0.3	1.9	0.99
10	2020	bv1	10	94	44	101.7	100.8	12.7	14.5	0.9	4.6	0.95

JER summery stastistics for SS and previous breeding value for nordic AI bulls with minimum 15 offspring, by birth year

Obs	diff	d_milksp	p_milksp
1	-6	1	0
2	-5	1	0
3	-4	1	0
4	-3	3	1
5	-2	3	1
6	-1	43	19
7	0	105	48
8	1	51	23
9	2	6	3
10	3	2	1
11	4	2	1
12	5	2	1
13	8	1	0

JER summery stastistics for SS and prev SS breeding value for nordic AI bulls with no offspring, by birth year

Obs	BYR	name	no	mean_noff	std_noff	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2019	bv1	20	0	0	102.5	102.5	10.7	10.4	0.0	1.3	0.99
2	2020	bv1	13	0	0	99.2	99.1	6.5	6.4	0.2	0.8	0.99
3	2021	bv1	39	0	0	96.9	97.2	8.5	8.4	-0.2	1.4	0.99
4	2022	bv1	34	0	0	102.8	103.0	8.4	8.9	-0.2	2.2	0.97
5	2023	bv1	34	0	0	99.4	99.6	8.0	8.2	-0.1	1.3	0.99
6	2024	bv1	12	0	0	100.8	101.0	7.7	7.6	-0.3	0.9	0.99

JER summery stastistics for SS and prev SS breeding value for nordic AI bulls with no offspring, by birth year

Obs	diff	d_milksp	p_milksp
1	-5	1	1
2	-3	7	5
3	-2	16	11
4	-1	34	22
5	0	48	32
6	1	33	22
7	2	5	3
8	3	5	3
9	4	2	1
10	5	1	1

sum sta for SS and prev SS breeding value for genotyped females without phenotype, by birth year

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2019	bv1	11935	98.8	98.8	8.3	8.1	0.0	1.1	0.99
2	2020	bv1	14746	100.9	100.8	8.5	8.4	0.1	1.1	0.99
3	2021	bv1	14354	99.0	99.0	8.0	8.1	0.0	1.3	0.99
4	2022	bv1	15019	100.3	100.1	7.8	8.0	0.2	1.9	0.97
5	2023	bv1	15845	100.9	101.2	7.9	8.2	-0.2	1.9	0.97
6	2024	bv1	14809	100.6	100.6	7.6	7.7	0.0	1.6	0.98
7	2025	bv1	123	102.2	102.5	6.9	7.4	-0.3	1.7	0.97

sum sta for SS and prev SS breeding value for genotyped females without phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-27	1	0
2	-12	1	0
3	-8	2	0
4	-6	9	0
5	-5	117	0
6	-4	710	1
7	-3	2925	3
8	-2	8621	10
9	-1	19139	22
10	0	25044	29
11	1	17450	20
12	2	7938	9
13	3	3155	4
14	4	1232	1
15	5	387	0
16	6	86	0
17	7	9	0
18	8	1	0
19	9	1	0
20	11	1	0
21	12	1	0
22	31	1	0

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2015	bv1	725	98.1	98.0	8.9	8.9	0.1	0.9	0.99
2	2016	bv1	1034	96.7	96.6	9.1	9.1	0.1	1.0	0.99
3	2017	bv1	1064	98.0	97.9	10.0	10.1	0.0	1.0	1.00
4	2018	bv1	1042	99.6	99.4	8.6	8.6	0.2	1.0	0.99
5	2019	bv1	1266	99.0	99.1	8.9	8.7	-0.1	1.1	0.99
6	2020	bv1	1353	101.0	100.9	8.9	8.9	0.1	1.1	0.99
7	2021	bv1	1347	99.5	99.6	8.5	8.5	-0.1	1.2	0.99
8	2022	bv1	1161	100.2	100.1	8.3	8.6	0.1	1.8	0.98
9	2023	bv1	8	.	.	.	.	.	.	0.98

sum sta for SS and previous breeding value for genotyped females with phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-6	1	0
2	-5	4	0
3	-4	31	0
4	-3	103	1
5	-2	551	6
6	-1	2035	23
7	0	3281	36
8	1	2185	24
9	2	608	7
10	3	147	2
11	4	39	0
12	5	12	0
13	6	2	0
14	7	1	0

JER summery stastistics for SS and previous breeding value for nongenotyped females with phenotype, by birth year

Obs	BYR	name	no	mean_ss	mean_oss	std_ss	std_oss	mean_dif	std_dif	corr_SS
1	2015	bv1	1424	97.9	97.7	7.3	7.3	0.2	0.6	1.00
2	2016	bv1	1220	97.1	96.9	7.3	7.4	0.2	0.6	1.00
3	2017	bv1	1078	98.2	98.1	7.8	7.9	0.1	0.6	1.00
4	2018	bv1	1245	98.7	98.4	6.8	6.9	0.2	0.7	1.00
5	2019	bv1	1266	98.5	98.5	7.0	6.9	0.0	0.8	0.99
6	2020	bv1	1190	100.3	100.2	6.8	6.7	0.1	0.8	0.99
7	2021	bv1	1124	98.8	98.9	7.1	7.2	0.0	1.0	0.99
8	2022	bv1	748	99.3	99.0	6.7	6.9	0.2	1.5	0.98
9	2023	bv1	3	.	.	.	.	.	.	0.99

JER summery stastistics for SS and previous breeding value for nongenotyped females with phenotype, by birth year

Obs	diff	d_milksp	p_milksp
1	-7	1	0
2	-5	1	0
3	-4	10	0
4	-3	35	0
5	-2	166	2
6	-1	1207	13
7	0	5560	60
8	1	2029	22
9	2	188	2
10	3	80	1
11	4	19	0
12	6	2	0