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Focal actors and ecoinnovation

Paul Dewick

Manchester Business School
paul.dewick@mbs.ac.uk

Chris Foster

chris.foster@mbs.ac.uk

Abstract

The challenges of sustainable development call for eco-innovation in systems of production and distribution. ?Focal actors? within production/distribution systems can be thought of as those with the greatest influence to drive innovation; they are likely to be responsible for innovating themselves, but they also demand innovation from others upstream or downstream. Our analysis focuses on the milk production and distribution system, which has evolved to become structured predominantly around the supply-chains of the (focal) retailers. A 2008 UK government funded ?Milk Roadmap? intended to accelerate the improvement of environmental performance across the system by reinforcing the current trajectory. This paper argues that by relying on existing actors to chart a path towards sustainability, the Milk Roadmap risks entrenching existing industry structures and power relationships, which may inhibit the emergence of new structures that could be more ?sustainable? across a range of themes. We show how the current focal actors in the milk production/distribution system can facilitate some eco-innovations whilst hindering others, exemplifying best practice dissemination on the one hand and anaerobic digestion technology on the other.

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Focal actors and eco–innovation in milk production and distribution

1. Introduction

The challenges of sustainable development require accelerated, multi-targeted and multi-faceted innovation in systems of production and distribution. Accelerated innovation is particularly important in the short to medium term – before energy systems are decarbonised – both to reduce absolute levels of resource use and to improve the efficiency of resource use. Multi-targeted innovation is required because in any production and distribution system (PDS) – whether defined as a value chain, product life cycle or system of provision – there are likely to be a number of environmental 'hotspots'. Combined radical and incremental innovations that act on these points in the system are most likely to bring large environmental gains. But the combination of radical and incremental innovations can have many, far-reaching effects on the PDS itself and on other, less material-based, systems in which it can be considered to be embedded: the 'socio-technical regime' or the 'innovation system' for example. For such innovations to be successful, they need to be multi-faceted because systems change demands both technical change and organisational change in key actors, and also wider change in the environment in which the system operates. So changes in institutions (government policy, regulation and standards), physical infrastructures (transport and energy networks), networks of knowledge generation and diffusion, life styles and consumer behaviours may be necessary elements in the success of any innovation.

When considering the scope for change in PDS, we argue that understanding the role of 'focal actors' is useful from both an environmental and an innovation perspective. We define 'focal actors' as those who have significant market power and/or can stimulate eco-innovation beyond the boundaries of their own organisation. In our definition, it is important to stress influence beyond the organisation itself as characteristic of focal actors: they are likely to be responsible for innovating themselves, but it is their ability to stimulate accelerated, multi-targeted and multi-faceted innovation from suppliers upstream or customers downstream that gives them their 'focal' status. Currently in the UK, in many food product PDS (especially for own-label products), the supermarkets can be considered to be 'focal actors', largely by virtue of their buying power and their knowledge of the purchasing patterns of final consumers. Yet the environmental impacts associated with the production and distribution of food products are not principally associated with retailing itself or with inbound transport of products to retailers. In many cases the greatest impacts are associated with primary production and/or the processing stage, or beyond the PDS at the consumption stage (see Foster *et al*, 2006 for many examples). It is clear though from the extent to which environmental policy-makers and other stakeholders in the food industry have engaged with supermarkets that there is a widespread expectation that these organisations can use their influence to bring innovation to bear on the environmental hotspots.

In this paper we argue that, if the most effective green innovation paths are to be found and followed to reduce the environmental impacts associated with production/distribution systems, it is necessary not only to understand how the PDS has evolved to have the structural characteristics it currently exhibits, where the environmental impacts are along the system and which actors now have the power to stimulate eco-innovation within it, but also to explore the benefits and drawbacks[1] of a reliance on current 'focal' actors and to consider green innovation paths that involve some disruption to the existing system and its underpinning relationships. We know from a couple of decades of innovation studies that radical technologies bringing step changes in "performance" are more often disruptive than sustaining. And although it is not possible to know with foresight which technologies will be dominant, their evolution follows a relatively ordered path of design competition and substitution during the so-called 'era of ferment' (Anderson and Tushman, 1990).

[1] Drawbacks include the reinforcement of existing unequal power distributions and accompanying inequalities in economic returns, or inhibition of promising innovations that threaten the economic interests of the current focal actors.

This paper explores these themes through the case of the UK milk PDS. The UK dairy industry is an economically significant sector. It is the third largest milk producer in the European Union and the tenth largest in the world; dairying accounts for over one fifth of total agricultural production by value in the UK and is the largest single farming sector by value. Drinking milk is a staple of the British diet: the average person in the UK consumes 116 litres of milk per year, equivalent to 3.8 pints per person per week[2]. It is also a staple of UK supermarket sales, with fresh milk representing the single largest food category by sales value for most major retailers. Milk also has a significant environmental impact, especially at the primary production stage but also at the processing and consumption stage. It is not our intention to detail here the environmental impacts across the PDS (instead, see Foster *et al*, 2007), suffice to say that according to Tukker *et al* (2005): "milk and other dairy products account for around 5% of global warming potential, 10% of eutrophication potential and 4% of photochemical ozone creation potential across the EU….fluid milk is one of the 'top 10' contributors to total impacts for all of the environmental themes considered except ozone depletion".

The last 25 years have seen the UK milk industry changing in response to the need to balance economic, social and environmental challenges and opportunities. The structure of the industry was disrupted first by the deregulation of retail prices for liquid milk in 1984 and then by the dissolution of the Milk Marketing Board (a government-mandated monopsony) ten years later (Dairy UK, 2010). The market for milk supply, contractual arrangements, and supply-chain relationships have since evolved along a new trajectory. This restructuring has underpinned a 'focal' role for the supermarkets and we evaluate where their influence has been brought to bear on reducing environmental impacts and where their role hinders eco-innovation that could also deliver socio-economic objectives for rural communities (for example the "European rural development model based on the promotion of family farms" that Gray (2000) portrays as deeply-rooted in the European "Common Agricultural Policy"). To that end, the paper is structured as follows. In section 2, we explore how the milk system has evolved to have the structural characteristics it currently exhibits, highlighting the co-evolution of the milk PDS with other systems in which it is embedded. In section 3 we discuss the emerging 'focal' role of the supermarkets across a time period of increased environmental awareness and concern for the sustainability of the industry. In section 4 we consider an environmental technology – anaerobic digestion – whose widespread deployment seems a distant possibility under the currently- structured PDS and 'focal' role of the supermarkets. We conclude in section 5 by reflecting on the trajectory of the industry and what opportunities remain for a more sustainable future.

2. Co-evolution of the milk production and distribution system

Innovation, technological change in particular, plays a central role in the evolution of industries. New technologies do not evolve randomly. At the organisational (both public and private) level, there are powerful heuristics, problem-solving strategies and expected payoffs behind the advancement of technology in certain directions. Path creation and dependency are influenced strongly by the interplay between factors at the 'systems' level: scientific advances (e.g. generation of new knowledge, networks of knowledge diffusion), economic factors (e.g. investments in human capital, research and development), institutional conditions (e.g. 'rules of the game' set by government policies, regulation, standards), infrastructures (e.g. energy, transport) societal factors (practices, life styles and behaviours) and unresolved or unintended difficulties in established technological paths. The dynamic interaction of agents and factors in the innovation system helps shape the direction *and* pace of change. Although there is not one single approach to the study of 'systems', pervading the various approaches is a sense of the co-evolution and co-dependency of agents and factors at a bounded systems level (e.g. for food systems see Geels, 2009; Wilkinson, 2006; Green and Foster, 2005; Bloemhof and van Nunen, 2005).

A few studies have exemplified the co-dependent, evolutionary dimensions in the milk industry. Atkins (2010) provides a comprehensive historical review of milk production and retail in the UK over the last

[2] http://www.dairyco.net/datum/consumer/uk-dairy-consumption/uk-dairy-consumption.aspx, last accessed May 2011

200 years, highlighting the scientific, technological, commercial and legal influences on the industry's development. Atkins traces the transformation of what was a variable, perishable, organic fluid intended for a cow's calf into a standardised product loaded with technicity and artificially lengthened shelf life. Milk quality provides the focus of attention throughout Atkins' analysis, and he argues that as science and technology revealed and controlled 'nature's secrets', legal standards began to shape the production process of individual farmers, dairies and retailers. For example, Atkins describes: how the path created by developments in analytical tools and techniques underpinned the 1901 Sale of Milk and Cream Regulations on grading the fat content of milk (minima of 3% butter-fat and 8.5% solids-not-fats), which persuaded farmers to take seriously the composition of their cows' milk; how composition monitoring regimes spread with the establishment of the milk marketing boards in 1933; and how breeding and feeding changed to suit the state-prescribed standard, contributing to a restructuring of the national dairy herd[3]. The first two institutions endured: the 1901 standard remained until the implementation of the European Union Single Market in 1993 when the UK accepted standardisation of 3.5% fat minimum, and grading as a form of governance remained until the dismantling of the Milk Marketing Board of England and Wales in 1994. The industry experienced significant disruption as a result of the dissolution of the Milk Marketing Board, which allowed a new path to be forged around supply chains. These supply chains are now controlled to a large degree by the retailers.

Atkins (*ibid.*) also discusses how, in the early to mid twentieth century, the increased movement of milk from the rural farmer to the urban doorstep was supported by an expanding rail network, special railway wagons and slots in the railway timetable; developments in preservation technologies (refrigeration, additives, pasteurisation, glass bottles); and changing wholesale and retail arrangements. Blake (1979) provides a more contemporary account of this path dependency: in the UK in the 1960s and 1970s doorstep delivery propped-up high volume sales and stable overall consumption levels when other countries saw milk consumption decline; regular morning delivery helped keep the milk fresh (before mass ownership of domestic refrigerators) and arguably led households to continually over-estimate their intake by rounding up their requirements; efficiencies were based on high trippage rates for glass bottles and the system suited the weekly expenditure planning habit of households at the time (when many salaries were also paid weekly); furthermore, dis-economies of scale with respect to weekly cash collection limited individual 'milk round' sizes while depot sizes limited the number of 'milk rounds' any one company could control (dis-economies of scale here kicked-in above 30 'milk-rounds' per depot). In 1980, doorstep deliveries still accounted for 89% of household sales of milk (MDC, 2004). Since then there has been an almost complete transition, with most recent figures showing that doorstep delivery accounts for well below 10% of all liquid milk sales (Dairy UK 2010); the five leading supermarkets account for around 95% of household purchases . Albert de la Bruheze and van Otterloo (2004) and Van der Vleuten (2003) tell a similar story about how in the Netherlands long producer-consumer chains emerged as a result of on-farm milk storage and preservation and milk transportation practices, enabling the concentration of local milk chains into regional and national milk chains and industrial milk processing. Direct government intervention (e.g. fiscal incentives and training programmes) and indirect effects (e.g. the introduction of the mandatory 5-day working week) supported the transition. Ultimately, the milkman-based collection and delivery system using glass bottles was compromised by the growing number of high rise apartments and the liberalisation of retail trade.

These studies show how change within the milk industry in both the UK and the Netherlands was influenced by a cast of diverse actors and interests (e.g. large dairy companies, government, retailers), practices (e.g. laboratory, social practices), institutions (e.g. regulation, law) and infrastructures (e.g. transport network, utilities network). The role of the state in stimulating innovation through their buying power (one defining characteristic of 'focal organisations' for our purposes) is exemplified in the analysis of Albert de la Bruheze and van Otterloo (2004) and Van der Vleuten (2003). They discuss how the

[3] The genetic diversity of cows was compromised by the need for high yielding cattle that would produce a quality satisfactory to the market. The efforts of the British Holstein Cattle Society, founded in 1909, produced a breed of cow with these characteristics, which went on to dominate the UK herd: accounting for 20% of the cow population in 1947, 76% in 1970, 95% in 2010.

emergence of milk as a mainstream drink (not simply confined to babies, infants, the elderly and sick) was stimulated by government supported agricultural research and efforts to improve the international competitiveness of Dutch agriculture. During the inter-war years government promoted milk as a healthy foodstuff, not just because of the poor public health situation and increased knowledge of the nutritional aspects of milk but also because there was a need to find an outlet for a surplus of milk. Free milk distribution to primary school children began. After the Second World War, government backed industry as it invested in mechanisation (for storage, preservation, transport) and modernisation (for milking, milk treatment, milk processing and cattle management). In Atkins' (2010) work, the 'focal' role of the state is also apparent: for example, in the inter-war years, the Borough of Plymouth introduced a system of identifying dairy farms that complied with their regulations on milk composition and issued certificates to that effect: farmers were incentivised by a guaranteed market of large firms, hospitals and clubs; doctors would recommend their milk to patients. Today in the UK, nearly 20 years after the dissolution of the MMB, over 70% of all fresh liquid milk is sold by the five largest supermarkets. Importantly, the vast majority of this milk is own-label; supermarkets can exert more control over supply chains for own-label products than for branded products. By virtue of this own-label control, the volumes they buy and their pivotal role as 'gatekeepers' to individual consumers, we argue that the supermarkets have become 'focal' actors in the milk PDS. The next section considers how the supermarkets have begun to exert their 'focal' power in milk production and distribution over a time period of increasing environmental awareness and concern for the broader sustainability of farming.

3. Accelerating and redirecting eco-innovation in the milk production and distribution system: the synergistic role of the focal actor

Reducing the environmental impacts of milk production was not a key driver of change in the trajectories discussed above. Over the last couple of decades however, concurrent with the increased market power of the supermarkets, we have seen the emergence of an explicit acknowledgement of the need to reduce environmental impacts – whether that is cutting greenhouse gas emissions, reducing waste, protecting biodiversity – whilst maintaining community cohesion and quality of life, and without compromising economic growth. This challenge is arguably more acute in the food industry given farmers' assumed role as 'custodians of the countryside', the necessity of food production and current concerns over food security (see, for example DEFRA 2010a and The Government Office for Science 2011). The need to respond to the challenge of environmental sustainability whilst addressing some of the causes of economic un-sustainability has exercised both government and industry. For example, DEFRA funded a study into the environmental impacts of liquid milk production and distribution (Foster *et al*, 2007); the *Milk Roadmap* (Dairy Supply Chain Forum, 2008), produced by a taskforce involving participants in the existing system, trade organisations and the UK Government, set targets for the reduction of environmental impacts in the system and identified steps to be taken on-route towards these targets. These initiatives, and others, were certainly intended to accelerate the improvement of environmental performance across the milk PDS and we have seen the supermarkets use their 'focal power' to intervene in the system.

One high profile effect of the shift toward supermarket domination of milk sales has been the allocation of margins across the supply chain. Dewick et al (2010) discussed the imbalance in the power relations and economic returns for actors in the UK milk production and distribution system; Figure 1 shows how retailers have increased their margins on the sale of milk while average returns to milk farmers have changed little:

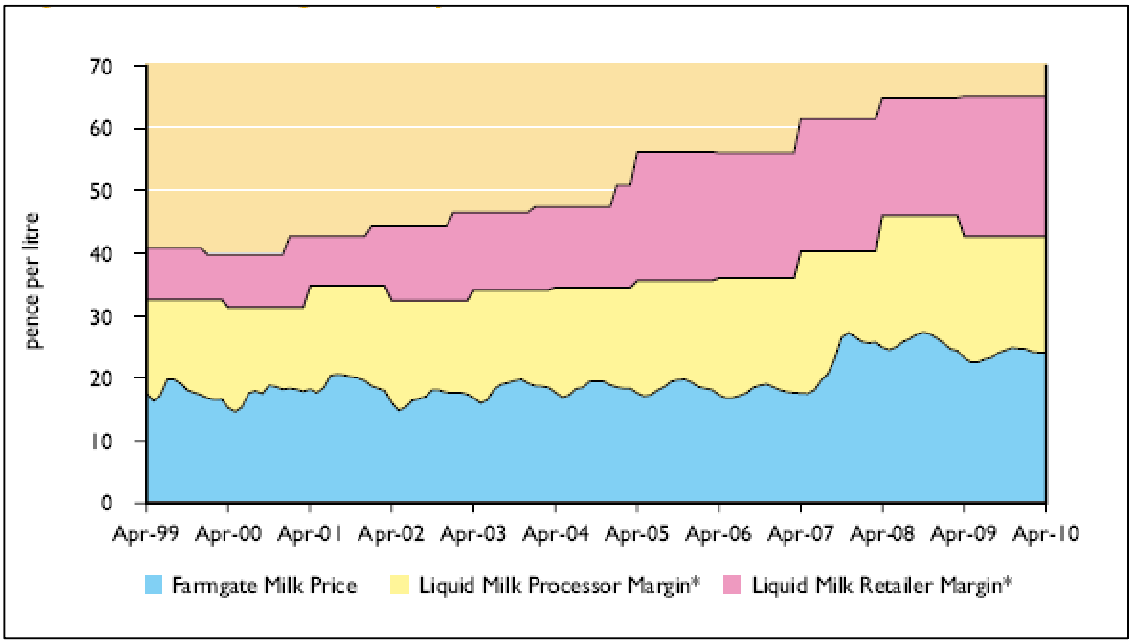

Figure 1: UK milk price margins 1999-2010, from Dairy Co.

In 2007, in response to public pressure, the supermarkets established long-term purchasing commitments offering higher farm-gate prices to their supplier groups: dedicated liquid milk suppliers in October 2010, for example, received up to 15% above the average farm gate price (Walsh, 2010). Supermarkets linked these premiums with meeting demands for improved quality. Quality is a transient notion in the history of milk. We see in Atkins' work how the large dairy companies stimulated innovation by dedicating resources to monitoring quality and imposing on suppliers contractual obligations with regard to milk composition and cleanliness; they were, for a time, in Atkins' words: "the custodians of quality milk". Today, notions of what constitutes quality milk have moved on. Fat content is associated with cholesterol and heart disease and whilst some notions of purity as a proxy for quality persist (e.g. in *Cravendale*, Arla UK's ultra-filtered milk), other dimensions of quality have emerged e.g. animal welfare, "local" milk production and consumption. These quality characteristics – although often certified and endorsed by independent third parties – are demanded by supermarkets in exchange for their long-term commitment to the producer; they are one growing element of the supermarkets' 'focal' role, and reflect their action in that role to stimulate innovation. Coupled with attempts to build collaboration between producers and processors over technical standards, these changes have led to considerable strengthening of links in milk supply-chains[4].

A long-recognised characteristic of farms is the wide difference between the performance (against many measures) of the "best" farmers and of the "worst". The uptake of best practice, for example use of manure management plans or nutrient planning, is identified in the *Milk Roadmap* (Dairy Supply Chain Forum, 2008) as one route toward the targeted reductions in environmental impact of milk production. And because of its close link to the efficient use of resources (material and energy inputs) environmental best practice is also generally held to improve economic performance. The uptake of best practice is commonly facilitated by the engagement of specialist advisors. In the last century, non-commercial dairy research was dominated by the National Institute for Research in Dairying (NIRD): "the intellectual focus of the clean milk movement" (Atkins, 2010). The NIRD established standards for 'clean' milk; it was

[4] The retailers have driven developments in this area (e.g. Waitrose's group of dedicated milk suppliers was established first, some 10 years ago; Tesco's more recent group is probably the largest).

instrumental in the standardisation of laboratory methods in the bacteriological examination of milk; arranged large scale 'clean milk competitions'; and offered advice to farmers and reporting to local authorities. More recently, advice to farmers was provided by ADAS (the Agricultural Development & Advisory Service), a part of MAFF, the then Government Ministry for Agriculture, Fisheries and Food. This agency was privatised in the mid 1990s, but the government remained a key provider of such advice through contracted service providers (consultancies). Such advice was available to all farmers. The restructuring of the milk PDS around the supply chains of the supermarkets has led to a change in this provision of knowledge and demonstrates another growing element of their 'focal' role. Thus, over the last few years, major retailers have developed supplier-improvement programmes for their long-term supply contracts. These supplier-improvement groups started with a focus on improving animal welfare (Lindsay, pers comm.) but for most the remit has broadened to include improvement of environmental performance. Tesco, for example, has established a "sustainable dairy group" for farmers that supply its own brand milk. The 800-strong farmers group not only disseminates best practice amongst its members but benefits directly from the Tesco funded 'centre of excellence' farm at Liverpool University. Research is being conducted into feeding, energy technologies and re-use/recycling and, according to ENDS (2010), "*Tesco expects its milk suppliers to start using the technology by the end of the year".* Sainsbury's and other major supermarkets, and some of the leading processors[5], have acted in similar vein. So a new mechanism for the spread of best practice has emerged, to some extent replacing the previous government-funded one[6], although often using the same technical consultants (Webster, pers. comm.). Whilst this mechanism may well be considered more discriminatory (or selective) – it is after all available only to those farmers supplying one or other of the major retailers – the involvement of the supermarkets in creating and facilitating the dissemination of advice to farmers both extends and leverages further their 'focal' power to accelerate innovation, sustaining the system by directing advice towards those farmers holding supply contracts to major buyers with public reputations to defend.

In these two examples we can see how supermarkets have extended and exerted their 'focal' power to stimulate eco-innovation whilst improving the economic and social sustainability of the milk industry. The evolution of the milk industry since 1994 has first enabled and then facilitated the 'focal' role of supermarkets in triggering eco-innovation from their suppliers, identifying and adopting best currently available technologies through their support of knowledge creation and engaging with processors and farmers to disseminate knowledge and good practice through their supply chain groups. The next section reflects on the challenges presented by an eco-innovation that doesn't fit with the evolved structure of the industry and 'focal' role of the supermarkets.

4. Accelerating and redirecting eco-innovation in the milk production and distribution system: the antagonistic role of the focal actor

Cow excrement (manure) accumulates on farms when cows are indoors for milking or over winter. Since it contains both nitrogen and phosphorus, the resulting slurry has traditionally been spread on farmland - partly for fertilisation, partly for convenience. Poor storage and uncontrolled slurry spreading have been associated with pollution of the wider environment. Even when good practice is implemented, slurry storage and spreading involves greenhouse gas emissions which constitute around 5% of the overall "carbon footprint" of liquid milk (Foster *et al* 2007, Table 7, p.16). Feeding slurry into an anaerobic digester represents an alternative method for handing this waste which avoids these emissions. Anaerobic digestion (AD) converts undigested material into "biogas" (mostly methane) which can be used as a fuel, potentially displacing fossil fuels in the wider energy supply system, leaving a more

[5] Dairy Crest, for example with their 'White Gold Scheme' have similar relationships with their suppliers (see http://investor.dairycrest.co.uk/ir/dcg/html/corporate-responsibility/mr_farms.htm, last accessed May 2011).

[6] The latter remains, e.g. in delivery of the CAP requirement for advice on "cross-compliance" measures by the Rural Development Service in England. Technical advice to Dairy Farmers is also provided by DairyCo's 20-strong "Extension Team". DairyCo is a not-for-profit organisation funded by a levy on all milk produced by farmers (0.06p per litre in 2020).

concentrated, nitrogen-rich liquid that can be used as fertiliser. So implementation of AD for slurry handling can reduce the environmental impacts associated with milk production, particularly greenhouse gas emissions.

There are two modes of uptake for anaerobic digestion (AD) noted in the *Milk Roadmap (*Dairy Supply Chain Forum, 2008): centralised AD (centralised at, or very close to, the dairy-processing site) and on-farm AD.
If handling manure, the centralised mode requires transfer of slurry from farms to the processing site: it offers the potential of scale efficiencies and co-treatment of dairy processing and dairy farming wastes. These centralised AD plants could be owned and operated by organisations within the dairy industry – dairy processors for example – or by new entrants to the industry – bio-energy technology companies for example. From within the dairy industry, BV Dairy have been involved in a DEFRA funded AD demonstration project. The dairy processes 35 million litres of milk per year sourced from 35 farms (DEFRA, 2010b); waste liquids from the dairy (but seemingly not waste from farms) are converted to biogas in an AD plant and this gas fuels a Combined Heat & Power unit which produces the electricity and heat needed for dairy operations (http://www.bvdairy.co.uk/anaerobic_digestion.html). The involvement of new entrants is reported by Zglobisz et al (2010) in discussing broader (non-dairy) AD initiatives that are the fruits of collaboration between biogas technology proponents, food producers and supermarkets; these are mostly aimed at handling food waste.

Regardless of ownership and control, a centralised manure-handling AD plant would need to be close enough to sufficient numbers of dairy farms for transport of the low-energy content manure to the processing plant to be viable, with local availability of other suitably-priced inputs at and of uses for heat and power produced also bearing on this. The economic return on manure processing would need to be sufficiently high to cover the costs of compliance with waste management regulation, the costs of establishing and maintaining contractual relationships with supplying farms and the risks to the dairy processor's reputation of running a "waste treatment" facility co-located with a food production operation. Given these constraints centralised AD plants taking slurry from farms seem unlikely to occupy more than a small niche within the dairy industry.

On-farm AD systems are likely to be smaller in scale than centralised plants; at first glance this seems a more flexible route for the introduction of AD as environmentally-friendly manure management. It does however require farmers to access the skills necessary to operate what is effectively a biochemical processing plant. Moreover, the economics of operating on-farm AD plants, and the payments available for electricity exported to the National Grid are reported to be such that single-farm units are unlikely to be viable without a dramatic reduction in the capital costs of plant (ENDS, 2010, p.21; Farm Futures, 2010). Furthermore, the low energy content of manure – which is, after all, well-digested grass - makes it a poor candidate as the sole feedstock for an AD plant. Whilst they would be unlikely to take food waste because of the need to comply with waste management regulations, a mixed input of energy crop and manure provides a better economic return (Farm Futures, 2010) suggesting that a grass-based dedicated dairy farm would need to shift some land into arable production or collaborate with (an) arable farm(s) to achieve a good return on an investment in AD.

In the light of these considerations, we argue that two pathways to successful uptake of farm-level AD seem open to farmers at this stage:

First, there is what we might term the 'co-operative route'. One or more dairy farmers collaborate(s) closely with geographically-proximate arable farmers to develop an AD plant on a scale sufficient to be viable and to allow engagement of the skills needed to operate it. In this model, the individual farms remain dedicated to their existing specialisations, diversifying their businesses by investment in a co-operative venture (an energy business) to which each farm is a supplier. The "Blackdyke" Co-operative Group (Storr, 2010) is an example of this option being implemented. In this case the AD plant is located on one of the participating farms.

Close collaboration between geographically-adjacent farmers for the development of infrastructure occurred in the Netherlands as part of the dissemination of milk tanks on farms (Albert de la Bruhéze and van Otterloo, 2003). The installation of a multi-farm AD plant would arguably be easier if collaborative structures, such as locally-based farmer co-operatives, were in place already. Farm co-operatives are, however, relatively rare in the UK; Atkins & Bowler (2001) (p.59, Table 5.2) state that in the UK 4% of milk is marketed through farm co-operatives, whereas in France the proportion is 50%, in the Netherlands it is 84% and in Denmark 91%. Co-operatives might also facilitate entrepreneurial activities of farmers to vertically integrate into processing, or promote more local production and consumption, challenging the current purchase of milk through supermarkets and allowing farmers to capture more of the value added along the milk chain. Currently, and in contrast to the dairy industries in other European countries, there is little formal concentration (i.e. vertical integration) between stages in the UK. In the absence of collaborative arrangements, it seems unlikely that this route will flourish without the involvement of a 'systems integrator' to provide resources and knowledge to facilitate renewable energy projects. To this end, Community Renewable Energy (CoRE), a social enterprise, has played such a role for the Blackdyke CoOperative Group.[7]

Second, there is what we might term the "Expand & Diversify" route for individual dairy farms. In this case, an individual farm expands to incorporate arable crop production (possibly for cattle feed and AD feedstock) and to a point at which AD becomes viable and energy supply becomes a significant part of the farm business. This would represent a major expansion for the average dairy farm in the UK; the average herd size in the UK was 100 in 2008, up from 72 in 1996 (Dairy Supply Chain Forum, 2008; Foster et al, 2007), while Rural Futures (2010) estimated that on-farm AD would be viable for a farm with a 300-head dairy herd and producing around 2000 tonnes of maize silage per year. Very large scale farms based on predominantly cereal feeding of dairy cows would of course offer greater economies of scale and more easily justify investment in the various skills required efficiently to operate arable agriculture, cattle husbandry and biochemical plant in an interconnected manner. The 3700-head farm proposed in Lincolnshire during 2009/10 (known as Nocton Dairies) exemplifies this route, and did indeed incorporate an AD plant in the plans (the project was abandoned in 2011 because of concerns about pollution risks).

Up-scaling and concentration have a long provenance in the dairy industry going back to the standardisation of milk composition and restructuring of the national herd. In their own right, efforts to raise yields and increase cow longevity (to reduce culling rates and the burdens associated with breeding replacements) have contributed to reduced greenhouse gas emissions at the primary production stage of the system. However, whilst the drive to maximise productivity from farmed area, coupled with higher resource efficiencies achieved at larger farms, offers some economic and climate change improvements, it is likely to exacerbate other environmental and social concerns. In terms of the environment as people experience it, concentration disfavours both the multiplicity of farm units that many would say characterises the UK landscape and the maintenance of non-productive areas that nurture biodiversity. Widespread public opinion, shaped by strong advocates such as Compassion in World Farming, RSPCA and Friends of the Earth, is that concentrated farming leads to welfare problems for cows (including increased mastitis, increased lameness and increased infertility) and that cows *should* be grazing outdoors (see the objections to the Nocton Dairies proposal)[8]. Given prevailing public opinion and the public relations sensitivity of the supermarkets, supermarkets would need to invest considerable effort in consumer education if they were to exercise their 'focal' role to facilitate this route. But milk production costs on such units are likely to be lower than on the current average farm. This may well be sufficient incentive for retailers to make that investment and to counter the longer term risk that farmers adopting the "Expand & Diversify" model might, by virtue of the diversification into supplying an energy business, reduce their commercial dependence on supermarkets. Such a change has the potential to counteract (if only slightly) the concentration of power that appears to have accompanied the broadening of the retailers' focal role. ,

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[7] See http://www.corecoop.net/, last accessed May 2011

[8] See http://www.noctondairies.co.uk/industry-views.html, last accessed May 2011

So whilst trajectories of 'quality' improvements and best practice are underpinned by the current supply chain structure of the milk PDS and some eco-innovation seems to be accelerated by the concentration of 'focal' power into the hands of supermarkets, the environmental opportunity presented by AD seems likely to hinge on some restructuring of the milk PDS and the relationships within it. This could involve emergence of stronger farmer-farmer or farmer-processor links, further significant increases in farm scale, or a new entrant acting as a systems integrator to facilitate horizontal, local co-operation among farmers. Some routes to AD adoption may need change to the waste regulation regime to "unblock" adoption. . And whilst the supermarkets could play the role of systems integrator – establishing a centralised AD plant, subsidising the capital costs that represent a significant obstacles – this seems unlikely given the rewards of the status quo. Indeed, the manner in which the industry has co-evolved over the last few decades, with the supermarkets playing an increasingly 'focal' role, an alternative structure remains difficult to forecast.

5. Conclusions

This paper has considered the importance of understanding the provenance of an industry when assessing how innovation can be accelerated and redirected to bring major, long-term reductions in the environmental impacts associated with production/distribution systems. We argue that the co-evolution of the industry with the increasing power of 'focal' actors – those whose behaviour can lever more innovative and environmentally sustainable practices and change the nature of competition – necessarily facilitate some eco-innovations whilst hindering others. Our analysis has focused on the milk industry in the UK. Following deregulation in the 1980's and 1990's, the industry became structured predominantly around the supply-chains of the supermarkets. The 'focal' role of the supermarket enables the pursuit of some "sustainability" targets by virtue of their purchasing power, control of the supply chain and knowledge base. But a reinforcement of the supply-chain structure may inhibit some routes to uptake of certain eco-innovations, AD technology arguably being one of them..

We could think of AD technology in dairy industry as going through an era of ferment (Anderson and Tushman, 1990) with design competition in the system configurations for AD (see Zglobisz et al, 2010) and substitution between the existing uses of dairy waste and AD. New firms and other organisations are entering the industry (bio-chemical technology suppliers, food processors, water companies) alternative configurations of networks are emerging with different actors involved in the build, own and operating of the facility and supply of waste products. Government is stimulating AD innovation by funding demonstration projects to increase awareness and understanding of the technology, creating the economic framework by implementing fiscal incentives (e.g. renewable obligation certificates, feed-in-tariffs), creating the regulatory framework to facilitate AD, and promoting standardisation through best practice guidance, permits and protocols (DEFRA, 2010). But we have argued that anything other than the supermarkets exercising their 'focal' power by engaging in the waste-use networks (e.g. subsidising the supply chain to run AD facilities) is likely to involve some major disruption to the structure of the milk industry. And many innovation studies tell us that disruptive, path creation events are few and far between; what's notable in the development of milk, like many other industries, is how much remains the same over long periods of time and how change emerges incrementally along an established trajectory. This means that by relying on existing actors to chart a path towards sustainability, the industry risks entrenching existing structures and power relationships, which may inhibit the emergence of new structures that could be more sustainable across a range of themes.

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