Environmental policy as an enabler and directing factor of eco-innovation in the UK food packaging sector

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Abstract

This paper aims to show how environmental policy can change the direction of eco-innovation in an industrial sector. It uses the example of the planned reforms to the UK Extended Producer Responsibility (EPR) system, and the UK food packaging sector, drawing on a small number of semi-structured remote interviews with experts from this sector. Concepts from the Multi-level Perspective (MLP) such as "niche-innovation trajectory" are used to engage with the idea of innovation direction, and this approach is also used to explore how this idea of direction relates to broader socio-technical transitions and transitions at a sectoral level. This paper also presents more specific findings relating to the changing dynamics within the food packaging industry and contributes new insight into how social, contextual issues affect the implementation of process innovation. The directionality of innovation within industrial sectors has not been addressed fully within innovation studies, but this paper demonstrates a possible way to address innovation directionality directly.

Keywords

Environmental policy, Low and medium technology sectors, Packaging, Sustainability, Eco-Innovation.

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1. Introduction

Plastic food packaging is a recognisable part of the plastic pollution problem (Galloway and Lewis, 2016; Liboiron, 2019). The food packaging industry has responded to increased public concern about this issue in various ways (Dilkes-Hoffman, 2019; Kakadellis and Harris, 2020; Burgess et al, 2021; Franklin et al, 2022; WRAP, 2022; White and Lockyer, 2020; Borg et al, 2022). One approach involves applying eco-innovation to the creation of packaging designed to ameliorate plastic pollution by addressing its end-of-life options (DEFRA, 2011). From a cursory overview and the experience of the authors at major UK trade shows in 2022 and 2023, it seems that industry stakeholders have been pursuing a variety of different technological areas of innovation, but this may change with impending policy changes. While there is research on the direction of innovation within firms (Hohberger et al, 2015) there has not been extensive attention to how policy affects the technological trajectory and direction of innovation in particular sectors. Within innovation studies, the focus has generally been on more direct innovation policy (Kefidou and Demirel, 2012; Fagerberg and Versparen, 2018).

This paper draws on expert interviews with packaging industry experts to describe some of the current broad areas of innovation being pursued by the food packaging industry in the UK and how these areas are likely to progress. Analysis of these interviews reveals that reformed Extended Producer Responsibility (EPR) regulations in the UK are likely to enable innovation towards recyclability (as a quality of packaging materials) to become the most prominent area of eco-innovation in the sector.. EPR policies are not strictly innovation policies, but they strongly affect the overall business environment for the food-packaging sector and the understandings of risks at various levels. The interviews were completed by May 2023, before this new area of regulations was due to come into force, but in August of that year the enforcement of the new EPR regulations in the UK was delayed until 2025. However, according to the experts interviewed for this research, the consistent and clear direction of the policy is likely to effect significant change in the packaging industry. As a result, the sector may prioritise product and process innovations that make packaging materials more easily recyclable.

These findings reinforce several areas of prior study in the field of innovation studies pertaining to LMT sectors, while contributing some additional details. These relate mainly to the effect of national environmental regulation change on innovation in this sector and the specific mechanism of action,

but some findings also relate to specific aspects of the dynamics within the UK food packaging sector (Trott and Simms, 2017). There are also more general theoretical insights which demonstrate the utility of concepts from the Multi-level Perspective (Geels and Schot, 2007; Geels, 2011; 2019) for the study of particular sectors within innovation studies (Robertson et al, 2009). This paper uses these insights to advance a broader argument that the directionality of eco-innovation should be taken into account, especially in situations where environmental policies coordinate or link certain industrial sectors.

To communicate the background of eco-innovation in Low and Medium Technology (LMT) sectors, and why innovation studies should consider the role of policy in directing innovation areas, this paper begins with a literature review comprising two sections, in Section 2. The first addresses innovation processes in LMT sectors and the various theories used to conceptualise this. The second section will address why the EPR regulations associate innovations in the food packaging sector with the waste recycling system and industry, and how we can understand this in theoretical terms. Following this, Section 3 sets out the origin of this research and the methodological underpinnings as well as details of the analytical approach. Section 4 uses selections from the expert interviews to illustrate aspects of the analysis building towards Section 5, which discusses the overall argument of the paper and the conclusion in Section 6.

2. Literature review

2.1. Innovation and eco-innovation in LMT sectors, and the UK food packaging industry

Innovation Studies attempts to understand what determines innovation (new or improved products, or new or improved production processes) and how it can be encouraged or supported in policy to enhance economic performance (Pavitt, 1984; Fagerberg and Versparen, 2018). High-tech sectors with high levels of investment in research and development (R&D) tend to be the dominant focus of innovation studies, but there are instances in which lower and medium technology (LMT) businesses are critical to economic performance (Archibugi et al, 1991; Fitjar and Rodriguez-Pose, 2016). In these cases, innovation drives high economic performance, but in different modes without significant R&D investment (Parilli and Alcalde Heras, 2012). This has been partially explained by the identification of two separate modes of innovation, with LMT firms focussing on the process-based DUI (learning by doing, by using and my interacting) mode of innovation, which finds improvements

in industrial production processes rather than improvements in the products themselves. DUI innovation is distinct from R&D-focussed product innovation mode (STI) which is common in high-tech sectors (Jensen et al, 2007). DUI innovation is not easily captured by traditional measures of innovation, explaining why it has perhaps not received the same level of attention as other modes of innovation (Robertson et al, 2009). Here, we focus on specific issues relating to the UK packaging sector.

Robertson et al (2009, p.445) observe that missing knowledge about innovation processes prevents effective policymaking for innovation, and they call for case studies which focus on particular examples of LMT sectors. Several works (Simms and Trott, 2014; Trott and Simms, 2017; Simms et al, 2020) focussing on the UK food packaging sector goes some way to meeting this call. Trott and Simms (2017) provide a detailed picture of a number of food packaging innovations in the UK, identifying how innovation processes in the food packaging industry correspond to the model of innovation for LMT sectors. They find evidence of difficulties emerging for innovation among packaging firms in the UK, due to supply chain relationships and sectoral dynamics, but they also highlight the significant creativity employed on the production line, to repurpose materials and machinery.

Environmental policy is recognised as a driver of eco-innovation in the UK (Kesidou and Demirel, 2012; Mylan et al, 2015) but the relationship between environmental regulation and eco-innovation is not straightforward (Mylan et al., 2015) (Kivimaa, 2007), with eco-innovation sometimes preceding or responding to new regulations. Kivimaa (2007) also highlights the importance of the context-specific “suitability” of environmental policies in driving eco-innovation and the need for a deep examination of the directionality of eco-innovation influenced by environmental policies. . Hohberger et al (2015) discuss the tendency of innovation to align future trends but this is too general an approach when examining eco-innovation in a particular sector. Sector-specific technology has particular details and socio-economic constraints which affect adoption and implementation, likely in a manner akin to path-dependency (Hommels et al, 2007).

This paper goes on to argue that the direction of eco-innovation in the UK packaging sector is strongly affected by environmental policy on this basis, even if this policy does not explicitly focus on innovation. Ultimately this is part of the broader argument that types of policy which link industrial sectors and determine the direction of industrial innovation should be considered specifically as part of innovation studies. The following section will outline the specific mechanism used as an example in this paper, the case of the recently changing EPR regulations in the UK and the UK food packaging sector.

2.2. Understanding EPR in the UK in terms of innovation

2.2.1 Extended producer responsibility in the UK

The primary rationale of EPR systems is to make producers more accountable for the waste arising from the products they produce, providing an economic incentive for them to reduce or "design-out", the negative environmental impacts of those products as waste (Kieren Mayers, 2007). The implementation and policy design of EPR systems varies hugely between countries but there is often a companion to the avoidance of negative impacts, with EPR schemes aiming to encourage or drive an increase in recycling (Walls, 2011). This often means that producers of certain products will get involved in waste collection as an activity in some way. This involvement can be in a number of forms, which are helpfully listed by Walls (2011, p.2-5) alongside other similar policy schemes which can have similar effects.

The EPR system in the UK is a "Product take-back and recycling rate targets [system] with a tradable recycling credit scheme" (Walls, 2011. p.3). Recycling companies can issue tradable credits, which are known as "Packaging waste recovery notes" (PRNs), which firms and Producer Responsibility Organisations (PRO), more commonly known as compliance schemes, can trade amongst themselves. These PROs then arrange for recycling and ensure their recycling obligations are met. This system has been in place in the UK since 1997 (The Producer Responsibility Obligations (Packaging Waste) Regulations, 1997) for packaging 'producer' companies handling over 50 tonnes of packaging annually, with turnovers over £2 million (Valpak, n.d.). In 2019, the UK government and the devolved governments of the UK began consultation processes to review and replace this system with an enhanced form of EPR, to make packaging producers take more responsibility for the packaging they put on the market (DEFRA, 2021). Further consultations took place in 2022 and the regulations were due to come into force in 2023, but in August 2023 were delayed until 2025. The new EPR system would have included increased data reporting requirements, eco-modulated fees for plastic packaging that favoured recyclable materials, and the commitment of funds raised through EPR for use in local authority collections and recycling systems directly (DEFRA, 2021). The delay was due to a number of factors that caused concern in the food and retail sector, such as uncertainty over eco-modulation structures, unclear mechanisms for the earmarking of funds for local authorities, and a period of food price inflation (The Grocer, 2023; Packaging News, 2023). Despite this anxiety, many in the packaging and recycling sectors were confident in and supportive of these changes. Flaws in the UK recycling system have been noted for a long time and are the subject of periodic public scandal (Greenpeace, 2021) and to a degree this is to be expected, as

recycling firms and packaging firms have different interests in the sector compared to retailers (Trott and Simms, 2017).

During the consultation process and in response to the finalised plans for implementation, a number of packaging industry bodies raised the issue that bio-degradable products were not included in the eco-fee structure in any way (Vegware, 2023). There were other concerns about how refillable or reusable packaging may be included, and if other kinds of packaging eco-innovation would be included in the regulation. The decision of the UK government to focus changes in regulation on tackling the existing issues with the recycling system, targets and prioritises one area of eco-innovation (recyclable materials) over others. While this is an admirable goal, there are other areas of innovation in the packaging industry that were being de-incentivised by the proposed plans.

2.2.2 Socio-technical transition pathways

It is still necessary to specify what we mean by "direction" in innovation, so we can discuss how it can be affected by EPR as a form of environmental policy. To address this, we need to engage with the notion of transition. Suarez and Oliva (2005) provide a typology of how firms change in response to changes in the external business environment Geels and Schot (2007) have developed upon this in the form of a typology of sociotechnical transition pathways. Socio-technical transitions are an explanatory structure for understanding how sets of technologies at various levels change from one form to another, from sailing ships to steam ships for instance (Geels and Schot, 2007). This is associated with the broader work of Frank Geels (2011; 2019) on the Multi-level Perspective on socio-technical transitions (MLP). This "mid-level" theory posits that new technological developments (niche innovations) move between contexts, from supportive niches, through various development trajectories, to regime status, depending on landscape factors (Geels, 2002. p.1263). It is possible for technologies to become less integrated over time or to be displaced, becoming progressively more isolated from the wider socio-technical environment, as trajectories are not inexorable (Geels and Raven, 2006). This approach excels at providing a broad account of technological changes in social context, but there are a number of key ideas that may be useful to consider for assisting with the specification of innovation directionality on smaller scales.

Sustainability transitions are a particular kind of socio-technical transition relating to sets of linked technologies (infrastructures) that are relevant to entire economic sectors, such as energy or transport. They are of particular interest in this case because they are strongly affected by public policy, as noted by Lindberg et al (2019). The particular sector that this paper is focussed on is the food packaging sector, which is not so large in scale and the potential changes to the underlying

technology are not so fundamental as in the “energy sector”, meaning that different concepts suited to the scale of the sector may be required. The concept of the niche-innovation trajectory is perhaps more appropriate, as it captures the idea that areas of new technological developments or innovations, referred to in the previous section as “areas of innovation” may represent qualitatively different technological development pathways. These niche-innovation trajectories will each have their own sets of technical expertise, forms of lock-in, and different enabling or obstructing factors (such as different or changing policy contexts). They may also result in different consequences for subsequent innovation and policy. Røpke (2012) for example has explored how technological transitions can progress in unsustainable directions with reference to one example comprising a set of linked technologies in the form of broadband and the broadband transition for instance. In this paper, we are adopting this idea of transition at a smaller scale through the notion of directionality, in order to explain why particular changes in UK environmental policy will prioritise some forms of eco-innovation over other competing forms of eco-innovation. Developing this notion of directionality further may also assist with future studies of other similar sectors (Robertson et al, 2009), and the effect of policy on sustainability transitions within sectors. The following methods section will describe how we have been able to explore this issue.

3. Materials and Methods

The research that informs this paper was designed to assist the modelling project: ‘Reducing plastic packaging and food waste through product innovation simulation’ (Ref: NE/V010654/1). This project was funded by the Natural Environment Research Council (NERC) as part of the Smart Sustainable Plastic Packaging (SSPP) challenge. This project aimed to model improve simulation modelling for various interventions related to household food and packaging waste. When considering future modelling projects, it became difficult to assess which areas of innovation were most likely to be implemented in the industry. This research therefore intended to provide insight into the current areas of technological preoccupation for innovation in the food packaging industry. The following research questions were generated based on the needs of the project, through discussion among the project team:

1. What are the main areas of interest, materials, and packaging forms which are being considered for packaging innovation among UK retailers / packaging suppliers?
2. What is driving this innovation in packaging? How do UK firms come to understand this need to introduce new packaging substances and forms?

3. How are packaging innovations developed and brought to market?
4. What are the barriers for different kinds of innovation?

In focussing on a particular sector, this paper is following the approach taken by Trott and Simms (2017), which in turn follows the call made by Robertson et al (2009, p.445) for 'detailed studies of individual sectors in practice'. In choosing to focus on different areas of innovation within this sector, we are at once following the call for specificity and departing from it, as general insights can be gained for wider consideration.

Expert interviews were selected as an appropriate method to provide the insight to answer these questions (Trott and Simms, 2017. p.612; Steinhorst and Beyerl, 2021). We sought a selection of figures from different types of organisation which have a role in the packaging industry (e.g. packaging focussed NGOs, packaging producers, polymer and packaging consultants, refill system design organisations). We included retailers in our selection criteria, as they can have a significant impact on packaging forms in particular situations (Simms and Trott, 2017. p.621). For this reason, purposive sampling was an appropriate method (Strauss and Corbin, 1998). Several members of the advisory board of the research project were understood to have significant influence or experience within the industry, and we approached them to participate in this research. Similarly, project members had extensive networks of contacts within the industry and a number of invitations to participate were made in this way to potential participants, or via email introductions. In addition to this, the authors attended a number of events aimed at or organised by the packaging industry, including the Materials Research Exchange in October 2022 and Packaging Innovations in April 2023. A number of participants were identified through personal networking at these events. See table 1 for a full list of pseudonymised participants with their role outlined. Details were collected from the participants, and formal consent was granted for the interviews. Ethical approval was granted for this project and this proposed sampling approach (ref: 049768).

The interviews that were conducted used a relatively unstructured approach. Interview guide questions therefore served more as prompts to start discussion of particular topics, because the participants were packaging industry insiders and were considered to have significant experience and opinions regarding the topics of interest. This less structured approach is often used in qualitative interviewing to offer space and power to the participant to guide the interview and direct it towards the issues they consider the most relevant or prominent (Scott and Powells, 2020. p.3875; Folkes, 2022. p.12-13). In this case it had the effect of allowing free discussion and follow-up

conversations during the interviews, which resulted in interesting additional detail being shared with the interviewer.

In total, 9 participants completed an interview, from December 2022 to April 2023. This is a relatively limited number of participants, due to time and resource constraints and the difficulty of recruiting busy experts in this field within a short time frame (Flick, 2012). It is worth noting that research involving 49 interviews conducted with similar stakeholders, in the same industry took place as part of a long-term research project running since 2009 (Trott and Simms, 2017). These interviews were transcribed and the transcripts were anonymised. A plan was devised for this process, with changes tracked in a separate document, and the anonymised transcripts were approved by the participants. The participants were able to suggest changes to make sure they and their employer would not be identifiable. This was done to reduce the risk of disclosing commercially sensitive or identifiable information, or remarks that may harm future opportunities for participants. Pseudonyms were allocated for each participant. Pseudonyms were also given for companies, organisations and geographical regions, where this could result in identity disclosure, except in cases where express permission was given by the participant to release these names. The nature of the method adopted and the data produced from these interviews have some significant limitations and therefore the conclusions made on the basis of the analysed data also have limitations. These are discussed in more detail in the discussion section.

One participant wished to withdraw from the research at the anonymisation stage, so their transcript and interview recording was removed along with any other retained details. The remaining 8 interviews were analysed thematically, following an inductive approach. Codes were identified from the texts after repeated and deep reading of the transcripts, followed by generation of themes from these codes, which would satisfy the research questions for the project.

Table 1 sets out the pseudonyms of the research participants, along with their role and relative position in relation to the packaging industry:

Table 1: Research Participants

	Pseudonym	Role	Interview Duration

1	Malcolm Bonas	Consultant - Polymer science relating to packaging	1 hour 14 minutes
2	Eddie Jones	Bioeconomy officer / researcher	59 minutes
3	David Yeates	Section head, Plastics recycling organisation	47 minutes
4	Tim Howarth	Innovation & Research manager, multinational food packaging corporation.	50 minutes
5	Jon Roberts	Convenience Food Retailer packaging manager	46 minutes
6	Maria Clarke	Innovation role, Refill organisation	53 minutes
7	Mark Carlton	Sales Director, national packaging company	1 hour 1 minute
8	Christine Sandwell	National recycling organisation MD	47 minutes

4. Results

This section addresses the most prominent area of eco-innovation, the drivers motivating the packaging industry to focus on this area, and why EPR has lifted some of the barriers to the development of recyclable flexible packaging materials. The following sections deal with other innovations, and drivers and barriers to innovation separately. Each of these sections covers the research questions, with respect to particular areas of innovation.

4.1 Recyclability as the major focus of innovation in the UK Food Packaging Sector

4.1.1. Industry focus on Recyclability

The participants represented a range of positions within the packaging industry that could reasonably be assumed to have diverse opinions on the major goals of the packaging sector. From the data however it appeared that the packaging industry is remarkably focussed in one way or

another on increasing the recyclability of packaging through innovation, ahead of any other goal. This can be seen in comments from a number of the participants.

"Right now there's an enormous amount of emotional stuff going on to the consumer, trying to push them in the direction of recycling".

[Malcolm Bonas]

"the place that I'd start really, is about using new materials, because there's a drive for the simplification of materials. [...] And that's mostly driven by recycling, because you want materials that make recycling easier, and so the interesting bit, the drive that we've made, over the past five or six years, [multinational packaging corporation] have made a pledge, you can see that on our website, to make everything we make recyclable, or compostable or reusable; But the main drive is clear, it's been recyclability"

[Tim Howarth]

In contrast to the cases above, recyclability was often discussed indirectly or implicitly throughout the rest of the interviews. The participants often talked about the specific technical challenges of achieving recyclability across a wide range of flexible packaging products without necessarily mentioning it directly. As Tim Howarth notes, the bulk of innovations in this area are related to moves towards mono-material flexible packaging and away from multi-material composites and laminates, sometimes attached to containers of other materials. The process of achieving the same product functionality with mono-materials often involved forms of R&D, and also more incremental process and product innovations. The following sections will outline why EPR enabled these processes of innovation in practice.

4.1.2 - New EPR regulations as a driver towards recyclability

While the current context of the new EPR regulations is certainly disheartening for those concerned with the efficient functioning of recycling systems, participants had a lot to say about the incoming regulations as they appeared in early 2023. The unified direction they provide for industry was considered to be a major driver toward recyclable materials in the packaging industry. Participants were positive about this unified direction of travel towards recyclability and were also positive about the potential for these new regulations to affect the quality of plastic that could be collected and recycled into new products from kerbside collections.

Christine Sandwell noted that the modulated fee structure introduced as part of EPR alone was likely to drive improvements in recyclability, purely because of the additional comparative costs that will come with introducing new packaging products which are not recyclable to the same level.

"I think it [EPR] is a factor and it will grow, because it will be part of this push to have higher degrees of recyclability. So if we've got higher degrees of modulation, so we're proposing just as a working model, 5% of modulation, but the steps between those degrees of modulation are going to have to be significant. So if you're gonna do that, then that's gonna mean that, there's an economic driver [to] going from recyclable C to recyclable A. So anyone who is trying to put something new on the market that's not better than what's already there, that's just different, will be struggling I think, because the cost implications on obligated producers are going to be considerable".

[Christine Sandwell]

The EPR regulations significantly affect perceptions of the likely future efficacy of recycling systems and as such they also affect the perceived efficacy of different areas of eco-innovation to reduce environmental impact as the following quotes demonstrate. A successful EPR scheme would incentivise a whole new category of materials (flexible plastics) to be integrated with kerbside recycling systems as they currently exist. As can be seen from Jon Roberts quote below, waste recycling systems in the UK often do not accept hard to separate packaging comprised of materials for recycling. Mono-material packaging resolves this issue without having to change collection practices too much.

"This EPR programme is meant to be sorting that all out by 2027 and we've been lobbying for a long time about the collection of films at kerbside, and we've been part of the one bin to rule them all project in manchester, since that started, pots tubs and trays in greater manchester is a particular bugbear of mine [...] we have removed all polystyrene, all PE layers, moved to a lot of mono-layer materials, but beside spending all that money, quite a bit of money actually, we budgeted for, you know it's in the millions the amount of money that we spent to get those projects over the line. In the northwest they still all go to incineration, so that's quite frustrating, but with this EPR, by 2027 it's meant to ensure that all these materials are collected at kerbside, so we'll see what happens with that".

[Jon Roberts]

"Now we've got the EPR it does define, so people that 3 or 4 years ago that were thinking about going into compostables was a good idea will now have to backtrack on that. So we're all being

pushed in one direction, which is lightweight, recycled content and recyclability, which does lend itself back to in my case, lightweight plastics, with recycled content, or renewable feedstock. So that's good I think because we do have a direction but it probably limits development outside of that because will there be a market for that? [other innovations and materials] I suppose as we go into the EPR and more products become available too, presumably they'll get a new EPR rating, but at the moment I would expect it to be, plastic or reduced but better"

[Mark Carlton]

Here, Mark and Jon make two points which illustrate an important additional point about eco-innovation in this context. Previous to the introduction of the EPR guidance, there was little to indicate or incentivise eco-innovation in any particular area. As Jon notes, companies like his which act as first movers in taking action on packaging sustainability issues without a structure of incentives, or the appropriate links with the waste system in place are essentially choosing to enhance aspects of their own sustainability independently, at their own expense without any guarantee of wider success, or actually creating any improvements to sustainability. Mark notes that many companies were considering moving into compostables as one area of eco-innovation but notes that such investments in innovation that differ from recyclability, made much like the early commitments described by Jon, would effectively be marooned by an exclusive focus on recyclability in regulations, if this is maintained through future adjustments to the EPR system. This kind of environmental policy clearly affects the overall direction of eco-innovation in this sector in particular ways, but it is worth noting why this is the case and what can be translated to other contexts.

A waste management system which is able to offer materials of sufficient quality and consistency to make recycling economically viable, requires significant coordination between the industries which recycle waste and the industries which produce the packaging that ultimately become waste. In this sector, the direction of eco-innovation appears to be strongly determined by forms of environmental policy like EPR systems, because of the need for coordinated forms of eco-innovation. There are other sectors of the economy that include similarly high degrees of coordination, including but not limited to other instances where waste and recycling are involved. Beyond supportive niches, technologies very often have to integrate with wider infrastructures and social structures (Geels and Schot, 2007) and this integration is often enforced or regulated by policy to a degree. Industries that produce goods to legal standards, or which produce infrastructural items which depend on consistency and coordination, present themselves as possibilities for the future study of innovation directionality. In these sectors, environmental policy has the potential to direct eco-innovation in various forms.

4.1.3. Technical and economic barriers to recyclable packaging as an area of eco-innovation

In a previous quotation, the participant Tim Howarth noted that simplification is a key area for increasing the recyclability of flexible packaging. This is a deceptive term for a complex process. This is a form of eco-innovation that involves both process and product innovation, operating in the STI and DUI modes. Even though the material is simpler by virtue of there being fewer materials involved, the packaging materials must be reconsidered and reworked in complex ways. There are an array of technical and economic challenges for packaging producers to overcome, rooted in the need for single materials, like PE or PET, to perform the complex, multiple functions of composites (commonly PE, PET, and Nylon, but also including metallized layers etc.) for flexible packaging. This involves changing materials, but also often means changing and making technical adjustments to production lines, which involves significant capital expenditure (and thus risk). It is much more than a 'drop-in' product innovation and can change the fundamental economics of a product in unfavourable ways (As described by Tim Howarth and Mark Carlton separately). This is leading packaging companies and retailers to make sure that the functions of new mono-material flexible packaging are at least equal with non-recyclable composites before making a switch. Tim Howarth explained this in detail as can be seen below, but a number of other participants also explored this issue.

"So how do we take, these multi-layer highly engineered composites, you know we don't use a complex mixture of PE, PET, Nylon without good reason; it's there because we're making composites, and the composite is there to be the most efficient, lowest environmental [consequence] thing you can design. So now we kind of say, let's think about that and let's just redesign everything. And say instead of three different polymers in a structure, we have one. And that has been the biggest thing we've been able to focus our innovation around. And it's been great actually, I've had more fun in the last four years than in the last 25 actually because it's not about incremental innovation anymore, it's about how do we transform something. And as a scientist that's great, that's music to our ears. You know it's not let's take half a micron off here or a little bit smaller over here. It's completely changing the rules, you've got a new set of design criteria to work to. Which for our operations team is a complete nightmare, because they might not have the machinery to make it but for a packaging designer and innovator nothing is off limits anymore. So you asked about new materials, well a lot is actually about simplifying materials, and making materials do things they have no right to. So we redesign and re-engineer our processes, and put the more similar materials together to do something that is like a much more complex composite material".

[Tim Howarth]

Tim Howarth went on to give an example illustrating the technical problems this sort of change causes on the production line and why these changes towards simplified packaging can be barriers to innovation towards recyclability, which we have paraphrased here. Tim proposed that there are existing solutions for transitioning to mono-material flexible packaging, but that these may not run on the machinery operated by their customers, who buy the packaging from the multinational packaging corporation that Tim works for. Switching from an option involving PET (Polyethylene terephthalate) and PE (Polyethylene) laminated together which is not recyclable, to another option involving PE (which is easily recyclable and widely collected for recycling in the UK) changes the heat sealing properties and lowers the heat resistance of the material. Tim stated that in many cases, a packaging machine that had been running for years and which was badly set up, would not work with this new construction. Either the packaging machine would need to be replaced or updated, involving significant capital expenditure. Tim expanded this argument to discuss the consequences of these kinds of changes on the entire sector, and the resulting effect being more expensive packaging overall.

Transitioning to such materials as a form of eco-innovation is difficult and expensive, and involves considering the real-world conditions which packaging machines operate in, as a form of process innovation or additional investment required by the primary product innovation in the material. David Yeates made a similar argument concerning PET-PE packaging designs and recyclability affecting production line times.

"One of them is PET-PE, and what I mean by that is that there's currently cooked meat especially, ham especially, is packed in a PET base web, a base film, and it looks like a tray when it's formed. And when you buy your pack of ham it looks like a tray really. But its two polymers, PET and PE. So you've got a top film that you're asking the public to rip off, and recycle the base bit, if that base bit, as I've just said, PET PE, two polymers you can't separate them, so let's do it a different way. If you get a slightly different film, which is mono PET, and change the top film slightly so it will adhere to it, but from what I've been told, in the factory you have to make one or two adjustments as well and that will slow things down slightly"

[David Yeates]

Changes to operational details of production lines, which would qualify as process innovation, are required to enable product innovation, and this has costs and risks associated with it. Christine Sandwell made a similar argument concerning the speed of production lines and innovations for recyclability, concerning paper teabags and combined plastic and paper teabags. Process eco-

innovation to enable paper teabags to be packed at the same speed as plastic and paper ones was not viable in that particular case, so losses occurred when production lines had to slow down to accommodate paper as a new packaging material. The issues discussed here appear to be very similar to some of the issues noted by Simms and Trott (2017), namely the difficulties associated with overcoming technological lock-in and the innovation that is embedded in capital intensive machinery. These difficulties then necessitate a more incremental approach, focussed around process innovation. However, what is novel is that product eco-innovation in packaging appears to require process innovation in some cases. The nature of these technical production line issues and how environmental policy interacts with them as potential barriers to eco-innovation are discussed further in section 4.2.2.

A number of participants expressed that although EPR was pushing change towards recyclable materials, and that such simplified packaging materials were being adopted, there was also concern that while some mono-material flexible packaging can be recycled, current kerbside collections do not accept it, and it has to be deposited in-store. This has not necessarily stopped companies from moving to this form of packaging as an eco-innovation however, as even unimplemented the EPR still provides a sense of direction for future policy and as noted by Kivimaa (2007), eco-innovation can pre-empt regulation and social integration.

4.2 Other Areas of Innovation

4.2.1. Bioplastics

It was generally understood by the participants that bioplastics (including both biodegradable and bio-based plastics) have a high degree of support from consumers. It was also understood that there is currently significant ongoing innovation and research into various kinds of biodegradable polymers, bio-based polymers and other materials (See: Purkiss et al (2022) for a breakdown of the differences between bio-based and biodegradable plastics as well as a summary of different biodegradable plastics). According to the participants, this interest plays into a nexus of problems that bioplastics seem to encounter as a broad category of innovations. This begins with some definitional issues. The shared 'bio-' prefix does not communicate whether it refers to the origin and production of the material or the route to disposal. There are also a number of biodegradability/compostability standards, and many commonly misused or misunderstood terms referring to biodegradability. Most importantly, the UK does not have an adequate disposal route for biodegradable packaging, due to a lack of industrial composting capacity. This nexus of problems appears to prevent systematic integration of bioplastics innovation with the waste collection and

recycling industry, at least in the UK currently and especially given the omission of compostable packaging from the new EPR regulations. Packaging producers will supply it and packaging managers for retailers will find applications for it, but generally the experts interviewed considered it to be troublesome outside particular niches.

"*There's a lot of interest in making biodegradable polymers. I've worked on these for twenty-odd years, and I've come to the conclusion that their major value from a waste management viewpoint is where you have contamination like food waste and you can compost the plastic packaging or food service items in the same way and at the same time as the food waste. The problem is that we can make each packaging component compostable, but now we need a totally separate infrastructure from the present recycling infrastructure for collecting and composting them, and the compostable polymers are significantly more expensive than polyolefins".*
[Malcolm Bonas]

Other participants also discussed the potential place/applications that existed for biodegradable packaging materials, and the various issues that these posed for the end of life or disposal systems for those products, including certification schemes and the eventual environmental impact of disposal.

"I do think there's probably a place for it, because things like the knife and fork that you get in a throwaway pack thats made of the same material, then you can throw it in the same bin, but in terms of packaging I can't see any [...] when I'm asked about biodegradable films and stuff my normal cop-out answer is that there's not the infrastructure in place to deal with it at the moment, and I can say that, and not get shot for it, anything else, no opinion".
[David Yeates]

"So most of the leadership is happening in Europe on sustainability and pack design. And it's interesting in Europe because the movement seems to be to not permit compostable packaging materials to go in with food waste systems. So in terms of having a viable end of life on those material, there is not- unless you've got a compost bin or garden, which in most cities is not the case, you're not going to, there's not a viable end of life for compostable packaging materials".
[Tim Howarth]

"On pack we put these teabags are certified to EN13432 so we also have to be really careful about the green claims code, and as [convenience food] we're probably a bit more conservative with the risks that we take, on the green claims, and we spent ages debating the wording on the compostable teabags. [...] in the end we just said, put it in your food waste bin, and then at the end we said, this liner has been converted into a biopolymer which is certified under EN13432 to avoid any potential issues with the green claims code, whereas if you look at the big brands they've just put compostable tea bags".
[Jon Roberts]

Each participant here described a reluctance or wariness around working with biodegradable plastics on the basis that they did not fit easily into existing recycling collection systems. As such they would inevitably end up in landfill or would contaminate recycling and thus would be an environmental burden. The other reason given was that bioplastics were not featuring strongly in government plans to reform waste collection and recycling systems. While the lack of collection for flexible materials does not hinder work to introduce or innovate recyclable materials, the proposed changes to collection systems makes recyclable, simplified materials for packaging appear to be worth the commitment, as opposed to bioplastics of various kinds. It is worth noting here that a number of the participants had explicitly discussed their interest in pursuing sustainability in their roles, either as a personal commitment or as part of a corporate commitment. For many of them, it was important that these improvements in sustainability were meaningful, even if waste collection infrastructure is not in place. It is the combination of the lack of current provision for biodegradables in the current system, and the exclusion of them from plans in the EPR regulations that appears to be deterring some in the packaging industry from engaging with bioplastic eco-innovations currently.

4.2.2. Downgauging

Generally reducing the amount of packaging on products was discussed as one option explored by many companies as a way to reduce the amount of plastic used in packaging, but downgauging in particular (reducing the thickness or gauge of packaging) was only discussed a couple of times. Mark Carlton discussed it at length however, arguing that reductions of 15% across the range of packaging he sells would be possible with no adverse effects on packaging function. This seems like a relatively minor change with high potential for reductions in material use. He argued however that the challenge here is not necessarily the technical or economic aspects of the change, but instead the challenge lies with how risk and fears of problems and failures are addressed on the 'factory floor', and issues with how marketers establish the value of products through packaging. These issues are

effectively a linking element or hinge between recycling/waste management policy (EPR) and packaging manufacturers. He also suggested that in cases where there is little economic rationale (established to encourage change) for changing how packaging is produced, it is an uphill struggle for sales managers like himself to sell or convince manufacturers that this relatively minor technical change is worth the risk.

Participant (P): "*there is one thing I would like to say actually Jack, one low hanging fruit which I wish people did more of was downgauging. I could bet blind that we could take out 15% of what we do, but you're banging your against a brick wall a lot of the time for genuine reasons, because people are scared of having a factory problem and we try really hard to support people into changing, but even though you're offering people quite a lot of saving, people are nervous, because as a purchasing person for instance, if you make that change, people will soon forget about the change that you made, but if it goes badly, you'll never live that down and I don't blame them but I don't know how to get around that, what do you do?*

Interviewer (I): does it [downgauging] cause technical problems?

P: no, I suppose you're gonna get one, one time, but to me it's, we'll support them, we'll literally be on the shop floor with them, and try and do it slowly, because I actually think that would make the biggest difference in the short term. You know, it's also the first principle of reduce reuse recycle. I am certain I could take 15% out, if given free rein on everything I did I could take 15% volume out of everything overnight. But nobody's prepared to do that now. [...] It's going to affect your sales, a company's not going to thank you for that and again, you might save 5 grand or something, and that's if there's no big problem with the factory or the product. [...] I've had a discussion today with a company we don't supply, and they do that to some degree, but some of the products are left and it's a higher volume [...] so thankfully they let us have a site visit, so we can say no we feel confident you could drop that, the downside is if they decide to go for that rather than for like for like, it'll slow my orders down, because it might put me winning the orders back 6-12 months"
[Mark Carlton]

From this discussion, Mark moved on to discussing why EPR is likely to drive more changes/innovations that ensure recyclability and which enable the lightweighting of packaging (this has already been quoted in the section on recyclability). While this eco-innovation is not directly

related to recycling, it does highlight some of the same dynamics that were introduced in the previous section on the technical and economic constraints of eco-innovation towards recyclability. These comments from Mark echo the points made by Simms and Trott (2014) regarding the difficulty of engaging with the production process due to the high costs of changing such processes, but also suggest that the difficulties perhaps emerge from the fears created by the perceived costs rather than real costs. Mark employs various techniques to deal with these fears of perceived costs and it is worth bearing in mind the personal terms he uses to describe the fears and anxieties of technical staff, and the particularly personal nature of the fears purchasing staff have of being associated with a costly mistake. The sunk capital costs in the food packaging sector, and the risks and limitations to making changes to production can lead to path dependency as noted by Trott and Simms (2017), but it would also seem that the pressure put on the production line to make savings and to remain efficient perhaps changes how these risks are understood in practice. Innovating in this sector can be difficult due to a wide range of factors, and it is possible that these problems also apply to the other areas of eco-innovation like recyclability, that also pose challenges for production lines.

5. Discussion

This paper has been able to demonstrate that EPR has the potential to shape the direction of innovation in the food packaging sector, through government commitment to a consistent direction in packaging waste related environmental policy. Simms et al (2020) and the participants of this research both note the inconsistency of government policymaking as a barrier to waste-reducing eco-innovations. As a result of this barrier being selectively lifted in the case of EPR, a number of the participants are hopeful about, or had examples of how eco-innovations focussed on packaging material recyclability could now be adopted in the sector. This addresses research questions 1, 2 and 4 as named in the methodology section. To extend a metaphor, the main contribution of this paper has been to propose how such barriers being lifted can direct innovations in particular ways specific to the sector or industry under discussion. The mechanism which does the directing in this case is the eco-modulated fee system planned as part of the new UK EPR regulations, which heavily favours recyclable packaging materials, or at least according to the draft regulations before August 2023. This advances a line of inquiry concerning the direction of innovation proposed by Hohberger et al (2015), and brings it into conversation with the study of eco-innovations (Mylan et al, 2015; Marzucchi and Montresor, 2017). Further research will be able to identify and examine the extent of

the effect other similar instances of environmental and other types of indirectly related policy have on eco-innovation and innovation more generally. Due to the limitations of the dataset, this paper is unable to make generalizable claims about the extent to which eco-innovations have been or will be adopted across the industry, and the authors hope that others will pursue this further.

This paper has been able to support several points made by Simms et al (2020) and Trott and Simms (2017) regarding the nature of innovation in the UK food packaging/packaged food sector and some of the features of the industry that prevent eco-innovation. We are also able to contribute some detail concerning how industry dynamics and firm structures influence perceptions of risk and hinder innovation on the "shop floor", and how some firms attempt to overcome this. Trott and Simms (2017) argue that processing is the centre of the packaged food sector, and the actual social or technical dynamics of production lines feature prominently in two examples provided by Tim Howarth and Mark Carlton, and other participants. These examples reinforce the observations made by Trott and Simms (2017) about the various factors that make this particular part of the industry resistant to innovation: high capital costs, risk of losses from slowing or stopping high volume production and industry dynamics mean producers lack sectoral power. However, in the example provided by Mark Carlton concerning downgauging, he focussed on the emotional and interpersonal dimension that underpins how many of these factors work in practice, and had a strategy for dealing with this on the ground. The barriers to eco-innovation have clear roots in economic dynamics between and within firms, but risk is also a highly emotional area where perceptions may not accurately match reality. Future studies could consider how particular sets of contextual factors may affect and influence perceptions of risk in relation to process innovation, through particular sets of emotional, social, and technical dynamics in the organizational context of the "shop-floor".

Aside from the contributions relating to EPR and the food packaging sector, this paper is able to offer some insights into how some social science theories could be usefully repurposed. The argument made by Robertson et al (2009, p.445) regarding the need for more attention to the framing of innovation as a subject of study is particularly relevant. Studies of innovation framed in terms of individual innovations or case studies of innovation (Trott and Simms, 2017) appear to be allied with approaches to innovation in general (Fijar and Rodriguez-Pose, 2016) in the sense that the purpose or directionality of innovation is not considered explicitly. In a strange inversion, studies that directly address the idea of directionality within particular areas of innovation appear to operate with a broader analytical unit with bundles of technologies (e.g. broadband; biogas plants) considered on a wide historical timeline (Geels and Raven, 2006; Røpke, 2012). These studies are informed by the Multi-level Perspective (MLP) on socio-technical transitions (Geels, 2002) and

appear to provide appropriate meso-level concepts and ideas with which to orient framings of innovation, for future meso-level studies (Robertson, 2009. p.445). Concepts such as niche-innovation trajectory (Geels and Schot, 2007) appear to be particularly useful, as they allow for an understanding of process and change within firms, as well as providing terms of reference which enable evaluation of different areas of innovation with respect to their spread and sector-wide or society-wide significance. In the case of this paper, this concept allows broad areas of ongoing innovation at a sector level to be placed within a teleological framework. Innovations progress from niches towards integration into wider socio-economic structures. It is then possible to conceive of research projects which evaluate and compare contextual factors, like the new EPR policy described in this paper, as potential enabling and inhibiting factors for different directions of innovation with regard to specific sectors and industries.

There are a number of limitations of the methodology and dataset for this project that should be considered in parallel with our argument, in order to set the appropriate scope for the discussion and conclusions. Firstly, the decision to focus on packaging industry experts recruited from personal networks, additional networking and forms of social media is likely to create some form of self-selection bias, but this is not necessarily a limiting problem when it is the expertise of the participants that is desired (Williams et al, 2020). This partiality is to some degree mitigated by our decision to seek out participants from different parts of the food packaging and related sectors, and to extend this to a wider field including related NGOs. Secondly, the decision to conduct semi-structured interviews, rather than building case studies from multiple sources of data, as demonstrated by Trott and Simms (2017) mean that this research deals purely with the opinions of participants, rather than any practices or events verifiable by other kinds of data. Bearing in mind these limitations, the authors have made sure that this paper does not claim generalizability.

6. Conclusions

This paper proposes that there may be cause for studies of innovation to focus on the direction of innovation and eco-innovation within sectors. This may be most important in areas of technological development or economic sectors where public policy is involved in coordinating transitions in coordinated infrastructures or in heavily regulating industries. The MLP approach to socio-technical transitions informs our argument, as it has transferrable concepts that can apply to the sector level. The findings of this paper, generated from an analysis of interviews conducted with experts working in the UK food-packaging sector provide an example of this approach. The particular case demonstrated indicates that upcoming EPR regulations in the UK are incentivising firm innovation

towards recyclable packaging in this sector as a coherent and distinct area of innovation. It also indicates that these same policy developments are de-incentivising other areas of innovation, such as bioplastics. In addition, the findings from this paper have been able to contribute some detail to our understanding of how well documented barriers to innovation in the industry operate in practice (Trott and Simms, 2017), such as the difficulties with risk-taking on the "shop-floor". The limitations of the dataset and the methods used mean that we cannot make claims about the extent of the innovations incentivised or de-incentivised by EPR. However, we can indicate that this policy change has had an effect on the sector, and encourage future researchers to explore potential approaches for capturing this effect in quantitative terms, and in other situations and sectors.

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