Dynamics of Innovation in Livestock Genetics in Scotland: An Agricultural Innovation Systems Perspective

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Abstract: The application of genetic selection technologies in livestock breeding offers unique opportunities to enhance the productivity, profitability, and competitiveness of the livestock industry in Scotland. However, there is a concern that the uptake of these technologies has been slower in the sheep and beef sectors in comparison to the dairy, pig and poultry sectors. This is rather paradoxical given the fact that Scotland’s research outputs in farm animal genetics are widely perceived to be excellent. A growing body of literature, popularly known as Innovation Systems theories, suggests that technological transformations require a much broader approach that transcends formal research establishments. Accordingly, this paper reports on preliminary work exploring whether and how an agricultural innovation systems perspective could help identify the dynamics of technology uptake in the livestock sectors in Scotland. Although the work has been undertaken in dairy, sheep, and beef sectors, in this paper, we provide the preliminary results obtained from a case study of the sheep sector only. The key objectives of this work were to map the sheep genetics innovation system in Scotland and identify the barriers prevailing within the system with regard to the uptake of genetic selection technologies. Although the sheep innovation system was characterised by the presence of all key domains and actors, it was found to suffer from some crucial weaknesses relating to network integration, technological infrastructure, and policies and institutional frameworks. The implications of these findings are discussed.

Keywords: Genetic Selection, Sheep, Scotland, EBV, Innovation System

1. Introduction

The livestock sector makes a significant contribution to the Scottish economy (Scottish Government, 2012; QMS, 2011). Excluding farm subsidy payments, ancillary industries and further processing, the sector generated revenues of approximately £1.8 billion and employed some 27,000 people in 2010 (QMS, 2011). Despite its importance the Scottish livestock sector faces some crucial challenges, including: a decline in livestock numbers (Scottish Government, 2012), fall in Total Factor Productivity (Barnes et al, 2011), increased competition in export markets (QMS, 2011), and the need to address consumer concerns for health and safety, animal welfare, and environmental sustainability (Simm, 2009; Wall, 2011).

Historically, genetic improvement of livestock through selective breeding has played a key role in maintaining the productivity, competitiveness and profitability of the Scottish livestock industry. Recent studies by the Scottish Agricultural College (SAC) and partners show a value of £29 million in sheep, £23 million in beef, and up to £147 million in dairy resulting from 10 years of genetic improvement. With higher uptake of modern breeding practices it is estimated that the value to the sheep sector alone could rise to £111 million (Simm, 2009). In addition to increased production and profitability, selective breeding has the potential to improve product qualities (e.g. leaner meat products), improve animal health and welfare, and lower Greenhouse Gas (GHG) emissions (Simm 2009, Wall, 2011).
Traditionally, farmers have selected animals by “eye”, that is through visual inspection of the candidates for selection and their relatives. Since the phenotypic expression of animal traits are influenced by both genetic and environmental (including management) factors, animals selected in this way may not optimise genetic management for superior performance. Modern scientific inventions have provided unique opportunities to estimate the true genetic merits of animals more accurately. The key underlying procedures include the collection of pedigree and on-farm performance data of individual animals and then analysing these data through sophisticated statistical methods such as Best Linear Unbiased Prediction (BLUP). The results are then expressed as Estimated Breeding Values (EBVs).

An EBV is basically a numerical figure assigned to an animal for a certain trait, such as growth rate, muscle yield, maternal ability, etc. EBVs are often expressed in the same unit as the trait of interest, e.g. kilogram for live weight, millimetre for fat and loin depth, and percentage for number of lambs born. These EBV figures then indicate the predicted genetic merit of an animal for these traits. For example, a ram with an EBV of +4kg scan weight means that the ram’s progeny are expected to be 2kg heavier at 20/21 weeks compared to the progeny of a ram with an EBV of zero. Depending on the breeding/selection objectives of farmers, EBVs on individual traits are weighted and combined to develop a selection index which farmers could use in their breeding programmes to optimise selection across many traits affecting profitability.

The adoption of EBVs in selective breeding is growing in Scotland. However, there is a concern that the uptake has been slower in the sheep and beef sectors in comparison to the dairy, pig and poultry sectors (Simm, 2009; Vipond, 2010). This is indeed a policy concern in Scotland, especially given the fact that Scotland’s research outputs in farm animal genetics is widely perceived to be excellent (Islam, Lamprinopoulou, and Renwick, 2012) and that genetic improvement using EBVs is generally accepted as a working tool. Therefore, there is a need to understand why the uptake of EBVs in the sheep and beef sectors has been slower.

Until recently, the development and diffusion of agricultural technologies was thought to be a linear process involving public sector research and extension organisations. Such an approach, however, appears to be limited in explaining the slower uptake of EBV technologies in the Scottish livestock industry, in particular, given the strength in livestock genetics research that the country has. However, an emerging approach, popularly called the Innovation System (IS) approach, provides a much broader perspective and hence appears to be promising in investigating the Scottish context.

Accordingly, this work (on-going) explored whether and how an agricultural innovation systems perspective could help identify the dynamics of EBV uptake in the livestock sectors in Scotland. Although the work has been undertaken in dairy, sheep, and beef sectors, in this paper we report the preliminary results obtained from the sheep sector only. The specific objectives of this work were: (i) to map the EBV innovation system in the Scottish sheep sector, (ii) to identify the barriers within the system with regard to the uptake of EBV practices, and (iii) to discuss policy implications to further improve the uptake of EBV practices within the sheep sector.

The remainder of this paper is organised in the following way. In the next section we lay out a conceptual framework of the Innovation Systems approach. In section three, the research methods used in this study are described. The results of this study are presented in section four and in section five we draw the key conclusions and implications of this study.
2. The Agricultural Innovation Systems Approach

Innovation system thinking is not new in agriculture and dates back to as early as the nineteen sixties. For instance, the concepts of NARS (National Agricultural Research System) and AKIS (Agricultural Knowledge and Information System) that underpinned agricultural science and technology policies in many countries from the sixties up to the nineties were also based on systems thinking (see World Bank, 2006 for details). What makes Agricultural Innovation Systems (AIS) approach different from NARS and AKIS is basically its wider focus on organisations responsible for innovation, for example, the role of supply chain actors. As the World Bank (2006: iv) states “The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It extends beyond the creation of knowledge to encompass the factors affecting demand for and use of knowledge in novel and useful ways.” Accordingly, the Bank defines an AIS as the network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the system’s behaviour and performance (World Bank, 2006).

However, as Klerkx et al (2009) state, although there is much emphasis on knowledge creation, exchange and use in the above definition of AIS, innovation systems need to fulfill several other functions that are essential for innovation. These functions include: fostering entrepreneurial drive and activity, vision development, resource mobilisation (e.g. capital), market formation, building legitimacy for change, and overcoming resistance to change by means of advocacy and lobbying (Hekkert, Harmsen, and de Jong, 2007).

The IS is however not a unified concept. Rather, depending on the boundary around which a system is conceptualised, four types of IS approaches are generally found, including: National Innovation System (NIS) (Lundvall, 1992), Regional Innovation System (RIS) (Saxenian, 1994), Sectoral Innovation System (SIS) (Malbera, 2002), and Technological Innovation System (TIS) (Carlsson and Stankiewicz, 1991). Regardless of their names, the basic elements that constitute an innovation system are more or less the same across these various approaches. They are: actors, networks/interactions, and institutions. The SIS and TIS approach however adds a fourth element – technology.

**Actors** within an IS approach could be any individual and organisation that contributes to the development, diffusion, and utilisation of a new technology, product or service, either directly or indirectly. As mentioned earlier, the IS approach takes a wider perspective in conceptualising which actor is inside or outside of a system. According to the activities and roles of these actors they are generally conceptualised under four key domains – research (or according to some, knowledge), enterprise, intermediary, and demand.

Examples of actors in the research domain include universities, research institutes, and so on, who create codified knowledge based on basic and applied research. In the enterprise domain are actors like technology companies who actually convert the scientific knowledge into innovative products or services and bring them into the market. Put together, the research and enterprise actors could be conceptualised as the suppliers of innovation. On the demand side are actors who use the innovative products or services. In between the supply and demand sides are the intermediaries such as extension and advisory services, farmers’ organisations, trade associations, non-governmental organisations (NGOs) (World Bank, 2006), as well as specialized systemic intermediaries which merely facilitate interaction but do not give expert advice, which have been coined ‘innovation brokers’ (see Klerkx and Leeuwis, 2009) . These actors/domains are, however, not mutually exclusive. An actor on the demand side, for example a farmer, may be an entrepreneur. Similarly, research institutes/universities may sometimes undertake knowledge diffusion activities and therefore could be conceptualised as playing the roles of intermediaries. Ideally, a good performing system is characterised by the
presence of a sufficient number and diversity of actors (World Bank, 2006). On the other hand, systems with missing actors may fail to perform (Woolthuis, Lankhuizen, and Gilsing, 2005).

Networks/interactions/linkages are the central components of an innovation system, as it appears from the very definition of the concept provided above. This is through networks of relationships (ties) that the different actors within an innovation system interact with each other, share resources and information, and harmonise their activities towards a common goal. This interconnectedness, harmonisation, and complementarities between various system parts are central in all systems theories (see for example, von Bertalanffy, 1976). However, these networks/linkages/interactions do not necessarily have to be formal. Instead, they can be informal and, sometimes, actors within a system may not even be aware of their existence. Whilst, all sorts of interactions are vital for an innovation system, a special focus on the IS literature is the flow of information/knowledge and competencies (skills) rather than the flow of ordinary goods and services only (Carlsson and Stankiewicz, 1991). Although ties are immensely important in technology diffusion, it does not mean that all ties within a system are always useful. For instance, although strong ties between system actors can be very productive and a source of synergy, they can sometimes be counterproductive (see Woolthuis, Lankhuizen, and Gilsing, 2005 for details).

Institutions are the rules-of-the-games that constrain (enable) the behaviour of actors in a society (North, 1990; Scott, 2001). Institutions are generally considered as the “environment” within which organisations are embedded. They can be formal and informal. Examples of formal institutions include government laws, policy decisions, firm directives, contracts, etc. and their enforcement mechanisms (e.g. rewards and punishments). Informal institutions are sometimes called “cultural rules” and can have normative and cognitive dimensions (Scott, 2001). Normative rules include values and norms, whilst cognitive rules include shared beliefs, mental models, perceived logic of action, and so on. Institutions have immense implications for new ideas, technologies, etc. to develop and diffuse. For instance, if a new technology does not correspond with the value system of a society, it will be difficult for the technology to develop and diffuse. This problem is widely documented in the diffusion literature and is known as “technological incompatibility” (see Rogers, 2003). A similar argument is forwarded in the so called “technological lock-in” theory (Arthur, 1989), which states that old technologies are difficult to replace as they are supported by existing institutions. By the same token, new technologies find it hard to be accepted because of a lack of corresponding institutions. Recent insights from innovation studies therefore point at the crucial importance of co-evolution between technology and institutional arrangements, such as markets, labour, land tenure and distribution of benefits (Geels, 2004; Hounkonnou et al., 2012).

At this stage it is useful to briefly outline the different categories of innovation system failures that have been identified in the literature as they provide a framework by which our results can be classified and analysed. Klerkx, van Mierlo, and Leeuwis (2012), following Woolthuis, Lankhuizen, and Gilsing (2005) and van Mierlo et al (2010), provide the following definition of innovation systems failures:

- **Infrastructural failures** concern (the absence of) the physical infrastructure, such as railroads and telecom are constraints requiring major investments that cannot be made independently by the actors of the system. They also concern investments in knowledge infrastructure (R&D facilities) and financial infrastructure.
- **Hard institutional failure** refers to laws, regulations and any other formalised rules, or the lack of them, hampering innovation. For example, lack of IP regulation takes away incentives
from innovators as they cannot protect their innovation. Absence of environmental regulation on radically different systems, having an institutional vacuum, may slow down certain developments.

- **Soft institutional failure** refers to unwritten rules, norms, values, culture, or ‘the way business is done’. They affect how actors interact, but also relate to their (in)ability to change their norms and values in order to enable innovation to take place.

- Related to institutional failures is **strong network failure**, which refers to actors locked into their relationship, which causes myopia and blocks new ideas from outside and prohibits other potentially fruitful collaborations. **Weak network failure** refers to a situation where actors are not well connected and fruitful cycles of learning and innovation may be prevented because there is no creative recombination of knowledge and resources. These two failures indicate an apparent paradox in networking for innovation: a quest for a balance between openness and closure, informal or formalized interaction, trust relationships or contracts (Håkansson and Ford 2002).

- **Capabilities failure** points to the lack of technical and organizational capacity of the system to adapt to and manage new technology and organizational innovations, such as a certain level of entrepreneurship, adequately educated persons, time to dedicate to innovation, and networking skills.

- Finally, **market structure failures** refer to the positions of and relations between market parties, such as a monopoly or the lack of transparency in the ever enlarging food chains, but also imperfections in the ‘knowledge market’ (Klerkx and Leeuwis 2009).

### 3. Methods

This research used an exploratory case study approach (Yin, 2003). The sheep innovation system was mapped and analysed using qualitative methods. Data were collected mainly through in-depth key informant interviews with scientists, industry experts, extension and consultancy service providers, farmer organisations/farmers, and other relevant stakeholders involved with the development, diffusion and use of EBV practices within the Scottish sheep sector. Furthermore, a workshop was held on 11 June 2012 with these stakeholders whereby various types of mapping exercises, group discussions, and brainstorming exercises were carried out. In addition, published and unpublished documents relating to EBV practices were collected and analysed. These results were then organised according to the concepts outlined in section two.

### 4. Results

In this section we first describe the EBV innovation system in the Scottish sheep sector and then discuss the factors within the system that constrained the uptake of EBVs.

#### 4.1 Scottish sheep EBV innovation system: Key actors and their roles

The sheep EBV innovation system in Scotland was found to be characterised by the presence of all key domains of an innovation system, namely, research, enterprise, intermediary, and demand (Table 1). On the research domain there are two key actors – the research wing of the Scottish Agricultural College (SAC) and the Roslin Institute of the University of Edinburgh. In the enterprise domain are three key organisations – Signet Breeding Services, Edinburgh Genetic Evaluation Services (EGENES), and Basco Data Limited. For simplicity, these various actors could collectively be labelled as the suppliers of EBVs. This supply side, however, is stretched beyond Scotland and is a unique blend of Scottish and English organisations. For instance, although Signet provides its services to Scottish farmers, the
organisation is part of EBLEX (English Beef and Lamb Executive), which is an industry body for beef and sheep levy payers in England. Similarly, although EGENES provides its services UK-wide, the organisation is part of SAC and is based in Scotland.

Table 1: Key actors within the Scottish sheep genetic innovation system and their roles

<table>
<thead>
<tr>
<th>Key actors</th>
<th>Roles</th>
<th>Domain(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAC and Roslin Institute</td>
<td>Conduct basic and applied research on selection traits; create new methods/tools for genetic evaluations; provide technical support to EGENES; offer courses on animal genetics and breeding; organise workshops, seminars, etc. on animal genetics</td>
<td>Research (knowledge)</td>
</tr>
<tr>
<td>Signet</td>
<td>Compiles data provided by breeder members; cleans and stores data on Sheepbreeder or Basco website; provide EBV results back to breeder members; provide recording-related technical support, if required by members; publish EBV-related information on company website</td>
<td>Enterprise</td>
</tr>
<tr>
<td>Basco Data Ltd.</td>
<td>Stores and maintains an online database containing pedigree and performance data provided by breed societies, individual breeders, and Signet</td>
<td>Enterprise</td>
</tr>
<tr>
<td>EGENES</td>
<td>Performs genetic analyses by using data stored on the Basco database and/or provided by Signet; develop search engines for Basco database</td>
<td>Enterprise</td>
</tr>
<tr>
<td>Breed Societies</td>
<td>Collect, record and manage pedigree information provided by members; organise shows and events; publicise wide range of technical information, case studies, etc. on society websites; manage the Basco database (Texel and Suffolk societies only)</td>
<td>Intermediary</td>
</tr>
<tr>
<td>Press</td>
<td>Publicise EBV-related practices and events and activities, e.g. shows or sale information on indexed sheep, etc.</td>
<td>Intermediary</td>
</tr>
<tr>
<td>QMS (formerly MLC)</td>
<td>Collect levy money from abattoirs (paid by producers) and uses this money to provide funding support to Signet for undertaking genetic analyses and to SSS for undertaking KTE activities and events</td>
<td>Intermediary</td>
</tr>
<tr>
<td>SSS</td>
<td>Publicise EBV related technical information, case studies, etc on company website; undertake KTE activities on behalf of QMS; organise workshops and field days on EBV; conduct on-farm trials of EBV practices to demonstrate their effectiveness; publicise indexed rams and ewes on sale; work with supermarkets on EBV trials</td>
<td>Intermediary</td>
</tr>
<tr>
<td>SAC consultancy</td>
<td>Provide one-to-one advice and assistance to farmers on breeding and other wide range of agriculture-related services</td>
<td>Intermediary</td>
</tr>
<tr>
<td>EU, and Scottish/UK</td>
<td>Create agricultural policies in Scotland; provide CAP support payments to farmers; formulate rules for payments; monitors activities of QMS; provide funding grants for R&amp;D activities; publicise sheep industry information on official websites</td>
<td>Enabling (policy)</td>
</tr>
<tr>
<td>Governments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NFUS</td>
<td>Promotes and protects members’ (farmers’) interests by influencing government, supply chain actors, and consumers</td>
<td>Intermediary (policy)</td>
</tr>
<tr>
<td>Pedigree breeders</td>
<td>Record on-farm performance of sheep on selection traits; submit data to breed societies or to Signet or store directly on Basco database; receive EBV services from Signet; select and breed indexed animals; sell breeding ewes and rams</td>
<td>Demand</td>
</tr>
<tr>
<td>Crossbred lamb producers</td>
<td>Purchase rams from pedigree breeders and use them in cross-breeding to produce lambs for meat purposes</td>
<td>Demand</td>
</tr>
<tr>
<td>Auction Marts</td>
<td>Act as markets for the buying and selling of sheep; provide levy money to QMS based on per animal sold</td>
<td>Demand</td>
</tr>
<tr>
<td>Abattoirs/Processors</td>
<td>Buy and slaughter sheep; provide levy money to QMS based on per animal slaughtered; process slaughtered sheep – cutting, grading, packaging, etc</td>
<td>Demand</td>
</tr>
<tr>
<td>(maybe same)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retailers (supermarkets)</td>
<td>Sell lamb meat and meat products</td>
<td>Demand</td>
</tr>
</tbody>
</table>
On the demand side (actual and potential) there are pedigree breeders and commercial lamb producers who are expected to use EBVs to improve their flocks. In order to receive Signet services they have to pay an annual membership fee to Signet. These breeder members are required to record on-farm performance data in their flocks and submit these data to Signet and Basco. These data are then analysed by EGENES to estimate EBVs, which are then sent back to the breeders by Signet. The other actors within the sheep supply chain – such as auction marts, abattoirs, processors, and retailers – can also be placed on the demand side as they provide markets for the animals improved through genetic selection.

In between these two sides – EBV suppliers and EBV users – a number of intermediaries can be found (Table 1). One of these is the sheep breed societies for each of the major sheep breeds - including, Blackface, Bluefaced Leicester, Border Leicester, Cheviot, Texel, Suffolk, Charollais, etc. Some of these societies operate UK-wide whilst others operate within Scotland only. As shown in Table 1, the breed societies play a number of roles that have implications for the uptake of EBVs within the sheep industry. Moreover, two of the sheep societies – Texel and Suffolk societies – are the founding members of Basco Data Limited. Not all breed societies are however supportive of EBVs and some are, according to our interviewees, more “forward thinking” than the others. We have discussed this in detail in the next section.

Our findings suggest that other key intermediaries include the Scottish agricultural press, Quality Meat Scotland (QMS), Scottish Sheep Strategy (SSS), and SAC Consultancy Limited. The QMS is a Scottish statutory levy body run by the money collected from abattoirs (but paid for by producers) based on per animal sold or slaughtered and from exporters based on per animal exported. The QMS was created in 2005 as part of administrative devolution in the UK. During this, the then UK-wide levy body named the Meat and Livestock Commission (MLC) was dissolved and three regional structures were created – QMS in Scotland, EBLEX in England, and HCC in Wales.

The SSS is a subsidiary organisation created by QMS to undertake knowledge transfer activities with regard to EBV practices. SAC Consulting Limited, on the other hand, is a division of SAC that provides a wide range of advisory services to farmers on a fee-for-service basis. The organisation also provides free public good advice funded by the Scottish Government. Apart from these organisations, the research wing of SAC and the Roslin Institute also carry out some knowledge transfer and exchange activities through workshops, seminars, etc.

Furthermore, the EU and Scottish/UK governments were found to be important actors in terms of shaping an enabling environment for innovation (or, reversely, disabling). They provided policy and regulatory contexts within which the other actors operated. Also, the National Farmers’ Union of Scotland (NFUS) had influence on the government policy actors and therefore was an important intermediary at the policy level.

4.2 Systemic challenges in the uptake of EBVs

Five major systemic challenges were identified: a weakly integrated sheep 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, and an outdated and inflexible data management system. These are described below.
Weakly integrated sheep supply chain

Weak integration within the sheep supply chain was identified as one of the key factors affecting the uptake of EBV practices. If we look into the EBVs/selection indexes provided by Signet – the sole provider of sheep and beef EBV services in the UK – we see that these are promoted based on economic rationale, that is, as a means to increase farm productivity and profits (see Table 2). However, uptake of EBVs at the farm level and realising profits from this uptake were found to be constrained by a number of factors within the supply chain.

Table 2: Selection Indexes provided by Signet Breeding Services

<table>
<thead>
<tr>
<th>Index</th>
<th>Main breeds</th>
<th>Main traits/EBVs</th>
<th>Breeding objectives/usefulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Sire Index</td>
<td>Charollais, Hampshire Down, Ile de France, Meatline, Poll Dorset, Suffolk, Texel Vendee</td>
<td>Leanness (Muscle and fat depth)</td>
<td>Increase lean meat and reduced fat in carcase</td>
</tr>
<tr>
<td>Maternal Index</td>
<td>Some Lleyn and Poll Dorset flocks</td>
<td>Litter Size, 8-week Weight, Mature Size and Maternal Ability</td>
<td>Increase lamb survival and pre-weaning growth rates (for high profitability)</td>
</tr>
<tr>
<td>Longwool Index</td>
<td>Blue Faced Leicester</td>
<td>Scan Weight, Muscle Depth and Litter Size</td>
<td>Enhance the carcase quality (conformation) of longwool rams and their progeny and thereby enhancing their financial productivity as crossing sires; growth rates are controlled so that mature size does not become excessive</td>
</tr>
<tr>
<td>Hill 2 Index</td>
<td>Scottish Blackface and North Country Cheviot</td>
<td>Mature weight, maternal ability, longevity and the number of lambs reared on weaning</td>
<td>Enhance the overall productivity of the ewe by improving several traits simultaneously, most significantly the number of lambs successfully reared; useful for ewe replacements</td>
</tr>
</tbody>
</table>


As shown in Table 1, the main actors within the chain are pedigree breeders, commercial lamb producers, auction marts, abattoirs/processors, and retailers. As regards EBVs, these actors are engaged in the transaction of two key products: genetically improved live animals – such as high EBV or high index breeding rams and ewes – and genetically improved lambs for meat purposes (also called “prime lambs”). The selling and buying of breeding sheep, however, constitute only a small proportion of the market and the majority (around 75%) is for prime lambs.

The pedigree breeders sell their animals in two major ways: home sale (limited), and auction sale (main channel). In addition, pedigree breeders participate in show-based competitions with the potential to win awards. These awards in turn increase the prospects of attracting buyers. We found that in these marketing outlets, the EBVs and indexes offered by Signet have very little value. Rather, animals are judged based on their aesthetic attributes. For instance, in the case of Scottish Blackface – a Scottish hill breed – the valued criteria are features such as *bonny* heads,\(^1\) curved horns, black faces with a V inside, black nose, and so on. Breeding animals sold on the basis of these aesthetic attributes could sometimes fetch a breeder a figure as high as £30-35 thousand for a single ram. Obviously, therefore, pedigree breeders achieving these figures have very little incentive to adopt Signet’s EBVs. On the contrary, according to a number of interviewees, pedigree breeders may feel threatened by EBVs as these could potentially jeopardise, what in some cases, are their substantial incomes.

\(1\) *bonny* is a Scottish colloquial term for attractive
We also found that, over time, a culture has developed where the ability to raise and sell a sheep for a very high price not only brings pride to the sheep farmer concerned but also provides them with something of a celebrity status in their society. These so called successful breeders provide a kind of role model whom other farmers, including the younger ones, tend to emulate. An interviewee explained how this culture has perpetuated in Scotland by saying: “it is the influence of the perceived leaders in each breed who get these ridiculous amounts of money; whether or not they are genuine, I am not going to comment on that, but everybody aspires to that……the young men are aspired to selling a sheep at £100,000, not to selling 160% of their lambs you know; R3L’s 21.4 Kilo – that’s what they should be aspiring to, but no, they want the £100,000 Tup, and the rest maybe worth nothing (Farmer)”.

The commercial lamb producers sell their products (crossbred lambs) mostly through auction marts and sometimes directly to abattoirs on a deadweight basis. For instance, approximately 75% of the finished lambs in Scotland are sold through auction markets (Scottish Government, 2007). In these auctions, in particular in the North of Scotland, the vast majority of the crossbred lambs are bought by other farmers, called “finishers”, who then fatten (finish) them within a short period of time and then sell them on to the abattoirs. This market is called the “store market”.

Our study revealed that the above supply chain is characterised by three major problems that prevent breeders from seeing the financial benefits of genetic improvement. First of all, in auction marts, the quality of lambs is often judged based on their external looks, and according to one interviewee, this has created “a generation of people who just really want to top that sale, and there is a lot of pride in it”. Second, the predominance of store trade means that a vast majority of the crossbreed lamb producers are unable to see whether and how their sheep are valued at the end of the chain, i.e. at abattoirs. Moreover, lamb prices in Scotland are heavily influenced by seasonality and a poor quality lamb may sometimes get a higher price if it is available in the right time of the year. Consequently, in the words of an interviewee, “producers are not rewarded for the product they have but for the time of the year they have it and the way they sell their sheep”.

Third, farmers selling lambs to the abattoirs also face many disincentives. The Scottish abattoirs use a system of carcass classification, called the EUROP system, based on carcass conformation, and fat range. This provides the basis for payments to producers. Therefore, lambs that do not conform to these specifications – for example, lambs with high fat content – could face penalties. These EUROP criteria directly correspond with many EBVs or selection indexes provided by Signet, for example, the Terminal Sire Index (see Table 2). Although this, in theory, provides an incentive for commercial lamb producers to use the Terminal Sire Index, it fails to do so, since the criteria like fatness and conformation are assessed “subjectively” by abattoirs (Maltin, 2010; Vipond, 2010). Moreover, there is no mandatory provision in place for abattoirs to report back the performance of individual sheep to farmers. This is despite the fact that all sheep in Scotland, by EU mandate, use ear-tags. Rather, according to an interviewee, farmers are getting slaughter records back from abattoirs that just number their lambs, say, from 1 to 50. The records do not tell “which lamb is which” and, hence, the farmers concerned are getting no real feedback on how the different Tups – high and low index –eventually perform in terms of producing lean/low fat meats.

Although there is a widely held perception in Scotland that the deployment of video image analysis (VIA) technologies could improve objectivity about carcase quality (Maltin, 2010; Vipond, 2010), and the use of electronic identification tags (EIDs) could improve the
traceability of individual sheep, interviews revealed that these technologies are still to be adopted widely. Although the QMS, supported by the Scottish Government, have pilot-tested EID technologies (through the so called "ScotEID project") in partnership with marts and abattoirs for over five years, interviews revealed that, only one abattoir has agreed to deploy the infrastructure needed for EIDs to be applicable.

From an innovation system perspective, the above findings highlight that the weakly integrated value chain means that there is a lack of ‘demand pull’ from the commercial production sector for EBVs. At the same time it highlights why there is also a lack of ‘supply push’ for EBVs from pedigree breeders. In terms of systemic failures, there are several institutional and ‘hard network’ failures which cause a lock-in of the system.

**Antagonistic faction within the system**

From a network failure perspective, we found that the sheep innovation system in Scotland was not a cohesive and fully integrated structure. We have already discussed the problem of this weak integration within the sheep supply chain. A similar lack of integration was also found amongst the various intermediaries in that there was an informal antagonistic coalition comprising breed societies, a section of the local agricultural press, and some influential pedigree breeders. According to our interviewees, this faction may be seen as a barrier to the widespread uptake of EBVs. In IS terms, what these factors mean is that the system is characterised by both ‘weak network failure’, the inability to form new innovative coalitions, as well as some ‘strong networks’ which keep the system locked-in to its current state.

As we have already mentioned in section 4.1, breed societies are influential players in the sheep innovation system, but not all of them are supportive of EBVs. Although many do not oppose EBVs in public, in reality, they just pay “lip service”. A key reason for this is that the breed societies are reliant on the donations of powerful breeders – the ones making substantial incomes from agricultural shows. The breed societies and the powerful breeders, on the other hand, work through some influential local agricultural press. These newspapers rarely provide coverage of EBVs and, in some instances, are critical of the technology.

Our interviewees believed that a key reason why these newspapers may not be positive towards EBVs is that the funding generated from the shows is an important component of their income and therefore they are more willing to support an industry where the external looks of a sheep (e.g. bonny head) are more valued than those being associated with EBVs (see Table 2). During the workshop, the interviewees explained this situation by saying: “Negative press attitude ... [towards EBV].... is linked to the breed societies, which are being influenced by the top breeders. The top breeders work through the press. They come up with all these negative reasons [for non-uptake of EBVs], these people are working against people who want to innovate and improve because they [the former] have got vested interests; they want to keep the status quo. The whole point of a breed society is to maintain the looks of an animal, basically..... (Consultant) ....well, the X [name] society draws £20,000-30,000 a year ....... and that’s all about bonny, bonny, bonny. So if you do away with bonny, bonny bonny and try and replace it with lean meat and growth rate, where is your £20,000? (Farmer)”.

However, it is to be mentioned here that the roles played by breed societies are heavily influenced by whether the societies were led by “traditionalists” or “modernists” (these can be seen as soft institutional failures within the IS conceptual framework). Also, because of rotational (generally two year) leaderships within some breed societies, the advances made by modernist leaders are often reversed when they are replaced by the traditionalists. Interviews
also revealed that QMS/SSS and Signet have tried to overcome this challenge by working with breed societies and there has been a slow but steady shift in attitudes.

**Challenging policy environment**

We found that, whilst the underlying rationale of EBVs and selection indexes provided by Signet emphasise farm productivity (see Table 2), some government policies and incentive mechanisms for agricultural development may be seen as incompatible with this purpose. The key policy in operation in Scotland, as in the rest of the European Union (EU), is the Common Agricultural Policy (CAP). Due to major challenges with the profitability of the sheep sector, the extent and nature of CAP support has an important role in the decision making of farmers in Scotland. Until the introduction of decoupling in 2005, the payment had been strongly correlated with the number of sheep stocked rather than the productive quality of the sheep. Therefore, as the market was not directly rewarding productivity, many farmers acted rationally and maximized stock numbers rather than productivity. Since 2005 this payment has not been linked with production (although the total amount received does depend on past levels of production). Rather, farmers now receive payments (known as the single payment scheme) regardless of the number of sheep they have. The only restriction is they have to maintain the land in good agricultural and environmental condition. However, for those receiving extra payments due to disadvantage (identified as Less Favoured Areas) there are minimal stocking rates that have to be maintained. There has also been a move to support agriculture in providing more general public goods (environmental benefits, etc.).

The fact that the link between stock numbers and payments has largely been broken could be seen to encourage farmers to focus on productivity rather than just the numbers of sheep – consequently encouraging the uptake of EBVs. However, a cross section of our interviewees believed that the decoupled CAP payments under such a public goods agenda were in conflict with the goal of raising farm productivity and profitability through genetic improvement. In reference to the negative effects of the greening payments on technological change in the sheep sector one of the interviewees (a geneticist) said, “the signal [from CAP payments] is all you have to do is keep your grass short and here is the money to do it; you don’t need a Ferrari-style Texel or something to do that, you just need the thing with four legs that licks grass...there is very little impetus to think about things like meat and product quality, and disease resistance, and so on”.

The existence of decoupled payments was also argued to enable producers who were not focused on productivity to remain in production despite an inherent lack of profitability. That is the existence of the payments meant they could carry on producing using traditional methods rather than having to adopt new technologies.

**Dismantled and weak advisory support relating to EBVs**

Within the context of the privatization of advisory services across the EU (and worldwide), Scotland can be seen to have a relatively highly developed and successful farm advisory/extension service. Examples include the Monitor Farm extension network (see QMS, 2010). Despite this, however, the advisory support available to farmers with regard to genetic selection and improvement was found to be weak.

As shown in section 4.1 (Table 1) the advisory services with regard to EBVs are provided mainly by QMS and SAC Consulting Limited. QMS uses two main channels to provide their advisory support: Scottish Sheep Strategy (SSS) and local press. The SSS, in partnership with Signet and breed societies, uses a wide range of knowledge dissemination activities, including
workshops, field days, on-farm demonstration trials, and publicising EBV-related information on company websites. According to our interviewees, whilst, these knowledge transfer activities have been useful in influencing farmers’ attitudes to EBVs, they are deficient in two aspects.

First, many farmers, especially those who are the beginners, need one-to-one support (which farmers called “handholding”) in such matters as which animal to select, when to select them, how to record and monitor their performance, how to handle the large quantities of data that the procedure generated, and how to analyse the costs and benefits of EBV uptake. According to some farmers, learning about these issues requires patience and could take from five to ten years. One particular challenge is data handling and calculating the benefits of EBV uptake that require considerable IT and computational skills. However, very few farmers, especially the older ones (whose mean age is around sixty years) that comprise the vast majority of the farming population, have these skills. Moreover, each farm has their unique biophysical and economic contexts that require individually-tailored support services. According to our interviewees, as these supports were not available, many farmers who had begun recording soon dropped out as they found “too much hassle with too little benefit”. This does point to the fact that the advisory service may not be appropriate in terms of facilitating a local learning process instead of transferring a technology package.

This was however not always the case. Up until the year 2005, when the recording system was maintained by the UK-wide levy body (the Meat and Livestock Commission MLC), there were provisions for one-to-one advisory support to the farmer members. In the post-devolution period, the levy bodies have been unable to maintain such a service. In referring to the effect of this dismantled one-to-one advisory support a farmer interviewee said: “Before that [pre-devolution] there were quite a lot of consultants who used to come around on to farms and help someone who started recording, when results [EBVs] arrived they used to take farmers through it [i.e. interpret for them]….there is absolutely no back up now …”

Linked to this is the view that devolution has made it harder for the Scottish to achieve the necessary scale of investment in activities to promote uptake of EBVs when compared to their English counterparts. As one informant commented, “the reason that it [uptake] has varied in England is ……. on the back of huge amount of work and investment that EBLEX [devolved English organisation equivalent to QMS] made at the early stages of … what they called the Better Return Programme, their knowledge transfer programme. And they promoted it very very well, huge numbers of meetings, two to three hundred meetings in a year, very very widespread coverage, they mailed every sheep producer in the country regularly with EBV information, and breeders saw direct results from that. I suspect if you ask English breeders you would get that kind of response. It hasn’t been that great [here]….. the level of publicity and promotion has not been as high and QMS just don’t have the budget to compete with that.”

We found that the above situations arose because of what we call “transition effect”. As one interviewee explained, “the break up of the UK levy board into English, Scottish and Welsh has a dramatic impact. I think the Scottish and Welsh players have become much smaller in scale and much less influential in some respect, certainly as they have got smaller budgets. Around this is also the turmoil to decide what they are there for”.

In terms of the domestic advisory landscape, historically the consulting arm of SAC has been the main provider of advice (including on breeding) to farmers. However, the organisation has gradually moved away from technical advice on animal breeding and focused more on helping farmers to manage CAP payments in the form of Pillar 1 and Pillar 2 payments (see
Renwick, 2012 for details). This is largely because there are demands for these services within the farming community and hence they serve to provide good income for SAC consultants. In addition, the focus of government on supporting advice that was targeted at public good provision meant that public funds to support breeding were less available.

**Outdated and inflexible data management system**

As we have explained in section one, good quality pedigree and performance data are the keys to EBV estimation. In Scotland, the breeders (Signet members) are expected to record and provide these data to Signet, either individually, or through their respective breed societies. They also have the option to record data on an online database provided by the Basco Database Limited. Within this approach it is possible to identify some failures in terms of capabilities and infrastructure.

The database system used by Signet has been manual or paper-based. According to this, the farmers are required to record performance data on Excel sheets provided by Signet. Its staff then re-type the data into their database. Some interviewees have been critical of this approach as they feel it allows errors to occur and also has not kept up with new technologies. There was a view that this outdated data recording system also resulted in loss of economies of scale, which was in contrast with the situation in countries like Australia and New Zealand.

As one farmer said, “Here, the big flocks end up paying more, whereas the big flocks are automated. I can send in the lambing dates of 800 ewes with practically no errors electronically and we are paying miles more than the guy who has got 50 sheep. We should be paying less. In New Zealand, if you send electronically you pay a certain rate, but if you are a hobby farmer and you prefer paper you pay an hourly rate. What we should be doing is encouraging people to record bigger flocks and make it cheaper, but here it goes the other way round. We are being penalised…So, Signet is not ideal and people who are not recording are doing so because of these things”.

A concern was also raised that the antiquated nature of the technology involved meant that it was hard to evolve the system to allow for changes in the sector. For example, it was argued that the template for data entry used by Signet did not provide room for recording all traits and breeds such as those of Easycare systems where a major focus of selection was a sheep’s wool-shading ability. Since the market value of wool was low, many farmers were replacing their traditional stocks with Easycare systems in order to save time and costs of shearing.

A similar problem was found with the Basco database. As already mentioned in section 4.1, the database was created through a partnership between three pedigree breed societies – Texel and Suffolk sheep societies, and Limousin cattle society. Later, through a UK government grant Signet and Basco Data Ltd. developed a partnership that allowed EGENES (SAC) to have access to the Basco database. However, according to our interviewees, the Basco database was not suitable for crossbreeds (e.g. Easycare) as “it sucked in data by breed rather than by animal”.

However, interviews revealed that Signet and Basco, supported by EGENEs, have been updating the database system into a fully automated online system. The change however has been slow because of two main reasons. First, the high average age of Scottish farmers means that many are not fully skilled in the use of computers. Therefore, a paper-based system may be seen as more justifiable for them. Second, lack of availability of monetary resources constrained Signet’s ability to update its technological infrastructure.
5. Discussion and Conclusions

In this paper we intended to explore whether and how an innovation systems perspective could help us identify the barriers to the uptake of EBV practices within the sheep sector in Scotland. The results support many of the well-known problems as stipulated in the diffusion of innovation theory (Rogers, 2003). These include a lack of compatibility of the technology (EBV) with the existing values of end users, absence of one-to-one advisory support, and so on.

However, our analysis based on an innovation systems approach provides some additional perspective in that the barriers to the uptake of EBV practices transcend far beyond the remits of the individual adopter and the formal science and advisory service providers and involve a wide range of actors, including breed societies, governments, farmers’ union, supply chain actors, and the farmers. Moreover, the policy and institutional frameworks within which these actors operate/interact play important roles. Also important is the technological infrastructure needed for new behaviour and practices to be feasible. The results therefore support the claims often made by the proponents of agricultural innovation systems (e.g. World Bank, 2006; Klerkx et al., 2012).

This study also shows that a crucial aspect of the innovation system analysis is that it points to the importance of interconnectedness and complexity. As we have seen, many of the challenges faced by the sheep innovation system emerged over time out of complex co-evolutionary interactions between actors, policies, institutions, and technology. For instance, devolution in UK government administration affected the nature and scale of advisory support available to sheep breeders with regard to EBVs. Similarly, the uptake of EBVs is negatively affected by lack of uptake of other technologies – such as video image analysis and electronic ID’s within the industry. Therefore, the innovation system analysis provides a holistic tool to diagnose systemic problems and improve agricultural innovation by going beyond investing in formal science (World Bank, 2006), and seeing innovation as a process of broadly reordering technical, social and institutional relationships within a given value chain (Klerkx et al., 2010).

For instance, based on our analysis we can see that an improvement in the uptake of EBV practices within the Scottish sheep industry would require a number of steps. First of all, there is a need for major reforms on the supply sides of EBVs, including the modernisation of Signet and Basco recording infrastructures. One way forward could be to use genomic tools in selective breeding that, arguably, can provide faster results and is less demanding in terms of time and efforts needed on the farmers’ side. Although works on genomic selection have already been undertaken by SAC and Roslin (Wall, 2011), the science is still at a rudimentary stage and the requisite tools are not still widely available.

There is a particular need to reform and improve the capacity of Scottish marts and abattoirs to provide objective feedback to farmers regarding product traceability and quality. Adoption of video image analysis and EID technologies may help achieve this objectivity. Although the on-going schemes undertaken by QMS in conjunction with abattoirs are clearly in the right direction, as we have found, the uptake of these technologies has been slower. Research is therefore needed in order to better understand why this is happening and how the situation could be improved.

The above developments alone are however unlikely to improve the situation. As our results indicate, at present, there is a vacuum in the advisory landscape as there are very few consultants with expertise in genetic selection and improvement. Decades of diffusion research (Rogers, 2003) have shown that technology uptake is a complex socio-psychological
process in which adopters require not just information through mass media but also skills training and mentoring support over a long period of time. This means that a mere reliance on newspapers and websites as the channel of EBV knowledge transfer is unlikely to be useful, unless this mass media campaign is combined with one-to-one advisory support, keeping in view the needs and situations of individual farmers.

The findings of this study also indicate that it would be necessary to counteract the resistance created by some powerful breeders (together with some breed societies and agricultural newspapers). Lessons from diffusion studies indicate that this could be done by promoting and rewarding innovative breeders and helping them to get established as role models in their societies. Another way is to provide one-to-one advisory support to farmers as interpersonal communication can help build trust with change agents and thereby reduce farmers’ dependency on traditional leaders within their communities.

The above changes, on the other hand, would require substantial investment in terms of manpower and funding. The question that needs answering is where the money for these changes in research and advisory systems would come from. This raises the need for discussions as to whether genetic improvement is a public or private good problem and how much of public money could justifiably be invested for this purpose. In order to reduce costs of one-to-one advisory support, innovative extension methods such as Farmer-led Extension (FLE), in which innovative farmers are employed as extension providers (Islam, et al., 2011), could be tried. Lessons from various countries indicate that these methods are often cheaper and more effective in dealing with community level resistance to change (Killough, 2003).

However, criticisms on the individual orientation of diffusion research have shown that the context in which these individuals are embedded should also change. Therefore, beyond advisory services targeted at farmers, facilitation of joint learning process across the sheep value chain is a key requirement in order to create an enabling environment for individual behavior change (Leeuwis, 2004; Klerkx and Leeuwis, 2009). This would concern incentives such as product prices, legislation, which co-determine farmers behavior (Leeuwis, 2004). There is hence a need for both individual oriented advice, as well as systemic facilitation.

As regards systemic facilitation, there appears to be the need for work to be undertaken to allow the sector to jointly articulate visions for future development. This would also involve the development of an environment which enables the realisation of these visions in terms of changing hard and soft institutions, the establishment of new networks and breaking the lock-in in incumbent strong networks (Klerkx and Leeuwis, 2009; Smits and Kuhlmann, 2004). For example, in such a visioning and innovation agenda setting process, dialogues and clarifications are needed as to how the greening and other public goods agenda under the CAP could be promoted in a way that does not affect the productivity of agriculture in Scotland. One way forward could be to incorporate CAP payments with selection traits that minimise environmental impacts, such as the emissions of greenhouse gases of ruminant origin, and making emission reductions mandatory for farmers as is currently the case for ear tagging of animals. This, on the other hand, would require the development of selection indexes for reducing GHG emissions which is on-going at SAC and Roslin but still at an early stage.

However, we would like to mention that, although this study provides some useful insights, it is still in its relatively early stage. Moreover, the generalizability of this study is limited as it is based on a single case analysis. A comparison of the sheep sector with the dairy sector, which has been relatively fast in taking up EBVs, is expected to develop more robust conclusions regarding the dynamics of innovation in genetic selection in the Scottish livestock sectors.
References


