SMARTER

SMAll RuminanTs breeding for Efficiency and Resilience

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Report on cost-effectiveness of harmonization in phenotyping and of international evaluation

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About the SMARTER research project

SMARTER will develop and deploy innovative strategies to improve Resilience and Efficiency (R&E) related traits in sheep and goats. SMARTER will find these strategies by: i) generating and validating novel R&E related traits at a phenotypic and genetic level ii) improving and developing new genome-based solutions and tools relevant for the data structure and size of small ruminant populations, iii) establishing new breeding and selection strategies for various breeds and environments that consider R&E traits.

SMARTER with help from stakeholders chose several key R&E traits including feed efficiency, health (resistance to disease, survival) and welfare. Experimental populations will be used to identify and dissect new predictors of these R&E traits and the trade-off between animal ability to overcome external challenges. SMARTER will estimate the underlying genetic and genomic variability governing these R&E related traits. This variability will be related to performance in different environments including genotype-by-environment interactions (conventional, agro-ecological and organic systems) in commercial populations. The outcome will be accurate genomic predictions for R&E traits in different environments across different breeds and populations. SMARTER will also create a new cooperative European and international initiative that will use genomic selection across countries. This initiative will make selection for R&E traits faster and more efficient. SMARTER will also characterize the phenotype and genome of traditional and underutilized breeds. Finally, SMARTER will propose new breeding strategies that utilise R&E traits and trade-offs and balance economic, social and environmental challenges.

The overall impact of the multi-actor SMARTER project will be ready-to-use effective and efficient tools to make small ruminant production resilient through improved profitability and efficiency.

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1 Summary

The deliverable involves pulling the development of a deterministic recursive gene flow model to determine the cost-benefit of international genetic evaluations. The model is sufficient generic to be applicable to a whole multitude of different scenarios and enables the inclusion of different population parameters depending on the populations under investigation. A presentation was made to the SMARTER group on the model itself as well as demonstration of how to populate it and run the program; the results based on a case study of Ireland importing germplasm from New Zealand was also presented. The latter case study is published in the peer review scientific journal Genetics, Selection, Evolution. This model therefore, in conjunction with other tasks, enables the determination of the cost effectiveness of international genetic evaluations – cost is dependent on the resources required for a separate country breeding program versus the importation of germplasm from another jurisdiction.

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2 Introduction

Selection in small ruminants is generally based on smaller breeding programs than that for cattle. The selection tools are not used as intensely as in cattle because of their cost (performance recording, especially milk recording in dairy small ruminants) compared to the gross margin per animal and because of physiological limits. Moreover, the usage of AI is less in small ruminants with fresh semen being preferred over frozen; this all limits the international exchange of germplasm to create genetic linkages.

Genomics coupled with trait harmonisation and international cooperation may be one strategy to accelerate genetic progress in small ruminant populations. Even if some of the sheep and goat breeds are more or less exclusively local breeds, some of them are bred in several countries, including international breeds, such as the Alpine and Saanen goat breed, the Lacaune or Assaf dairy sheep breed as well as some terminal sire breeds in meat sheep (eg., Texel, Suffolk). Consequently it was important to study the feasibility of an international evaluation in sheep and goats as a means of increasing both the accuracy of selection but also possibly the selection intensity (as well as available genetic variability). This should translate to accelerated genetic gain.

Such across-country genetic evaluations were implemented in SMARTER on existing traits as a proof of concept for future efficiency and resilience traits. The purpose was to build the pipelines and estimate the parameters needed for such evaluation and to assess if the level of connectedness of the populations (genealogical connection across countries and characterization of the populations with SNP information) was sufficient to undertake the evaluation and to estimate the genetic correlations across-country.

The different across country genetic evaluations implemented in SMARTER are the following:

-in meat sheep, an international evaluation of early life weight, scan weight, muscle depth, fat depth (efficiency-related trait) involving Texel, Suffolk and Charollais from the UK and Ireland;

-in dairy sheep, an international evaluation of milk yield involving Red-Faced and Black-Faced Manech from France and Blond-Faced and Black-Faced Latxa from Spain (Manech and Latxa being two different names representing similar strains across the border.

-in goats, an international evaluation of milk yield (efficiency-related trait) and udder traits (efficiency-related trait) involving Alpine and Saanen from Canada, Italy, France and Switzerland.

The work presented in this deliverable is related to the development of a deterministic recursive gene flow model to determine the cost-benefit of international genetic evaluations The associated article is attached in the appendix.

3 Objective

To develop a sufficiently generic model to firstly quantify the impact of importation of foreign germplasm into a breeding program which can later be used to derive the overall cost benefit; the model must be sufficiently flexible to cater for a range of different scenarios that may exist among SMARTER members

4 Results & Conclusion

A generic a deterministic recursive gene flow model was developed to predict the commercial performance of lambs born across various subpopulations.

Overview of the model

A gene flow model with multiple flows of predicted genetic merit across subpopulations of a sheep industry was created using Microsoft Excel. The model predicted the genetic improvement in overall economic merit of future generations of commercial sheep as a consequence of the incorporation or exclusion of foreign germplasm in a proportion of ram breeder flocks. The model also assessed the impact of the implementation of various breeding strategies using multiple scenarios.

The model can be refined to suit any species or any (group of) countries. To start, the model generated predictions for the genetic merit of animals within a number of subcategories including: ewes mated, rams born, rams mated and lambs born during a historic phase from the year -10 to year 0 (Figure 2). This historic phase was identical for every strategy and reflected the current genetic merit of subpopulations and their recent genetic trends. Year 0 was described as the base year for the model. Thereafter, a recursive predictive phase was generated from year 1 onwards. This predictive phase modelled future gene flow and genetic trends in accordance with each breeding strategy scenario. Standard partial budgeting techniques were used to aggregate the benefits into present values, with a focus on the overall industry impact after a certain time horizon.

Input parameters

Depending on the scenario under investigation, the market share of each subpopulation varied on an annual basis. Similarly, for each subpopulation, the age structure of the ram and ewe population, genetic trends, genetic merit, selection proportions and selection differentials could also be varied. Discount factors, frequency of importation of foreign germplasm, the extent of genetic superiority of foreign sires over domestic sires and the standard deviation of the domestic index as well as the size of the national ewe population and weaning rate, which ultimately determined the number of lambs born alive per year, can be adjusted within each modelled scenario.

Output parameters

Annualised cumulative (monetary) benefits were calculated to quantify and compare the impact of each alternative breeding strategy investigated. The final output of the gene flow model was the predicted average genetic merit value of commercial lambs born during a given year, which were then aggregated to industry-level benefits and expressed as a cumulative monetary value.

A case study was developed using Ireland-New Zealand parameters. The ‘Base scenario’ represents the current Irish industry; ‘PRO-intense scenario’ incorporates an increase in selection intensity and no shift in market share; ‘PRO-market scenario’ gradually shifts the market share of the CON subpopulation to the PRO subpopulation; ‘PRO-intense-market scenario’ includes a combination of a shifting market share towards the PRO subpopulation and increasing selection intensity; ‘PROFOR scenario’ shifts the market share of the CON subpopulation between PRO, FOR and PROFOR; ‘FOR scenario’ the commercial subpopulation sourced FOR sires directly from New Zealand; FOR-5 and FOR-10 scenario the commercial subpopulation sourced FOR sires directly from New Zealand, however new shipments were imported every 5 or 10 years, respectively.

The findings of the case study demonstrate that it is possible for the domestic industry, i.e. Ireland, to substantially increase the genetic and economic benefits without foreign sire contributions, i.e. from New Zealand, but through the strategic use of domestic germplasm. Essential to its success is a shift in the market share from conservative breeders towards progressive breeders. The use of foreign germplasm may play a key role in triggering this shift. Results are demonstrated in Table 5. This model now provides a template for other industries to quantify their genetic and economic benefits as a result of foreign sire contributions, regardless of country or species.

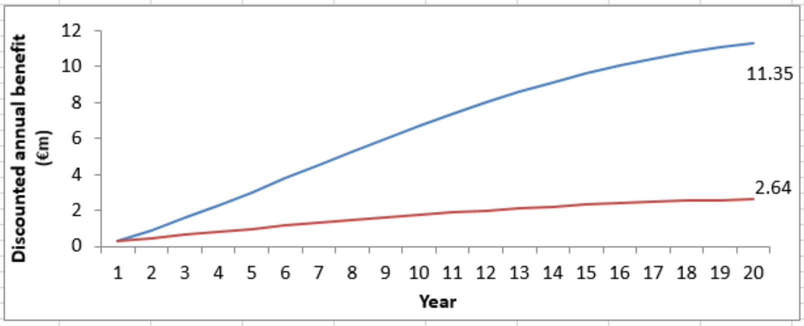
	Proportion that use	Proportion of COM farmers that use..			
Year	PROFOR-AI	CON	PRO	PROFOR	FOR
-11					
-10					
-9					
-8					
-7					
-6					
-5					
-4					
-3					
-2					
-1					
0					
1	0	0.870000	0.130000	0.000000	0.000000
2	0	0.826500	0.173500	0.000000	0.000000
3	0	0.785175	0.214825	0.000000	0.000000
4	0	0.745916	0.254084	0.000000	0.000000
5	0	0.708620	0.291380	0.000000	0.000000
6	0	0.673189	0.326811	0.000000	0.000000
7	0	0.639530	0.360470	0.000000	0.000000
8	0	0.607553	0.392447	0.000000	0.000000
9	0	0.577176	0.422824	0.000000	0.000000
10	0	0.548317	0.451683	0.000000	0.000000
11	0	0.520901	0.479099	0.000000	0.000000
12	0	0.494856	0.505144	0.000000	0.000000
13	0	0.470113	0.529887	0.000000	0.000000
14	0	0.446608	0.553392	0.000000	0.000000
15	0	0.424277	0.575723	0.000000	0.000000
16	0	0.403063	0.596937	0.000000	0.000000
17	0	0.382910	0.617090	0.000000	0.000000
18	0	0.363765	0.636235	0.000000	0.000000
19	0	0.345576	0.654424	0.000000	0.000000
20	0	0.328298	0.671702	0.000000	0.000000

Figure 1. Market share shifts at a specified rate from one subpopulation to another from year to year, e.g. market share shifts from the conservative breeders (CON) towards progressive breeders (PRO) at a rate of 5% per year of the value in the previous year as part of the PRO-Intense and PRO-Intense-market scenarios.

EWE MATED					RAMS BORN				
CON	PRO	PROFOR	FOR	COM	CON	PRO	PROFOR	FOR	COM
0.000000	-2.651250	-2.651250	3.594665	0.195140	0.000000	1.306688	1.306688	5.487603	0.334032
0.000000	-2.272500	-2.272500	3.775150	0.209400	0.000000	1.685438	1.685438	5.668088	0.348292
0.000000	-1.893750	-1.893750	3.955635	0.223660	0.000000	2.064188	2.064188	5.848573	0.362552
0.000000	-1.515000	-1.515000	4.136120	0.237920	0.000000	2.442938	2.442938	6.029058	0.376812
0.000000	-1.136250	-1.136250	4.316605	0.252180	0.000000	2.821688	2.821688	6.209543	0.391072
0.000000	-0.757500	-0.757500	4.497090	0.266440	0.000000	3.200438	3.200438	6.390028	0.405332
0.000000	-0.378750	-0.378750	4.677575	0.280700	0.000000	3.579188	3.579188	6.570513	0.419592
0.000000	0.000000	0.000000	4.858060	0.294960	0.000000	3.957938	3.957938	6.750998	0.433852
0.000000	0.378750	0.378750	5.038545	0.309220	0.000000	4.336688	4.336688	6.931483	0.448112
0.000000	0.757500	0.757500	5.219030	0.323480	0.000000	4.715438	4.715438	7.111968	0.462372
0.000000	1.136250	1.136250	5.399515	0.337740	0.000000	5.094188	5.094188	7.292453	0.476632
0.000000	1.515000	1.515000	5.580000	0.352000	0.000000	5.472938	5.472938	7.472938	0.490892
0.000000	1.893750	1.893750	5.515097	0.366260	0.171652	7.017295	5.832888	7.472938	0.501812
0.000000	2.272500	2.272500	5.695582	0.387374	0.221110	7.582542	6.208631	7.472938	0.704752
0.051461	2.651250	2.651250	5.941666	0.436432	0.302627	8.154317	6.584268	7.472938	0.951701
0.110898	3.076624	3.029248	6.154693	0.533264	0.387918	8.706621	6.960218	7.472938	1.235684
0.177373	3.542795	3.406588	6.338602	0.682467	0.479222	9.268730	7.336011	7.472938	1.561824
0.256577	4.031578	3.783563	6.507384	0.882772	0.577298	9.811904	7.712109	7.472938	1.919657
0.349226	4.542017	4.160190	6.704802	1.137919	0.689668	10.379401	8.087815	7.472938	2.325086
0.434729	5.100058	4.536048	6.800155	1.441750	0.795994	10.937450	8.463673	7.472938	2.751900
0.532000	5.661068	4.911858	6.902661	1.784428	0.911470	11.497692	8.839496	7.472938	3.207680
0.633657	6.217897	5.287736	6.987982	2.162188	1.031397	12.055246	9.215363	7.472938	3.688456
0.740648	6.777169	5.663575	7.060501	2.572277	1.156450	12.614472	9.591202	7.472938	4.192527
0.853207	7.332523	6.039477	7.124079	3.011507	1.286628	13.171183	9.967082	7.472938	4.717008
0.971028	7.893715	6.415284	7.182637	3.478571	1.422024	13.731177	10.342909	7.472938	5.261060
1.092972	8.451871	6.791141	7.223671	3.968708	1.561530	14.289523	10.718762	7.472938	5.821137
1.220498	9.010845	7.166984	7.262213	4.481082	1.706224	14.848382	11.094607	7.472938	6.396515
1.352781	9.569191	7.542838	7.294238	5.013309	1.855533	15.406838	11.470459	7.472938	6.985275
1.489960	10.127946	7.918684	7.321430	5.563448	2.009536	15.965567	11.846306	7.472938	7.586037
1.631967	10.686168	8.294540	7.344767	6.129626	2.168163	16.523952	12.222159	7.472938	8.197312
1.778719	11.245166	8.670383	7.364887	6.710238	2.331361	17.082781	12.598005	7.472938	8.817958
1.930123	11.803679	9.046234	7.380958	7.303566	2.499029	17.641344	12.973855	7.472938	9.446673

RAMS MATED					LAMBS BORN				
CON	PRO	PROFOR	FOR	COM	CON	PRO	PROFOR	FOR	COM
0.000000	2.628525	2.628525	5.619850	0.380235	0.000000	1.124888	1.124888	5.148713	0.330467
0.000000	3.007275	3.007275	5.800335	0.394495	0.000000	1.503638	1.503638	5.329198	0.344727
0.000000	3.386025	3.386025	5.980820	0.408755	0.000000	1.882388	1.882388	5.509683	0.358987
0.000000	3.764775	3.764775	6.161305	0.423015	0.000000	2.261138	2.261138	5.690168	0.373247
0.000000	4.143525	4.143525	6.341790	0.437275	0.000000	2.639888	2.639888	5.870653	0.387507
0.000000	4.522275	4.522275	6.522275	0.451535	0.000000	3.018638	3.018638	6.051138	0.401767
0.343072	4.901025	4.901025	7.472938	0.637133	0.171536	3.397388	3.397388	6.494017	0.501697
0.441988	5.652769	5.273759	7.472938	1.021898	0.220994	3.962635	3.773130	6.584260	0.704636
0.553561	6.417569	5.646283	7.472938	1.466739	0.302511	4.534409	4.148767	6.707302	0.951585
0.664706	7.096803	6.020187	7.472938	1.937872	0.387802	5.086714	4.524717	6.813815	1.235568
0.780839	7.754850	6.394432	7.472938	2.440950	0.479106	5.648822	4.900510	6.905770	1.561708
0.897786	8.352414	6.769653	7.472938	2.956310	0.577182	6.191996	5.276608	6.990161	1.919541
1.029879	8.976969	7.144439	7.472938	3.512021	0.689553	6.759493	5.652314	7.088870	2.324970
1.157027	9.535026	7.520297	7.472938	4.061819	0.795878	7.317542	6.028172	7.136546	2.751785
1.290710	10.094502	7.896132	7.472938	4.630700	0.911355	7.877785	6.403995	7.187799	3.207564
1.428905	10.652780	8.271987	7.472938	5.214492	1.031281	8.435339	6.779862	7.230460	3.688340
1.572021	11.211959	8.647827	7.472938	5.812546	1.156335	8.994564	7.155701	7.266719	4.192411
1.719817	11.770028	9.023685	7.472938	6.422277	1.286512	9.551276	7.531581	7.298508	4.716892
1.872788	12.328824	9.399531	7.472938	7.043317	1.421908	10.111269	7.907408	7.327787	5.260944
2.029857	12.887359	9.775381	7.472938	7.673334	1.561414	10.669615	8.283261	7.348304	5.821021
2.191719	13.446103	10.151228	7.472938	8.311717	1.706108	11.228474	8.659106	7.367575	6.396399
2.358053	14.004670	10.527078	7.472938	8.957009	1.855417	11.786930	9.034958	7.383588	6.985159
2.528881	14.563372	10.902926	7.472938	9.608394	2.009420	12.345659	9.410805	7.397184	7.585921
2.704128	15.121922	11.278776	7.472938	10.264766	2.168047	12.904045	9.786658	7.408852	8.197196
2.883772	15.680582	11.654625	7.472938	10.925446	2.331246	13.462874	10.162504	7.418912	8.817842
3.067704	16.239194	12.030474	7.472938	11.589550	2.498914	14.021436	10.538354	7.426948	9.446558

Figure 2. Subcategories used to generate the model include ewes mated, rams born, rams mated and lambs born.



	Eq10			Eq8			Eq13	Eq14		Eq9	Eq11	Eq12
				AB	CB		PVB	ACB		AB (dis)	DCB	DPB5
Number lambs	COM value	Discount Factor	Year	Annual undis	Cumulative u		Present valu	Annualised	Year	Discounted a	Discounted c	Additional fiv
				m	m		m	m		m	m	m
3328234			-11						-11			
3328234			-10						-10			
3328234			-9						-9			
3328234			-8						-8			
3328234			-7						-7			
3328234			-6						-6			
3328234			-5						-5			
3328234			-4						-4			
3328234			-3						-3			
3328234			-2						-2			
3328234			-1						-1			
3328234	0.401767	1.000000	0	0	0				0	0	0	0
3328234	0.501697	0.952381	1	0.332587844	0.332587844				1	0.316750328	0.316750328	1.371363155
3328234	0.704636	0.907029	2	1.008016529	1.340604373				2	0.914300706	1.231051034	3.958443577
3328234	0.951585	0.863838	3	1.829922198	3.17052657				3	1.580755597	2.811806631	6.843844478
3328234	1.235568	0.822702	4	2.77508363	5.9456102				4	2.28306817	5.094874801	9.884490379
3328234	1.561708	0.783526	5	3.860555244	9.806165444				5	3.024846051	8.119720851	13.09600041
3328234	1.919541	0.746215	6	5.051505143	14.85767059				6	3.769510914	11.88923177	16.32000956
3328234	2.324970	0.710681	7	6.400868032	21.25853862				7	4.548977407	16.43820917	19.69469156
3328234	2.751785	0.676839	8	7.821407194	29.07994581				8	5.293836256	21.73204543	22.91954057
3328234	3.207564	0.644609	9	9.338347131	38.41829294				9	6.019581823	27.75162725	26.06163907
3328234	3.688340	0.613913	10	10.93848261	49.35677555	**10year**	**63.5405524**	**8.22879223**	10	6.715279446	34.4669067	29.0736457
3328234	4.192411	0.584679	11	12.6161494	61.97292495				11	7.37640126	41.84330796	31.93595717
3328234	4.716892	0.556837	12	14.36174517	76.33467012				12	7.9971571	49.84046506	34.6235051
3328234	5.260944	0.530321	13	16.17247654	92.50714665				13	8.5766096	58.41707466	37.13223117
3328234	5.821021	0.505068	14	18.03654448	110.5436911				14	9.109680598	67.52675525	39.44014963
3328234	6.396399	0.481017	15	19.95153805	130.4952292				15	9.597030936	77.12378619	41.55012154
3328234	6.985159	0.458112	16	21.91106795	152.4062971				16	10.03771269	87.16149888	43.4580429
3328234	7.585921	0.436297	17	23.9105442	176.3168413				17	10.43209123	97.59359011	45.16549562
3328234	8.197196	0.415521	18	25.94501029	202.2618516				18	10.78068767	108.3742778	46.67473575
3328234	8.817842	0.395734	19	28.01066598	230.2725176				19	11.08477169	119.4590495	47.99126041
3328234	9.446558	0.376889	20	30.10317834	260.3756959	**20year**	**179.925007**	**14.4376481**	20	11.34557132	130.8046208	49.12038634

Figure 3. Genetic and economic benefits to the domestic industry as a result of the implementation of a given scenario are reported over a specific timeline, i.e. twenty years, and are compared to the base value, i.e. as of year 0.

Numerous breeding strategies were evaluated by varying market share, proportions of rams selected for mating, genetic trend, superiority of foreign genetics over domestic genetics and frequency of importation. The results of the cost-benefit of a case study for Ireland and New Zealand (full details in https://gsejournal.biomedcentral.com/articles/10.1186/s12711-020-00594-y) are given in the table below.

	Total benefit after 20 years		Benefit after 20 years	
	Cumulative benefit (€m)	Annualised benefit (€m/year)	Cumulative benefit (€m)	Annualised benefit (€m/year)
Base	33.598	2.696	-	-
Scenario 1	134.723	10.811	+101.125	+8.115
Scenario 2	135.601	10.881	+102.003	+8.185

Complementary to the model developed, a survey to assess the willingness of the countries to share data and their expectations and concerns about an across-country evaluation was undertaken by all the SMARTER countries. On average, 75-80% of the respondents agree or strongly agree to share genotypes, phenotypes, pedigree for use in international genetic evaluations. The major expectations were the benefits for the domestic breeding programs and the breeders, far ahead of the economic benefits and the international cooperation. The major concerns were the loss of independence on genetic evaluation process, the unbalanced benefits across countries, and the cost (euro and persons).

In conclusion using the information for all tasks within this WP together, sufficient connectedness exists among some countries to enable international genetic evaluations. The use of common germplasm between some countries could strengthen genetic connectedness. There is a willingness among the countries surveyed to participate in international genetic evaluations. Also, there is a cost benefit of same. Nonetheless, depending on the population parameters, there is opportunity for a domestic industry to increase industry benefits without the use of foreign genetics but through an attempt to shift the market share away from conservative domestic breeders towards progressive domestic breeders. However, the importation and use of progressive foreign genetics may be an effective method to trigger a change in behaviour of conservative domestic breeders towards the use of progressive genetics.

5 Deviations or delays

No deviation or delay

6 Acknowledgements

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7 Appendix

Paper "Genetic and economic benefits of foreign sire contributions to a domestic sheep industry; including an Ireland-New Zealand case study" Genetics Selection Evolution.

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Genetics Selection Evolution

RESEARCH ARTICLE Open Access

Genetic and economic benefits of foreign sire contributions to a domestic sheep industry; including an Ireland-New Zealand case study

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Abstract

Background: Importation of foreign genetics is a widely used genetic improvement strategy. However, even if the foreign genetic merit is currently greater than the domestic genetic merit, differences in foreign and domestic trends mean that the long-term competitiveness of an importation strategy cannot be guaranteed. Gene flow models are used to quantify the impact that a specific subpopulation, such as foreign genetics, can have over time on the genetic or economic benefit of a domestic industry.

Methods: We used a deterministic recursive gene flow model to predict the commercial performance of lambs born across various subpopulations. Numerous breeding strategies were evaluated by varying market share, proportions of rams selected for mating, genetic trend, superiority of foreign genetics over domestic genetics and frequency of importation. Specifically, an Ireland-New Zealand case study was simulated to quantify the potential gain that could be made by using foreign sire contributions (New Zealand) in a domestic sheep industry (Ireland).

Results: Genetic and economic gains were generated from alternative breeding strategies. The 'base scenario' (i.e. representing the current industry) predicted an average genetic merit value of €2.51 for lambs born and an annualised cumulative benefit of €45 million (m) after 20 years. Maximum genetic (€9.45 for lambs born) and economic (annualised cumulative benefit of €180 m after 20 years) benefits were achieved by implementing the 'PRO-intense-market scenario' which involved shifting market share away from conservative domestic breeders and reducing the proportion of rams that were selected for mating by progressive domestic breeders from the top 40% to the top 20%, without the use of any foreign genetics. The 'PROFOR scenario', which considered the use of foreign and progressive domestic genetics, predicted an average genetic merit value of €7.37 for lambs born and an annualised cumulative benefit of €144 m, after 20 years.

Conclusions: Our results demonstrate that there is opportunity for a domestic industry to increase industry benefits without the use of foreign genetics but through an attempt to shift the market share away from conservative domestic breeders towards progressive domestic breeders. However, the importation and use of progressive foreign genetics may be an effective method to trigger a change in behaviour of conservative domestic breeders towards the use of progressive genetics.