A comparison of innovation in the Scottish livestock sector: the case of genetic selection techniques

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Abstract

This paper compares innovation systems in three main Scottish livestock sectors: dairy, beef, and sheep, using the uptake of Estimated Breed Values (EBVs) across these three sectors. We apply an innovation systems approach to identify systemic challenges within these sectors. Barriers to the adoption of genetic techniques in all three sectors were identified through interviews with national experts and via a stakeholder workshop.

Three types of barrier emerged: practical barriers – such as low fertility rates for artificial insemination in sheep; social barriers such as farmer's scepticism; and market/supply chain barriers, such as limited information flow to farmers within the beef and sheep sectors. We use the innovation system failures framework developed by Weber and Rohracherb (2012) to identify the broad failures within these sectors such as information asymmetries, infrastructure and institutional failures.

We show the dairy sector avoids some of these challenges, particularly practical barriers, and market/supply chain barriers. The attributes of the dairy innovation system which enable this are discussed such as data collection management, information on bulls frequently published, and the involvement of breed societies. Finally, solutions are suggested to resolve these innovation systems failures in the livestock sectors.

Keywords Innovation systems, Estimated Breed Values, Dairy, Beef, Sheep, Systemic failures

JEL code **Agriculture Q1**

Introduction

The livestock sector is an important part of the Scottish agricultural industry, generating net revenues of approximately £1.8 billion in 2010 (QMS 2011), with the beef, dairy and sheep sectors being important contributors to that total. However, over the last decade changes in prices, rising costs and shift in CAP support payment policies have led to decreases in livestock populations, including cattle (7.6% decline) and sheep (18.6% decline) in Scotland against a base line of 2002 figures (National Statistics 2012).

Increasing cost pressures lead to a key role for improving efficiency within these sectors in order to maintain a sustainable industry. However, significant variance has been found within these sectors in terms of efficiency (Barnes et al., 2012) and the key role of technology adoption needs to be investigated.

Genetic technologies and breeding techniques have enhanced the performance of these three sectors over the past decades, with estimates valuing these improvements at £29 million in sheep, £23 million in beef and up to £147 million in dairy over the past ten years (SRUC 2013, DairyCo 2013, Amer et al 2007). Recommendations have been made that breeding could also make savings in terms of green house gas emissions (Sheane *et al* 2011).

One such breeding technique is Estimated Breeding Values (EBVs), which assigns numerical figures to an animal based on certain selection traits (see Table 1) which then indicate an animals predicted genetic merit for that trait. This process enables breeders to select on genetic merit, and not on how well the animals are managed or other environmental factors (Simm 1998). The EBVs on individual traits are combined to create a selection index used to direct a farms breeding programme. Examples of selection criteria are live weight, fat and loin depth, or number of live lambs born (Islam et all 2012). The uptake of genetic improvement techniques varies across livestock sectors: pig and poultry have the highest uptake, with dairy close behind. Beef and sheep have lower uptake rates, with more beef breeders registering with various EBV schemes (pers. coms). Cattle and sheep experienced a significant drop in recorded animals as a result of the 2001 foot and mouth uptake (Amer *et al* 2007).

Table 1 EBV indexes available in the UK and traits associated

Index	Main breeds	Main traits/EBVs
Sheep		
Terminal Sire index	Charollais, Hampshire Down, Ile de France, Meatlinc, Poll Dorset, Suffolk, Texel Vendeen	Leanness (Muscle and fat depth)
Maternal Index	Some Lleyn and Poll Dorset flocks	Litter size, 8-week weight, mature size and maternal ability
Longwool Index	Blue Faced Leicester	Scan weight, muscle depth, litter size
Hill 2 Index	Scottish Blackface and North Country Cheviot	Mature weight, maternal ability, longevity and the number of lambs reared on weaning
Beef		
Terminal Sire index	NA	Birthweight, gestation length, calving ease, 200-day growth, 400 day growth, muscle depth, backfat depth
Maternal Index	NA	Longevity, age at first calving, 200-day milk, maternal calving ease,
Dairy		
Cow	Ayrshire, brown Swiss, Friesian, Guernsey, Holstein, jersey, Montbeliarde,	Production traits: milk, fat and protein, persistency of milk production, somatic cell count, fertility (calving interval, non-

Shorthorn	return rate at 56 days, body condition score, milk yield at around the time of insemination, days from calving to first insemination, number of inseminations needed to get a cow in calf), life span, locomotion. Management traits: temperament, ease of milking, calving ease. Type traits: stature, chest width, body depth, angularity, rump angle, rump width, rear leg side view, foot angle, fore udder attachment, rear udder height, udder support, udder depth, etc.

Source: Signet website at: http://www.signetfbc.co.uk/index.aspx, DairyCo Breeding+ (2011)

Previous studies of the barriers to innovation in the UK dairy industry (Kearney et al 2005) identified a lack of 'genetic opportunity' in the UK as a barrier to innovation, attributed to a lack of international aspirations and limited national funding for improving genetic technologies. This study also referred to the perception that the UK dairy sector is 'not seen as innovative' (Kearney et al 2005 p.4). While previous studies based on the data analysed in this paper have discussed the barriers to uptake of genetic technologies in the agrifood innovation system in general (Lamprinopoulou *et al* 2012) and the sheep sector specifically (Islam 2012). Islam's (2012) analysis of the Scottish sheep sector identified the following systemic challenges to genetic innovation: a weakly integrated supply chain; the presence of a powerful faction antagonistic towards EBVs; a challenging policy environment; a dismantled and weak advisory service with regard to EBVs, an outdated and inflexible data management system; and AI is physically difficult to apply with low conception rates. This study will assess to what extent these challenges are experienced in the dairy and beef sector and to relate them to Weber's (2012) 'failures framework' to gain a deeper understanding of the structural and functional constraints experienced in these sectors.

Innovation Systems, and the application of a comparative analytical framework

This section describes current approaches to agricultural innovation systems, we then present the 'comprehensive failures frameworks' developed by Weber and Rohracher (2012) which we use to identify failures within and across the sectors analysed in this paper.

Knowledge exchange and agricultural extension have traditionally followed the 'top down' model, whereby researchers answer questions and disseminate these answers to farmers who then change their behaviour accordingly. This is described by Koutsouris (2012) as 'the paradigm of experimental, reductionist science' and has, since the 1980s been replaced in favour of a model which acknowledges the complex array of human, institutional, policy and technological actors which interact in order to create knowledge, share knowledge and encourage behavioural change. The 'innovation systems' approach takes into account these multiple interactions, as well as aiming to respond to frequent changes in supply chains and policy contexts (Koutsouris 2012).

The world bank defines an Agricultural Innovation System (AIS) as *'a network of organisations, enterprises and individuals focused on bringing new products, new processes, and new forms of organisations into economic use, together with the institutions and policies that affect the systems behaviour and performances'* (Islam et al 2012, World Bank 2006).

Innovation systems approaches regard the development and uptake of technologies as non linear and requiring an understanding of the structural and functional context in which technologies operate (Morriss et al 2006). This is done through the analysis of actors, which can be any individual, organisation, object, or institution which contributes to the development, diffusion and utilisation of a technology, technique, product or service (Islam *et al* 2012, Klerkx et al 2010).

Weber and Rohracher (2012) recognise the innovation system approach outlined above, and go on to present a 'comprehensive failures framework' which this study applies to the comparison of the three sectors. This helps to identify and explain at a structural and functional level the failures/barriers expressed by participants in the innovation system itself. This extends work by Lamprinopoulou *et al* (2012) which uses this failure framework in an empirical case study of agrifood systems in Scotland and the Netherlands, however, our paper uses a sectorial approach at a national level to demonstrate the miso level barriers to innovation within national agricultural systems.

The 'comprehensive failures framework' is summarised in Table 2.

Table 2 Overview of comprehensive failures framework. Sourse Weber and Rohracher 2012

	Type of failure	Failure mechanism
Market failure	Information asymmetries	Uncertainty about outcomes and short term horizon of private investors lead to undersupply of funding for R and D
	Knowledge spill-over	Public good character of knowledge and leakage of knowledge lead to socially sub-optimal investment in (basic) research and development
	Externalization of costs	The possibility to externalize costs leads to innovations that can damage the environment or other social agents.
	Over-exploitation of commons	Tragedy of the commons
Structural system failures	Infrastructural failure	Lack of physical and knowledge infrastructures due to large scale, long term horizon of operation and ultimately too low return on investment for private investor
	Institutional failures	HARD: Absence or shortcomings of formal institutions such as laws, regulations, and standards create an unfavourable environment for innovation. SOFT: Informal institutions (eg social norms, values, culture, entrepreneurial spirit, trust, risk-taking) that hinder innovation.
	Interaction or network failure	Strong network failure: Intensive cooperation in closely tied networks leads to lock-in into established trajectories and a lack of infusion of new ideas, due to too inward-looking behaviour, lack of weak ties to third actors and dependence on dominant partners. Weak network failure: too limited interaction and knowledge exchange with other actors inhibits exploitation of complementary sources of knowledge and processes of interactive learning.
	Capabilities failure	Lack of appropriate competencies and resources at actor and firm level prevent the access to new knowledge, and lead to an inability to adapt to changing circumstances, to open up novel opportunities, and to switch from an old to a new technological trajectory.
Transformational system failures	Directionality failure	Lack of shared vision regarding the goal and direction of the transformation process; Inability of collective coordination of distributed agents involved in shaping systemic change; Insufficient regulation or standards to guide and consolidate the direction of change; Lack of targeted funding for research, development and demonstration projects and infrastructures to establish corridors of acceptable development paths.
	Demand articulation failure	Insufficient spaces for anticipating and learning about user needs to enable the uptake of innovations by users. Absence of orienting and

		stimulating signals from public demand. Lack of demand-articulating competencies.
	Policy coordination failure	Lack of multi-level policy coordination across different systemic levels (e.g. regional–national–European or between technological and sectoral systems; Lack of horizontal coordination between research, technology and innovation policies on the one hand and sectoral policies (e.g. transport, energy, agriculture) on the other; Lack of vertical coordination between ministries and implementing agencies leads to a deviation between strategic intentions and operational implementation of policies; No coherence between public policies and private sector institutions; No temporal coordination resulting in mismatches related to the timing of interventions by different actors.
	Reflexivity failure	Insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance; Lack of distributed reflexive arrangements to connect different discursive spheres, provide spaces for experimentation and learning; No adaptive policy portfolios to keep options open and deal with uncertainty.

Using EVB as a focus in this empirical study is useful as this technique, while based on collecting data about specific traits of an animal, also involves a complex network of actors including individual animals, farmers, breeding societies, artificial insemination companies as well as actors further along the supply chain such as processors and abattoirs (Morris and Holloway 2013).

Methodology

Data on the innovation system of the three sectors was collected through in-depth interviews with researchers, industry experts and consultancy providers. These interviews were used to develop workshops where stakeholders were asked to map the innovation systems for their sector, discuss barriers to innovation uptake, and identify possible solutions. Stakeholders represented researchers, intermediaries and farmers from all three sectors. A total of (N) attended the workshop, which consisted of three main tasks.

Task one: Understanding the innovation system

The group of participants were separated into three groups representing each sector, each group was given a list of key actors in the innovation system based on national expert interviews. They were also given a list of flows. Each group was asked to draw a diagram indicating the innovation system consisting of the key actors and the flows between them. The groups were encourages to add or remove actors and flows depending on their expertise and knowledge. Examples are given in Table 3 and Table 4.

Table 3 Innovation System Actors (Beef)

Co-ops	Non-SAC consultants	Genotyping companies
Processors	Multipliers	Breeding companies BIG
NBA/umbella bodies	AI companies	BASCO database
SAC consultancy	AI operators	Cattle information services
Commercial farm	Marts	Levy boards
Co-op producer groups	Pedigree breeders	
Supermarkets/retailers	Biosciences KTN	International genetics
Animal nutrition	Pedigree cattle services ltd (Angus)	EGENES
Abattoirs	Breed socieites	Interbeef
Catering	Signet	Other research (Roslin)

Research funding/government departments	SRUC research

Table 4 Innovation System flows (Beef)

Phenotypic records	Genotypes
Progeny in testing	DNA samples
Pedigree recording	Biological samples (e.g. Animal blood samples)
Elite bulls & cows	Information about quality of the final product
Semen	Financial/Public funding
EBV	Obligations/Contractual information
GEBV	

Task two: Identify barriers to innovation

The participants were separated into groups according to the role: researcher, intermediary, or farmer. Each group was given a set of barriers drawn from the literature and national expert interviews. Participants were asked to discuss each barriers and decided their significance. They were also encouraged to add any barriers they felt were missing.

Task three: Identifying solutions

The participants were brought together in one group for the final task, during which they were asked to present potential solutions to the barriers identified in task 2.

Recordings from all three tasks were transcribed and coded and combined with notes taken by each group. These were used to describe the innovation system for each sector, the barriers and potential solutions.

Sectorial overview: Dairy, Beef, Sheep

The Scottish dairy sector

Dairy cows accounted for 10% of Scottish cattle in 2012 (National Statistics 2012). Approximately 1.1 billion litres of milk was produced in 2011, valued at £277millio (NFU 2013). Milk production in Scotland has fallen since 2005, and price per litre has increased (Scottish Government 2011). Most dairy cattle are ilocated the South West of Scotland. The supply chain consists of producers, milk processors, some of which are located in Scotland, retailers and consumers. As with the pig and poultry livestock sectors (Amer *et al* 2007), dairy farmers in Scotland use a small number of AI companies which provide semen from a relatively small number of elite bulls. This semen can be sourced from the UK but also internationally.

The Scottish beef sector

The Scottish beef sector, as with the sheep sector is characterised by small-to medium-sized farms (Amer *et al* 2007). There are strong links between the dairy and beef sectors, with many mixed farms and a great deal of cross breading. There is a drive to increase the use of high EBV beef cattle in dairy breeding schemes which may offer potential benefits such as reduced methane production (Bruce 2012a). 25% of cattle in Scotland are beef. The Scottish beef sector accounts for 24% of total agricultural output at £671 million in 2011. The average Scottish beef suckler herd is 50 cows, almost twice that of the national UK average. Beef farming is predominantly located in the South West and North East of the country. There was a slight decrees in animals slaughtered in 2011, from 461,000 in 2010 to 460,200 in 2011. Cattle prices increased in 2011 peaking at 349p/kg at the beginning of December (QMS 2012).

The Scottish sheep sector

In June 2012 there was a population of 6.74 million sheep in Scotland, 49% of which are lambs. As with the beef sector, sheep farming occurs in a wide range of environments (Amer *et al* 2007).

The UK sheep industry is 'stratified' according to topography. There are three main groups of breeds: hill/mountain; upland; and lowland. These breeds are transported between regions, and interbreed with longwool breeds in a complex systems reliant on hybrid vigour, and tailored to the slaughtered lamb market (Spedding 2010). Both the beef and sheep sectors use a wide variety of breeds (Amer *et al* 2007).

Results

Overview of innovation systems

The following diagrams illustrate the perceived key actors and a summary of the number of ties linking those actors. The lines between nodes (actors) represent a summery of the number of types of interactions/what flows between actors. The thicker the line, the more flows there are. It is beyond the scope of this paper to present the full network analysis of these sectors, this will be carrier out in further studies.

Figure 1 Dairy Innovation Chain

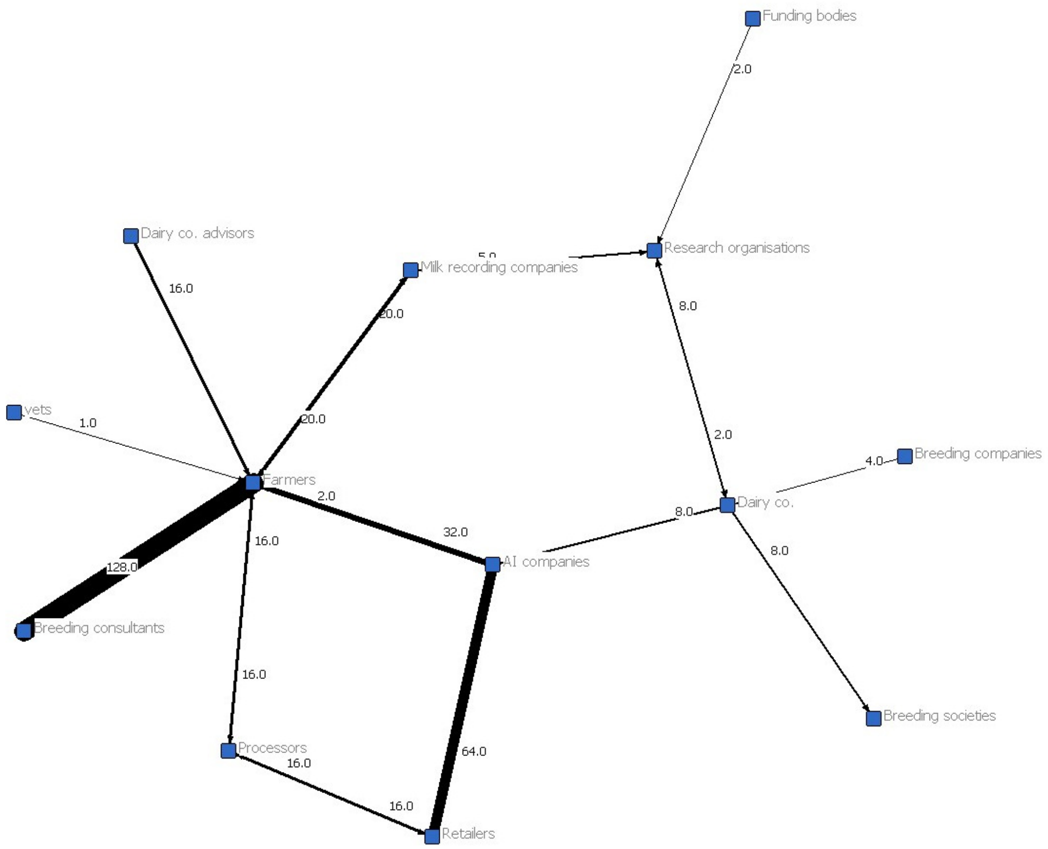


Figure 2 Beef Innovation System

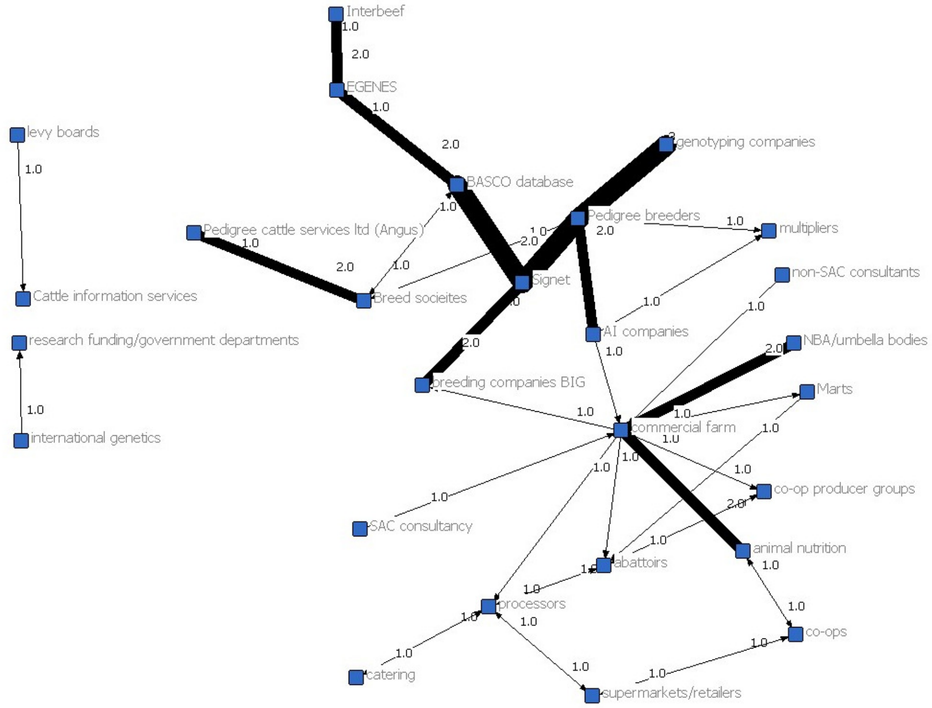
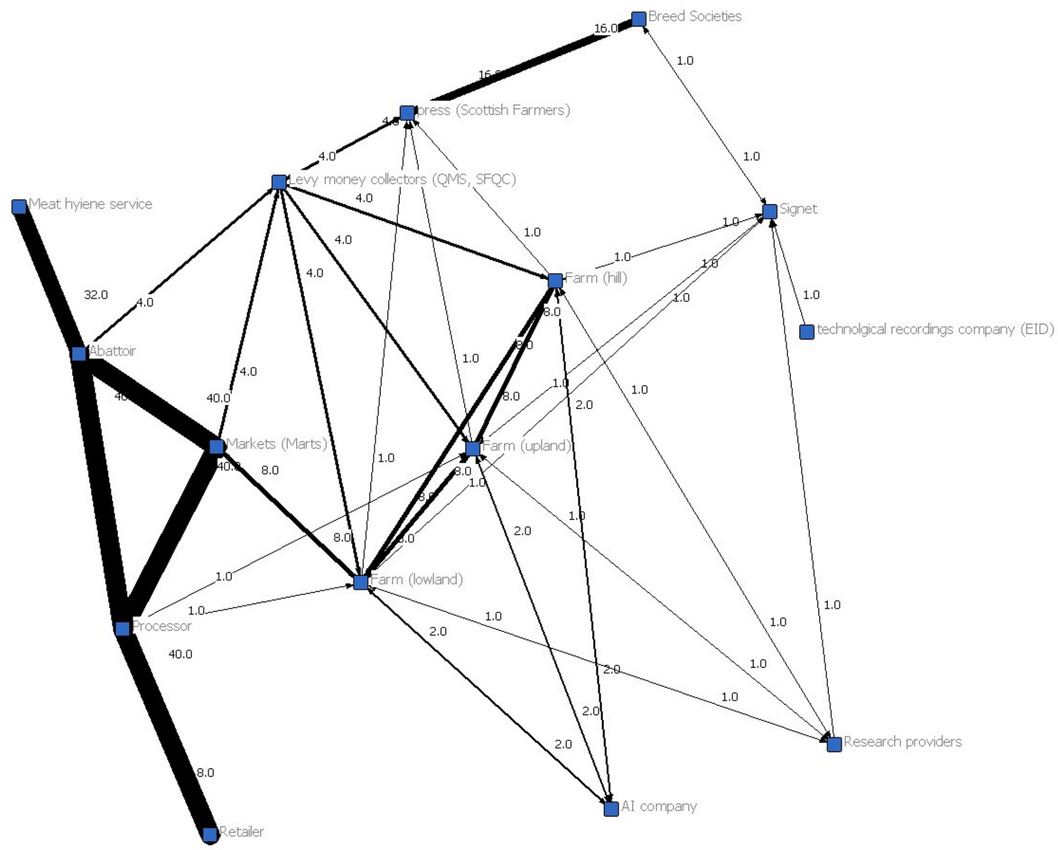


Figure 3 Sheep Innovation System



Briefly comparing the innovation systems, in all cases the farm is the most connected within the networks, however, the level of connection varies a great deal. In the dairy innovation system, we see a simpler system, with the greatest connectivity/flow between farmer and consultant. For beef, there appears to be greater connectivity in the AI and genetic data base section of the system, whereas there is less between the supply chain actors. In sheep, again we see a different story with greatest connectivity between markets, abattoir and retailers, and less between the rest of the system. For detailed Social Network Analysis of the beef innovation system see Borthwick (2014).

Barriers

The following barriers were selected from a wider list (Appendix A) by the workshop participants as having a strong role to play in the uptake of genetic technologies in the dairy, beef and sheep sector. These barriers are discussed in full below.

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Table 5 Barriers to innovation

Barrier	Dairy	Beef	Sheep
Practical barriers			
Stratified nature of the British Sheep sector			-
Industry structure – large number of small farms	+		-
Difficult to apply AI		-	-
EBV associated with intensive production conditions, fear performance will not be repeated in more demanding conditions		-	-
Practicality of implementing genetic evaluation tools for small herds/flocks		-	
Current scientific breeding involves too narrow a selection criteria and potential side effects. Perceived infertility problems with high yielding dairy cattle or calving problems with beef calves.	-	-	-
The size and structure of the pedigree beef industry in the UK does not lend itself to the adoption of more sophisticated breeding aids.		-	
Social Barriers			
Lack of collective action amongst farmers		-	-
Lack of use of consultancy services by farmers (intermediaries only)	-	-	-
Language barrier (farmers only)	-	-	-
Lack of farm demonstrations on benefits of up take of genetic evaluation technologies (intermediaries only)	-	-	-
Privatisation/commercialisation of advisory services has a negative effect on information flow (intermediaries only)	-	-	-
Farmers believe that the genetic make up of sheep has developed over hundreds of years and cannot be change quickly. (farmers only)		-	-
A lack of understanding of EBV technologies is a reason for non-adoption (intermediaries/farmers)			-/+
Some farmers prefer to trust their own visual judgement rather than computer generated numbers	-	-	-
Farmers who do not adopt EBVs are sceptical of scientific experts	-	-	-
Compared to other sectors, inadequate knowledge transfer activities is a reason for poor uptake of EBVs in the sheep sector.			-
Failure to bring on board (mobilise) influential breeders is a reason for poor uptake of EBVs.		-	-
Barriers relating to market/supply chain			
Centralised publication of international proofs, e.g. Interbull and the centralisation of the global dairy sector has led to harmonisation of breeding objectives across counties	+		
Routine publication of bull proofs in the dairy sector	+		
Farmers enrolled in milk recording schemes for management reasons	+		
Economic benefits from faster growth rates, improved feed efficiencies or superior carcase quality are not immediately visible to farmers.	-	-	-
Unequal distribution of benefits of uptake of genetic evaluation technologies between different parts of the supply chain	-	-	-
Sheep breeders have responded to market signals based on size and appearance in an auction-based supply chain where EBVs hardly feature.	+		-
Lack of profitability of sector (farmers/intermediaries)	+	+	+/-
Reliance on support payments creates inertia (farmers/intermediaries)	+	+	+/-

KEY: + = driver of uptake, - = barrier to uptake

Table 5 shows us there are a number of barriers which act in all three industries at the practical, social and market/supply chain level. However, there are areas where drivers operate in one industry and not others. It is clear from this workshop that a great deal of progress has been made in the dairy sector, where supply chain actors like AI companies have encouraged the uptake of technologies such as EBV. The availability and usefulness of data collected within the dairy industry is also a clear driver that has yet to be utilised in beef and sheep industries.

In relation to practical barriers we see far more identified in the beef and sheep sector than in dairy. One common barrier was identified – the narrow trait selection criteria. The key practical barriers in beef and sheep are discussed below.

The data required for EBVs in beef and sheep are seen to be difficult to record. This can be because they require lengthy periods of observation and there can be an element of subjectivity in the observations. For example some sheep traits require observations during the first 20mins of a lambs life at a time when farmers are often dealing with lambing problems. The perception of subjectivity in recording, coupled with a lack of trust between farmers leads them to question the accuracy of EBV data. In the dairy sector, many of the traits selected for were considered to be easier to record, such as milk production.

Table 2 gives some examples of the type of data required for EBV indexes in the three sectors discussed. It should be noted that while many more traits are recorded in some dairy indexes, the ease of data recording should be investigated as dairy cows move through the farm yard more regularly. The data in dairy is often recorded for the farmer by service providers and so little action is required. It could also be the case that this perception in the beef and sheep sector is due to lack of knowledge.

There is a perception that beef evaluation tools are hard to apply, especially for small herds. With the correct training and information it was felt that it can be show that this is not the case.

The participants from the beef and sheep sectors identified a **'Pendulum Effect'** - the shift in emphasis on different traits over time by researchers, advisory bodies or government. This led to the system being over complicated with too many index's. Examples include an emphasis on weight, then ease of birth. It was felt that farmers needed a simplified system where they could understand the key traits that would make a difference to their herd/flock.

In certain sectors it was felt that it was difficult to compare flocks or individuals, this was especially the case in the sheep sector. This issue has been overcome to some extent in the dairy sector through the routine publication of bull proofs. It should be noted that AI also enables direct comparison of progeny raised on different farms, which cannot be done in beef and sheep where AI is not the norm.

A number of difficulties in the application of these technologies emerged. One was the frequency with which animals were in the yard – for dairy this is twice a day, for beef and sheep rarely, therefore recording and application of AI becomes difficult in sheep and beef.

A significant barrier that was identified for the sheep sector was the requirement for a surgical procedure for AI, and the subsequent low conception rates which makes the procedure prohibitively expensive and not in the farmer's interest.

Farmers often find it difficult to see improvement which they relate to the technology. If farmers fail to see a benefit they will not spend money on adopting new techniques. Examples of this include:

- The benefit of EBV in the sheep sector is wiped out due price fluctuation – in some cases later in the season price fluctuations actually favour the poorest lambs which have developed later.
- If farmers do not get information on individual animals back from auction and abattoir they cannot see the link between price and traits.

- Particularly in the sheep and beef sector many farmers have narrow interests: they are concerned with the price their top animal got, rather than how many they sold or the price by kilo. This was discussed in relation to the important emphasis placed on shows and prise winning.
- Many improvements are attributed to weather or feeding regime changes (related to nutritional problems, and underfeeding), rather than breeding.
- Farmers perceive that the benefits of EBV cannot be achieved on small farms.
- Farmers have little incentive to invest in production traits, while traits which reduce management costs are rarely looked at. In the dairy sector farmers enrolled in milk recording schemes for management reasons, which provided regular data on performance and encouraged the use of EBV.

In recent decades labour on farms has decreased, resulting in higher workloads and lack of time. This was identified as the driver of a lack of engagement with farm demonstrations, new technology and knowledge transfer. The Scottish Agricultural Census supports this perception. It shows a long term trend in decreased labour in agriculture between 2002 and 2008. There have been small increases since 2008, however this has been attributed to changes in the way the census data is collected. Numbers of full time staff fell by 16.6% between 2002 and 2012 and have remained static since then. Part time workers have remained static over this period with small increases since 2008 (National Statistics 2012).

Table 5 indicates that all three sectors experience a greater number of common social barriers than the other categories. A number of these relate to interactions between advisors, consultants, researchers and farmers and can be attributed to the complex relationships between actors in an innovation system.

Lack of collective action between farmers was felt to be a significant barrier in the beef and sheep sectors. With many technologies such as EBV a large proportion of the sector needs to be involved in order for the systems to work efficiently and for the benefits to be realized at a sectorial level. In the beef and sheep sector there is limited collective action. Participants discussed this in terms of adopting the same technologies and techniques, trusting neighboring farmers and the way they record data and share information.

There is reasonably good KT, but it is problematic encouraging participation, and engaging the 'average farmer'. This was attributed, as discussed above, to reduced amounts of labour on farms, thus reducing farmers time for engagement. This situation has led cconsultants to become nervous about holding events due to lack of engagement.

Intermediaries need to be good at translating scientific information and making it relevant to the individual farmer – this skill was felt to be in limited supply. If researchers and consultants do not have this ability a language barrier emerges, when, for example they use Latin names for pests/diseases rather than on farm terminology. This language barrier then leads to a lack of understanding, or the impression that the researcher/consultant does not understand the specific conditions/environment that farmer is dealing with therefore their advice will be invalid. This situation leads to a lack of trust developing on the part of the farmer. This lack of trust has led to a sense in the sheep sector and to a lesser extent in the beef sector, that EBVs are eroding the role of the stockman. This impacts on the sense of pride and recognition of the skills the farmer has developed over their career.

The participants felt that agronomists are highly respected and their advice valued, while genetic scientists and consultants do not seem to be trusted in the beef and sheep sector. The participants identified a lack of advice and advisers on genetics in sheep, while plenty was available for the dairy sector. Dairy advice was however felt to be biased as it was provided by feed companies.

Participants identified a need for more collaboration between the various groups who provide information to farmers, this was the case in all three sectors. Vets, nutritionists, feed companies and genetic consultants need to work more closely to provided coherent and complementary advice.

- farmers do not want to pay for consulting, but are sceptical of free advice, as they question is legitimacy
- negative attitude has been perpetrated through the close relationships of influential breeders with the press and breed societies

In terms of barriers linked to the structure of the industry and market/supply chains Table 5 shows two key barriers acting in all three sectors relating to where in the supply chain the economic benefits of the current system are felt – and they tend not to be focused on the farmer. The beef sector experiences more drivers relating to the supply chain, while there are common drivers as well – relating to a lack of profitability and the impact of subsidies.

The sheep sector is considered to be fragmented with a large number of small farms, as well as 87 commercial breeds in the UK as apposed to 6 in New Zealand. This can hinder sector wide changes as there are many decision makers to engage. This fragmented nature is linked to the 'stratification' of the sheep sector which creates a complex network of sheep movements and crossbreeding, discussed above.

The size and structure of the dairy and pedigree beef industry is an example of a structure which encourages EBV uptake, with fewer farms which are larger in size this can make changing behaviour easier.

The dairy sector has become international with breeding goals set at a global level and international data available. The participants felt this competition helped to 'focus the mind' of dairy farmers and encourages behaviour change and EBV uptake. It was felt that there was a lack of UK specific data in the dairy sector and this acted as a barrier.

In both the beef and sheep sectors current influential breeders regard EBVs as a threat. Participants felt that wider adoption of EBVs would expose these prize winning animals as being no better than others, thereby compromising the influential breeders position, and threatening their income.

Market signals have acted as a significant driver of EBV uptake in the dairy sector because they are closely related – EBVs are known to improve milk production either through increased quantity or through increase protein content depending on the buyers requirements. However, that connection between EBV and market is not as apparent in the beef and sheep sector. Indeed, studies by QMS have shown that product quality is also poorly linked to price in the meet sector in Scotland (QMS 2013).

The economic benefits of systems such as EBV have been well documented for all three sectors in this study (Amer *et al* 2007). These economic benefits for beef and sheep include beef value per calf born, calving ease for beef, and profit per lamb, per breeding ewe. These are seen quicker in the dairy sector than in beef and sheep due to the structure of the sectors and the nature of the products.

The three sectors investigated in the study show common barriers as discussed above, there are certain sectorial characterises that have emerged as part of the study. These are discussed in the following section

The dairy industry was identified as differing from beef and sheep in a number of ways. Dairy farmers tend to work more closely together and collaborate as the structure of the supply chain encourages this.

[This structure comprises of the individual farms, international AI companies, feed companies, who provided a great deal of advice, milk recording companies, milk co-operatives and retailers (Sheane *et al* 2011). Both farmers and intermediaries felt this structure led to more collaboration between farmers, a greater flow of information between the different parties, which encouraged the uptake of EBVs] International AI companies have a significant influence on the dairy sector, and have diminished the influence of influential/traditional breeders – which are largely absent from this sector.

Other characteristics of the dairy sector that emerged were the large amount of data that is available to dairy farmers from milk recording companies, as well as the publication of international bull proofs. This improves the knowledge of the farmers and aided uptake of technologies. PLIs and PTAs in the dairy sector have also improved the general understanding of EBVs. The participants in this workshop felt that dairy farmers have a positive view of breeding programmes, not shared by beef and sheep.

Dairy farmers benefit from a large number of consultants, it was felt that the best dairy farms have high quality consultants working with them. There was concern that a lot of the advice is biased as it comes from feed companies and is not independent.

All groups acknowledge that the sheep sector lags behind the dairy and the beef sector in terms of adoption of breeding and genetic technologies. The issue of commercial farming was discussed on several occasions, and a failure within the sheep sector to separate commercial farming, and the 'fancying,' or pedigree industry. The former is focused on increased productivity and quality of product, while the latter is interested in wining prizes at shows and securing record prices for individual animals, rather than the sale of a high turnover of product.

The visual appraisal of animals at market, and the lack of data concerning individual carcass quality exacerbate this situation and prevents adoption of EBVs. This is also due to the stratified nature of the industry. The groups discussed the impact of the stratified nature of the sheep sector in terms of there being a large number of small farmers with complex interactions, a large number of breeds in use, as well as an overlap between the commercial objectives of the farmer and the showmanship objectives.

The complexity of applying AI to sheep must be addressed if EBV is to be adopted in the sheep sector as without AI there are limited advantages to the EBV system. It must be noted that there are applications of AI in sheep, particularly for milk, as-well-as successful uses of EBV in sheep herds, however these are anomalies within the Scottish sector.

The beef sector seemed to lie between the success of the dairy sector and the failure of the sheep sector when it comes to adoption of new genetic technologies. Similarities with the dairy sector include the feasibility of AI, and market signals within the cattle sector as a whole driving uptake of EBV. The beef sector lags behind the dairy in its uptake of EBV, and barriers to this include a more negative perception of EBV, a stronger emphasis placed on prize winning and the showmanship aspect of farming, as well as negative perceptions of trait recording and benefits for small herds. Many of the factors which act as barriers to EBV uptake in beef relate to the increased management burden AI and EBV recording place on the farmer.

Other key issues that emerged during the workshop are highlighted below.

Subsidies were identified in many discussions as having a negative impact on the uptake of technologies and changes in the industry as they removed incentives to become more cost effective, particularly in the sheep sector.

Showmanship emerged as a key theme in both the beef and sheep sector. Successful breeders in these sectors are ones whose animals do well at shows. The price of individual animals is often determined by awards at shows, and the press is instrumental in perpetuating the emphasis on shows, rather than on animals which have good indexes. Showmanship is linked with pride and the skill of the farmer in a number of the discussions. Shows are an important social event in these communities.

Figure 4 Number of show categories per sector at the Royal Highland Show

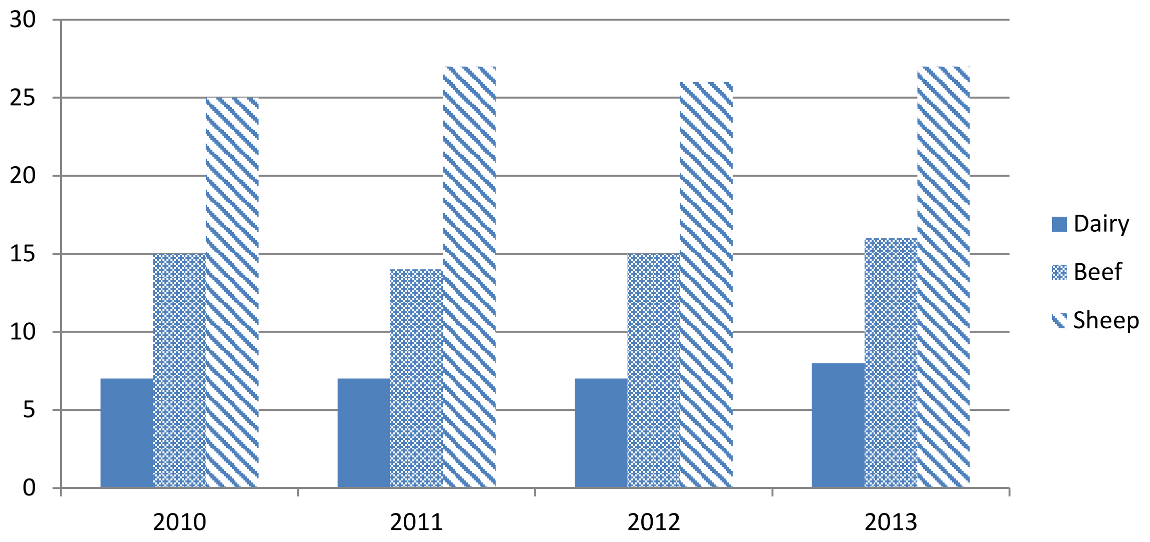

Figure 5 Number of animals entered into the Royal Highland Show

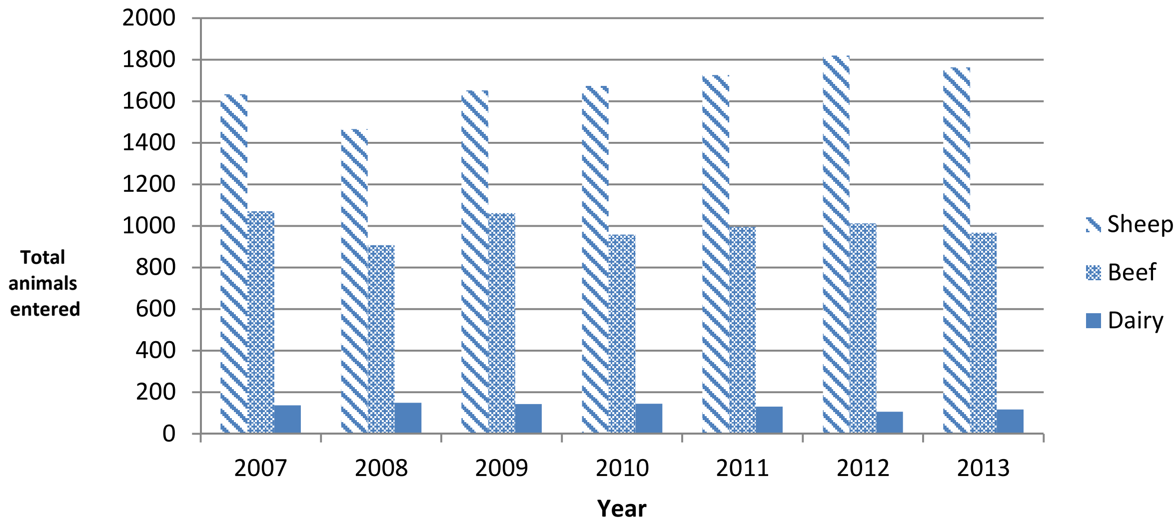

Figure 4 and Figure 5 show us that while dairy breeders do show, there are fewer categories dedicate to dairy cattle, and fewer individual animals entered into these categories compared to beef and sheep. This tells us that while dairy farmers do not show as much as beef and sheep, it is still an element of the dairy farming community, and pedigree livestock farming can exists along side the use of techniques such as EBV.

Discussion

Returning to the systemic challenges identified by Islam *et al* (2012), we can assess to what extent they are apparent in all three sectors.

Table 6 Systemic challenges compared across sectors

Systemic Challenge	Dairy	Beef	Sheep
Weakly integrated supple chain	No	Yes	Yes
Presence of a powerful faction antagonistic towards EBVs	No	Yes	Yes
Challenging policy environment	No	Yes	Yes
Dismantled and weak advisory service with regard to EBVs	Yes	Yes	Yes

Outdated and inflexible data management system	No	Yes	Yes
AI difficult to apply/low conception rates	No	Yes	Yes

Table 6 shows us that the common challenge across all three sectors identified by stakeholders is the availability of advisory services. The dairy sector has managed to overcome or avoid the other challenges. The mechanisms by which this has been achieved are related to the ease with which data is collected and handled in the dairy sector as a result of the involvement of milk recording companies. Other factors are the easy of management of herds which are seen at least twice daily, and the rapid visual gains (milk supply) genetic improvement has in dairy. Looking at the findings of this study in more detail and drawing on innovation systems research a number of systems failures can be identified. These are discussed below.

When we compare these sectors to the innovation systems failure matrix developed by Weber and Rohracherb (2012, Lamprinopulou *et al* 2012) (Table 2) we can identify a number of key failures.

Table 7 Innovation System Failures of the Scottish dairy, beef and sheep sectors

Market Failures:	Information Asymmetries	Within the beef and sheep sectors a lack of research to solve the practical limitation of applying AI in the sheep sector, and the managerial limitations in both beef and sheep has prevented this important breeding technology to be taken up with the same rate as it has been in the dairy sector. The widespread use of AI in dairy has aided the use of EBV with the direct comparability of herds with the same sirage, as well as pedigree breeders having an international market for top semen.
Structural System Failures:	Infrastructure failures	These are deficits in existing physical infrastructure which enable innovation (Weber and Rohracher 2012). The low return on investment in EBV, and the long term nature of this return acts as a barrier in the beef and sheep sector. The surgical requirement for AI in sheep and low conception rates, and the management requirements for AI in beef inhibit innovation in this area.
	Institutional failure (Hard)	These are formal mechanisms which hinder innovation (Weber and Rohracher 2012). The subsidy system which operates in the sheep sector has prevented market signals driving uptake of EBV. There is a complex system with many indexes and selection criteria which cause confusion, the simplification of the system may encourage more farmers to engage.
	Institutional failure (soft)	Soft institutions such as social norms, values, and trust play an important role in all three sectors. Within the dairy sector social norms have aligned around EBV and the use of AI, with greater trust of these technologies evident. In beef and sheep more traditional norms concerning showmanship, praise winning and appraisal by eye remain powerful forces. Dairy breed societies are involved with these breeding programmes, as are some beef and sheep, but it is vital that more collaboration and communication occurs with breed societies to create systems that work for their members if behaviours are to change.
	Interaction or network failure (strong network failure)	Strong network failures exist when interactions are extremely strong and do not allow for change (Weber and Rohracher 2012). Within the beef and sheep sectors there are strong network ties evident around breed societies, farming press, and influential breeders. Failure to engage

		with this network has hindered the uptake of EBV.
	Interaction or network failure (weak network failure)	These exist when there is not enough interaction within a network (Weber and Rohracher 2012). Lack of communication between actors such as consultants and researchers and farmers operates in dairy, beef and sheep sectors. This is a result of less time available to farmers, the privatisation of the advisory services, to some extent a lack of expertise within the advisory service and a significant language barrier and failure to provide useful specific information and training to farmers.
	Capabilities failure	When individuals and groups within a network do not possess the required capabilities to carry out a specific activity (Weber and Rohracher 2012). KT/advisory service – lack of independent and free advise operates in dairy, beef and sheep. This advice also lacks the local context which farmers require. It should also be noted that in beef and sheep the lack of assistance in data collection and management from external organisations increases the burden on the individual farmer in terms of the level of knowledge they require to partake in these programmes, as well as the time required. This is not the case in dairy as much of the work is carried out by milk recording companies and AI companies. As Le Gal *et al* point out (2011) farmers make decisions at the farm level, so if new techniques and advice is not targeted at this level they may discount it as inappropriate.
Transformational Systems Failures:	Directionality failure	Lack of shared vision and changing priorities has led to the 'pendulum effect' in all three sectors, but has most negative perception in beef and sheep. The lack of funding and targeting to resolve the AI issue for the sheep industry is also a significant failure.
	Reflexivity failure	The beef and sheep sector in particular lack the ability to monitor and anticipate processes of self governance (Lamprinopoulou *et al* 2012)– lack of information flow from abattoirs to farm so that quality improvements can be traced. The management requirements of the farmer have not been considered in the development of some recording schemes so that benefits are experienced on farm not just by the retailer and consumer. Work on 'user-centered design' of agricultural innovation has shown that in some cases engaging with users at the development phases of a technique can speed up the innovation process, and users can find the products easier to use and deliver more benefits (Haapala 2012). In their review paper, Le Gal, Dugué and Noval (2011) highlight that a number of farm based models of developing innovative production systems exists and can help to solve agricultural challenges while supporting farmers as decision makers.

Conclusions

In this paper we have identified a range of barriers inhibiting the uptake of genetic technologies and techniques in three livestock sectors in Scotland. We have shown that these are not universal and that sectors have been successful in creating behaviour change to embrace innovation. We have shown how these barriers relate to systemic failures, and that there are practical, social and structural barriers. We have then discussed these barriers in relation to wider theories of innovation systems and identified a range of failures in these three systems.

Practical barriers to the uptake of EBV are evident in the sheep and to a lesser extent the beef sector. These maybe addressed through research and by more engagement with farmers to understand the specific challenges on farm and how a technique such as EBV may be tailored to overcome this.

Social issues which were identified as acting as barriers show the importance of communication, transparency and the role for independent farm based advice. The social importance of showmanship and pride within the sheep and beef sector must not be overlooked and may offer the key to engaging with influential breeders and enabling more coordinated approaches to breeding in these sectors. It is easy to label those farmers unwilling to engage with EBV as 'problematic obstacles to the modernisation of livestock breeding' while those who do engage as 'confident, progressive' (Morris and Holloway 2013). These classifications ignore the complex individual requirements and social contexts within which the decision to use EBV are made and overlook potential failures of the system to account for broader factors such as ease of management and limited short term economic gains for the individual.

Structure and market/supply chain barriers were felt by participants to be significant barriers due to the lack of economic benefit seen by the farmer. The data flow through the supply chain in the dairy sector, and the direct link between EBV indices and economic benefits has helped drive uptake.

Linking across the supply chain is vital, to ensure that farmers can have access to data which assures them in their use of the technology.

These findings show that applying the innovation systems approach to these three livestock sectors allows us to highlight significant barriers at many different levels, and enable us to target specific solutions. It supports Weber and Rohracher's (2012) argument that innovation must be fostered not only from the supply side, but that the production and consumption side of a system is also vital. By using the systematic failure model we can make recommendations which target a broad range of actors and institutions throughout the system, making action more coherent and joined up.

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